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Abstract. Lars Björn doubts our assertion that ~~at the origin of life the fundamental molecules of life (those in the three domains) were UVC pigments, dissipatively structured under a thermodynamic imperative to absorb and~~ the driving force behind the origin and evolution of life has been the thermodynamic imperative of increasing the entropy production of the biosphere through increasing global solar photon dissipation.
Björn bases his critique on the ~~suggestion that non-living material can be more~~ fact that the albedo of non-biological material can sometimes be lower than that of biological material and concludes that ~~these~~ such examples counter our assertion. ~~However, Björn makes the erroneous assumption that albedo (reflection) is the only important factor related to photon dissipation (entropy production) occurring in the light-pigment interaction in living systems. He ignores the~~ Our reply to Björn, ~~in his critique of our article,~~ however, is that albedo (reflection) is only one factor involved in the entropy production through photon dissipation occurring in the interaction of light with material. The other contributions to entropy ~~production due to the photon interaction~~ production, which were listed in our ~~article; 1) the shift towards the infrared of the emitted spectrum, 2) the diffuse emission and reflection of light into a greater outgoing solid angle, 3) the coupling of photon-induced evapotranspiration in the~~ article, are; 1) the shift towards the infrared of the emitted spectrum (including a wavelength dependent emissivity), 2) the diffuse reflection and emission of light into a greater outgoing solid angle, 3) the heat of photon dissipation inducing evapotranspiration in the pigmented leaf, thereby coupling to the abiotic dissipative processes of the water cycle, which, besides shifting the emitted spectrum even father towards the infrared, promotes pigment production over the entire Earth surface. His analysis, therefore, ~~says very little about their photon dissipation potential, especially~~ does not provide legitimate reason for doubting our assertion that life and evolution are driven by photon dissipation. We remain emphatic in our assertion that the fundamental molecules of life were originally dissipatively structured UV-C pigments arising in response to the thermodynamic imperative of dissipating the prevailing Archean solar spectrum.

In the following, we respond to ~~each critique using the same section headings of Björn's~~

~~Comment.~~

Björn's Comment using the same section headings.

1 Introduction: Do living systems reduce the albedo of Earth?

Contrary to Björn's ~~assertions,~~ examples, in general, living organisms do, in fact, ~~generally~~ reduce the albedo with respect to regions devoid of ~~life,~~
~~and there are many data available in the literature.~~ life.
For example, the visible albedo of deciduous forests is 0.15 to 0.18 and that of coniferous forests is 0.09 to 0.15, while that of
sandy deserts is about 0.30 ~~[Barry and Chorley (1992)] and rocky deserts~~

(Barry and Chorley (1992)) and rocky deserts (Gobi) 0.21 ~~[Wang et al. (1998)]. And this~~ (Wang et al. (1998)). This is also true at

~~wavelengths greater than~~ wavelengths beyond the red-edge (~ 700 ~~nm), for example,~~ nm). For example, at these longer wavelengths, forest ~~1~~

albedo increases to about 0.3
~~[Coakley (2003)],~~ (Coakley (2003)), while sand and rocky desert albedo increases to about 0.50 ~~[Varotsos et al.~~
~~(2014); Coakley (2003)].~~

~~Our main~~ (Varotsos et al. (2014); Coakley (2003)).

1

More importantly, however, as emphasized in our article, determining entropy production due to light interacting with ma-
terial entails not only knowing reflection, but also wavelength dependent absorptivity and emissivity. In Michaelian and Cano
(2022) we show that, given a particular (non-zero) average albedo and emissivity, greater entropy production occurs when

absorption is strongest at short wavelengths and emission strongest at long wavelengths. Maximum entropy production occurs
when the material acts as if it were a black-body, i.e. with maximal absorptivity (zero albedo) and maximal emissivity (100
%) ~~of the radiation emitted by the Moon into space occurs~~
~~during the day and thus radiated basically only into a 2π solid angle.~~

across all wavelengths. Detailed calculations ~~of the entropy production of the Earth and compared it to that of its sister~~

show that biological material more closely approaches a black-body than non-biological material and produces more entropy through photon dissipation (Michaelian and Cano (2022)).

