

Lattice Energy LLC

4th Bi-Annual IGRS Research Symposium at NASA-Ames, Mountain View, CA

**Positive holes and low energy neutron reactions:
energy transfer within Earth's crust, terrestrial nucleosynthesis
and energy supply for bacterial colonies in the Deep Biosphere**

Earth



Image credit: NASA

Lewis G. Larsen

President and CEO
Lattice Energy LLC
December 10, 2014

**“In any field,
find the strangest thing
and then explore it.”**

John Archibald Wheeler

Other rocky planets



Venus - image credit: NASA

Dec. 13, 2014: added two new Slides #3 and #11 and reordered slide #4

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<http://www.slideshare.net/lewisglarsen/presentations>

p -holes first discovered by Freund over 20 years ago

Has since further characterized and measured these charge carriers

Detailed physics not yet worked-out: likely collective many-body quasiparticles

“Pre-earthquake signals: Underlying physical processes”

F. Freund, *Journal of Asian Earth Science* 41 pp. 383 - 400 (2011)

http://www.researchgate.net/publication/232411845_Pre-earthquake_signals_Underlying_physical_processes

- ✓ **First discovered by Freund, and noting that detailed physics of p -holes has not yet been worked-out, they are likely to be some type of many-body, collective electronic quasiparticle that propagates as a mobile carrier of positive charge thru wide variety of common crustal rocks (except marbles) and wet or dry soils**
- ✓ **Unpublished experiments conducted by Freund which generated p -holes in water ice strongly suggest that quantum entanglement amongst components of p -holes may also be an important feature - see all the work of Chatzidimitriou-Dreismann**
- ✓ **Strain-induced creation of p -holes occurs at *extremely low* activation thresholds**
- ✓ **Propagate at phase velocities substantially slower than seismic P- and S-waves**
- ✓ **p -holes can transfer electronic energy thru rocks for meters in lab experiments and for multi-kilometer distances in the Earth's crust before losing their integrity**
- ✓ **Can release their energy as high local electric fields when they finally dissipate**

Widom-Larsen theory of low energy neutron reactions

Electrons react directly with protons to make neutrons and neutrinos

Reactions are 'green': no emissions of deadly energetic neutrons and gammas

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces"

A. Widom and L. Larsen, *European Physical Journal C* 46 pp. 107 - 112 (2006)

<http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006>

Non-stellar neutron production in condensed matter under mild conditions:

Collective many-body
processes require
some input energy



Electric fields dominate



Magnetic fields dominate

Electroweak nuclear reactions produce neutrons (n) and neutrinos (ν_e)

Transmutation of elements and star-like nucleosynthesis in labs and Nature:

Neutron capture-
driven transmutation
in Earthly environs



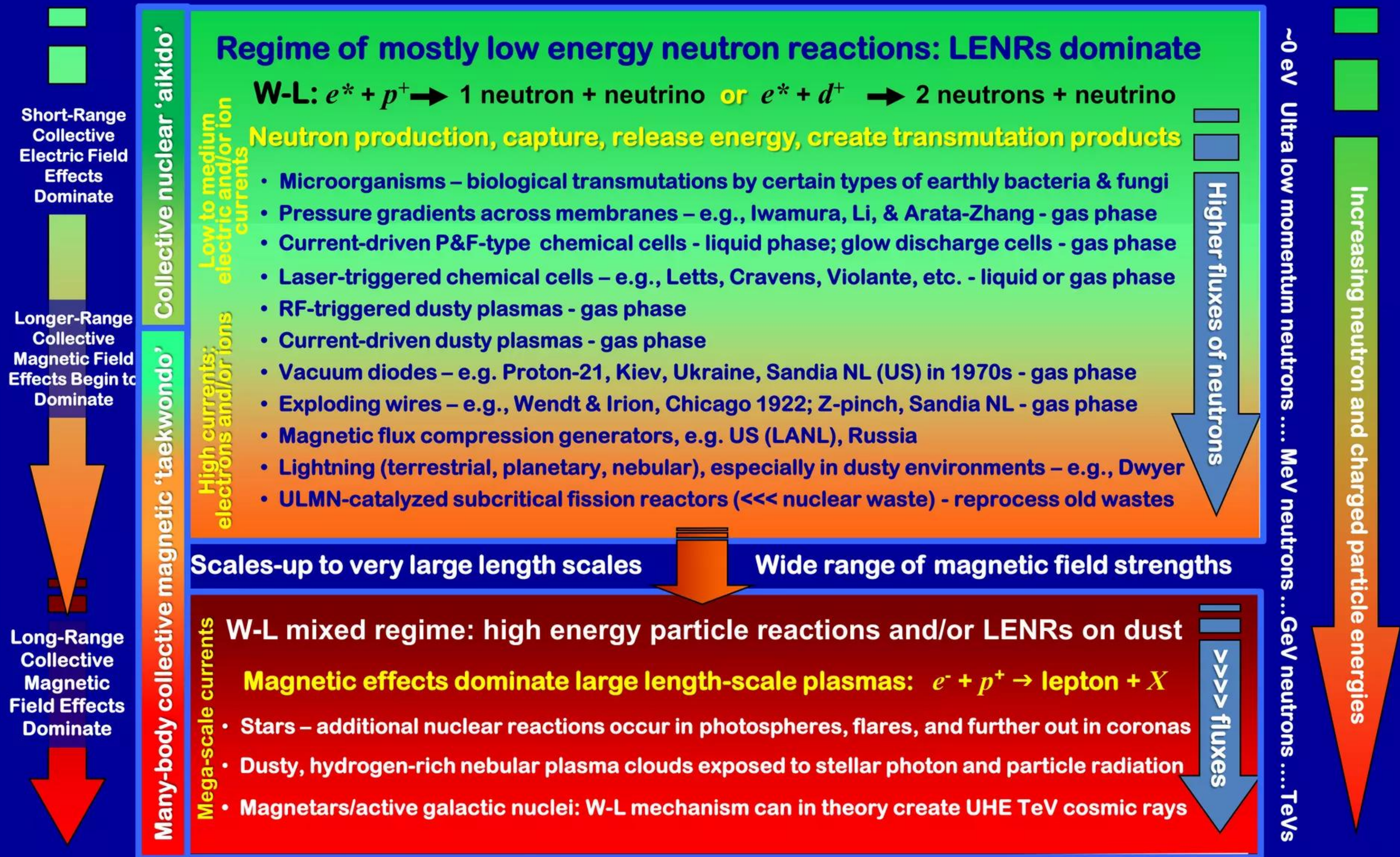
Neutron capture



Beta decay

**Unstable neutron-rich products of neutron captures will undergo beta⁻ decay
Create heavier stable isotopes or heavier elements along rows of Periodic Table**

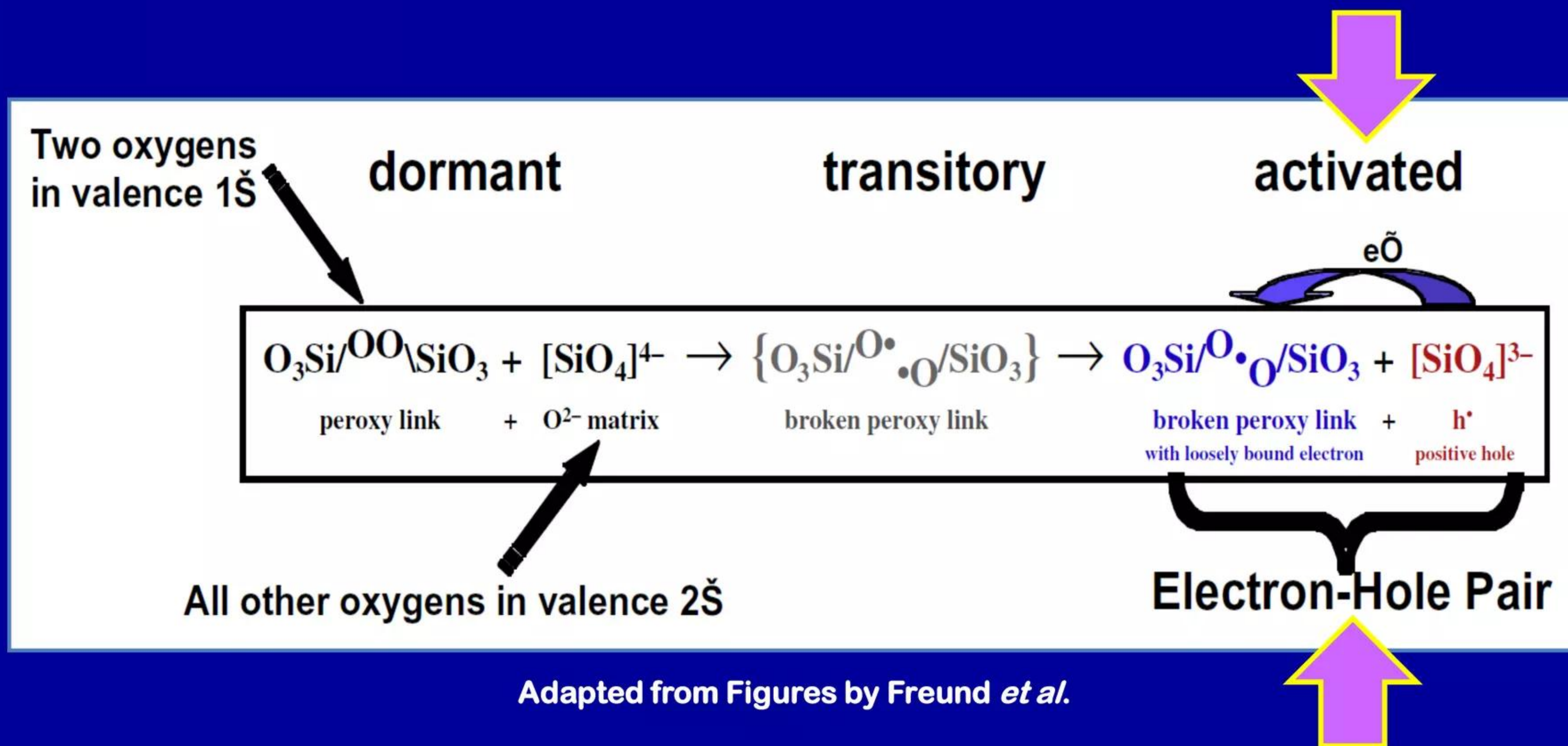
Widom-Larsen extends from microcosm to macrocosm



Mechanical breaking of peroxy bonds creates *p*-holes

Chemical bond energy converted into mobile positive charge carriers

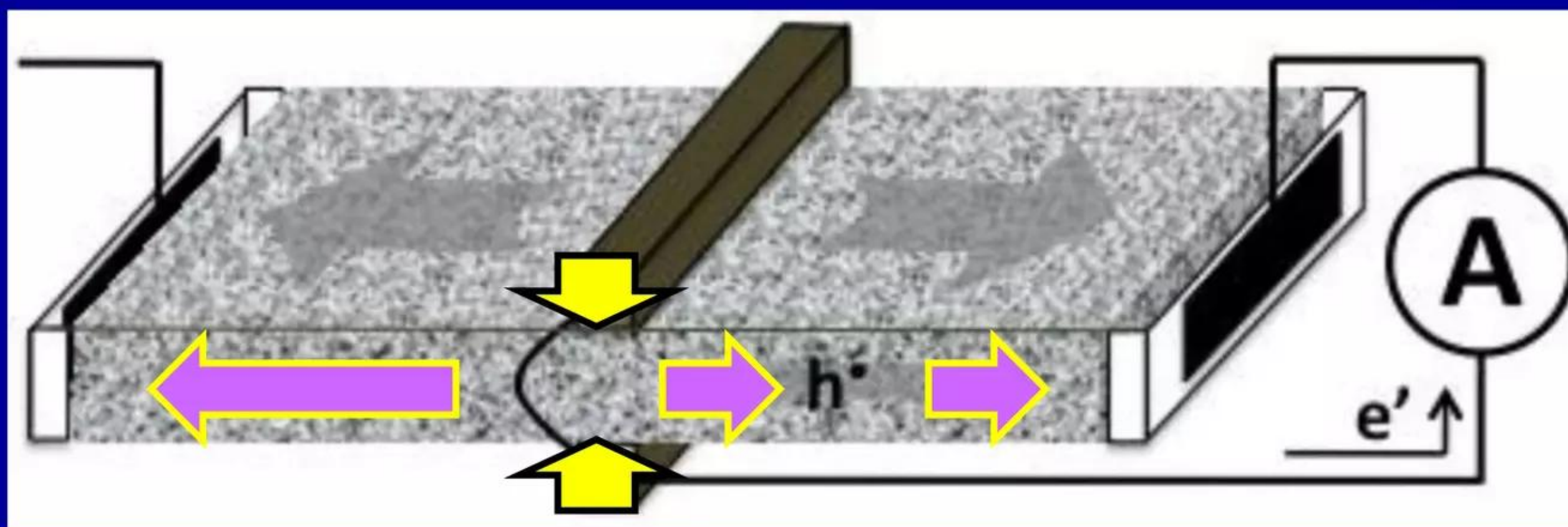
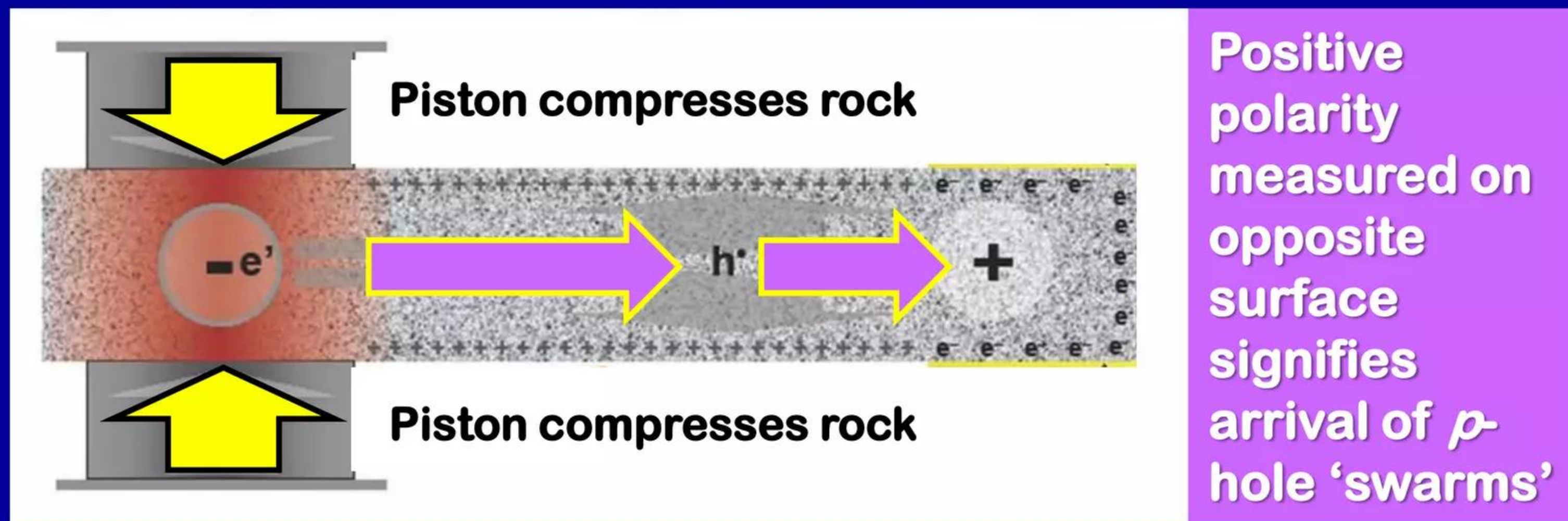
Energetic threshold for peroxy cleavage *very* low: handling rocks creates *p*-holes



