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Can bacteria reveal something about electrons and charge?

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Abstract: A brief consideration of the physiology of the ETC (electron transport chain) leads to questions concerning commonly held notions about electrostatics. This paper introduces a novel viewpoint that the ETC might reveal something unknown about the physical world. A focused view of the handoff of two electrons from FMN (flavin mononucleotide) to the nearest iron-sulfur cluster in Complex I of the ETC is presented. A suggestion of a possible theoretical loophole in the current understanding of electrostatics is proposed that might explain the configuration of that particular step in the ETC. Results of an experiment that was conducted using mutant bacteria to test this explanation are presented, along with potential implications for the future study of disorders that result from malfunction of the ETC in human mitochondria.

Introduction

Some views of the first part of the ETC, Complex I, are shown in Figure 1. Here two electrons can be transferred from an FMN molecule, the large molecule at the bottom of Complex I, to the nearest iron-sulfur cluster in the entire ETC. Each step of Complex I is capable of holding two electrons, except for the clusters shown in blue. Each of these two blue clusters can hold only one electron.

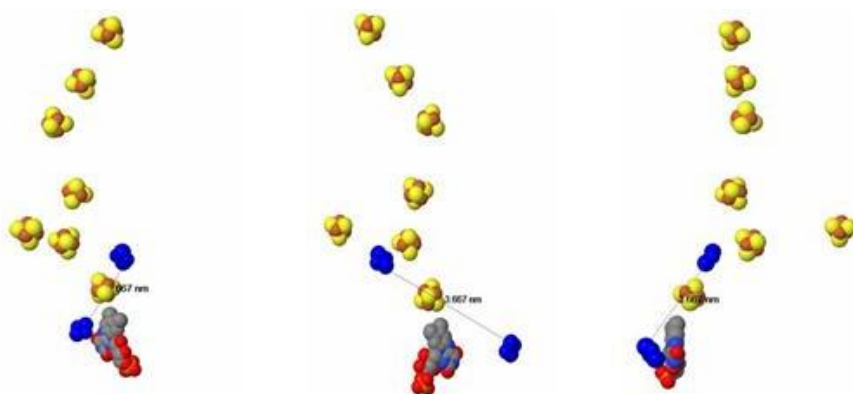


Figure 1. Different views of ETC Complex I. Reprinted with permission of the author.^[1]

It is a very curious fact that the ETC begins with accommodations for two electrons at each step, but later on, in Complex III, there will be accommodations for only one electron at a time. It is also strange that the two clusters in Complex I that can only hold one electron each, which are shown in blue, seem to form a well aligned configuration with respect to the two-electron iron-sulfur cluster that is closest to the FMN molecule. Figure 2 shows the factual but unlikely alignment of the two blue single-electron clusters with two iron atoms which are part of the nearest two-electron iron-sulfur cluster in the ETC. Geometry dictates that two points determine a line, but this view shows four points that participate in what could be called the first step of the ETC all residing on the same line.

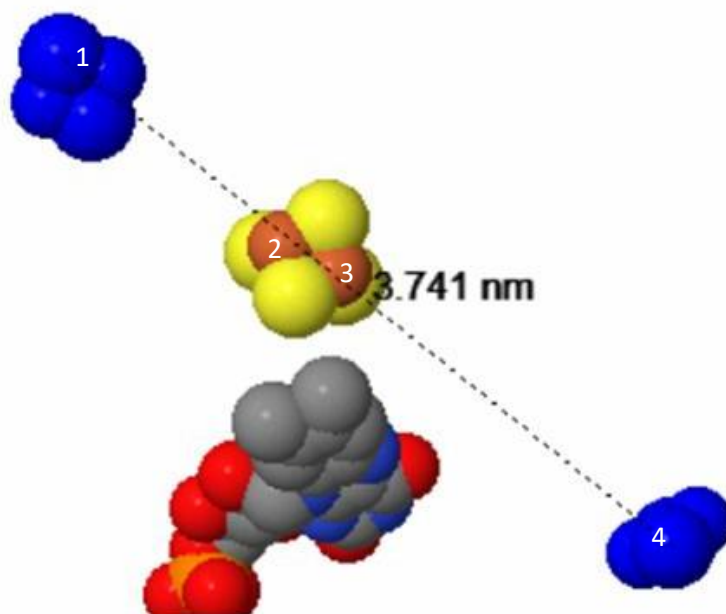


Figure 2. Close-up view of what can be called the first step of the ETC.

The ETC would seem to violate the laws of physics if two electrons are forced to come so close to each other on two adjacent iron atoms after somehow crossing the exceedingly narrow gap between the FMN molecule and the nearest iron-sulfur cluster. An indicator of the size of this gap is the fact that it barely would allow a water molecule to reside between the FMN molecule and the nearest iron-sulfur cluster while acting as a spacer between the two collections of atoms.

