Chapter 3
Extraterrestrial Life as the Great Analogy, Two Centuries Ago and in Modern Astrobiology

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Abstract Mainstream ideas on the existence of extraterrestrial life in the late 18th and early 19th centuries are examined, with a focus on William Herschel, one of the greatest astronomers of all time. Herschel viewed all of the planets and moons of our solar system as inhabited, and gave logical arguments that even the Sun, and by extension all of the stars, was a giant planet fit for habitation by intelligent beings. The importance for astrobiology both two centuries ago and now of the type of inductive reasoning called "analogy" is emphasized. Analogy is an imperfect tool, but given that we have only one known case of life and of a life-bearing planet, it is very difficult to make progress in astrobiology without resorting to analogy, in particular between known life and possible other life. We cannot overcome the "N = 1 Problem" without resorting to this "Great Analogy" to guide our research.

3.1 Introduction

The core questions of astrobiology are not new. They have always been asked and are central to Western intellectual history: How did life begin? How has it changed? What is the relation of *Homo sapiens* to other species? Does life exist elsewhere? If so, where might it be and what might it be like? For over 2000 years astrobiological ideas have been woven through the realms of natural philosophy, theology, and science—supported by evidence ranging from pure metaphysics to empirical science. Over that same period our perceived place in the cosmos has oscillated within and between the extremes of either (a) being the special, unique product of all creation, or (b) the *plurality of worlds*, in which every star is a Sun with peopled planets.

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D. A. Vakoch (ed.), *Astrobiology, History, and Society*, Advances in Astrobiology and Biogeophysics, DOI: 10.1007/978-3-642-35983-5_3,

In this chapter I will examine mainstream ideas on the existence of extraterrestrial life[1] in the late 18th and early 19th centuries, focusing on William Herschel (1738–1822), one of the greatest astronomers of all time. I will emphasize the importance of the type of inductive reasoning called "analogy" both then and now. For Herschel's context I rely heavily on the comprehensive histories of ideas on extraterrestrial life by Dick (1982) and Crowe (1986). The introductory chapter in this volume by Crowe and Dowd (2013) also provides excellent background.

Herschel asserted in 1795 that the Sun had a cool region below its surface and was in fact inhabited, and ever since this has been looked upon as an unfortunate misguided belief by the great astronomer. He in fact took *all* the planets (*and* our Moon) to be inhabited with intelligent beings, as were the myriad unseen planets that he presumed circled other stars. How did he come to such seemingly outlandish conclusions? In this chapter I will argue that this idea of Herschel's was no less rational than others of his that we readily applaud. We must look carefully at not only the science, but also its enveloping context. Whether two centuries ago or today, the scientific enterprise has always been shaped by metaphysics, doctrines, and predilections as received from philosophy, religion, and society. Both William Herschel *and* we today can do no more than tackle questions with the best tools available, apply the cleverest insight we can muster at the time, and struggle to fashion a consensus as to the nature of the world. For the case of extraterrestrial life, where we have only one known example to guide us, I argue that out of necessity the best one can do, in the past as well as today, is to follow as a guide the "Great Analogy," namely that of Earth and its life to other extraterrestrial locales and their possible life (Sullivan and Baross 2007, 5).

3.2 Analogy

Discussion of the concept of analogy and analogues can be found as early as Aristotle (Hesse 1966). Most modern philosophers discuss analogy with respect to the process of creating and verifying scientific models (say, of atomic structure), but a treatment more relevant to the present discussion was published in 1843 by John Stuart Mill in *A System of Logic* (Crowe 1986, 231–232; Crowe and Dowd 2013). In Chap. 20 of Book III Mills analyzes analogy as a form of induction that is incomplete in the sense that one has *not*, as in induction, experimentally ruled out all possible hypotheses except one (which must therefore be correct). Thus in analogical reasoning the conclusion can only be probabilistic, and establishing the correct degree of confidence in the validity of any given conclusion is very

[1] Until the 20th century, discussions of extraterrestrial life always centered on *intelligent* beings, with very limited interest in the possible existence of simple organisms.

difficult. Mill even uses the question of possible life on the Moon or planets as an example, deducing that it seems unlikely on the Moon, but somewhat likely on some planets.