Our objection to Björn's critique ~~of our paper, however, is that it is based on his erroneous assumption that albedo is the only important factor relevant to photon dissipation in the light-pigment~~ is thus that it is based on the assumption that albedo is the only important factor relevant to photon dissipation in the light-material interaction. Björn states, "Thus, it appears that if Michaelian and Simeonov are

correct, one would expect ~~organisms, in~~ organisms (in ~~large part due to life increasing the amount of water vapor in the atmosphere [Kleidon (2008)]).~~ particular phototrophic organisms, or the ~~biosphere~~ biosphere) to be less reflecting and more absorbing than dead ~~matter." Although, as stated above, this is generally the case, one should not a priori~~ matter.". But one should not de facto "expect" this since, as we mentioned even in the abstract of our original article ~~[Michaelian and Simeonov (2015)], albedo (reflected light) is only one part of the equation for determining global photon dissipation or entropy production which can be attributed to pigments in life. Other factors important to entropy production are; (1) the red-shifting of the absorbed~~

~~energy in the pigments,~~ (Michaelian and Simeonov (2015)), other factors important to entropy production are; (1) the red-shifting of the absorbed energy in the pigments (including wavelength dependent emissivity), (2) dispersion of the emitted, reflected, and

~~response to the thermodynamic imperative of dissipating the prevailing solar spectrum could only be~~ transmitted photon beams into a larger outgoing solid angle, and (3) the coupling of photon dissipation in pigments to other abiotic entropy producing processes, such as the water cycle ~~[Michaelian (2012a, b)]~~ (Michaelian (2012a, b)). The water cycle i) further red-shifts the ~~energy, and~~ incoming spectrum, ii) ~~allows greater proliferation and spread of organic pigments over an ever greater surface area of Earth.~~

~~Therefore, the plausibility of our assertion that the fundamental molecules of life arose as pigments and co-evolved in~~ reduces the difference between day and night temperatures, providing emission into a greater 4π solid angle, and iii) allows proliferation of organic pigments over the entire surface of Earth, ~~meaning emission of infrared radiation into a solid angle of 4π~~ all of which increase entropy production.

The importance of these other factors can be seen when performing a ~~very simple approximate black-body calculation (see Michaelian (2012b) for a more accurate grey-body calculation) which takes into account, not only the albedo (reflected light), but also the~~

~~emitted light due to the red-shift in~~
~~the pigments, emission into greater solid angle, and the additional red-shift due to photon dissipation in pigments coupling to~~
~~abiotic processes such as the water cycle.~~

~~2~~

~~The temperature that the Earth emits into space, including the effect of the coupling of the heat of photon dissipation in~~
calculation of the global entropy production of Earth.
In Michaelian (2012b) we evaluated ~~by considering~~

~~all the factors related to photon dissipation (entropy production) due to pigments, not only the albedo. This can easily be~~
~~achieved by comparing the incoming solar spectrum with the outgoing global Earth reflected and emitted spectra, determining~~
~~the entropy production from the differences of these spectra, and then comparing this to other similar bodies devoid of life. We~~
~~have, in fact, performed such detailed~~ this by determining the difference in the entropy of the incoming and outgoing photon
beams, and compare this to its neighboring planets Venus and Mars ~~in another paper [Michaelian (2012b)] cited in our article under discussion. We found that Earth's~~
~~entropy production per unit area is almost twice~~ . We find that Earth's entropy production per unit area,
~~per unit time, is thus about~~

~~2.6 times greater for the Earth than for the Moon, contrary to what Björn would~~ after normalizing for distance from the sun, is significantly greater then that of either ~~of its neighbors, and this may be attributed to the presence of~~
~~life on Earth [Michaelian (2012b)].~~ neighbor, and conclude ~~from his albedo comparison. This~~
~~is because the black-body spectrum emitted at a lower temperature by Earth is much more red-shifted than that emitted by the~~

that this is
most probably ~~the source of, human concerns over responsibility or irresponsibility for burning fossil~~