p -holes are created in controlled laboratory experiments

Compressed rocks generate mobile positively charged quasiparticles

Positive polarity emerges on distant surface after propagation thru sample rocks



Adapted from Figures by Freund *et al.*

Dahlgren *et al.* recently criticized Freund measurements

Did not follow Freund's very detailed published experimental protocols

Their claimed null results are invalid because experiments conducted improperly

“Comparison of the stress-stimulated current of dry and fluid saturated gabbro samples”
R. Dahlgren *et al.*, *Bulletin of the Seismological Society of America* 104 pp. 2662 (2014)
<http://www.crossref.org/iPage?doi=10.1785%2F0120140144>

- ✓ Dahlgren *et al.* published paper in which they claimed to have conducted lab experiments which produced data that cast doubt on the existence of Freund's p -holes
- ✓ Key problem with their experimental work and resulting reported data is that they did not explicitly follow Freund's published, very detailed experimental protocols
- ✓ They blatantly ignored the well-established fact that strain-induced creation of p -holes occurs at *extremely low* activation thresholds; simply handling rocks when setting-up an experiment will generate small fluxes of p -holes; need 0 baseline to measure properly
- ✓ Began measurements of positive currents only after subjecting rocks to significant amounts of variable compressive strain for variable periods of time; since only finite numbers of p -holes can potentially be generated from a given sample of rock at time t_0 , by the time they began measurements, large fractions of the total p -holes produced had already propagated and dissipated --- the inadvertent result of their peculiar method for conducting the experiments was to drastically minimize total measured p -hole fluxes
- ✓ **Dahlgren *et al.*'s claimed null results are thus invalid and do not refute Freund's data**

Johnston's 2001 *JGR* paper also consistent with p -holes

Dahlgren's coauthor published experimental data that supports Freund

Experimental results explained w. RFD; causation could just as easily be p -holes

"Rapid fluid disruption [RFD]: a source for self-potential anomalies on volcanoes"

M. Johnston *et al.*, *Journal of Geophysical Research* 106 pp. 4327 - 4335 (2001)

http://www.researchgate.net/publication/241581353_Rapid_fluid_disruption_A_source_for_self-potential_anomalies_on_volcanoes

- ✓ Quoting directly from the abstract, **"Self-potential (SP) anomalies** observed above suspected magma reservoirs, dikes, etc., on various volcanoes (Kilauea, Hawaii; Mount Unzen, Japan; Piton de la Fournaise, Reunion Island, Miyake Jima, Japan) result from transient surface electric fields of tens of millivolts per kilometer and **generally have a positive polarity**. These SP anomalies are usually attributed to electrokinetic effects where properties controlling this process are poorly constrained. **We propose an alternate explanation that contributions to electric fields of correct polarity should be expected from charge generation by fluid vaporization/disruption [RFD]."** Note: similar + anomalies have been reported since mid-1970s
- ✓ RFD mechanism proposed by Johnston *et al.* is physically plausible explanation and consistent with data reported in their laboratory experiments with granite. That said, in a careful reading of the paper it appears to me that Freund p -holes would be an equally plausible explanation; those interested are urged to read the paper and decide for themselves whether they concur
- ✓ In the fresh light of what is known today about Freund p -holes, geophysicists may find it very worthwhile and quite illuminating to reexamine extant literature to locate previously published papers such as this one which reported measurements of positive polarity anomalies. It might very well be determined that for some such data, p -holes may provide a much better and more satisfactory explanation for such observations versus previously proposed causative factors

Other researchers have observed p -holes and neutrons

These fascinating reports involve third-party measurements in Nature

Their data is consistent with Freund p -holes and Widom-Larsen theory of LENRs

“A large self-potential anomaly and its changes on the quiet Mt. Fuji, Japan”

K. Aizawa, *Geophysical Research Letters* 31 pp. L05612 - 05615 (2004)

<http://onlinelibrary.wiley.com/doi/10.1029/2004GL019462/full>

- ✓ So-called “self-potential anomaly” at summit could represent the continuous arrival of ‘swarms’ of positively charged p -holes associated with emergence of new fumaroles --- this is consistent with Freund’s theoretical expectations

“Observation of the prior earthquake effect on the flux of environmental neutrons, gamma-radiation, and on the local electric field in Tien-Shan mountain”

N. Salikhov *et al.* Cornell preprint *arXiv* (2013)

<http://arxiv.org/abs/1301.6965>

- ✓ Earthquake activity at Tien-Shan mountain associated with same type of “positive polarity anomaly” as seen by Aizawa at Mt. Fuji summit; dip in measured gamma radiation just prior to quake (formation of heavy electrons converts MeV gammas directly to infrared) and increases in low energy neutron fluxes afterwards are consistent with the Widom-Larsen theory of LENRs and would thus be expected

Take-away: p -holes cause positive polarity anomalies; provide input energy for LENRs

Antonova & Zhumabayev report more Tien-Shan results

Observed: positive polarity + anomalies correlated with earthquakes

“Anomalies of the electric field can be considered as precursors of earthquakes”

“Response of the activation of seismic processes in temporary and spectral characteristics of electric field on Tien-Shan” Vienna, Austria April 27 thru May 7, 2014
V. Antonova & B. Zhumabayev, *Geophysical Research Abstracts* 16 EGU2014-2610 (2014)
<http://adsabs.harvard.edu/abs/2014EGUGA..16.2610A>

- ✓ Quoting directly from the abstract, “Eight events for 2 days with a magnitude of more than 4.0 occurred on May 1-2, 2011. The main shock of magnitude 5.4 occurred on May 1st at 02:31 UT, 76 km North East of Almaty. Unusual temporal variations of the electric field with amplitude achieving the values of 6-7 kV/m were recorded as during series of earthquakes, and before them (April 28, 30). The duration of the electric field disturbances were 5-12 hours (5 hours on 28.04.2011 and 12 hours on 30.04.2011). **Another characteristic of the anomalous variations of the electric field was their positive polarity.** The analysis of meteorological and cosmophysical conditions was carried out for the purpose of identification of disturbance sources. It is shown that characteristics of temporal anomalous variations of the electric field don't correspond to these sources of disturbances. **It was concluded that the cause of anomalous variations can be sources of the lithospheric origin only. Respectively, anomalies of the electric field can be considered as precursors of earthquakes.”**

- ✓ If one accepts the proposition that these positive polarity anomalies are in fact caused by Freund p -holes, then one can conclude that they may also be precursor signs for earthquakes

Take-away: p -holes are likely earthquake precursors if they create + polarity anomalies

What process(es) produce(s) these 'background' neutrons?

Ambient neutron fluxes at ground level on Earth vary with lunar cycle

"Anomalous behavior of thermal neutrons...correlates with...seismic activity"

"Correlation of variations in the thermal neutron flux from the Earth's crust with the Moon's phases and with seismic activity"

V. Alekseenko *et al.*, *Izvestiya, Physics of the Solid Earth* 45 pp. 709 - 718 (2009)

<http://link.springer.com/article/10.1134%2FS106935130908010>

- ✓ Abstract: "The results of the long-term recording of thermal neutron flux near the Earth's surface with the use of an unshielded scintillation thermal-neutron detector are presented. **The data obtained indicate the presence of periodic variations in the thermal neutron flux with the lunar diurnal and the lunar monthly periods.** A hypothesis about the existence in the Earth's crust of radon-neutron tidal variations in the concentration of thermal neutrons, correlated with the Moon's phases and which have the gravitational origin, is formulated and confirmed experimentally. A simple mathematical model is proposed, which satisfactorily describes the observed variations. **The case of the anomalous behavior of thermal neutrons is presented, which correlates with the high local seismic activity.**"

- ✓ Similar to oceans, strain forces in rocks comprising Earth's upper crust will go up and down in synchrony with variation of tidal gravitational pull from the Moon as it circles Earth in its orbit. More p -holes will be generated and propagate through the crust as tidal forces increase strain put on crustal rocks. **If dissipation of p -holes provided input energy for LENR processes, would expect some components of total thermal neutron flux to mirror the lunar cycle, as observed**

Take-away: neutrons produced by LENRs in Earth's crust can also vary with lunar cycle

Widom-Larsen LENR theory is extremely multidisciplinary

Theoretical breakthrough achieved by combining multiple disciplines

Analogous to Maxwell: integrates many LENR effects into coherent whole

Fully explains previously inexplicable characteristic features in condensed matter systems in which electric fields dominate:

- ✓ Absence of deadly energetic neutrons (ultralow energy are almost all captured locally) and hard MeV gamma radiation (gammas directly converted to IR by heavy-mass electrons)
- ✓ Insignificant production of long-lived radioactive isotopes (serial beta-decays of short-lived, neutron-rich isotopes)
- ✓ Plus an array of anomalous effects that have been observed and reported in various scientific journals for over 100 years

Basic reactions in Widom-Larsen theory are simple

Protons or deuterons react directly with electrons to make neutrons

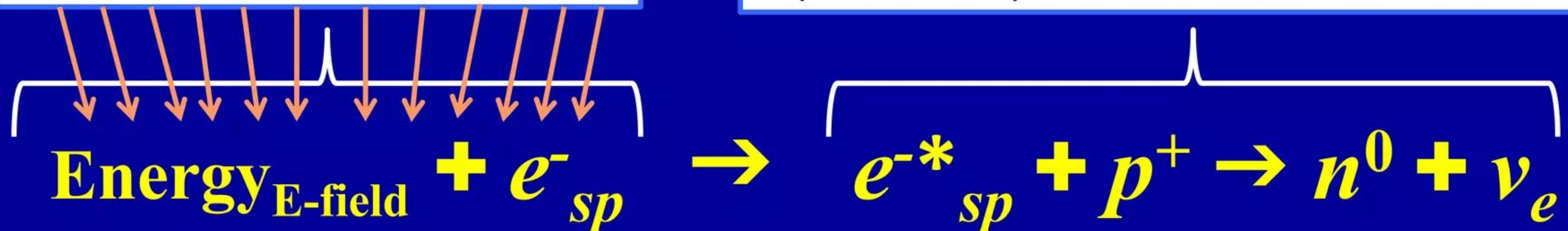
Neutrons are then captured by other atoms → catalyze nuclear transmutations

Input energy comes from E-M fields

Collective many-body quantum effects: many electrons each donate little bits of energy to a much smaller number of electrons that are also embedded in same high electric field

Ultralow energy neutrons mostly captured locally

Quantum electrodynamics (QED): smaller number of electrons that absorb energy from electric field can increase their effective masses ($m = E/c^2$) to point where they can react directly with protons (or deuterons) to make neutrons and neutrinos



ν_e neutrinos: ghostly unreactive photons that fly-off into space; n^0 neutrons: capture on nearby atoms

Neutron-capture-catalyzed transmutations release energy stored in atoms:

Neutrons + atomic nuclei $\xrightarrow{\text{Transmutation}}$ heavier elements + decay products