Here is an example of Mill's principles of analogy relevant to today's astrobiology:

1. *Two objects A and B are known to be similar in two properties*.
   Earth and exoplanet KOI 77 have (1) similar radii and (2) similar distances from the Sun and a Sunlike star, respectively.
2. *Object A has a further third property, but this is not known for B*.
   Earth also has [an atmosphere, plate tectonics, oceans, a ~300 K temperature, microbial life, complex life….].
3. *Can we deduce that B probably has that third property also*?
   KOI 77 probably also has [an atmosphere, plate tectonics, oceans, a ~300 K temperature, microbial life, complex life….].

The strength of an argument from analogy such as this depends on:

(a) the relevance of the known shared properties to the unknown property
(b) the number and variety of *known* cases [only one (A) in the example]
(c) for the known shared properties [only two in this example]: their variety, their number, their fraction of all relevant properties, and the relative weights to assign each property.

Examining the above three criteria, we see that they are all rather subjective. Regarding (a), who is to say exactly how relevant or not a planet's radius and distance from its star is to whether or not it has an ocean or the presence of microbial life? Regarding (b), we immediately run into astrobiology's "N = 1 Problem," namely that we have only *one* known example of (i) a life-bearing planetary system, (ii) a life-bearing planet, (iii) a form of life, and (iv) an evolutionary history of life (Sullivan and Baross 2007, 5).[2] Finally, regarding (c), myriad complexities and conundrums arise: How do we decide how to weight the various possible similarities and their presence or lack of same–is planetary size more important than distance from its star? How many similarities must we have before we consider an argument by analogy to be convincing enough to, for example, hand a Nobel Prize to someone for first finding "another Earth"?!

After making all of these philosophical and logical points, Mill asks whether analogical argument has any use in science, and then answers in the affirmative, namely that analogy's highest scientific value is as a guide-post, pointing out the direction for more rigorous investigations. His answer is very apt for astrobiology today, for although we frustratingly cannot make airtight inferences, analogies do nevertheless importantly guide useful further research.

[2] The N = 1 Problem leads to heroic mathematical and logical efforts to overcome it. For example, see the recent insightful Bayesian analysis by Spiegel and Turner (2012), who try to reach conclusions about planets in general based on the fact that life emerged relatively quickly for the one known case of early Earth.

In the following section I highlight salient ideas on extraterrestrial life leading up to Herschel's time, showing in particular the heavy role of analogy in the prevalent reasoning.

3.3 Eighteenth Century Views on Extraterrestrial Life

As detailed earlier in this volume by Crowe and Dowd (2013), a Principle of Plenitude was central in European natural philosophy and theology from the Middle Ages onward: a perfect and glorious God must bring to be all that is possible, out of the fullness and goodness of his Divine Power. Furthermore, nature exhibits a basic uniformity and unity indicative of God's perfection. When these principles were applied to the question of extraterrestrial life, most concluded that it must be ubiquitous. For example, in the late 17th century the Parisian Bernard le Bovier de Fontenelle wrote a slight book that had enormous influence on the reading public in Europe. *Conversations on the Plurality of Worlds* (*Entretiens sur la pluralité des mondes*) was published in 1686 and over a century ran through almost a hundred editions in many languages.[3] Under the guise of a series of moonlit conversations with a charming but unschooled marquise, Fontenelle lays out the latest in astronomical knowledge and employs the Principles of Plenitude and of the uniformity of nature to assert the existence of inhabitants not only on the planets we know, but also on presumed planetary retinues accompanying every star in the sky. Just as our world exhibits a profound fecundity and diversity, by analogy it would certainly be wasteful of Nature to possess all these other locales without populating them. There is a purpose for each and every element of Creation.