~~fuels or for preserving present ecosystems. Although most of~~ due to the presence of life on Earth. In support of this conclusion, Kleidon et al. (2000) ~~have compared the surface temperatures and amount of water vapor~~
~~of a simulated Earth with and without life and find~~ compare surface

45 ~~significantly greater entropy production for a planet with life.~~

~~2~~ temperatures and amount of atmospheric water vapor for a simulated Earth with, and without, life. They find an 8 ◦C average lower temperature and 3 times the amount of water vapor in the atmosphere for the simulation ~~with life; the lower temperature and greater amount of water vapor implying~~ including life. The lower temperature and greater amount of water vapor imply (see below) greater entropy production for an Earth with life.

2 Ancient life

The Thermodynamic Dissipation Theory of the Origin of Life suggests that the fundamental molecules of life (nucleic acids, ~~by~~ amino acids, fatty acids, cofactors, etc.) were originally UV-C pigments dissipatively structured on the ocean surface from

common precursor molecules such as HCN, cyanogen, CO2 and water under the UV-C photon flux (between 210 and 285 nm) arriving at Earth's surface during the Archean (Michaelian (2011, 2017, 2021); Hernández and Michaelian (2022)). This wavelength region has sufficient energy per photon to transform carbon covalent (and double covalent) bonds, but not enough energy to ionize these molecules and thereby destroy them. The best geochemical evidence presently available suggests that

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~~pigments to the water cycle (evapotranspiration) and other irreversible processes (winds, ocean currents, convection cells, etc.~~

~~), is approximately -18 ◦C (255 K) corresponding to the temperature of the middle of the troposphere, at the~~ this light would have been present on Earth's surface from before the origin of life (at ∼3.9 Ga) and for at least 1000 million years (and perhaps even for 1500 million years (Meixnerová et al. (2021))) until organisms evolved oxygenic photosynthesis and saturated available oxygen sinks (Sagan (1973); French et al. (2015); Meixnerová et al. (2021)), leading to an ozone layer. We thus consider ~~the temperature data of the emitted spectrum. There exists extensive data for this [Schneider~~ ozone as a biology-procured pigment dissipating the UV-C region. Also around this time, biosynthetic pathways evolved enough for life to dissipatively structure pigments in the visible using visible wavelengths.

~~The surface temperature of the Moon during daylight hours (days are ∼ 30 Earth days) reaches 127 ◦C (400 K) which is therefore the approximate black-body temperature at which the Moon surface will radiate (re-emit) into space. Since the temperature difference between day and night on the Moon is so large (127 ◦C to -183 ◦C) and since the total amount of emitted radiation goes as T 4 for black bodies, the majority (99.8~~ Although the composition of Earth's early atmosphere is still highly debated, the scenario presented above is consistent with the bulk of the available geo- and bio-chemical data from the era (Kasting (1993); Lowe and Tice (2004); French et al. (2015); Meixnerová et al. (2021)) and, most importantly, consistent with the very particular and finely tuned UV-C photochemical characteristics preserved in the fundamental molecules of life. These include their very strong UV-C absorption and extremely rapid dissipation of the electronic excited state energy into heat through a conical intersection to internal conversion (see Figure

~~Not all light is absorbed by the respective surface, some of it is reflected (albedo). To simplify the~~ 3 of our article under discussion and Michaelian (2021)).
The fully developed ~~biocrusts reduce significantly the albedo of the~~ methanogens that Björn refers to, ~~but at the same time~~ capable of filling the atmosphere with methane, would not, of course,

have been around at the origin of life, but perhaps 500 - 700 million years later (Lowe and Tice (2004)). At this point, complex biosynthetic pathways would have evolved allowing dissipative structuring of pigments in the visible using, for example, the free energy accumulated from various visible photons ~~than living material, is not valid because, 1) the Earth and moon are physically very different astronomical bodies, and, more importantly, 2) albedo is a poor proxy for photon dissipation and entropy production. We can see this~~

and stored in ATP molecules. The intensity of the solar spectrum at

~~dS = dE − 1~~

~~, (1)~~
~~T1 T2~~

~~the approximate ratio of the entropy production Earth/Moon per unit incident energy per unit surface area for emission plus reflection is,~~

