The Evidence for Gamma Ray Photosynthesis

by T.D. Luckey

Abstract. Limited data indicate that gamma rays can support photosynthesis. Pure cultures of a photosynthetic bacterium, *Rhodopseudomonas capsulata*, and an alga, *Anacystis nidulans*, were exposed for several days, without light, to continuous gamma rays from a Co-60 source at the University of Missouri Research Reactor. Both organisms remained green and, within limits, increased in proportion to the radiation flux. The results indicate microbial use of the energy of ionizing radiation in deep sea vents, hydrocarbon utilization, prebiotic reactions, and early life metabolism.

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Introduction. "The longer my experiments continued, the more mysterious the whole subject seemed." This was O.F. Atkinson's reaction to the increased growth of algae irradiated with X-rays in 1898.[1] During the 20th Century, about 3,000 scientific reports showed a biopositive effect for many physiologic functions following low doses of ionizing radiation in microbes, plants, invertebrates, and vertebrates, including humans.[2,3,4] Within limits, the response is directly proportional to the logarithm of the dose. When the dose exceeds the threshold for each set of parameters, a bionegative effect is observed. Increased photosynthesis was indicated by the increased mass of photosynthetic organisms following pulsed or continuous radiation with beta rays, gamma rays, X-rays, ultraviolet (UV) rays, or neutrons.[2] In the above experiments the plants were exposed to ambient light.

Would plants respond to ionizing radiation without light? A positive answer is indicated by the response of a photosynthetic bacterium, *Rhodopseudomonas capsulata,* and an alga, *Anacystis nidulans,* to continuous exposure of cobalt gamma rays without light. The implications of this finding are discussed below.

Method. Aseptic techniques were used throughout this study. Sets of tubes to be irradiated were put in an incubator which was placed at a convenient distance from the Co-60 source in the University of Missouri Research Reactor. For *R. Capsulata,* the front of the incubator was 24 cm from the Co-60 source; it had a 1.8-cm lead plate between it and the source. Within the incubator radiation was attenuated by a series of lead plates providing a sequence of 0, 1.6, 3.1, 4.8 and 6.4 cm of lead between the five sets of tubes and the source.

The Co-60 was elevated from the pool to give continuous in-air irradiation, with no light, of cultures throughout the incubation periods. Dosimetry for the five positions included backscatter from incubator, lead plates, and concrete walls. Control cultures were maintained in the dark with no irradiation at the appropriate temperatures in incubators in a separate building.

R. capsulata (B100) stock cultures were maintained anaerobically at 32°C under fluorescent light of 50 foot-candles, following procedures outlined by Madigan *et al*.[5] The complete medium, RCVB, of Johansson and Gest was used for stock

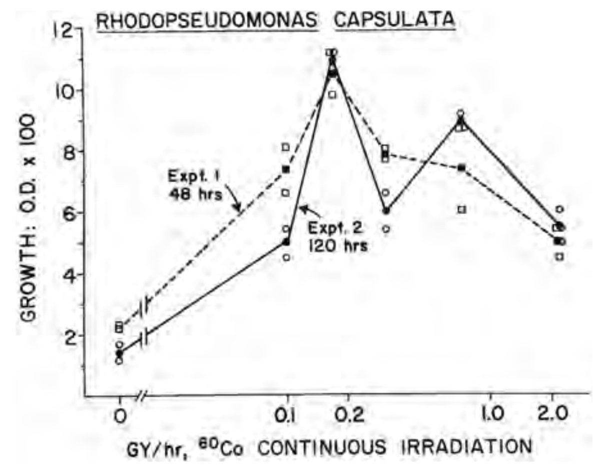

Figure 1
GROWTH OF *R. CAPSULATA* WITH CONTINUOUS IRRADIATION
Each circle represents an individual culture of growth of R. capsulata *in the dark, with continuous Co-60 irradiation.*