The close proximity of the two electrons on the adjacent iron atoms is not mitigated by the fact that electrons are very lightweight, and have only 1/1836 the mass of protons. The low electron mass doesn't relieve the high energy requirement of putting two charged particles so close together. That energy requirement is independent of mass, and forcing two electrons into such a close proximity at each two-electron cluster in the ETC would require more energy than the ETC is supposed to produce. It would completely negate the role that the ETC is supposed to play as the most important energy producer, not consumer, in the world of biology.

A Loophole in the Laws of Electrostatics

Several inviolable laws govern the way charged particles interact with each other. Charged particles of the same sign repel. Charged particles of opposite signs attract. The force of attraction or repulsion depends upon the inverse square of the distance of separation.

However, there is a seldom mentioned loophole in all of these laws having to do with a specific circumstance. That circumstance is extremely small distances of separation, distances so small as to be comparable to the size of the elementary particles themselves. An example of this loophole is encountered when an individual electron is considered. It holds one elementary charge in an extremely small space, so small that the repulsive force dictated by the inverse-square law should cause the electron to blow apart with explosive energy ($kq^2/r = mc^2$ if r is the classical electron radius). However, electrons do not spontaneously explode. This paradox is sometimes referred to as the self-energy problem.

The self-energy problem is a manifestation of a school of thought where nobody really claims to understand what is actually going on inside the electron or what the nature of charge really is. An illustration of the mysterious nature of what might be inside the electron is encountered when an electron is annihilated by an encounter with its antiparticle, the positron. The classic example is the release of two photons, i.e., two particles of light, as shown in Figure 3.

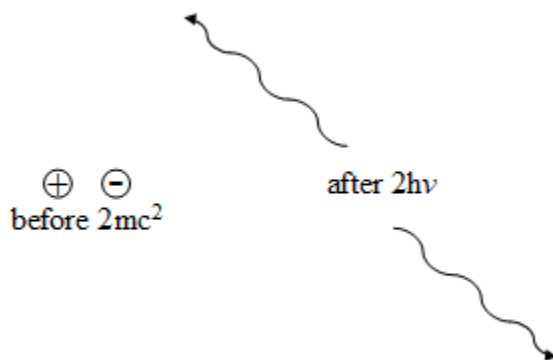


Figure 3. The most common result of electron-positron annihilation.

Several differing approaches to explaining this phenomenon have been attempted. The earliest approach involves a uniformly spread-out collection of charged particles.^[2] This uniform collection of charged particles is undetectable due to no net electric field anywhere. However, zero electric field everywhere results in zero divergence of the electric field and therefore zero charge density due to Maxwell's equations. So such a collection of charged particles is not allowed to exist.

The energy released during matter-antimatter annihilation is described by the simple equation $2h\nu = 2mc^2$. What if annihilation is just a glimpse of what is going on inside matter all the time, and $h\nu = mc^2$ is much more generally applicable than just to annihilation alone?

One approach to this question is to model an elementary particle as a photon moving in a circular racetrack of radius $r = \lambda/(4\pi)$. This elementary particle will sporadically interact with other particles in the rest of the world due to Lorentz contraction. In order to attempt to calculate the fine-structure constant that drives interaction between charged particles, we need to consider averaging sporadic interactions with other circular racetracks viewed randomly, i.e., ellipses. The height of an ellipse with semi-major axis r and semi-minor axis a that is tilted at an arbitrary angle ϕ with respect to the horizontal is:

$$H = \sqrt{r^2 \sin^2 \phi + a^2 \cos^2 \phi}$$

Now calculate H_{ave} by evaluating $\frac{4}{\pi^2} \int_0^{\pi/2} d\phi \int_0^{\pi/2} d\theta H$ where $a = r \cos\theta$.

$$H_{\text{ave}} = \frac{4}{\pi^2} r \int_0^{\pi/2} d\phi \int_0^{\pi/2} d\theta \sqrt{\sin^2 \phi + \cos^2 \theta \cos^2 \phi}$$

This elliptical integral does not have a closed-form solution, and has to be numerically evaluated to result in $H_{\text{ave}} = 0.842053r$.

The fine-structure constant becomes the product of two independent but numerically similar probabilities: the probability of sighting another racetrack, and the probability that the photon in the other racetrack is moving in the plane of the observer racetrack. There is a factor of 2 in front because each electron plays a dual role as both observer and target. Each interaction occurs in a very short time Δt with a force $\frac{\Delta p}{\Delta t} = \frac{\Delta E}{c\Delta t} = \frac{\hbar}{2c(\Delta t)^2}$.