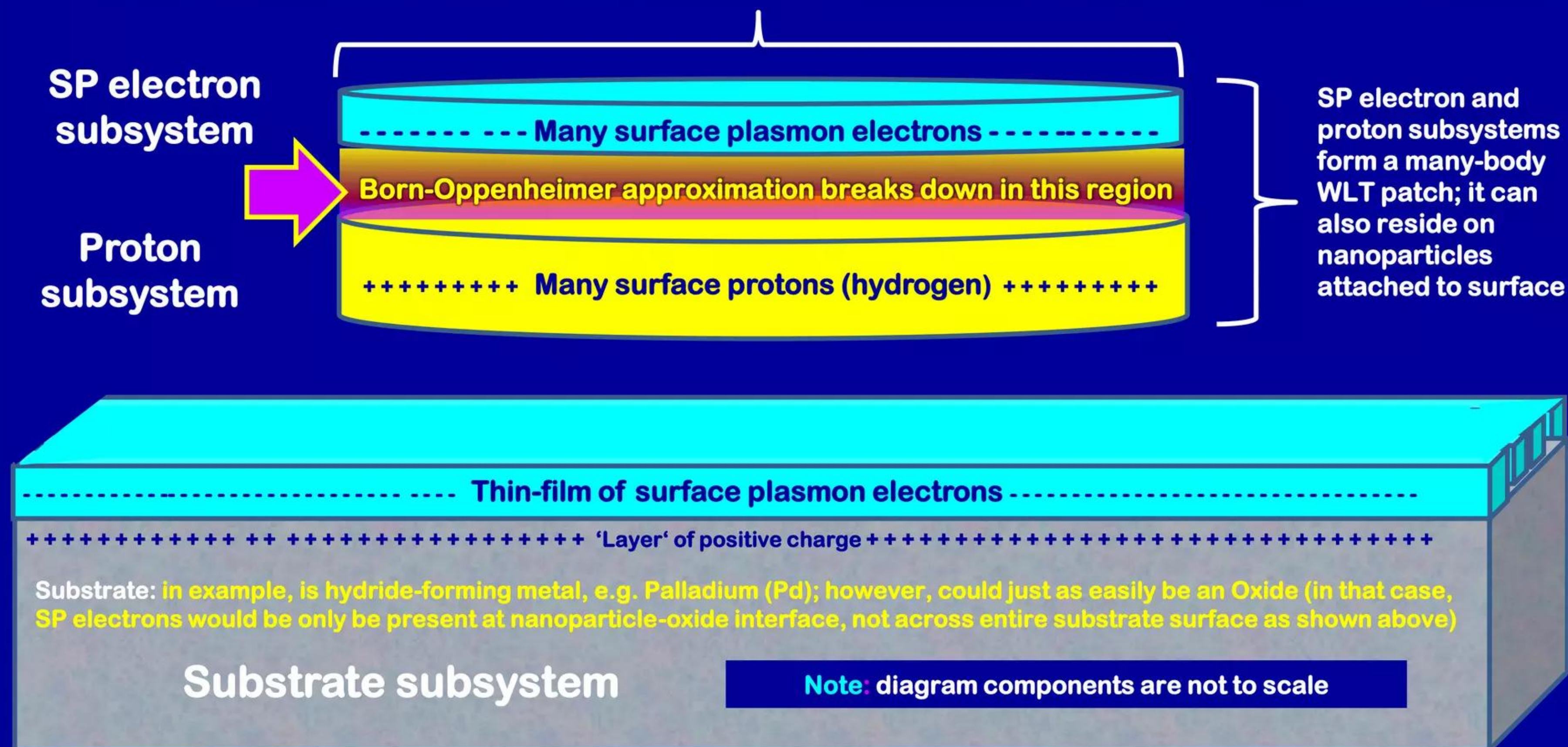
Releases vast amounts of stored nuclear binding energy as energetic particles/photons that create heat

Anatomy of a micron-scale LENR-active surface site

Conceptual overview of many-body patches that form on surfaces

SP electrons and protons all oscillate collectively and mutually Q-M entangled

Diameters of many-body patches randomly range from several *nm* up to perhaps ~100+ microns



Input energy creates very high electric fields in surface sites

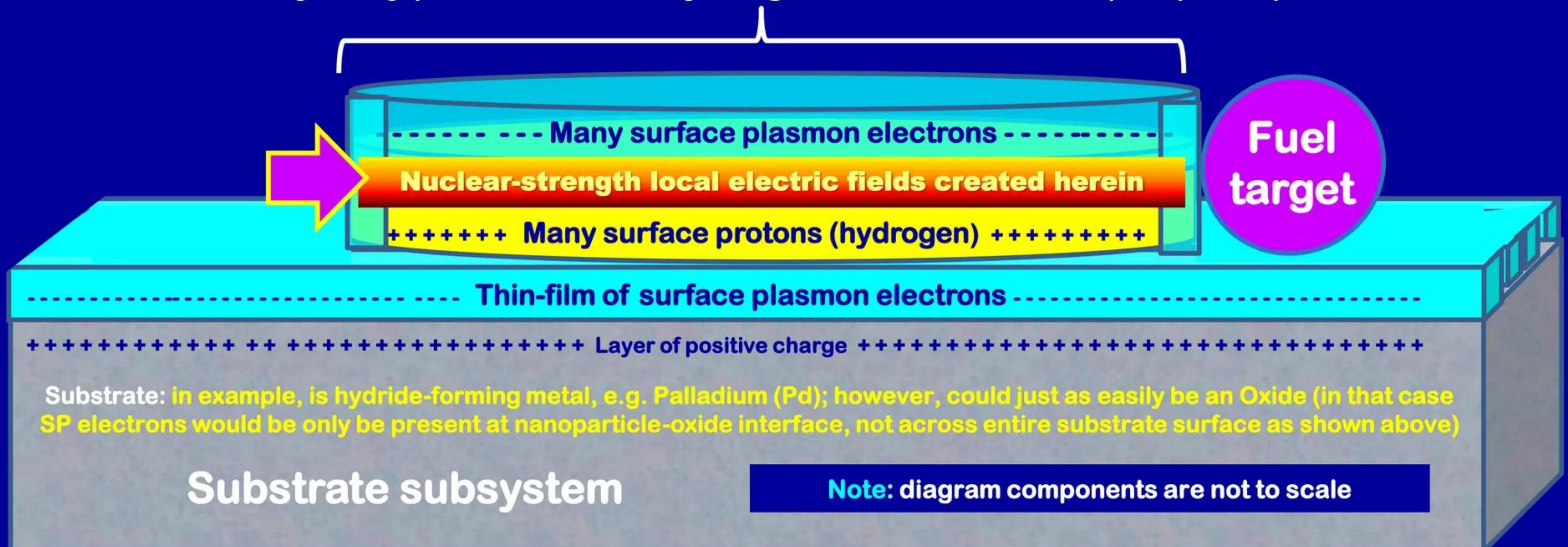
Born-Oppenheimer breakdown creates nuclear-strength electric fields

High electric fields increase effective masses of some patch SP electrons

Sufficient input energy will create local E-fields $> 10^{11}$ V/m within patch which permits:



Diameters of many-body patches randomly range from several *nm* up to perhaps $\sim 100^+$ microns



LENRs occur in microscopic active sites found on surfaces

Many-body collections of protons and electrons form spontaneously

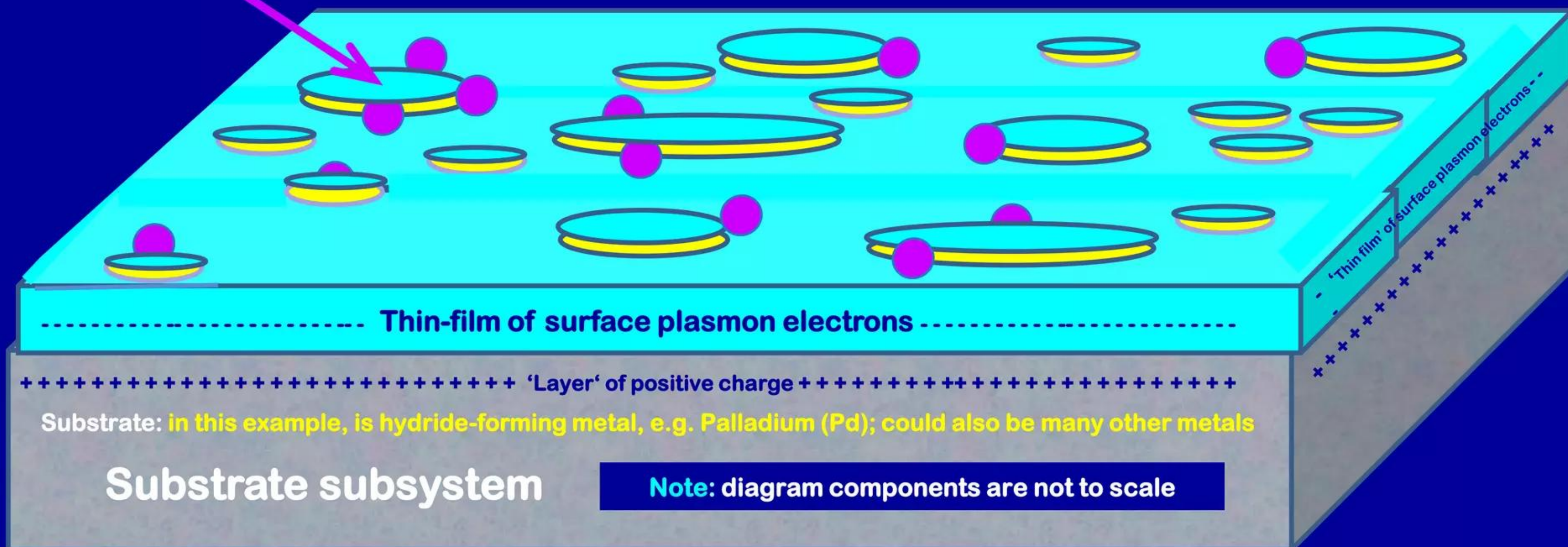
Ultralow energy neutrons are produced and captured close to LENR sites

Intense heating in LENR-active sites will form μ -scale event craters on substrate surfaces

After being produced, neutrons will capture on fuel targets:



Often followed by β^{-} decays of neutron-rich intermediate isotopic products



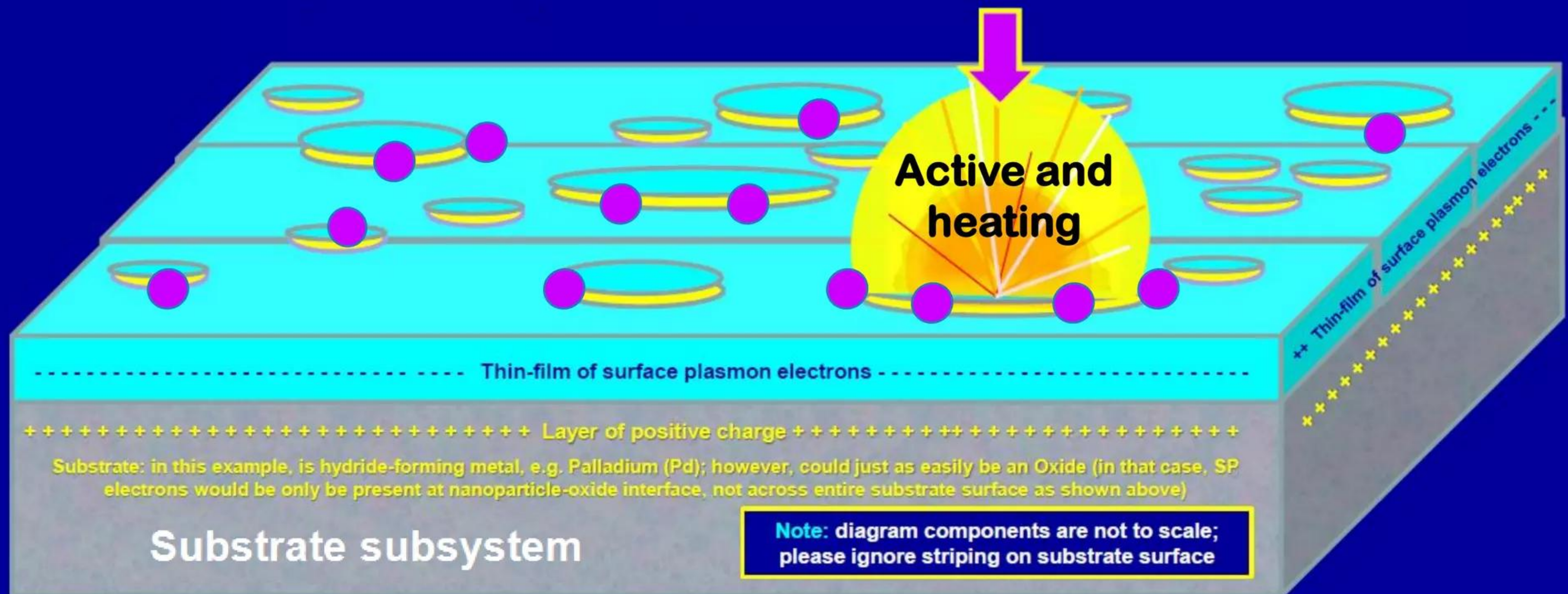
LENR-active sites only survive for ~200 - 400 nanoseconds

Intense heating destroys the local quantum coherence and site 'dies'

Releases nuclear binding energy stored in fuels and transmutes elements

Explosive LENR 'hotspots' create distinctive surface craters ~2 - 100 microns in diameter

Observed on LENR-active substrates post-experiment with scanning electron microscopes (SEM); LENR transmutation products are found in same areas with SIMS