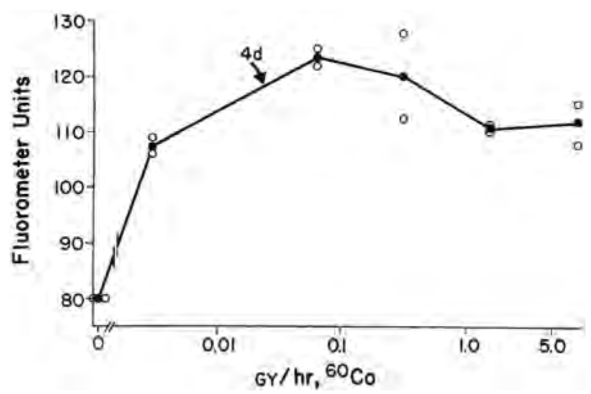

Figure 2
GROWTH OF *A. NIDULANS* WITH CONTINUOUS IRRADIATION
Each circle represents one culture of growth of A. nidulans *after four days of continuous Co-60 irradiation in the dark.*

cultures.[6] The culture medium was RCVB formula at pH 6.8 with 40 millimolar (mM) fructose replacing the malate. A 48-hour culture from the stock culture was centrifuged and re-suspended in 0.9 percent sodium chloride to form the inoculum. Tubes were flushed with sterile nitrogen (N_2), almost filled with culture medium containing 0.1 milliliter (ml) fresh inoculum per 10 ml, tightly sealed with screw caps, and mixed by inversion using the 0.2 ml bubble to provide motion.

All experimental and control cultures were incubated in complete darkness. Control tubes maintained at ambient radiation levels included uninoculated medium, inoculated negative control (not irradiated), and inoculated (not irradiated) positive control. The last group contained 60 mM dimethyl sulfoxide (DMSO) as an acceptor for electrons and protons in anaerobic metabolism. The total microbic mass was determined by turbidity using the uninoculated medium for the photometer blank at 620 nanometer; one O.D. unit represents approximately 108 bacteria per ml.

The stock and the positive control cultures of *A. nidulans* were maintained in light at 50 foot-candles with no ionizing radiation. All experimental cultures were maintained in the dark in an incubator (without a lead plate in front) 1.5 meters from the Co-60 source. Ten-ml medium (Alga-Gro, pH 7.0 from Carolina Biological Supply Co., Burlington, N.C.) was placed in each 20-ml tube with loose screw caps, autoclaved, cooled, and provided one drop of inoculum from a culture one week old. Total microbic mass was determined by spectrophotofluorometer at 350 nm in quartz cuvettes.

The Results

The dose-response curve of *R. capsulata* (Figure 1) showed a maximum growth at 0.16 gray per hour for both 48 and 120 hours exposure. Exposures greater than 2 Gy/h were not attempted. All cultures were a uniform green. Both irradiated and unirradiated cultures which contained DMSO had about six times more growth than the maximum in irradiated cultures without the DMSO.

The dose-response curve of *A. nidulans* (Figure 2) produced a partial rainbow, with the growth zenith at 0.08 Gy/hr. The far side of the rainbow was interrupted by a horizontal component which showed no evidence of a threshold at the highest exposure, 5 Gy/hr. Illuminated control cultures grew four times faster than any of the irradiated cultures. All cultures remained green.

Discussion

Gamma ray photosynthesis. The results show that continuous irradiation with gamma rays, without light, increased photosynthesis in two photosynthetic organisms. The mechanism of action of gamma ray photosynthesis is probably not the classic activation of plant chlorophyll, which requires many photons acting as a single cohort in one reaction center, to cleave water and produce free hydrogen and oxygen.[7] The only biological reaction which does this is photosynthesis. Improbably, the haphazard action of a multitude of free radicals could induce photosynthesis.

In contrast to the above, the consistent action of ionizing radiation is known. Low-energy gamma rays can transfer a photon to an atomic electron by either the photoelectric or the Compton effect (J. Muckerheide, personal communication). In this process, photosynthesis probably results from the transfer of energy to an atomic electron by the ever-decreasing photon energy as gamma rays penetrate matter.

Since gamma rays support photosynthesis, ionizing radiation may be considered to be a major source of energy for subsurface microorganisms. This has major implications for ionizing radiation as an energy source in deep sea vents, petroleum utilization, and the origin of life.

Deep Sea Vents. S.N. White listed various sources of light in deep sea hydrothermal vents: Cerenkov radiation, thermal (blackbody) radiation, temporary visible light, vapor bubble luminescence, crystalloluminescence, triboluminescence, chemiluminescence, and bioluminescence.[8] J.T. Beatty and associates suggest that anaerobic, green sulfur bacteria utilize blackbody radiation from deep sea hydrothermal vents.[9] Chlorophyll of similar bacteria from 100 meters deep in the Black Sea received one photon every eight hours. These are stored in a chlorosome and provide sufficient infrared photons for the bacterium to survive, with a cell division time of about 2.8 years. This is not fast enough for a colony to contribute to the ecosystem, or even survive, in the turbulent waters near the deep sea vents. A consistent, and much stronger, source of energy is ionizing radiation.