Then

$$\frac{q^2}{4\pi\epsilon_0 d^2} = 2 \left[\frac{\Delta t}{2\pi r / c} \frac{2H_{\text{ave}}}{\pi d} \right]^2 \frac{\hbar}{2c(\Delta t)^2}$$

$$\frac{q^2}{4\pi\epsilon_0 \hbar c} = \left(\frac{0.842053}{\pi^2} \right)^2 \cong \frac{1}{137.3786} \quad \text{and } q = 0.99875e_{\text{ch}}$$

The sign of the charge produced by this model depends entirely on whether the photon is right-handed or left-handed. The handedness of a photon is conserved, and is therefore as inviolate as conservation of charge. In this rotating-observer model, the energy associated with an interaction is $\Delta E = \vec{p} \bullet \vec{c}$ which can be positive (repulsive) or negative (attractive).

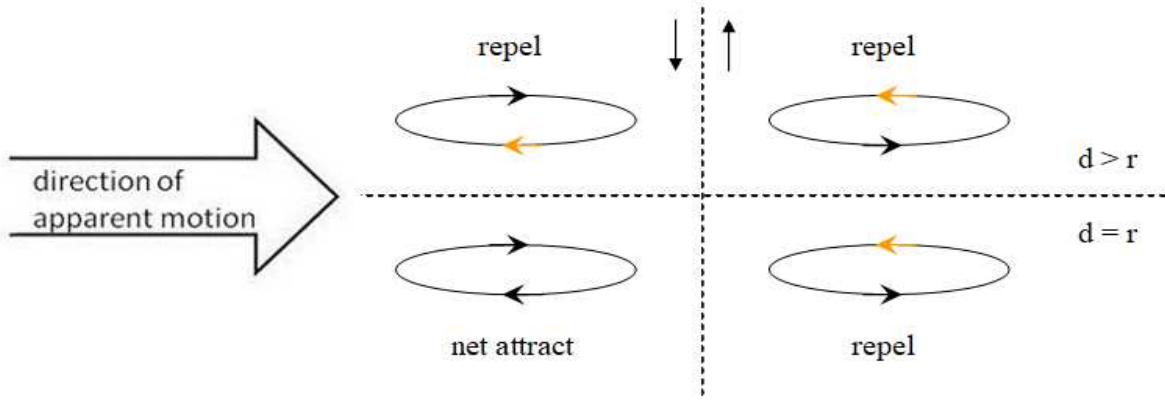


Figure 4. How an electron with spin up sees other electrons. The orange arrows are excluded because they oppose an apparent motion that is greater than the speed of light. Note the nearby electron with spin down shows net attraction since its near stroke is at r and far stroke is at $3r$.

At a distance, like charges repel and opposite charges attract. However, this model predicts something completely new when the particles come close enough to touch. In that case, like charges will attract if the particles have opposite spin. Thus the model predicts dielectrons,^[3] which can be the basis of most covalent bonds, but which constitute only about a quarter of a percent (e^{-6}) of free electrons. The e^{-6} factor comes from two electrons each in an attractive energy state that is exactly three times greater energy than the normal repulsive state, as mentioned in the caption to Figure 4. This quarter-of-a-percent population impacts measurements of the fine-structure constant in a very precise one-sided way, and explains almost all of the difference between the fine-structure calculation shown above and the experimental value $1/137.036$. A non-zero photon lateral size of 10^{-19}m would bridge the remaining gap.

$$\frac{1}{137.3786} * \frac{1}{1 - e^{-6}} \cong \frac{1}{137.038}$$

This correction factor describes how dielectron contamination will augment the strength of the electric field used to measure elementary charge. The same factor can be used to describe how dielectron contamination augments the strength of the magnetic field used to measure magnetic moment. For example, if we consider the Bohr magneton that contains $q = 0.99875e_{ch}$ and apply the dielectron contamination factor, then:

$$\frac{1}{1 - e^{-6}} * \frac{qh}{2m} \cong 1.00248 * \frac{qh}{2m} \cong 1.0012 * \frac{e_{ch} h}{2m}$$

To 5 significant figures, which is all the accuracy this theory claims to have, the expression directly above is the magnetic moment of the electron! It was arrived at without using quantum field theory, but it acknowledges the existence of a presently unknown particle, the dielectron.