LENR transmutation products seen near surface craters

Palladium transmuted to Silver with ULM neutron capture and β -decay

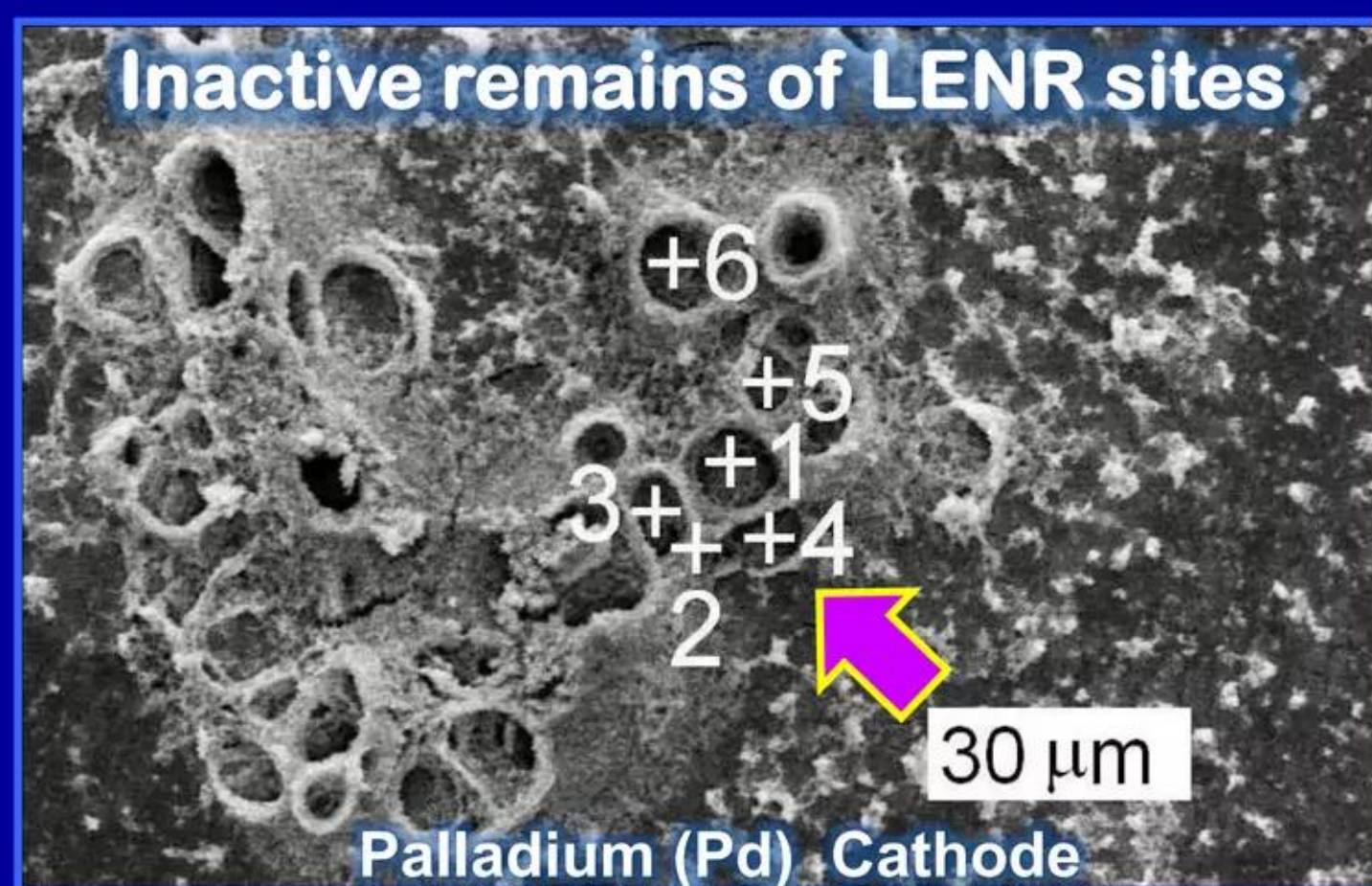
Following nuclear reactions explain how Silver was produced in the experiments

neutron capture process

β - nuclear decay process

[Multiple stable Palladium isotopes] $\text{Pd} + n \rightarrow$ [unstable neutron-rich Pd isotopes] \rightarrow Ag [two stable Silver isotopes]

LENRs: Zhang & Dash (2007) - Fig. 8



Note: Pd boiling point = 2,970 °C

Free copy of
Zhang & Dash
(2007) paper at:
<http://www.lenr-canr.org/acrobats/ZhangWSexcessheat.pdf>

LENRs: Zhang & Dash (2007) - Fig. 9

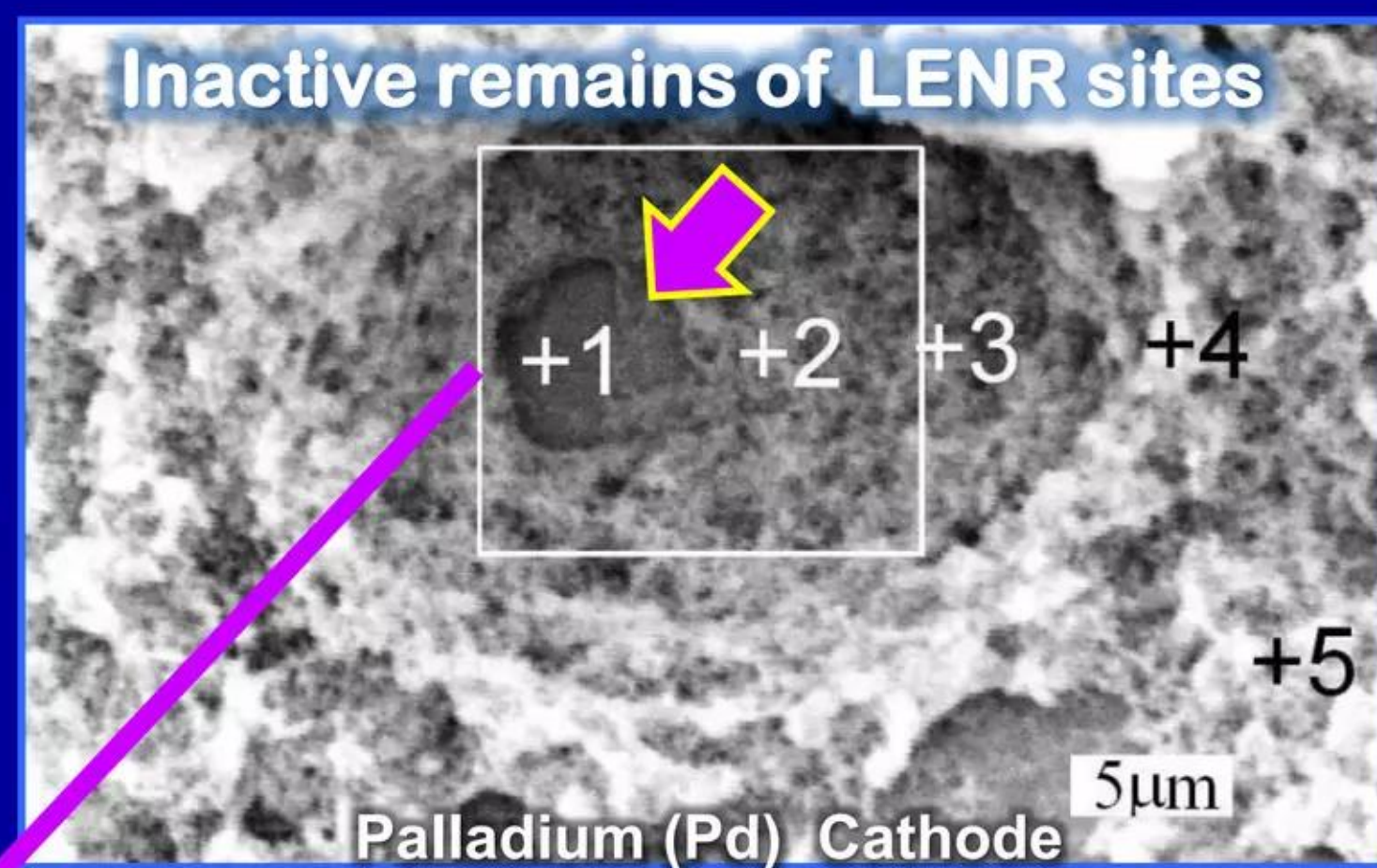


Fig. 9. SEM picture of crater at another time. SEM No.WS060607Pd-H-CC-i2-2kX

Quoting: “The most common finding is that Silver occurs in craters, such as those shown in Fig. 8. These craters with rims almost certainly formed during electrolysis. Pt deposition was concentrated on these protruding rims.”

Zhang & Dash: Table IX. Relative atomic percent concentrations of Silver (Ag) in area and spots shown in Fig. 9

Spot #	wa*	area**	+1	+2	+3	+4	+5
Ag/(Pd+Ag)	1.2 +/- 0.5	5.6 +/- 0.4	6.8 +/- 0.4	5.6 +/- 0.3	6.3 +/- 0.4	3.6 +/- 0.6	1.2 +/- 0.5

*wa = whole entire area comprising image in Fig. 9

** area = delimited by the white square outlined in Fig. 9

Stars, supernovae, and fission reactors are optional

Widom-Larsen theory suggests nucleosynthesis may be common

While natural LENR reaction rates low, effects accumulate over geological time



Lightning is like exploding wires



Earth: LENRs in many places

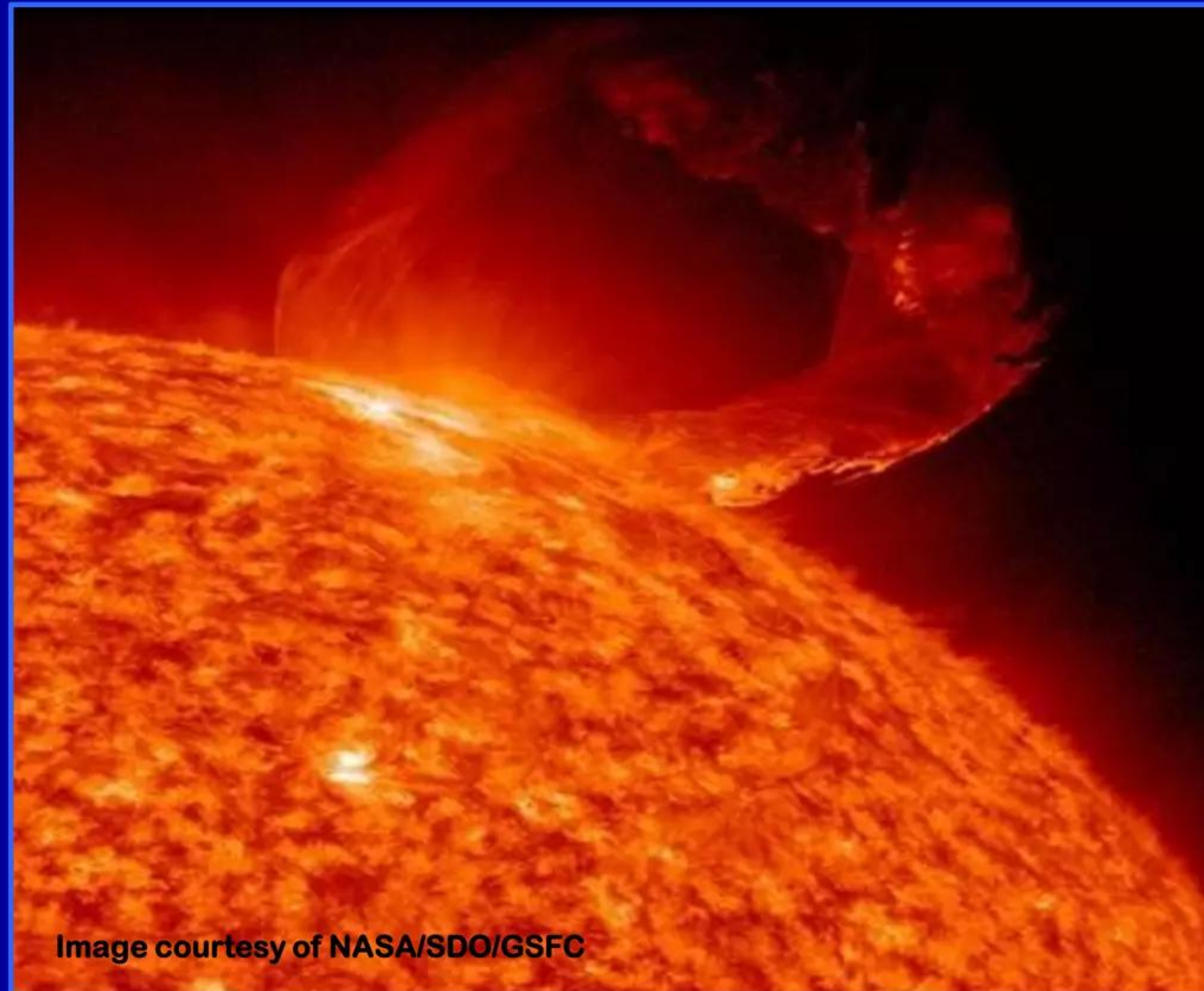
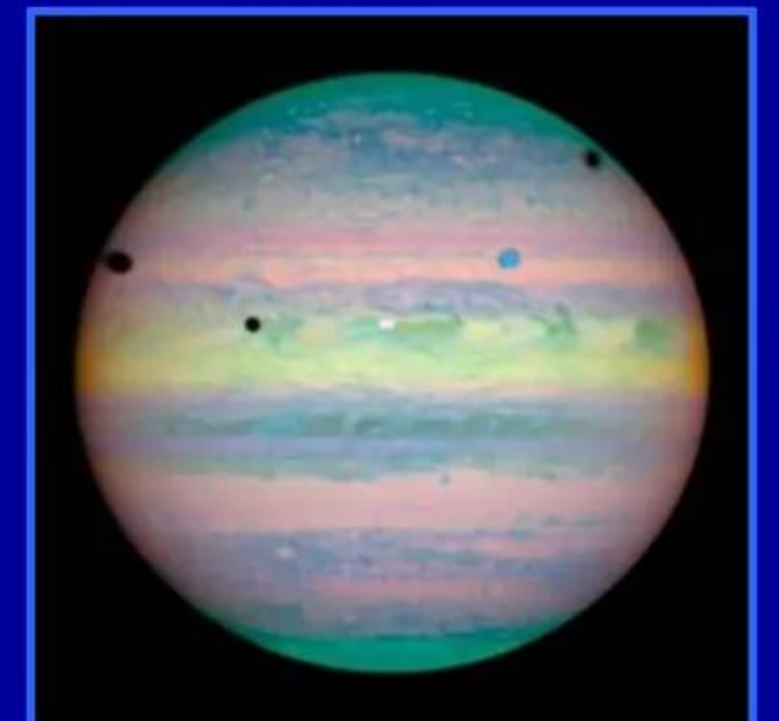


Image courtesy of NASA/SDO/GSFC

March 19, 2011 – image of major eruption on the surface of the Sun
Nucleosynthesis also occurs in photosphere, flux tubes, and corona



Very dusty Eagle Nebula



Jupiter is not just a 'failed star'

Reports of major isotopic anomalies are accumulating

For years researchers assumed $^{238}\text{U}/^{235}\text{U}$ ratio was invariant - it is not

What causes unexpected variance: just chemical fractionation or LENRs also?