As the mechanical Universe of Isaac Newton took hold in the 18th century, another important way of thinking called *natural theology* took its place alongside scriptural or revealed theology based on the Bible. Natural theology sought to reconcile religious beliefs and findings from natural philosophy by studying the "Book of Nature" to learn of God (and even prove his existence). It had an important influence on mainstream science throughout Europe and America as late as the mid 19th century,[4] with particular persistence and strength in Britain. For example, the Scottish minister Thomas Chalmers wrote an influential treatise entitled *A Series of Discourses on the Christian Revelation, Viewed in Connection with the Modern Astronomy* (1817). One argument of particular interest to today's astrobiology concerned microscopic realms, which, Chalmers said, revealed worlds and "tribes of animals" every bit as unknown and vast and fascinating as those seen in telescopes. Infinity in one direction was balanced by infinity in the

[3] A modern English translation with excellent commentary was published in 1990 by the University of California Press.

[4] Even today, there are those who very much work in this tradition by promoting the necessity, based on scientific findings, for so-called Intelligent Design. For a remarkable astrobiological example, see *The Privileged Planet* by Gonzalez and Richards (2004).

other. Since God's beneficence had applied to these realms even before we were aware of them, so God cared for humans even though we might be insignificant on a cosmic scale.

Three writers in the tradition of natural theology who were important for setting the stage for William Herschel were Thomas Wright of Durham, Immanuel Kant, and James Ferguson (Crowe and Dowd 2013). Wright, an Anglican cleric in the north of England, published *Original Theory or New Hypothesis of the Universe* in 1750. He thought it a ridiculous notion that all the stars and their presumed planets could have been made for "this diminutive World, our little trifling Earth." And in turn all those planets were populated because neither Nature nor God does anything in vain. Just as there are fish in every river, by analogy there were beings on every planet around every star.

Immanuel Kant, the great philosopher of Königsberg, early in his career wrote *Universal Natural History and Theory of the Heavens* (1755). He interpreted the Principle of Plenitude as implying that the entire Universe is full of an infinite number of forming and decaying worlds:

> Analogy does not leave us to doubt that these systems have been formed and produced in the same way as the one in which we find ourselves, namely, out of the smallest particles of elementary matter that filled empty space—that infinite receptacle of the Divine Presence.

Finally, William Herschel was directly influenced by James Ferguson, an English astronomer and lecturer, who in 1756 published his highly successful textbook *Astronomy, Explained upon Sir Isaac Newton's Principles*. In 1774, when Herschel was learning astronomy (as a fulltime musician), he bought the latest edition of Ferguson and learned not only about the planets, but also their "rational inhabitants," who were "creatures endowed with capacities of knowing and adoring their beneficent Creator." The stars must have a purpose and that purpose must be to illuminate nearby planets. Ferguson spoke of "a general analogy running through (all of Creation) and connecting all the parts into one scheme, one design, one whole." All the planets and their moons "are much of the same nature with our Earth, and defined for the like purposes."

3.4 William Herschel

Herschel was born in Hanover (now in Germany), but spent most of his life in England. After a successful career as a musician (and amateur astronomer) until his early forties, upon his spectacular discovery in 1781 of Uranus, the first non-telescopic planet, he became a fulltime astronomer, aided by the patronage of King George III. Over the next few decades he built unprecedentedly large and accurate reflector telescopes and became an indefatigable and astute observer of the heavens. Assisted by his sister Caroline, he singlehandedly revolutionized astronomy, then dominated by a concern with our solar system and accurate positions of stars and planets (Hoskin 2011). Herschel instead took his contemporaries outside the solar system by surveying the entire northern sky for faint nebulae, star clusters, and double stars. He also produced the first quantitative map of our stellar system (a process he called the "construction of the heavens"). To understand the nature of his thousands of newly catalogued objects, he brought into astronomy the novel idea of deducing their slow evolution by taking their present properties to be exemplars of various stages of maturity during the lifetime of any individual object. Furthermore, he demonstrated for the first time that some stars were in orbit about each other ("binary stars" was his neologism) and thus that gravity applied to the sidereal universe beyond the solar system.