Although interaction between particles is sporadic, self-interaction will be constant and cohesive since it will take place at point-blank, can't-miss range. The factor of 2 in front is no longer needed, and the product of probabilities becomes 1, resulting in a fine-structure constant of 1/2.

$$\frac{q_{\text{self}}^2}{4\pi\epsilon_0\hbar c} = \frac{1}{2} \quad (\text{Next, multiply by } 2c^2/r.)$$

$$\frac{q_{\text{self}}^2}{4\pi\epsilon_0\hbar c} \frac{2c^2}{r} = \frac{q_{\text{self}}^2}{4\pi\epsilon_0\hbar cm} \frac{2mc^2}{r} = \frac{q_{\text{self}}^2}{4\pi\epsilon_0\hbar cmr} 4\pi\hbar v = \frac{q_{\text{self}}^2}{4\pi\epsilon_0\lambda mr} 4\pi = \frac{q_{\text{self}}^2}{4\pi\epsilon_0 mr^2} = \frac{c^2}{r}$$

So there will be exactly enough centripetal acceleration to keep a photon on the circular racetrack. Although the photon has extremely small lateral girth, its size in the direction of motion is comparable to $\lambda/2 = 2\pi r$, the circumference of the circular racetrack.

The existence of presently unknown particles called dielectrons is indicated by two very well known phenomena in chemistry and biology. The primary technique for chemical detection of electrons is EPR (electron paramagnetic resonance). The term EPR-silence refers to the inability of EPR to detect electrons that are paired in covalent bonds. This lack of detectability can be explained by the existence of dielectrons, which have zero spin and zero magnetic moment. Finally, there is the ETC (electron transport chain), the most important source of energy for living things. It is more than interesting that electrons enter the ETC *in pairs*.

Instead of individual single electrons, dielectrons could move along the ETC through all of Complex I, and remain intact until they are separated in Complex III. If they happen to come apart prematurely at the first step in Complex I, then there are two single-electron iron-sulfur clusters perfectly positioned to catch the high-energy electrons flying out of a dielectron disintegration event.

If dielectrons actually exist, one could ask why they haven't been detected. Magnetic mass spectroscopy, quadrupole mass analysis, and time-of-flight analysis all depend upon the ratio of charge to mass, q/m , which is the same for dielectrons and electrons. All these techniques would not be able to resolve dielectrons from electrons. And EPR (electron paramagnetic resonance) only detects unpaired electrons. EPR is incapable of detecting electrons that are paired together in a covalent bond or in a dielectron which has zero spin and zero magnetic moment. The present understanding of the passage of one electron at a time through Complex I is largely based on EPR analysis, which is deaf to dielectrons.^[4] If dielectrons do indeed exist, we have been supplanting what would be true dielectron physiology with single-electron pathophysiology. One could also ask why the same principles that could result in dielectrons would not apply to other elementary particles, for example, protons. The answer to that question is: diprotons do indeed exist, although they are unstable. For over eighty years, diprotons have been understood to play a major role in powering the sun and other stars.^[5]

Experimental Approach

The focus of interest of most investigations of the ETC has quite properly been directed toward the ETCs contained in human mitochondria. If dielectrons do exist and disintegrate prematurely in Complex I, they may cause damage. An important point to emphasize is that mitochondria are seldom (if ever) considered to be sources of damaging radiation like soft x-rays.

However, there are indications that mitochondria could be a source of damage at a distance in addition to any short-range damage caused by free radicals. For one thing, mitochondria are often attached to microtubules that are stiffened with tau proteins, and tau proteins are the same proteins that constitute the tangles associated with AD (Alzheimer's disease).^[6] Secondly, a wide variety of living things make melanin in response to damaging radiation. An example of this would be melanin in human skin that is produced in response to exposure to UV radiation from the sun. Throughout its lifespan, the human brain produces neuromelanin that is very similar to melanin. Thirdly, the human brain contains opsins that are capable of detecting energetic radiation and influencing the production of neuromelanin.^[7] Fourthly, the areas of the brain that contain the most neuromelanin happen to be the areas that require the most energy.^[8] The most energy implies the most mitochondria. If the purpose of neuromelanin was only to bind to and detoxify trace metals and pesticides, a question arises as to why the areas of the brain with the most neuromelanin are the same areas that require the most energy. We would have to argue that contaminants are attracted to these high-energy regions.

Bacteria may be a good arbiter of differing models of electrons and charge, a better arbiter than the finest human minds. After all, bacteria are much closer in size to elementary particles than we humans are. Their grasp of energetic electrons has been an issue of survival for their species.