~~π~~
~~dS 0.71 · 4π · 1 +~~

~~Earth ≈ ΩSun (273−18) 0.29 · 2~~
~~Ω · 1~~

~~Sun 5800 0.0349887+3.1415926× 10−4 0.0353028~~
~~= = 2.612 (2)~~

~~dS π~~
~~Moon 0.85 · 2 · 1 0.15 · 2π 1 =~~

0.0133517+1.6249617× 10−4 0.0135142
ΩSun (273+127) + Ω ·

Sun 5800

where we are using a Sun surface temperature of 5800 K and ΩSun is the solid angle subtended by the Sun on Earth (or Moon),
Earth's surface as a function of time since present, including the effects of solar evolution, plate tectonics and methanogen
CH_4 production, leading to a period of atmospheric haze between 3.2 and 2.7 Ga was, in fact, discussed in our original article
and presented in figures 2 and 3 (Michaelian and Simeonov (2015)).

Björn seems to favor a hydrothermal vent, bottom of ocean, theory for the origin of life. However, Stanley Miller convinc-
ingly argued (Miller and Lazcano (1995)), that hydrothermal vents are regions of molecular destruction, not molecular creation.

75 7.193× 10−5 sr, but we have set it to one for the numerical values given in equation (2) since it anyway drops out of the ratio.

We have also ignored the term −1/T2 = −1/5800 in the first terms on the right hand side of the equation.
The entropy in the emitted plus reflected light per unit incident energy, per unit surface In fact, other than simple amino acids and fatty acids, no fundamental molecules have ever been produced in experiments simu-
lating hydrothermal vents. On the other hand, numerous experiments demonstrate that non-living material is better at
dissipating routes to most of the fundamental molecules
using UV-C light and common precursor molecules such as HCN and CO_2 in water, under UVC (see Michaelian (2021) and references therein). Furthermore,
bottom of ocean hydrothermal vent scenarios lead to the very difficult problem of explaining the very rapid appearance of pho-
ton absorbing than living material. He gives a tosynthesis (perhaps arising only a few million years after the origin of life (Mulkidjanian et al. (2006); Cardona (2022))) and

80 Moon at a much higher temperature, and also because the Earth emits its absorbed solar energy into a 4π instead of 2π solid
angle the even more difficult problem of explaining the very particular photon dissipative characteristics preserved in the fundamental
molecules (Michaelian (2021)).

3 Present vegetation compared to bare ground

Björn's second comparison of vegetation with "bare ground" suffers from the same oversight since it again considers only
albedo (reflection). Rather than looking only at reflection data, it is also important to
Contrary to Björn's assertion and examples, even beyond the red-edge, the albedo of areas covered with vegetation is usually lower than

~~that devoid of life [Barry~~ generally
lower than that devoid of life (Barry and Chorley (1992); Wang et al. (1998); Varotsos et al. (2014); Coakley ~~(2003)].~~

~~A further note of caution is that~~ (2003)). How-

~~if one of them is living material.~~

~~3~~

~~3 Vegetation~~ ever, as already emphasized, albedo (reflection) alone is insufficient to determine entropy production. Wavelength dependent
reflection, transmission, absorption and emission must be considered in a careful calculation, ~~we assume~~
~~that the albedo is the same over all wavelengths (a wavelength dependent albedo will not change the result). Therefore, we~~
~~assume that the Moon reflects 15% of all incident light and the Earth 29%. We assume, furthermore, that for~~ as performed, for example, in
Michaelian and Cano (2022). The result is that forests are 1.45 times more effective than a sand and rock desert at entropy