But Herschel did not neglect the solar system—40% of his publications dealt with observations of the Sun, planets, moons, comets, and the new *asteroids* (again his new term). He discovered four moons of Saturn and Uranus, and investigated in scrupulous detail many properties of the visible features of planets, including the Martian polar caps and the Saturnian rings. The Sun too was of great interest and, almost as a byproduct, he discovered (in 1800) infrared radiation from the Sun. It is also with the Sun that we encounter what is often put forward as one of the few serious mistakes of Herschel's career, namely his assertion in 1795 that the Sun had a cool region below its surface and was in fact inhabited. He in fact argued that *all* the planets (*and* our Moon) were inhabited with intelligent beings, as were the myriad unseen planets that he presumed circled other stars.

While still a fulltime musician in the fashionable resort town of Bath, Herschel became quite serious about his astronomy and was active in the Bath Philosophical Society, a group of gentlemen interested in all aspects of the natural world. He fabricated his first metal mirrors and began telescopic observations of everything from stars and nebulae to planets and the Moon. After a few years of experience, he grew bold enough in 1780 to submit his first paper to the prestigious Royal Society in London. But, as Crowe (1986, 62–66) has shown [also summarized in this volume in Crowe and Dowd (2013)], the originally submitted manuscript contained many claims concerning intelligent life on the Moon, backed up by his observations of, for instance, towns and a huge forest on the Moon. The Astronomer Royal (Neville Maskelyne), acting as referee, insisted that Herschel remove almost all of his enthusiastic arguments for lunarians. Herschel, anxious to break into the elite world of the Royal Society, obliged and focused on his detailed determination of the heights of lunar mountains (from measurements of their shadow lengths). But he also managed to slip in the statement: "[study of the Moon leads to] the great probability, not to say almost absolute certainty, of her being inhabited" (Herschel 1780, 508). In the paper as finally published, this was the lone sentence referring to lunarians.

In subsequent publications over 40 years he similarly severely limited his mentions of extraterrestrial life, while nevertheless maintaining his conviction in the ubiquity of alien beings. Note that unlike most of his predecessors, Herschel always backed his arguments for extraterrestrial life with empirical evidence: detailed observations of planetary surfaces, clouds, rings, and satellites (Schaffer

1980, 100–102). Following are some of his published statements from the seventy papers he published in the *Philosophical Transactions of the Royal Society*. (All bolding of phrases is mine.)

From Herschel (1784, 260 and 273) on detailed observations of Mars:

> The analogy between Mars and the earth is, perhaps, by far the greatest in the whole solar system.
> [Mars] has a considerable but moderate atmosphere, so that **its inhabitants** probably enjoy a situation in many respects similar to ours.

From Herschel (1785, 258) on the "construction of the heavens" (structure of the Milky Way system):

> As we are used to call the appearance of the heavens, where it is surrounded with a bright zone, the Milky-Way, it may not be amiss to point out some other very remarkable Nebulæ which cannot well be less, but are probably much larger than our own system; and, being also extended, **the inhabitants of the planets that attend the stars** which compose them must likewise perceive the same phænomena. For which reason they may also be called milky-ways by way of distinction.

From Herschel (1792, 5) on detailed observations of Saturn's rings:

> This opening in the ring must be **of considerable service to the planet**, in reducing the space that is eclipsed by the shadow of the ring to a much smaller compass.