Experimental Technique

Since human neurons are obviously difficult to obtain, it is fortunate for the purposes of this study that the very first step of the ETC is identical between humans and bacteria. An experiment was designed to look for differences in the emission of radiation between bacteria that have perfect FMN and bacteria that have damaged FMN. Damaged FMN is more likely to produce a flawed handoff of dielectrons to the nearest two-electron iron-sulfur cluster in Complex I, and is therefore more likely to result in premature disintegration of dielectrons into individual electrons. When dielectrons disintegrate into electrons, the electrons will fly apart at high speeds, and will subsequently slow down as they interact with water molecules. This deceleration will result in a release of energy, like the heat that is released when the driver of an automobile suddenly steps on the brakes. In this case, energy is released in the form of soft x-rays, and some of these x-rays will be able to travel through water because of the water window, a region of the electromagnetic spectrum in which water is transparent to soft x-rays. This spectral region is from 282 eV to 533 eV (2.33 nm to 4.40 nm wavelength).

Table 1. List of the necessary materials that were procured in order to produce and detect soft x-rays emitted by disintegrating dielectrons.

Material	Specifications	Source
Mutant Bacteria	ribB11/mutant BSV11/P.M. Rabinovich/CGSC stock #6991	Coli Genetic Stock Center, Yale University
Culture Media	Miller granulated Luria Bertani Agar. ^[9] Miller Luria Bertani Broth. ^[10] 40 mg/liter riboflavin solution (made from 400mg riboflavin capsules) added to both kinds of media.	HIMEDIA
Photographic Film	Professional Tri-X PAN 320 TXP 4164 Black & White Film, ISO 320, 4X5 in.	KODAK

If dielectrons really exist, bacteria with damaged FMN will be more likely to emit soft x-rays than bacteria with perfect FMN. Since FMN is constructed from riboflavin, one way to obtain bacteria with damaged FMN would be to start with mutant bacteria that can't make their own riboflavin, and feed them damaged riboflavin. An easy way to make damaged riboflavin is to expose it to ultraviolet light, such as is available in sunlight or a UV light bulb.

Two riboflavin solutions were made using purified water and a riboflavin capsule. The contents of one 400 mg capsule were suspended in 100 ml of purified water. Then 5 ml of that suspension were drawn into a pipette and deposited in 495 ml of purified water to make each solution. One solution was immediately stored in the refrigerator and therefore was in the dark most of the time. The other solution was made slightly basic using 200 mg of NaHCO₃. Then this basic solution was poured into an open container and exposed to a UV light bulb for six hours to create lumiflavin. After the UV exposure, for all experimental runs, the damaged riboflavin also was refrigerated until used to make media.

Ten milliliters of HiMedia Luria Bertani broth were dispensed into culture tubes. Undamaged riboflavin was added to the broth.

Two different types of HiMedia Luria Bertani agar were prepared: one with riboflavin that had been shielded from light, and one with riboflavin that had been exposed to UV. After all the media were prepared, the broth and the two types of agar were autoclaved. These agars were poured into two separate groups of Petri dishes.

To achieve the plating pattern in Figure 5, the mutant bacteria were used to inoculate a tube of Luria-Bertani broth. The tube was then incubated for 36 hours. Then the two types of agar plates had the bacteria applied by inserting a sterile swab into the broth culture and inoculating the plate in the pattern.

All of the Petri dishes were placed on edge with the agar toward the left in an incubator at 30°C. Sheets of photographic film were placed directly to the left and right of each Petri dish. Each sheet of photographic film consisted of an emulsion and a base. All sheets were put in place with the emulsion-side to the left. Optically dense 0.05-mm thick graphite sheets were placed between the Petri dishes and the right-hand sheets of photographic film. After the bacteria were allowed to grow into colonies for 1.5 days, the right-hand sheets of photographic film were removed in the dark and placed in a light-tight box. Then the Petri dishes were briefly exposed to light in order to photograph the position of the colonies on the left-hand sheets of film. The left-hand sheets were then removed in the dark and placed in a light-tight box. All the sheets of film were taken to a professional photography shop to be developed after washing in water to remove any condensate from the Petri dishes that may have touched the lower edges of the film sheets.



Figure 5. Typical streak pattern on a culture plate.

Experimental Results

An early attempt at conducting this experiment suffered from a tendency for the lumiflavin culture plates to become liquid even though the agar solids used to make the plates were at the recommended 4% concentration. The cause of this semi-solid condition was a failure on the part of the author of this paper to follow the directions to make sure the agar was fully dissolved prior to autoclaving. The mistake required that the experiment be repeated, but it also revealed something important about the orientation of the bacterial colonies on the plates. The mishap showed that colonies oriented perpendicular to the planes of the plates and the film sheets were much more likely to emit detectable radiation. See Figure 6. Note the three prominent spots of exposure on the film sheet. All three of these spots coincided with the edge of the agar that remained on the plate after much of it had liquefied.