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production due to photon dissipation. Furthermore, natural "bare ~~ground" is usually not devoid of life, or~~ ground", even over the recently formed volcano in Björn's
example, is usually not devoid of life, nor of life produced (biological) ~~pigments,~~ pigments. Biocrusts form rapidly and significantly

~~surements~~ reduce the albedo of the rock and soils they cover ~~[Ustin et al. (2009)].~~ (Ustin et al. (2009)). An important ~~component is the cyanobacterial pigment~~ cyanobacterial pigment reducing albedo
significantly is scytonemin ~~which reduces albedo significantly [Couradeau et al. (2016)].~~

(Couradeau et al. (2016)).

Infrared temperature measurements, obtained from airplane ~~fly-overs. The result is clear; the temperature~~ fly-overs, support our assertion that life, ecosystems, and the biosphere increase entropy production (Schneider and Kay ~~(1994)] compiled from infrared temperature mea-~~

(1994)). Temperature measurements over climax ecosystems are
lower than those measured over perturbed ecosystems, and these are lower than those measured over regions devoid of life. ~~Another simple way of seeing this is~~ This

~~Even beyond the red-edge, however, as mentioned above,~~ can be observed in the fact

that rocks (or ground without organic material) become much hotter (emit at shorter wavelengths)
under the sun than does vegetation – albedo plays only a small part, it is vegetation does. By expending free energy to convert liquid water in the leaf to further photon dissipating processes such as the water cycle, which further allows dissipating biopigments to flourish over all of Earth's surface. His assumption is therefore into a gas, which then condenses
at the cold cloud tops (~
5 Km), averaged over latitude. Since average day and night temperatures of the middle troposphere are similar (varying by
< 0.5 K [Muhsin et al. (2017)]) due to surface convection, winds, currents, the heat capacity of water vapor, etc., the radiation
re-emitted from Earth is effectively emitted into a 4π solid angle.

tops, releasing far infrared photons, the water cycle increases further still photon dissipation. It is the red-
shifted emission and the association of life with water and the water cycle that plays the greater
part.

is very important to global entropy production
(Michaelian (2012b)). This fact should not be conveniently or judiciously ignored.

Clouds, because of high albedo, do reduce entropy production locally, but they are an unavoidable part of the water cycle
which allows water, and thus entropy producing pigments and ecosystems, to spread over land far from ocean shores.

4 The temporal aspect

The forests, Forests, as Björn correctly indicates, are sometimes buried and later burned as fossil fuel by humans. However, they
produced at least 1000 times more entropy during their
lifetime than that obtained by burning the same trees as fossil fuel
today. Less than produce at least 1000 times more entropy than obtained by being buried consumed as fossil fuel today as compared to ecosystems of the past.

Nature's thermodynamic imperative of increasing global entropy production through increasing photon dissipation is indif-
since less than

dissipation in the leaves (the dissipation involved in 0.1% of the free energy in sunlight goes into carbon bond making, which is how photosynthesis stores free energy [Gates (1980)]. In (Gates
(1980)). Thus, even though
the Moon absorbs more light (has lower albedo), this increase in absorption does not compensate for the greater amount of
red-shift and the dispersion of the emitted light into a greater solid angle occurring on Earth attributable to pigments in life.

~~Simply comparing albedos of different~~ in living plants, more than 99.9% of solar photon free energy is simply ~~turned into heat through photon~~

dissipated into heat in the leaves (involving the process of photosynthesis itself, plus non-photochemical quenching). This heat of dissipation is then coupled by the living system to the water cycle through ~~evapotransporation from leaves which increases further the photon dissipation or entropy production of Earth [Michaelian (2012b)].~~

~~The fact that a~~ evapotranspiration from leaves, further increasing the photon dissipation or entropy production of the ecosystem or, more globally, the biosphere (Michaelian (2012b)).