Explanation: The "opening in the ring" refers to what is today called Cassini's Division, and Herschel presented detailed evidence that it was truly a gap, not just dark material. "Service to the planet" is an obtuse way to say "service to the Saturnians," who, because of the gap, are not shaded as badly by the ring(s) during the various Saturnian seasons, and who need every bit of solar warmth that they can muster at 10 AU from the Sun![5]

From Herschel (1805, 272) on observations of Saturn:

> There is not perhaps another object in the heavens that presents us with such a variety of extraordinary phenomena as the planet Saturn: a magnificent globe, encompassed by a stupendous double ring: attended by seven satellites:…all the parts of the system of Saturn occasionally reflecting light to each other: **the rings and moons illuminating the nights of the Saturnian**….

From Herschel (1814, 263) on the evolution of stars and nebulae:

> **Stars**, although surrounded by a luminous atmosphere, may be looked upon as so many **opaque**, **habitable**, **planetary globes**; differing, from what we know of our own planets, only in their size, and by their intrinsically luminous appearance.

In addition to the above short interjections, on one occasion Herschel included several pages of arguments for extraterrestrial beings. This, however, was not for any planet or moon, but for the *Sun*, and, by extension, all other stars. Based on detailed observations and plausible physics for his time, Herschel argued first that the Sun was in essence a giant planet, and secondly that it was probably inhabited by beings adapted to its decidedly unearthlike conditions.

[5] The usefulness of the Cassini Division to the Saturnians was a point that Herschel undoubtedly took from Ferguson's book, although he does not acknowledge this.

3.5 Herschel and the Inhabited Sun

It is extremely difficult for today's reader not to think that the Sun has always obviously been considered an extremely hot ball of gas. It has of course long been realized that the Sun was the source of all heat and light for the Earth, but it does not necessarily follow that (a) the surface of the Sun is extremely hot, or (b) that the interior of the Sun must be even hotter and in the gaseous state. In fact it was not until the early 20th century that physics and astronomy established that the Sun's entire interior was probably extremely hot and gaseous, not liquid or solid.

Most natural philosophers in Herschel's time took the Sun to be solid. Herschel himself (1795, 62) argued that "by calculation from the power [the Sun] exerts upon the planets we know [it] to be of great solidity." He does not give any further details, but he must be referring to the fact that Newtonian theory allowed one to calculate the mass of the Sun, which when combined with its volume yielded a mean density greater than that of water, implying that it was solid and planet-like.

Secondly, through years of carefully observing sunspots, Herschel confirmed that sunspots were actually depressions relative to the bright solar surface. He then hypothesized that the darkness of sunspots indicated that one was peering through "openings" in the bright clouds above the actual dark surface of the Sun below, not unlike an observer on the Moon looking at the surface of the Earth through gaps in the cloud cover. He then concluded (Herschel 1795, 63):

> The Sun, viewed in this light, appears to be nothing else than **a very eminent**, **large**, **and lucid planet**…. Its similarity to the other globes of the solar system with regard to its solidity, its atmosphere, and its diversified surface; the rotation upon its axis, and the fall of heavy bodies, leads us on to suppose **that it is most probably also inhabited, like the rest of the planets**, **by beings whose organs are adapted to the peculiar circumstances of that vast globe**.

Continuing, he emphasized that this was not some wild speculation (as in the past), but rather an eminently scientific conclusion, based on detailed observations and plausible deductions:

> Whatever fanciful poets might say, in making the sun the abode of blessed spirits, or angry moralists devise, in pointing it out as a fit place for the punishment of the wicked, it does not appear that they had any other foundation for their assertions than mere opinion and vague surmise; but now **I think myself authorized, *upon astronomical principles*** [italics in original]**, to propose the sun as an inhabitable world**, and am persuaded that the foregoing observations, with the conclusions I have drawn from them, are fully sufficient to answer every objection that may be made against it.[6]

Lastly, Herschel employed "analogical reasonings" concerning the "construction and purposes of the sun." The word *purposes* here is telling, for we see that he is implicitly making a teleological argument regarding the Creator's perfect

[6] See Crowe (2011) for a full historical account of the notion of an inhabited Sun, an idea that started long before Herschel and, abetted by his authority and arguments, lasted well past his time.