Perhaps this effect was due to the fact that the edges of the colonies were more likely to be alive and emitting radiation for the entire incubation time, while the central cores of the colonies have a tendency to be dead for most of the incubation time. This location-dependent survival effect is due to the fact that colony edges have consistently better access to the oxygen that the facultative anaerobic bacteria would prefer to have, as well as better access to the nutrients in the agar as the colony grows outward. So the likelihood of detecting radiation from the colonies can be orders of magnitude greater if the colonies are viewed on edge.

This result motivated that in future experiments, the agar surface would be deliberately scratched to allow for some colonies to have the orientation that increased the likelihood of detectable radiation.

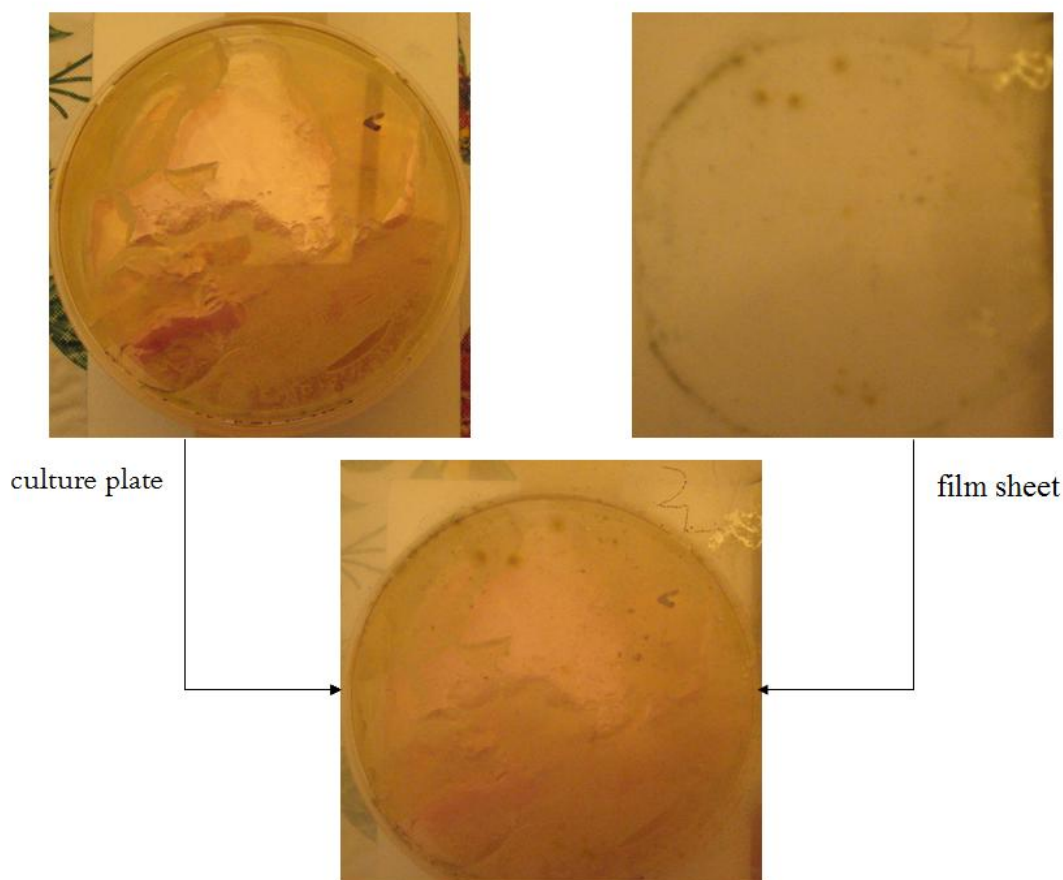


Figure 6. Deliquescence of lumiflavin agar.

Once the directions to make sure all the agar was dissolved prior to autoclaving were followed, the experiment was repeated. Two control plates with undamaged riboflavin both showed photographic films that were completely clear, like completely unexposed film.

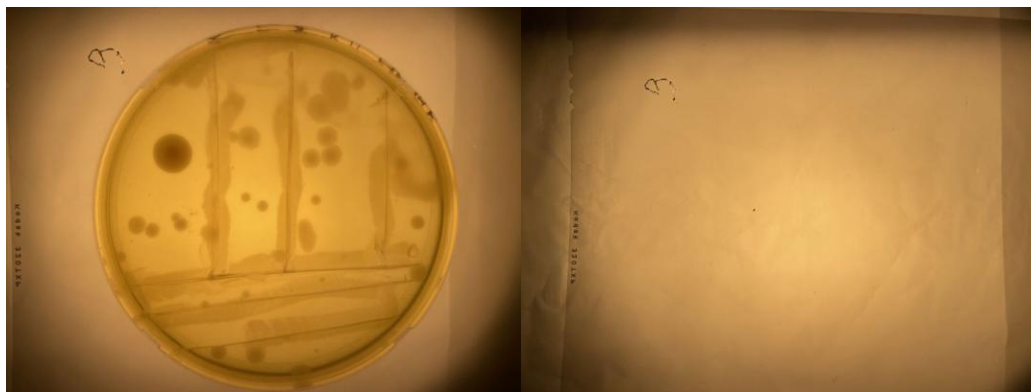


Figure 7. Good riboflavin plate with film (left). Film only (right).