D. Kadko reported an abundance of radionuclides in deep sea vents.[10, 11] Also, S. Charmasson et al. report unusually high concentrations of the uranium-thorium families in vent organisms.[12] Most forms of ionizing radiation stimulate physiologic functions in microbes, plants, and animals.[2] Thus, ionizing radiation is undoubtedly one source of energy for life around deep sea hydrothermal vents.

Petroleum. After hydrogen and helium, carbon is almost as abundant as oxygen in the universe and in our Solar System.[13] Methane was one component of the aggregates which spawned the Earth. T. Gold noted that great stores of liquid methane were deep in the Earth's crust and upper mantle, with pressures up to 40,000 times ambient and temperatures exceeding 1,000 °C.[14] Gold cites evidence that this is both the past and current source of hydrocarbons for gas, oil, and black coal (brown coal and lignite are exceptions with biogenic origins).

The upwelling of petroleum products through pores and crevices of rocks is food for an underworld of Archaea and primitive bacteria which exceeds the mass of living organisms of the Earth's surface by a factor of 10. Some thermophiles and hyperthermophiles have an optimum temperature of 80°C.[14] The data indicate ionizing radiation from Earth's radionuclides would supply ample energy for hydrocarbonphiles in the absence of sunlight. Here is the driving force for biochemical energy production in hydrothermal vents of the ocean floors and the deep hot biosphere of Earth or other planets.

Origin of life. These limited data on gamma ray photosynthesis provide evidence for a role of ionizing radiation in the origin of life. Radiolysis of water produces the troika of energy metabolism: oxygen, hydrogen, and electrons. This provides a constant source of different oxygen species (Table 1).[15] These reactive species oxidize the many free radicals of organic compounds produced by ionizing radiation. For example, oxidized hydrocarbons would stabilize newly formed cell walls, the bastions of life, and provide an inexhaustible source of energy. Ionizing radiation provides a framework for many prebiotic and early life reactions.

Because of the relatively short halflives of potassium-40 and uranium-235, Earth had about 10 times more ionizing radiation when life began, about 3.9 billion years ago[16] than it has now.[17] Activated electrons would migrate to form more stable (lower energy) compounds. About 3.7 billion years ago, low-energy radiation (light) became a source of activated electrons to utilize water in photosynthesis. As shown by stromatolite fossils, which are dated at 3.6 billion years ago,[16] photosynthesis evolved to utilize low-energy photons. These reactions continue on the Earth's surface while ionizing radiation fuels metabolism underground.

Acknowledgements. It is a pleasure to thank Dr. Donna Luckey for help in computerizing. The author is indebted for assistance from Dr. Bill Noteboom, Dr. Judy Wall, and Kathy Bradock of the UMC Department of Biochemistry. Bacteriology was performed in the laboratory of Dr. Olin Brown in the UMC Research Reactor. Much behind-the-scenes work was done by Vicki Spate, G. Krause, P. Rexroad and the professional staff of the UMC Nuclear Research Reactor.

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T.D. Luckey. The author became an honorary Samurai in 2003, for bringing knowledge of radiation health to Japan.

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Letters

Continued from page 3

eases, especially in those Boomers and others whose medical conditions are "too far advanced" for them to be treated successfully?

Also, when it comes to treatment with radioisotopes, there are many insurance companies which claim that this treatment is "experimental" and refuse to cover it as part of a health insurance plan, which may lead to a "rationing" of care with this type of treatment, where only the young who have a better possibility of survival will be treated with radioisotopes, while aging Boomers are denied this type of medical care because the insurance companies believe that treating an aging Boomer is "too risky," possesses no real "cost-benefit," and is not worth the extra expense.

In light of this, my second question is what would have to be done in order to convince medical professionals and the insurance companies—including Medicaid and Medicare—that nuclear medicine is a valuable resource and that using isotopes as part of medical treatment is actually more cost-effective and safer than feeding patients massive amounts of drugs which can compromise their immune system or do serious harm to their bodies?

I'm eagerly looking forward to the answers to these questions, because they've been on my mind for quite some time.

Stephanie Fryar

The Editor Replies

Your questions are good, and should be answered! We'll attempt a brief response here, and will pursue fuller answers from some of the scientists working in the field.

We have an article in preparation on medical isotopes, and in particular on the fact that despite several government studies saying that the United States should produce medical isotopes domestically, the government has shut down existing programs and has not funded new ones. So, we still must import 90 percent of the medical isotopes used.

There are some areas where treatment of medical isotopes has made it into the mainstream here: breast cancer and prostate cancer. But you are right: The