design, where each element of the design has achieved its highest possible purpose. Combined with the Principle of Plenitude, this purpose would be habitation by intelligent beings. Herschel then makes the case by analogy that the Moon should be inhabited because of all of its other similarities to the Earth: considerable size, mountains and valleys, variety of seasons and day/night cycle, stars and planets rising and setting, heavy bodies falling, and its own "capital satellite" (the Earth!).[7] And just as the lunarians would make a mistake in thinking that the Earth hanging in their sky had no denizens, so would we in dismissing the Sun as having no purpose other than to act as our attractive center and source of heat and light. He then concludes:

> From experience we can affirm, that the performance of the most salutary offices to inferior planets, is not inconsistent with the dignity of superior purposes; and, **in consequence of such analogical reasonings**, assisted by telescopic views, which plainly favor the same opinion, we need not hesitate to admit that **the sun is richly stored with inhabitants**.

Herschel's final leap is to link our solar system and the sidereal universe beyond: "But if stars are suns, and suns are inhabitable, we see at once what an extensive field for animation opens itself to our view." He concludes by pointing out that by analogy

> we may have an idea of **numberless globes that serve for the habitation of living creatures**. But if these suns themselves are primary planets, we may see some thousands of them with our own eyes; and millions by the help of telescopes.

In other words we cannot see the (inhabited) planets associated with each star, but we *can* actually see the inhabited "primary planets," i.e., the stars themselves. The stars/suns thus have a purpose in accord with the Principle of Plenitude (Herschel 1795, 71):

> **Many stars, unless we would make them mere useless brilliant points, may themselves be lucid planets**.

3.6 Conclusion

It is indeed a bold and provocative enterprise that astrobiologists tackle when they test the world and develop views on fundamental topics such as the role of life in the Universe. As we astrobiologists try to extend the Copernican Principle to the *biological* world, the issues become even more profound than for Copernicus, because the uniqueness of us humans, as well as our form of life, is more deeply vested in our psyche than is the uniqueness of any *physical* aspect of our home planet.

[7] Herschel (1795, 66) also lists the properties of the Moon that greatly *differ* from those of Earth: no seas, no atmosphere, no dense clouds and thus no rain, very different types of seasons, days, and climates. He then argues, however, that this diversity is no problem and only means that the lunarians will have adapted to these conditions and thus be notably different from us.

William Herschel *and* we today similarly tackle questions with the best tools available, apply the cleverest scientific insight we can muster, and struggle to fashion a consensus as to the nature of the world. To assay the chances of extraterrestrial life, Herschel and we can do no more than apply the best current science and analogical reasoning to overcome the "N = 1 Problem." As Mill has cautioned us, we must tread very carefully when employing astrobiology's Great Analogy—such an analogy can seldom *prove* anything, but it often can and does lead to the next steps in our research program.

Our best efforts in science are surely steadily improving in their usefulness and their verisimilitude to the natural world, but we should not forget the many historical examples that illustrate strong influences from the prevailing cultural milieu. What are these cultural biases and assumptions *today*? For us, as fish ensconced in the stream, they are frustratingly difficult to recognize. Boldly trying to "flop out on the land for just a minute," I offer a provocative first list, hardly exhaustive:

- the uniformity of physical laws throughout the cosmos (which assumption we share with the 18th century)
- the dogma that miracles are not allowed
- the Copernican Principle that our life and our Earth are *not special*
- the degree to which our investigations *and their results* are strongly influenced by society's wishes, e.g., through patronage such as that from NASA and its Astrobiology Roadmap, which even as it guides also excludes many possibilities
- the degree to which our investigations *and their results* are strongly influenced by our own psychological needs, e.g., the quest for *another Earth*, tellingly sometimes called a search for "the Holy Grail"

I do not offer this list to denigrate today's enterprise, but only to acknowledge the essential humanity woven through science, a powerful way to understand the world.

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