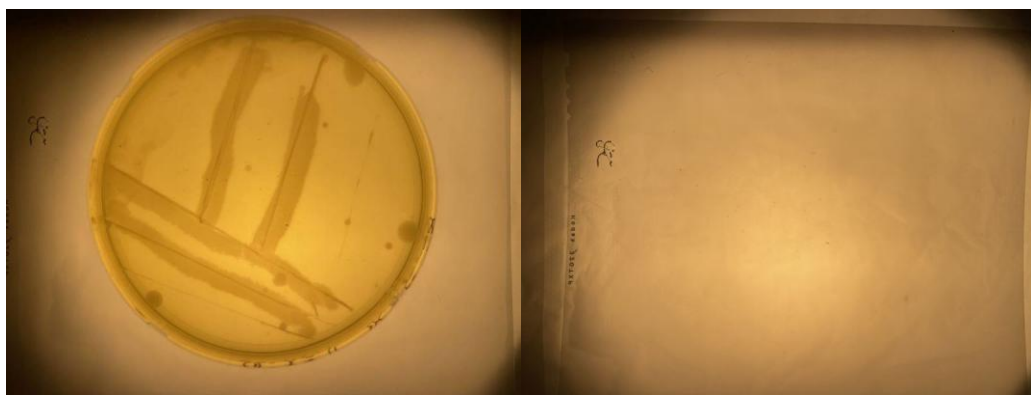


Figure 8. Another good riboflavin plate with film (left). Film only (right).

In contrast, the films associated with the lumiflavin plates were definitely not clear. One of the lumiflavin films had obvious contamination due to the graphite barrier sticking to the film. This contamination was visibly and tangibly on the surface of the film. In order to reduce the risk of having recurrence of contamination of the graphite barrier or any photographic film, the percent solids of agar was increased from 4% to 5% prior to the next experimental run.



Figure 9. Film contaminated with graphite after sticking to the barrier layer.

One lumiflavin plate showed film with exposure at the edge of the plate. This only occurred at the perimeter close to where there was a high density of swabbed culture. The exposure was easily distinguishable from the contamination event that took place in Figure 9.

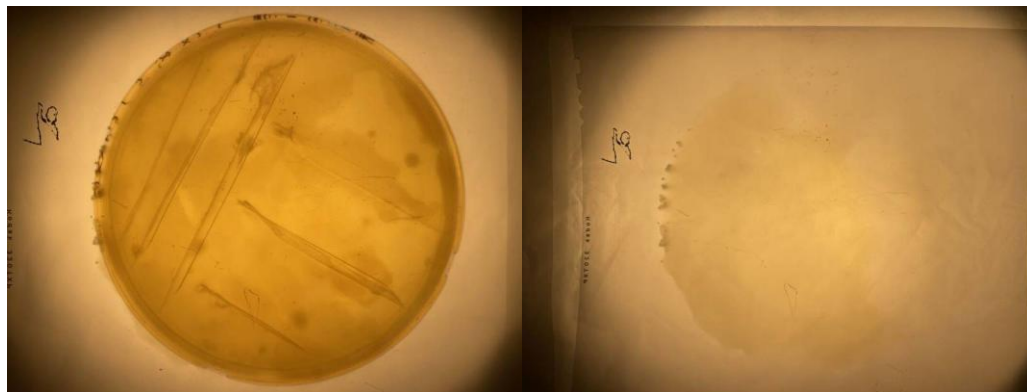


Figure 10. Lumiflavin plate with film (left). Film only (right).

The third lumiflavin plate had exposed film in areas corresponding to swabbed areas on the plate.



Figure 11. Third lumiflavin plate with film (left). Film only (right).

Some mention should be made about lumichrome, the riboflavin analog that can be made by exposing a riboflavin solution with pH less than 7 to UV light. Agar was made with lumichrome, but culture plates with lumichrome didn't produce any viable colonies. Although the human body doesn't treat lumichrome as a toxin, the bacteria used in this investigation demonstrated that they would rather die than use lumichrome. During one exercise to make lumiflavin, the addition of NaHCO_3 to raise the pH was forgotten prior to UV exposure. The NaHCO_3 was added mid-UV-exposure, which resulted in the presence of some lumichrome in the solution. In fact, all three riboflavin analogs were present. The results of that experimental run were that none of the plates showed any exposed spots on their associated film sheets. All the film sheets were like the good riboflavin plates. Therefore, the experiment was repeated, this time without lumichrome contamination.