" $^{238}\text{U}/^{235}\text{U}$ systematics in terrestrial Uranium-bearing minerals"

J. Hiess *et al.*, *Science* 335 no. 6076 pp. 1610-1614 (2012)

<http://www.sciencemag.org/content/335/6076/1610.full>

Highest variability in the $^{238}\text{U}/^{235}\text{U}$ ratio occurs in terrestrial materials originating in low-temperature chemical precipitates, redox ores, and/or sedimentary environments. **This category accurately describes the natural environment found in the Rifle, Colorado, study site in which soil bacteria are clearly involved in shifting the $^{238}\text{U}/^{235}\text{U}$ ratio as well as triggering significant, time-varying shifts in Sulfur isotope abundances during roughly contemporaneous, spatially nearby redox reactions. Fig. 3 again strongly suggests that terrestrial bacteria are the culprits behind observed isotopic shifts in Uranium and Sulfur in soils and rocks.** Crucial question: are these observed shifts produced by 'ordinary' chemical fractionation or LENR processes or both? This issue begs for further investigation.

Reports of major isotopic anomalies are accumulating

Bopp *et al.* show that soil bacteria are altering $^{238}\text{U}/^{235}\text{U}$ isotopic ratios

Question as to whether cause is chemical fractionation or LENRs still unresolved

“Uranium $^{238}\text{U}/^{235}\text{U}$ isotope ratios as indicators of reduction: results from an *in situ* biostimulation experiment at Rifle, Colorado, U.S.A.”

C. Bopp *et al.*. *Environmental Science & Technology* 44 pp. 5927 - 5933 (2010)

<http://pubs.acs.org/doi/abs/10.1021/es100643v>

- ✓ Although not explicitly acknowledged by chemical isotopic fractionation theorists, an intrinsic fundamental assumption underlying all such theory and interpretation of data is that no nucleosynthetic processes are occurring anywhere in any of these systems, at any time, that are capable of altering isotope ratios and/or producing new mixtures of different elements over time; ergo, they are assuming that chemistry alone explains everything
- ✓ If Widom-Larsen theory LENRs occur out in Nature, albeit at extremely low rates, above-noted fundamental assumption is evidently wrong for some subset of such anomalous isotopic data
- ✓ If hypothesized chemical fractionation mechanisms truly worked as well on Uranium isotopes in non-gas-phase systems as proponents claim, one would presume that such effects would have been utilized long ago in at least one government nuclear weapons or commercial Uranium enrichment program somewhere in the world, e.g. Iran today. To our knowledge, during the past 70 years they have never been used for such a purpose anywhere. This suggests that so-called “nuclear field shifts” are incorrect explanations for observed changes in Uranium isotope ratios

Many new exciting discoveries about bacterial energetics

“Extracellular reduction of Uranium via *Geobacter* conductive pili as a protective cellular mechanism”
D. Cologgi *et al.*, *Proceedings of the National Academy of Sciences* (PNAS) 108 pp. 15248 - 15242 (2011)
<http://www.pnas.org/content/108/37/15248.full.pdf+htm>

- ✓ Many papers involving the use of various types of very sensitive mass spectroscopy analysis report anomalous isotopic shifts in elements ranging from Hydrogen to Uranium that are obviously associated with activities of many bacterial species, especially the extremophiles
- ✓ Key question: how much might be caused by LENRs vs. just prosaic chemical fractionation?
- ✓ If some of it is LENRs, where does necessary external input energy to make ultralow energy neutrons come from? Is energetically expensive; requires equivalent of ~10 - 15 million ATP molecules to make one neutron. **It is known that electricity is ideal LENR input power source**
- ✓ Interestingly and importantly, microbiologists have recently discovered existence of highly conductive nanowires that interconnect many different species of soil and crustal bacteria. **More recently, have discovered bacteria that can live on electricity as sole energy source**
- ✓ This juxtaposition of exciting new discoveries opens-up the possibility that bacteria may be living in soils and deep in the Earth's crust that could utilize electricity as a source of input energy for driving LENR-based nucleosynthetic processes that can alter isotopic ratios

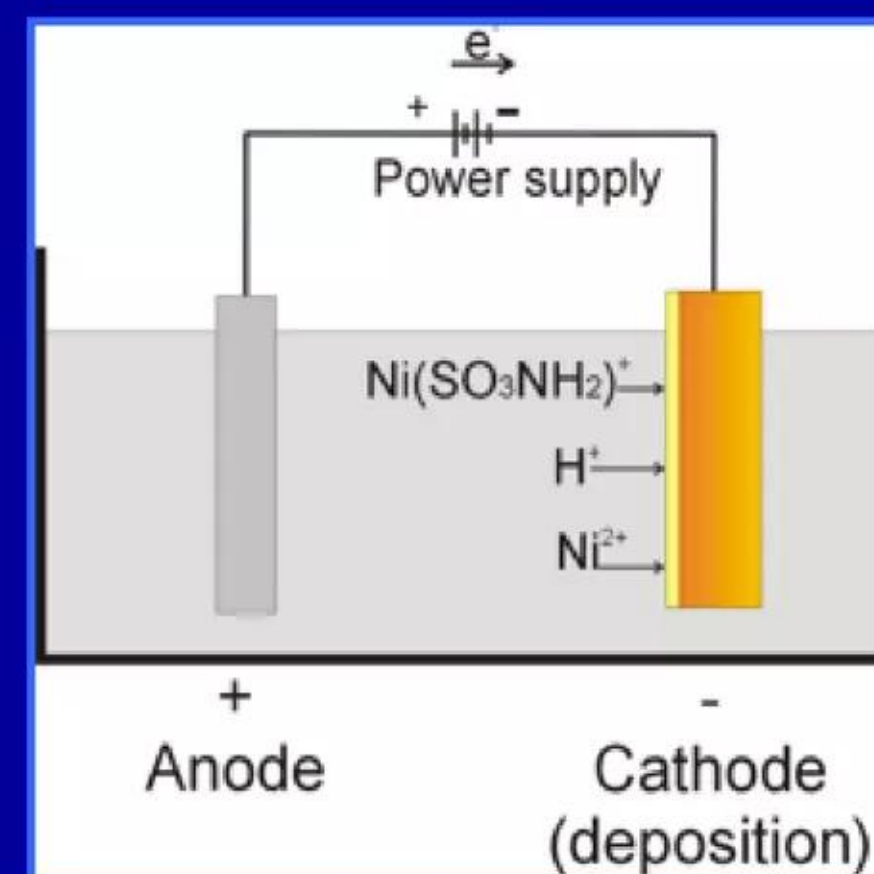
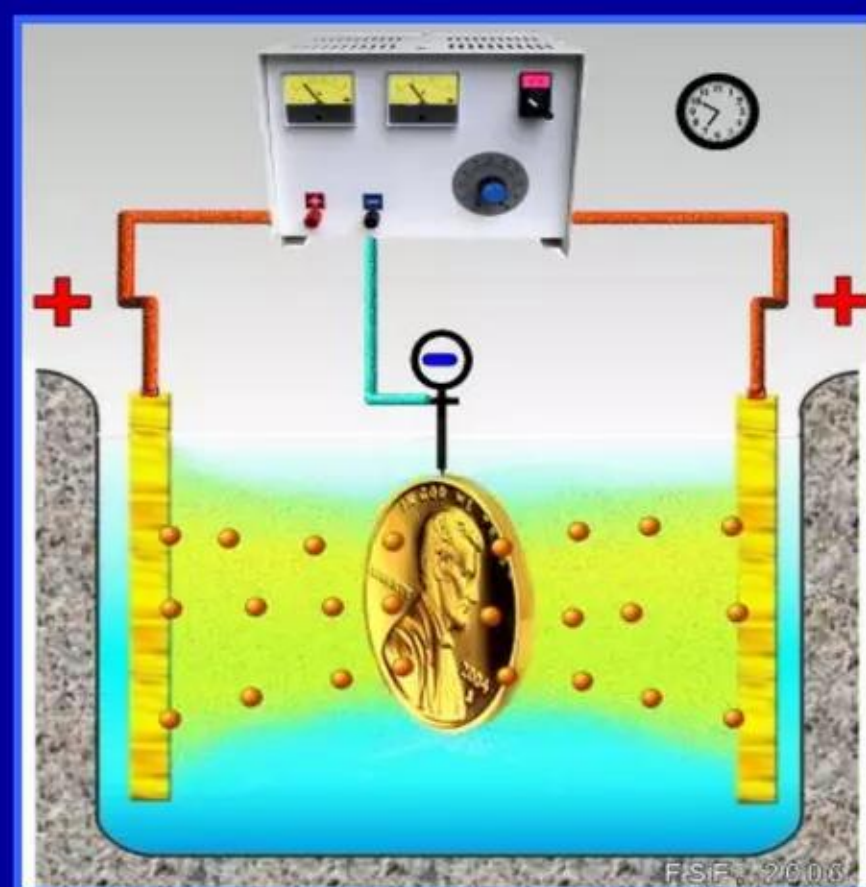
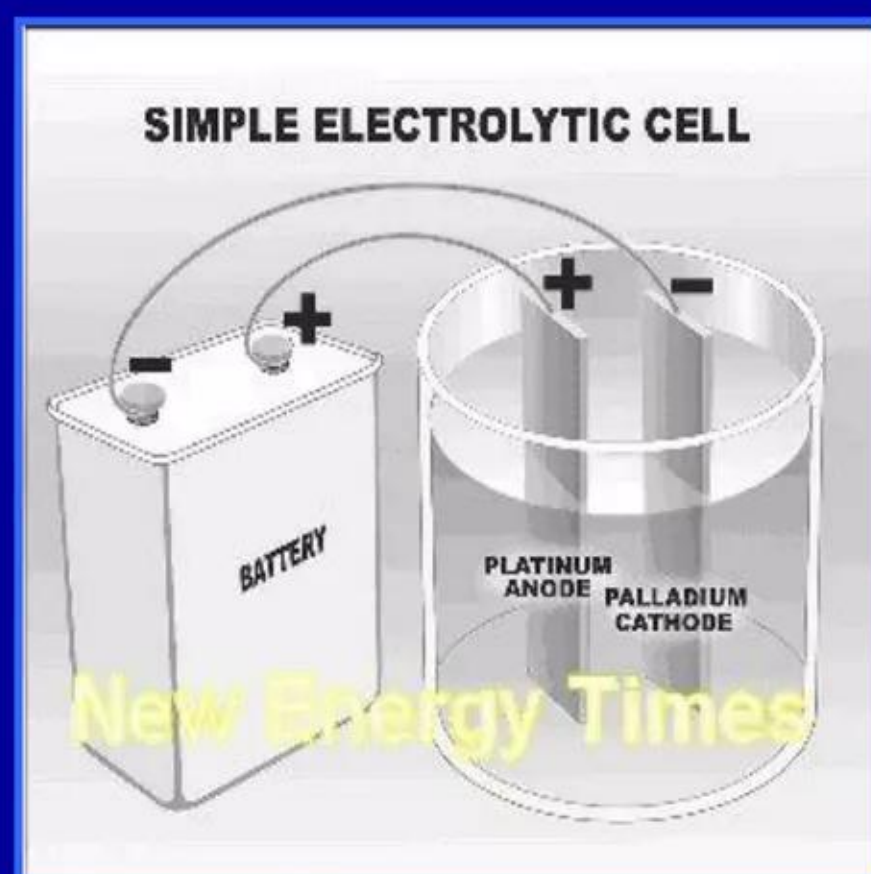
What process might potentially create source of electrical power inside the Earth that could be harvested by bacteria and used for chemical metabolism and LENR nucleosynthesis? We will see how dissipation of electronic energy by Freund p -holes could provide input energy

Are bacteria really transmuting elements out in Nature?

Possibly occurring in: soils, upper crust, undersea hydrothermal vents

Collective electronic interactions amongst bacteria akin to LENR chemical cells

Now, fascinating new facts and speculation about electric bacteria - recent exciting discoveries by microbiologists have revealed that electric potentials, currents, and nanowires are associated with the activities of a number of different species of bacteria; how might this relate to possibility of natural LENRs in hydrothermal vent systems? First, examine the concept of a LENR electrolytic chemical cell:



Above are various conceptual schematics of a type of aqueous light-water electrolytic chemical cells used in many LENR experiments (typically would use DC power supply instead of a battery as a source of electrical current). Please note that using mass spectroscopy for post-experiment analyses, LENR researchers have carefully documented and reported production (via transmutation) of minute amounts of many different elements and isotopically shifted stable isotopes on the surfaces of cathodes found in such cells. In certain cases, the array of transmutation products was quite large

Are bacteria really transmuting elements out in Nature?

Scientists discovering that “electric bacteria” may well be ubiquitous

“Shows that [bacterial] life can handle the energy in its purest form - electrons”

“Meet the electric life forms that live on pure energy”

Catherine Brahic in *New Scientist: Life* July 16, 2014

Source: <http://www.newscientist.com/article/dn25894-meet-the-electric-life-forms-that-live-on-pure-energy.html>

Quoting excerpts directly: “Unlike any other life on Earth, these extraordinary bacteria use energy in its purest form – they eat and breathe electrons – and they are everywhere.”

“Stick an electrode in the ground, pump electrons down it, and they will come: living cells that eat electricity. We have known bacteria to survive on a variety of energy sources, but none as weird as this. Think of Frankenstein's monster, brought to life by galvanic energy, except these ‘electric bacteria’ are very real and are popping up all over the place.”