~~ecosystems arose as a result of the thermodynamic imperative of entropy production through~~ The fact that a very small amount of free energy available in sunlight is not instantly dissipated by ecosystems, and instead is stored for different amounts of time, has no bearing on the point under discussion concerning whether or not pigments, life, and ecosystems arose as a result of the thermodynamic imperative of photon dissipation. Storage of free energy for later use is, of course, necessary for maintaining the different trophic levels of an ecosystem, and this hierarchy ~~actually improves global dissipation.~~

~~Although the storage of a small amount of free energy for larger times~~ can be shown to improve global photon dissipation (Michaelian (2016)).

~~at wavelengths greater than the red-edge, 3) that~~ Although the storage of a very small amount of free energy in a practically inaccessible form (for example, deposited underground as coal ~~and~~ or petroleum) may make ecosystems imperfect at dissipation, so too ~~does; 1) the fact that their albedo is not zero, 2) that pigments absorb less strongly~~

does the fact that; 1) their photon absorption is not complete (albedo is not zero), 2) their emissivity is not maximal, 3) the physical size of the pigments are not at their theoretical limit, 4) ~~that~~ fluorescence reduces entropy production, i.e. the quantum efficiency for dexcitation through a conical intersection for internal conversion to the ground state could be further increased, 5) ~~that~~ pigment distribution over the whole Earth

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~~be seen, for example, in the appearance of new pigments over time, in the spread of life over the whole Earth surface, in the~~

~~fact that increases in vegetation increase water vapor in the atmosphere and this maintains~~

surface could be further improved. In other words, ecosystems still have room to evolve under the thermodynamic imperative towards becoming even better dissipating ~~4~~

systems.

Modern ecosystems are, however, much more ~~apt~~ effective at dissipating sunlight than were ancient ecosystems, ~~and this can~~ which can be seen from the facts; 1) the appearance of new pigments over time covering ever more of the solar spectrum (Michaelian and Simeonov (2015)), 2) the spread of life over the entire Earth surface and the increase in biomass over time (Benton

~~ferent~~ (1978)), 3) the observation that vegetation increase water vapor in the atmosphere (Kleidon et al. (2000)), maintaining day and night temperatures similar, thereby increasing ~~the solid angle of the Earth's emitted radiation, and, in the fact that much less free energy stored in carbon bonding in organic matter is~~ to 4π instead of 2π the solid angle of the Earth's emitted radiation (effectively doubling this part of the entropy production), and, 4) the greater biodiversity of modern ecosystems implies more complete energy dissipation (Buzhdygan et al. (2020)).

The thermodynamic imperative based on the second law is also driving human ~~evolution and activity.~~ activity and evolution. Human free energy use (dissipation) has increased exponentially over the last few centuries and this trend ~~will~~ is projected to continue for as long as

we remain a ~~robust~~ viable knowledge possessing ~~and technical species on this planet.~~ species. Our future contribution to global dissipation ~~would appear to~~ will almost certainly go much beyond our present dissipation of the chemical potential stored in fossil fuels, ~~and beyond our traditional~~ or beyond our animal role as gardeners for the ~~plants, to spreading biopigments over the whole of Earth (global greening), and even to eventually~~ photon dissipating plants (e.g. fertilizers and seed spreaders). We have already significantly increased the entropy production of Earth through global greening (Piao et al. (2020)) and look soon to be capable of terraforming other planets.

~~pared to water without organic material~~ 5 Aquatic environments

~~Contrary to what Björn suggests, living~~ The data presented by Björn on light reflection from different water bodies, with and without organic material (their figures 4 and 5) are entirely consistent with our assertion that life on water surfaces increases entropy production, principally through short wavelength photon dissipation. As emphasized, both ~~bodies this~~

reflected light is diffuse and reflected into a 2π solid angle.