Another issue that needed to be addressed was the fact that the optimal conditions for the bacteria to grow were not the optimal conditions for the photographic film to function as desired. A temperature of 30°C with high humidity coming from the respiration of the bacteria sometimes caused the film emulsion to become sticky, and the film backing to curl. Not only did the film exhibit different physical characteristics, but it seemed to lose all sensitivity on some occasions, and sometimes didn't even register any exposure on the sheets that were deliberately exposed to light. Consequently, the incubator temperature was lowered to 26°C.

The results of the next two runs separated by 10 days are shown in Tables 2 and 3.

Table 2. Results of run completed on 01-19-2026. The only monitor film spots found on good riboflavin medium were at the very edge of the Petri dish where any colony growing would have to be perfectly on edge, and the spots were aligned with two of the fingers of the streak pattern. The spots found on lumiflavin media line up with the streak pattern, especially the edges of some of the fingers.

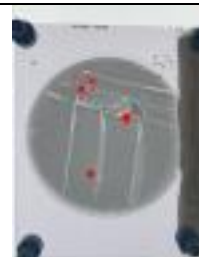
	Riboflavin	Lumiflavin	Riboflavin	Riboflavin	Lumiflavin
Reference Image					
Monitor Film					
Combined					

Table 3. Results of run completed on 01-29-2026. Only the lumiflavin media showed spots corresponding to the edges of the fingers in the streak pattern.

	Lumiflavin	Riboflavin	Lumiflavin	Lumiflavin	Riboflavin
Reference Image					
Monitor Film					
Combined					



Figure 12. An explanation was found for a light leak (encircled in yellow) on the monitor film in the 4th position. A piece of tape used to cover a manual hole in the box containing the culture plate and film assembly was partially lifted. Even though the tape was still on, a slight lifting was enough to result in a noticeable exposure of the high-speed film after 36 hours.

Both Tables 2 and 3 show that bacteria grown on lumiflavin media were much more likely to show unexplained spots on the monitor film than bacteria grown on riboflavin media. These spots were distinguishable from spots due to physical contamination of the surface of the film by the emulsion sticking to the cardboard used for shipping and storing the film. That contamination always noticeably protruded from the surface of the emulsion, and could be both seen and felt.

Discussion and Future Direction

Although these results do not prove that dielectrons exist and sometimes decay into energetic electrons, it is difficult to explain how bacteria can otherwise produce radiation capable of penetrating an optically dense layer of graphite. The ETCs in both bacteria and humans are never connected in series in such a way as to produce a high-voltage electrical circuit. Although mitochondria can fuse as needed, the ETCs within the mitochondria do not connect end-to-end to form some sort of super ETC. No known species of bacteria can generate the hundreds of volts needed to explain these experimental results. Bacteria are limited to small fractions of a volt. A thermal explanation for the spots on the film also seems unlikely since bacterial colonies are only a small fraction of a degree Celsius warmer than their surroundings.^[11]

However, if dielectrons do exist and sometimes decay into destructively energetic electrons, the question of what causes neurological disorders becomes more a question of why these disorders don't happen even more frequently than they do. The FMN molecule is highly sensitive to UV radiation. The defense mechanisms of FMN acting as a circuit breaker and the fortuitous position of some iron-sulfur clusters for catching energetic electrons are probably only a small part of what living things are doing to limit the risk.

The experiment conducted here seems to beg for other experiments to be conducted that use modern detectors to look for intermittent emission of soft x-rays from living cells. Although CMOS/CCD detectors have better sensitivity and resolution than film, there is a problem that we would encounter when trying to use them with exposure times comparable to bacterial incubation time (~36 hours). At such long exposure times, electronic noise accumulation can be overwhelming. Virtually every pixel would show exposure over such a long time. Electronic noise accumulation is not an issue with film.

If better designed experiments do indeed show that auto-generated radiation can be an issue, then that result would open new vistas for the investigation of neurological disorders. For example, recent research has shown a correlation between Alzheimer's dementia and migraine.^[12] Furthermore, there is also a study that suggests high-dose riboflavin may be useful to prevent or mitigate migraine.^[13] If one were to jump to conclusions, riboflavin might be a candidate for Alzheimer's treatment. While this approach is unlikely to work, there may be some benefit in looking at riboflavin as a complementary prophylactic measure to combat the early onset of Alzheimer's disease.

Data Availability Declaration

The author declares that the data supporting the findings of this study are available within the paper and at https://colorado-code.org/doc/4th_ed_dielectron_theory.pdf.

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