“Unlike any other living thing on Earth, electric bacteria use energy in its purest form – naked electricity in the shape of electrons harvested from rocks and metals. We already knew about two types, *Shewanella* and *Geobacter*. Now, biologists are showing that they can entice many more out of rocks and marine mud by tempting them with a bit of electrical juice. Experiments growing bacteria on battery electrodes demonstrate that these novel, mind-boggling forms of life are essentially eating and excreting electricity.” **Excellent, well-written popular article**

Are bacteria really transmuting elements out in Nature?

“Such bacteria are showing up everywhere we look, says Lars Nielsen.”

“Bacterial cells that both eat and breathe electrons will soon be discovered”

“Meet the electric life forms that live on pure energy”

Catherine Brahic in *New Scientist: Life* July 16, 2014

Source: <http://www.newscientist.com/article/dn25894-meet-the-electric-life-forms-that-live-on-pure-energy.html>

Quoting excerpts directly: “Electric bacteria come in all shapes and sizes. A few years ago, biologists discovered that some produce hair-like filaments that act as wires, ferrying electrons back and forth between the cells and their wider environment. They dubbed them microbial nanowires.”

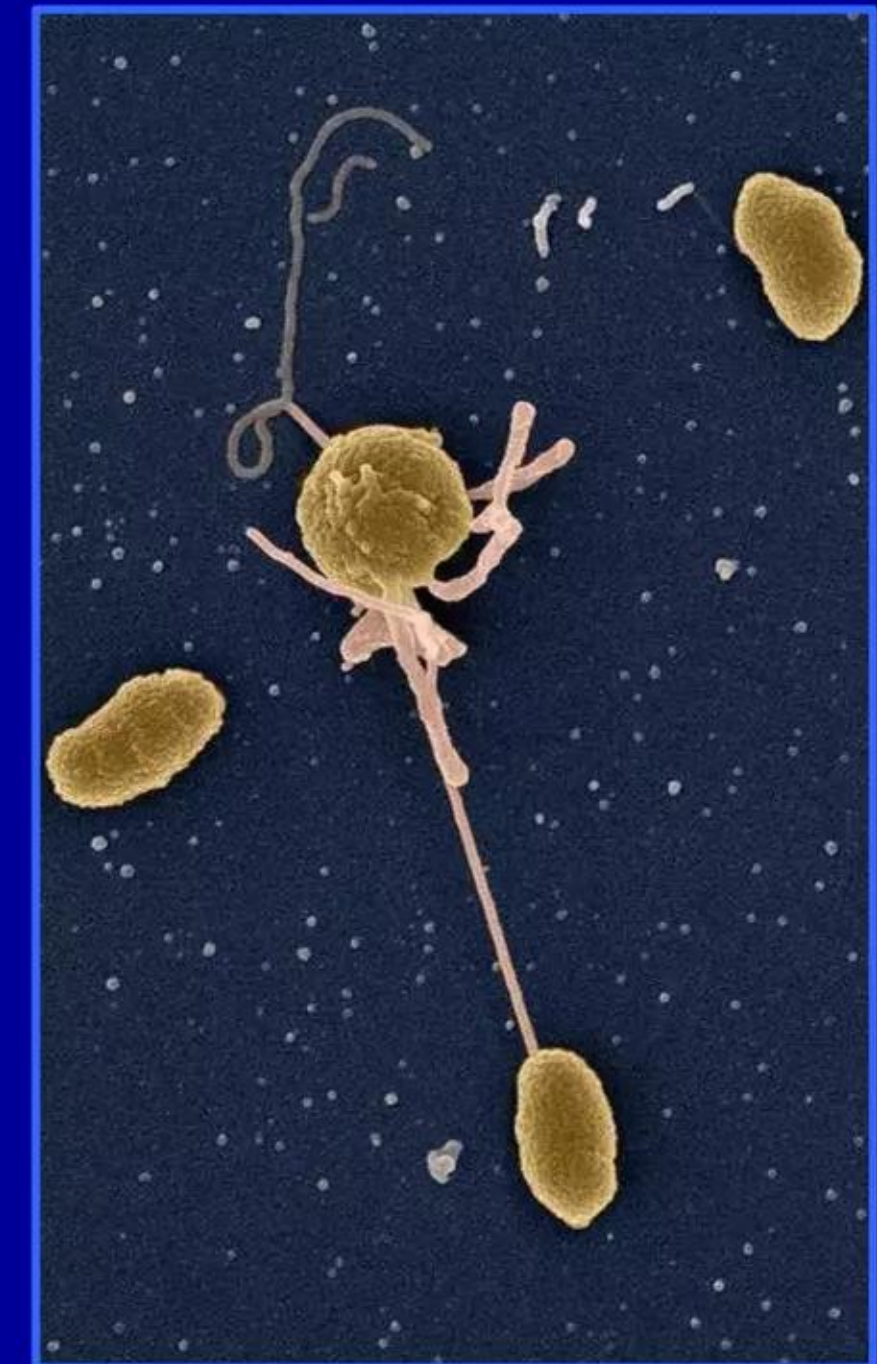
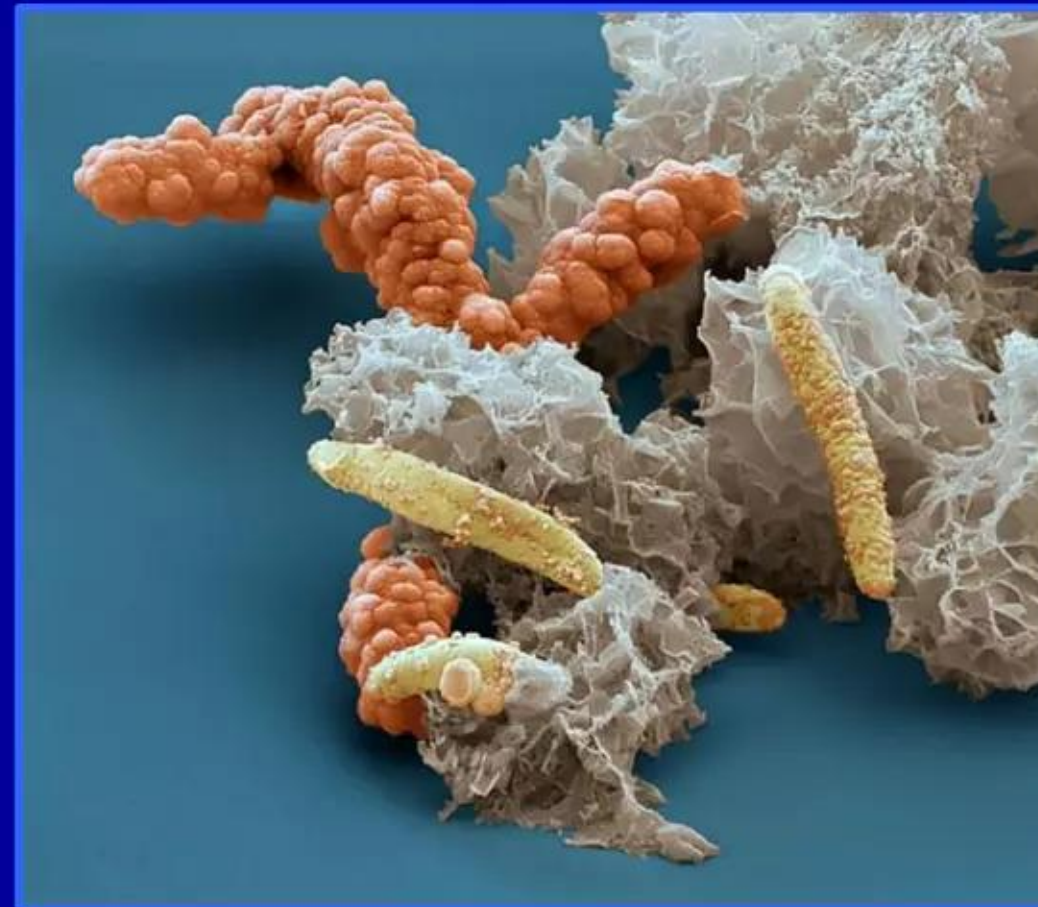
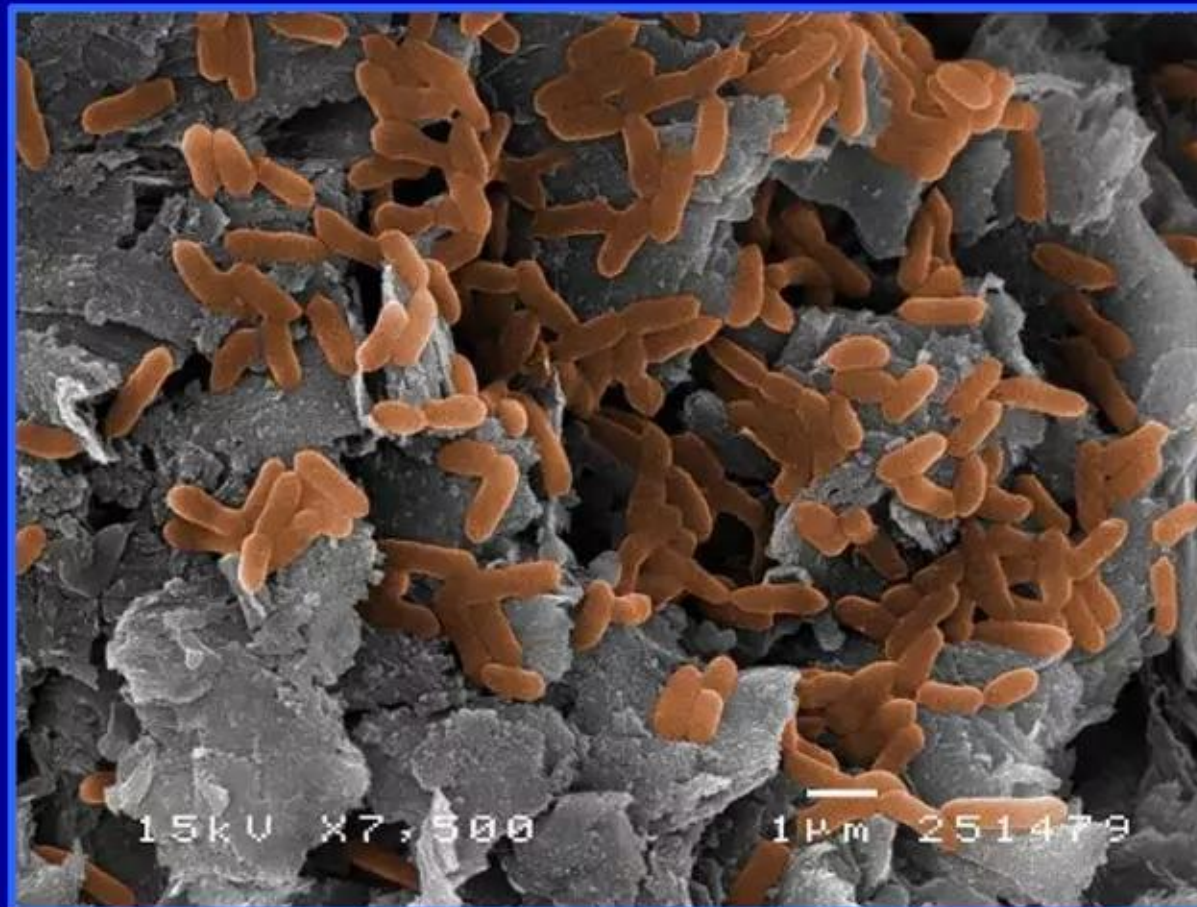
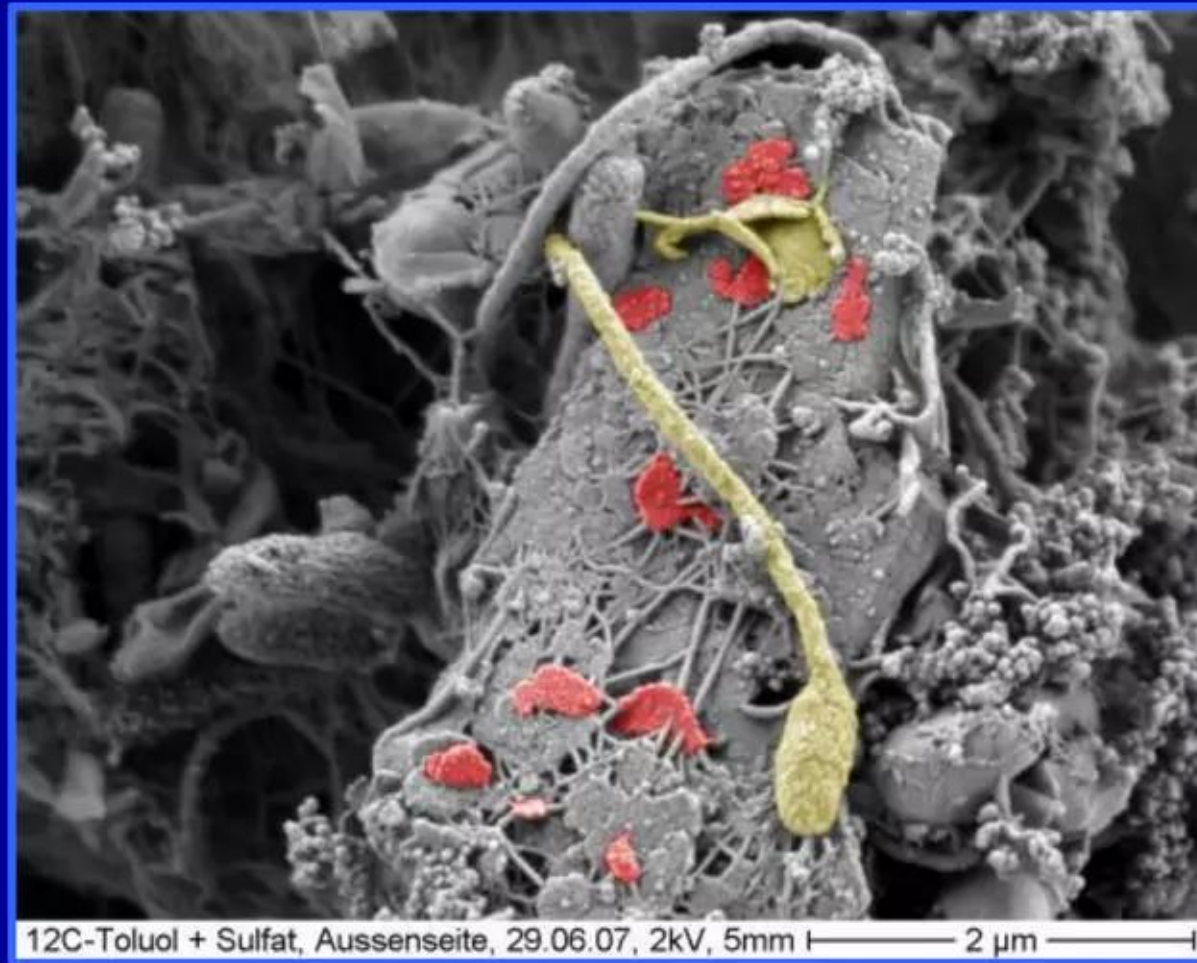
“Lars Peter Nielsen and his colleagues at Aarhus University in Denmark have found that tens of thousands of electric bacteria can join together to form daisy chains that carry electrons over several centimetres – a huge distance for a bacterium only 3 or 4 micrometres long.”