Since [P(rigogine ()1967)],

1

the wavelength dependent absorptivity and emissivity are needed to calculate the entropy production (see Michaelian and Cano (2022)). Albedo of the Moon, a world without life

Comparing the albedo of Earth to the Moon, in the manner Björn does to measurements alone are inadequate. Absorption

microlayer contributes an additional and dissipation into heat of the shorter incident wavelengths contributes more to entropy production. It is not the energy, nor the number of examples in which he shows that the albedo of material devoid of

5 life is lower than that of biotic photons, which is relevant to nature's thermodynamic imperative, but rather than of 2π, again increasing entropy production.

A grey-body calculation of the entropy production of the Earth compared to its neighbors Mars and Venus shows that Earth's

the dissipation of free energy, and

this quantity depends not only on the reflected, but also on the absorbed and emitted spectra.

Living organisms and free-floating, biologically-derived organic pigments – colored dissolved organic matter, CDOM matter – at the ocean surface microlayer certainly do augment photon dissipation (entropy production) com-

compared to water without organic material

ducing entropy), increases the probability of rain further inland from the coasts and thus the possibility of sustaining vegetation for photon dissipation far inland from ocean shores [Makarieva and Gorshkov (2007)]. Vegetation, by increasing the amount of water vapor in the atmosphere [Kleidon et al. (2000)], also helps keep the temperature similar on the day and night sides by, 1) increasing photon absorption at the surface, particularly for shorter wavelengths and at shallow incident photon angles, and, 2) increasing the red-shifting of the absorbed energy red-shift of the emitted spectrum by coupling it to evaporation from the ocean surface microlayer (see Michaelian (2012b) and references therein). A detailed calculation of the entropy pro-duction production as a function of incident photon wavelength for the ocean surface microlayer, with and without organic material, is given section Section 6 of Michaelian (2012b). By absorbing and dissipating UV and visible light, the organic matter at the sea surface

ocean surface microlayer contributes an additional

entropy production per unit surface area is almost twice that of Mars (even though, as

Björn correctly points out, Mars has

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lower global albedo than Earth), and about 1.6 times that of Venus [Michaelian (2012b)], and this is most likely attributable to
the presence of life on Earth.

6 approximately 23% to the total entropy production due to photon dissipation in this layer on a clear day, and a surprising 400%
[Michaelian (2012b)]. The particular data
presented by Björn on visible reflection alone, again, says little about photon dissipation or entropy production.

Forests do on an overcast day, it contributes an additional day (Michaelian (2012b)).

5

6 Ice and snow

At least for these materials, it appears that Björn is in agreement with us are blissfully unaware of it, that life does indeed have a tendency to increase cloudiness over land, but this is important for the other important entropy
producing process of the biosphere; the water cycle. Furthermore, cloudiness, although diffusely reflecting sunlight (also pro-

increase photon dissipation.

7 Conclusions

Björn incorrectly 155 rise to entropy production of Björn assumes that albedo (reflection) is the only important factor related to photon dissipation in pigments giving
entropy production due to light interaction with
pigments in living organisms, ecosystems, and the biosphere. He ignores the other components involved in entropy production attributable to photon interaction with biology
photon dissipation in
vegetation mentioned in our original article and abstract; the shift
towards the infrared of the emitted spectrum, the emission into a greater solid angle, covering all of Earth's surface with
pigments, the coupling of life to other photon dissipating processes such as the water cycle. 1) the shift towards the infrared of the emitted spectrum (wavelength
dependence of the emissivity), 2) photon emission into a greater solid angle due to similar day and night temperatures as a
result of the increase in atmospheric water vapor attributable to vegetation, 3) the coupling of life to other photon dissipating

~~thermodynamic dissipation theory of the origin of life [Michaelian~~ processes such as the water cycle, 4) the covering of all of Earth's surface with pigments and water. ~~Sufficiently~~ His conclusions are therefore ~~mistaken and~~ incorrect and ~~his analysis does not provide legitimate reason for doubting our assertion that the fundamental molecules of life arose as pigments as a response to the thermodynamic imperative of dissipating the prevailing~~ thus do not provide legitimate reason for doubting our assertion that "we have presented evidence that supports the thermodynamic dissipation theory of the origin of life (Michaelian (2009, 2011, 2016, 2017, ~~2021)], which states that life arose and proliferated~~ 2021))".

Our theory asserts that life arose as the dissipative structuring and proliferation of pigments under UV-C light to carry out the thermodynamic ~~function of dissipating the entropically most important part of the~~ imperative of dissipating the enthropically most important part of the surface solar spectrum (the shortest

~~Finally, since our first articles,~~ wavelength photons) prevailing at Earth's ~~surface and that this irreversible process began to evolve and couple with other irreversible abiotic processes, such as the water cycle, to become more efficient, to cover~~ surface, and that this irreversible process evolved and coupled to other irreversible abiotic processes, such as the water cycle, to increase the red-shift of the globally emitted spectrum, to dissipate ~~this UVC light into heat.~~ ever more completely the entire electromagnetic spectrum, and to cover ever more of Earth's ~~surface."~~

surface.

Since our first articles published on the topic beginning in 2005 ~~[Michaelian~~ (Michaelian (2005, ~~2009, 2011)],~~ 2011)), we have continued to uncover ~~evidence pointing to~~ more evidence supporting a connection between photon dissipation and the origin and evolution of life. These include; 1)

~~that many of the fundamental molecules of life strongly absorb UVC~~ that many of the fundamental molecules of life strongly absorb UV-C light in exactly ~~that~~ the wavelength region that was arriving at Earth's surface during the Archean ~~[Michaelian (2012b, a); Michaelian and Simeonov (2015); Michaelian (2016)],~~ (Michaelian (2012a, b); Michaelian and Simeonov (2015); Michaelian (2016)), 2) that many of the fundamental molecule of life possess conical intersections for rapid ~~radiationless dissipation of the photon-induced~~

radiation-less dissipation of the photon-induced electronic excitation energy ~~to the ground state [Michaelian~~ (Michaelian (2017, ~~2021)],~~ 2021)), 3) that efficient photochemical routes to production of the fundamental molecules from simple and common precursors, such as HCN, cyanogen, and CO_2 in water, under UV-C light have been found,

and that these routes have the hallmarks of dissipative structuring ~~[Michaelian~~ (Michaelian (2017); Michaelian and Rodriguez (2019); Michaelian ~~(2021)], 4) that we have found~~ (2021); Hernández and Michaelian (2022)), 4) that we have discovered a DNA and RNA enzyme-less denaturing mechanism ~~tied to UVC photon dissipation [Michaelian and Santillán Padilla (2014); Michaelian~~ involving UV-C photon dissipation (Michaelian and Santillan ~~(2019)],~~ (2019)), 5) that the homochirality of life can be explained from the morning/afternoon ~~temperature and UVC~~ ocean surface temperature asymmetry ~~at the ocean surface and the temperature dependence of UVC-induced denaturing [Michaelian (2018)],~~ and UV-C photon circular polarization at the ocean surface and the temperature dependence of UV-C-induced denaturing (Michaelian (2018)), 6) that the strong chemical

~~other astronomical bodies [Michaelian and Simeonov (2017)],~~ affinity of the ~~UVC~~ UV-C absorbing amino acids (the aromatics), and others, to their codons and anticodons can be explained based on the thermodynamic selection of greater photon dissipation afforded to the complex ~~[Mejía~~ (Mejía Morales and Michaelian ~~(2020)],~~ (2020)), 7) that dissipative structuring of the fundamental molecules under ~~UVC~~ UV-C light provides a simple explanation for their existence in space ~~and on~~

as well as on other astronomical bodies (Michaelian and Simeonov (2017)), and, 8) that plants appear to optimize evapotranspiration (the water cycle) over photosynthesis [see Michaelian (2012a, b) and references therein].

~~We~~ 6

We thank Lars Björn for his Comment and welcome and appreciate all challenges to our Thermodynamic Dissipation Theory for the Origin and Evolution of Life.

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