“Such bacteria are showing up everywhere we look, says Nielsen.”

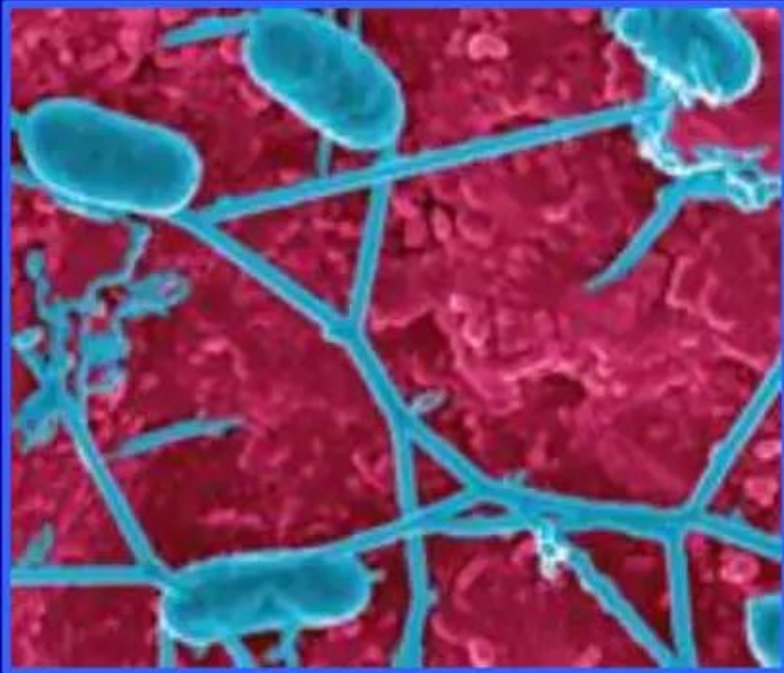
“Early work shows that such cables [bacterial nanowires] conduct electricity about as well as the wires that connect your toaster to the mains.”

Bacteria often grow in close proximity to mineral surfaces

Although not shown in all SEM images bacteria connected by nanowires

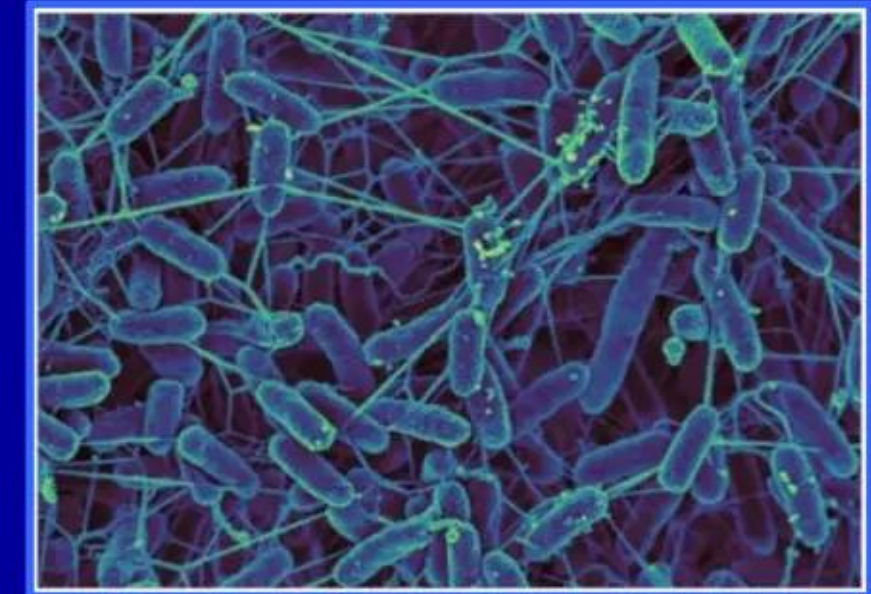


Bacteria often grow in close proximity to mineral surfaces



Geobacter sp. nanowires

Highly conductive bacterial
nanowires interconnect
bacterial cells



Shewanella oneidensis
nanowires



Typical rock surfaces are negatively charged

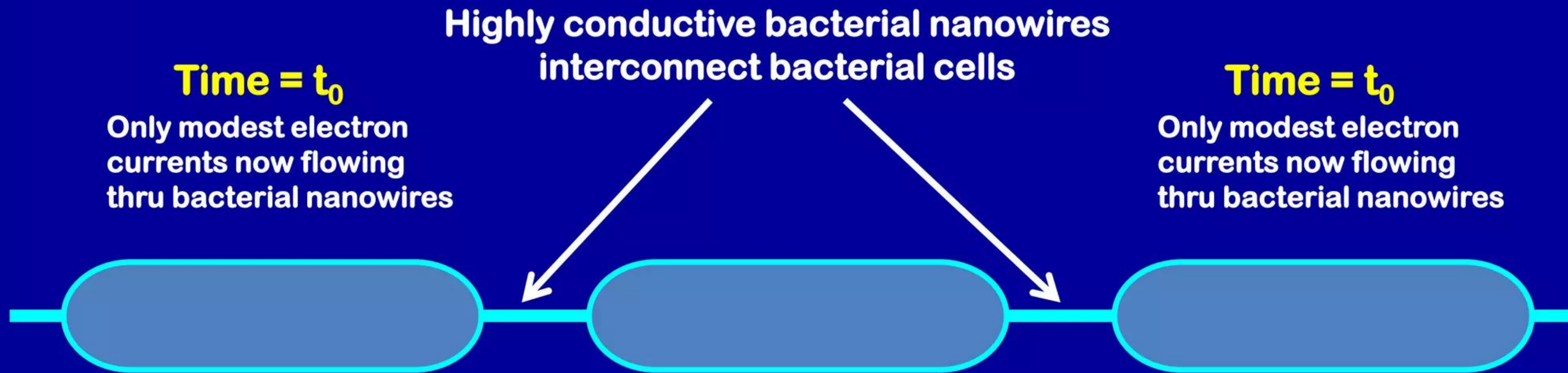
Rock substrate that is suitable conductor for Freund p -holes

Conceptual: not to scale

Bacteria interconnected by current-carrying nanowires

Mobile electrons are present at surface of conductive rock substrate

p-holes absent here; only modest currents now flowing thru bacterial nanowires



Typical rock surfaces are negatively charged

Rock substrate that is suitable conductor for Freund *p*-holes

Conceptual: not to scale

Hypothesis: *p*-hole approaches rock surface from below

Mobile electrons are present at surface of conductive rock substrate

Conceptual: many-body quasiparticle is now approaching surface (not to scale)

Time = $t_0 + 1$

Only modest electron
currents now flowing
thru bacterial nanowires

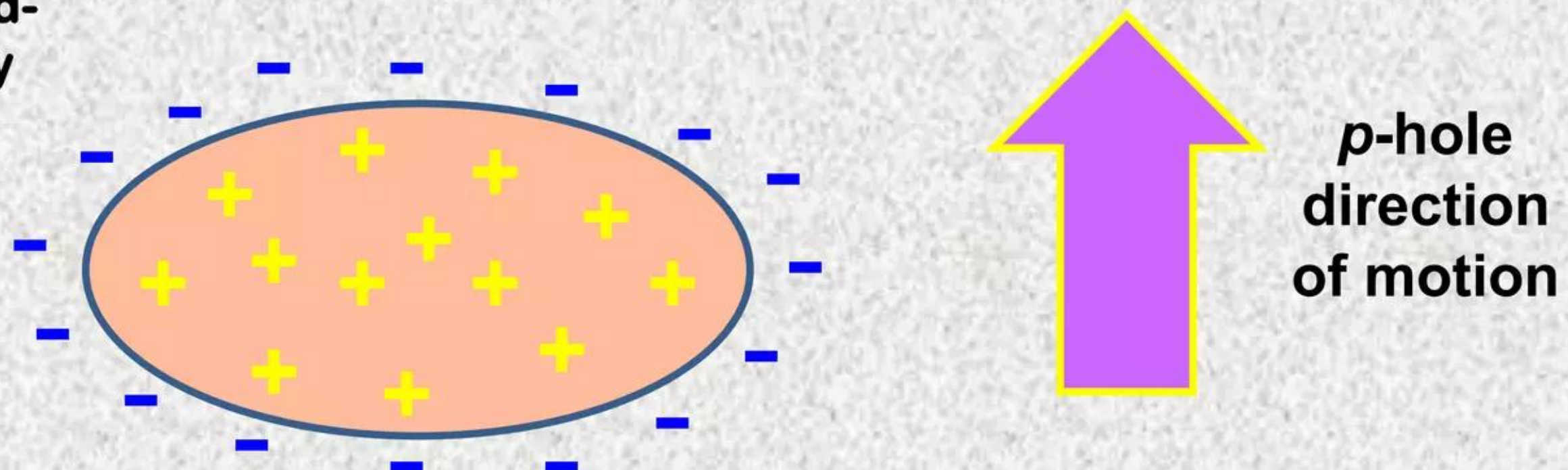
Highly conductive bacterial nanowires
interconnect bacterial cells

Time = $t_0 + 1$

Only modest electron
currents now flowing
thru bacterial nanowires



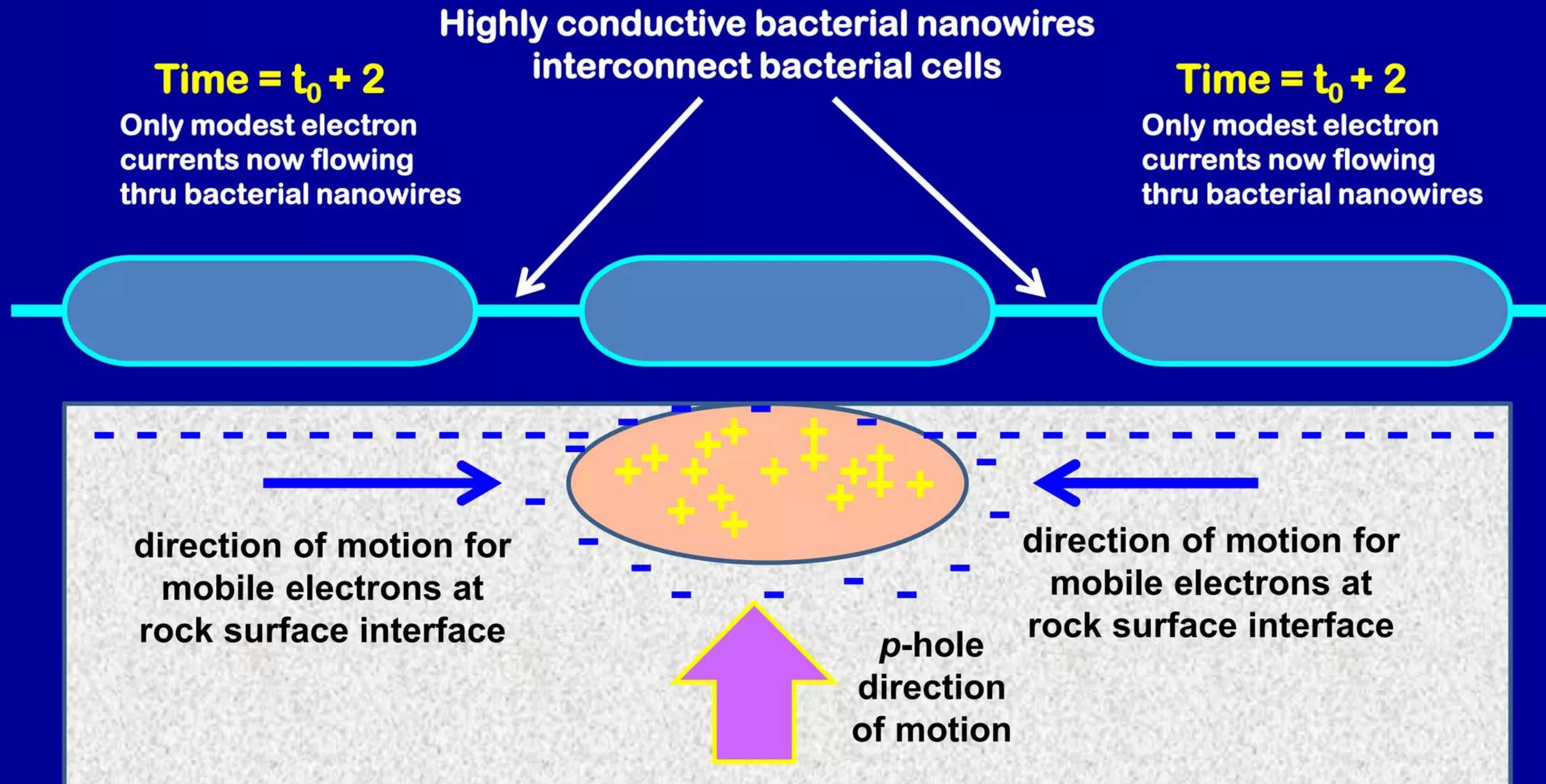
Note: detailed microphysics
of *p*-holes is not yet worked-
out; how much is chemistry
vs. how much is it a purely
electronic, quantum
mechanically entangled,
many-body collective
quasiparticle with a
positive charge???



Hypothesis: electrons rush-in to neutralize p -hole charge

Mobile electrons are present at surface of a conductive rock substrate

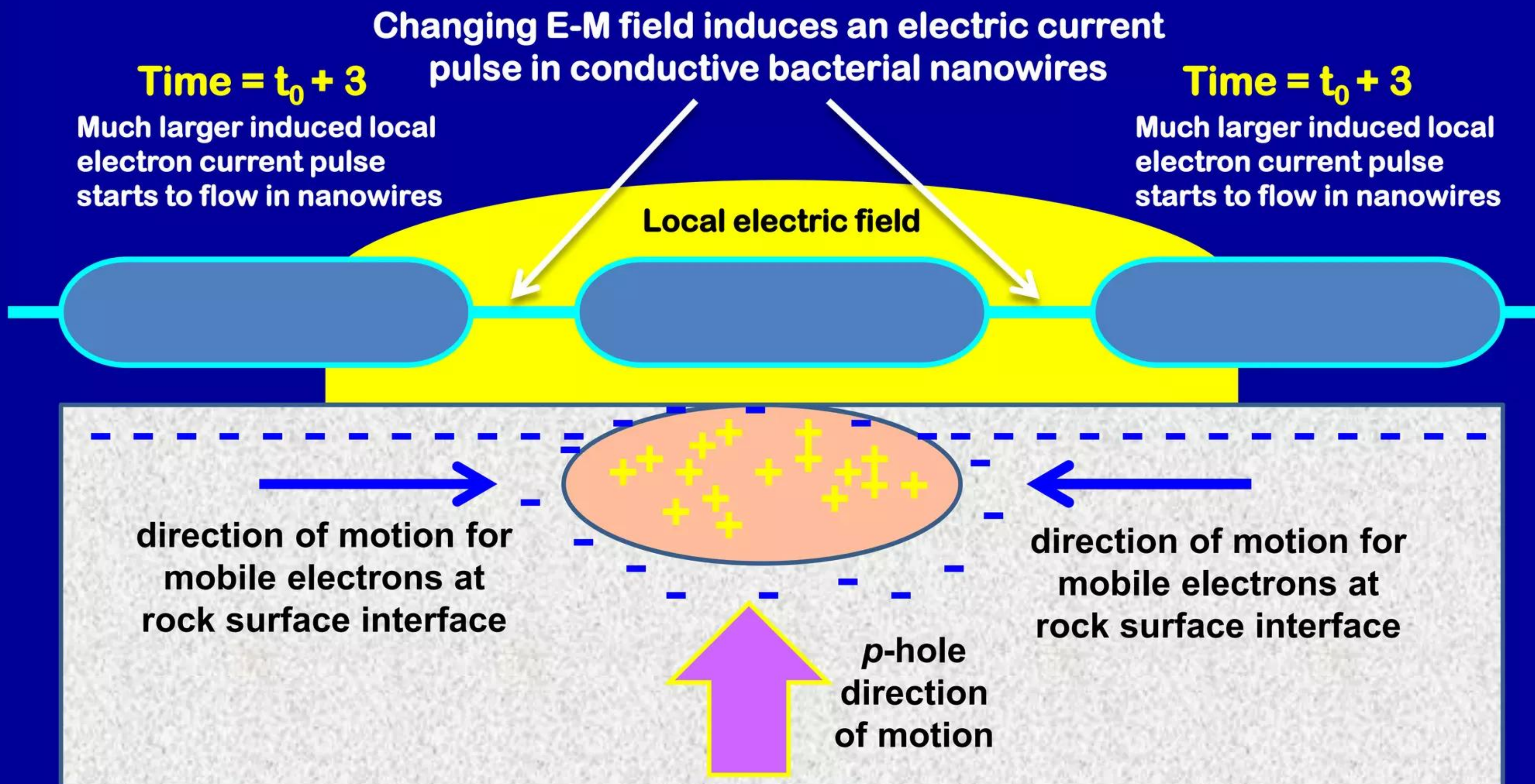
Conceptual: a many-body p -hole quasiparticle has just now impacted the surface



Hypothesis: high local E-field bathes bacterial nanowires

Mobile electrons present at surface of *p*-hole conducting rock substrate

Motion of surface charges creates high fast-changing local electromagnetic field

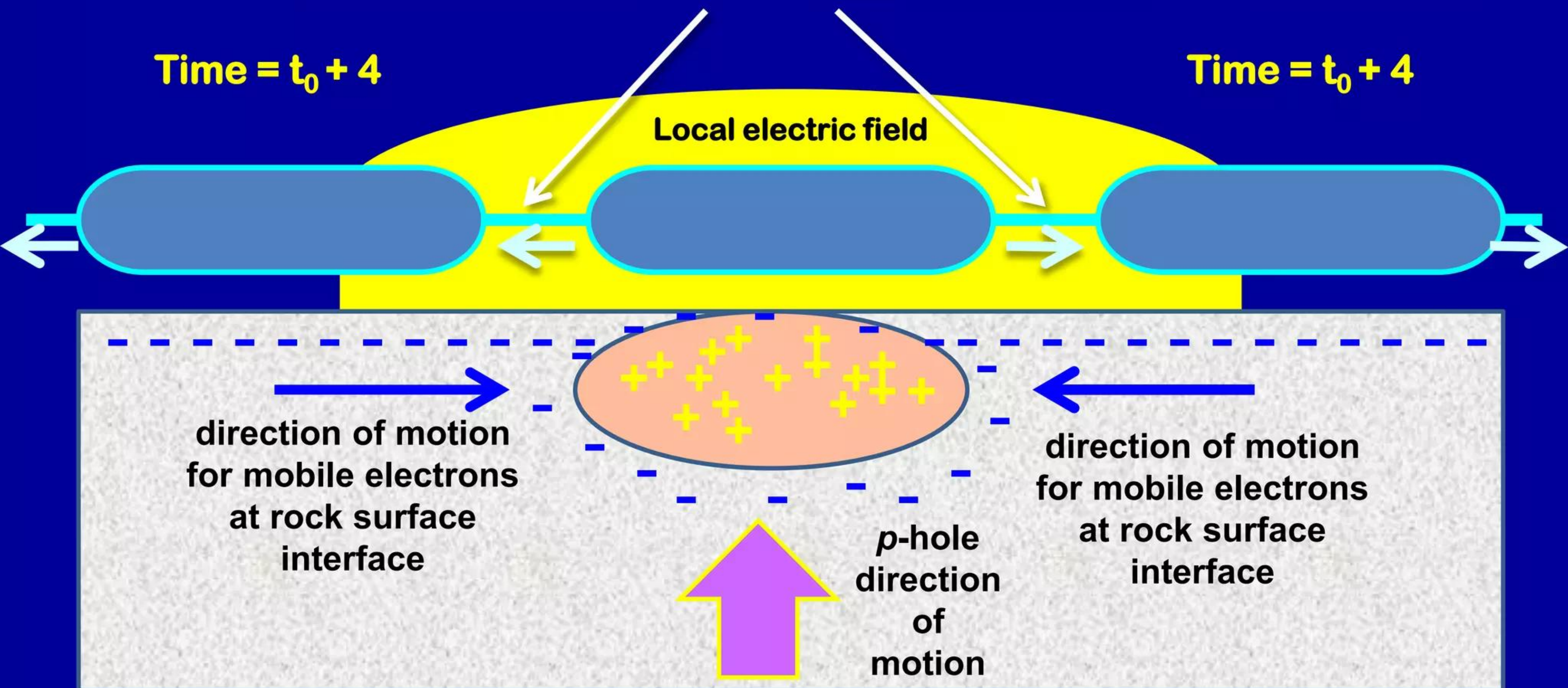


Hypothesis: bacterial networks harvest induced currents

Mobile electrons present at surface of *p*-hole conducting rock substrate

Motion of surface charges creates high fast-changing local electromagnetic field

Electric current pulse dissipated by rapidly distributing its energy via highly conductive nanowires across a collective many-bacteria local electrical network

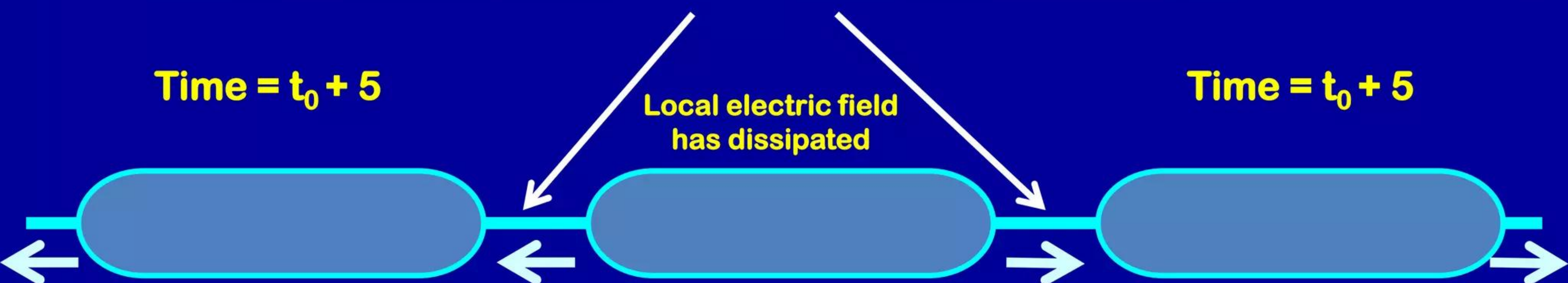


Hypothesis: bacterial electric network returns to t_0 state

ρ -hole now gone: the bacterial network has captured electrical energy

Bacteria are undamaged by ρ -holes because do not interact directly with them

ρ -hole energy has been harvested and mostly dissipated harmlessly as electric currents



Rock substrate that is suitable conductor for Freund ρ -holes

Summary: key take-aways

Several new and disruptive conceptual paradigm shifts are in play

p -holes are an important contribution to geo- and condensed matter physics

- ✓ **Freund p -holes provide a new electronic mechanism for transferring and dissipating energy in Earth's upper crust besides the well-accepted mechano-acoustic seismic P- and S-wave processes --- this entails a paradigm shift in geophysical thinking**
- ✓ **Documented existence of electric bacteria living in Earth's soils and crustal rocks suggests that they may have evolved to inductively harvest energy for metabolism from electric fields created by local dissipation of p -holes: a larger Deep Biosphere**
- ✓ **Electric fields associated with dissipation of p -holes in micron-scale regions at interfaces where appropriate metals and hydrogenous moieties are present can provide enough electrical input energy to drive abiotic LENRs via Widom-Larsen**
- ✓ **Energy transfers and subsequent dissipation processes via mobile p -holes can potentially operate within any rocky body in which appropriate conditions exist**
- ✓ **Freund p -holes may also provide a new and previously unappreciated mechanism for explaining otherwise inexplicable induced seismicity associated with fracking**
- ✓ **Others are invited to join this revolution: an enormous array of outstanding opportunities to make new and important discoveries awaits the efforts of all adventuresome experimentalists and theoreticians who may wish to contribute**

Lattice Energy LLC

4th Bi-Annual IGRS Research Symposium at NASA-Ames, Mountain View, CA

**“Not only is the
universe stranger than
we imagine,
it is stranger than we
can imagine.”**

Often misattributed to Sir Arthur Eddington;
more likely adapted from J.B.S. Haldane (1927)

Laura 13

Shewanella oneidensis

Image: R. Bencheikh and B. Arey

Nanowires interconnecting many bacteria

PNAS (DOI: 10.1073/pnas.0604517103)

Additional reading for further details

Lattice document discusses published experimental evidence that suggests microbial LENRs exist:

“Some bacteria appear capable of altering isotopic ratios of Uranium --- Is it the result of prosaic chemical fractionation processes and/or LENRs?”

Lewis Larsen, Lattice Energy LLC, December 7, 2010 [50-page technical MS-Word document]

<http://www.slideshare.net/lewisglarsen/bacteria-lenrsand-isotopic-shifts-in-uraniumlarsenlattice-energy-dec-7-2010-6177275>

Index to large collection of online documents re LENR theory, experimental data, and the technology:

“Index to key concepts and documents” v. #19

***** RECENTLY UPDATED *****

L. Larsen, Lattice Energy LLC, May 28, 2013 [119 slides] Updated and revised through August 19, 2014

<http://www.slideshare.net/lewisglarsen/lattice-energy-llc-index-to-documents-re-widomlarsen-theory-of-lenrsmay-28-2013>

Review paper that covers all theoretical aspects of basic Widom-Larsen theory published to date:

“A primer for electro-weak induced low energy nuclear reactions”

Y. Srivastava, A. Widom, and L. Larsen, *Pramana - Journal of Physics* 75 pp. 617 - 637 (2010)

Abstract: “Under special circumstances, electromagnetic and weak interactions can induce low-energy nuclear reactions to occur with observable rates for a variety of processes. A common element in all these applications is that the electromagnetic energy stored in many relatively slow-moving electrons can (under appropriate circumstances) be collectively transferred into fewer, much faster electrons with energies sufficient for the latter to combine with protons (or deuterons, if present) to produce neutrons via weak interactions. The produced neutrons can then initiate low-energy nuclear reactions through further nuclear transmutations. The aim of this paper is to extend and enlarge upon various examples analyzed previously, present order of magnitude estimates for each and to illuminate a common unifying theme amongst all of them.”

<http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf>