Mirror Bacteria: Between Fantasy and Reality

A group of scientists fascinated by mirror life wants to synthesize the unnatural (2^{nd} ed.)

Pietro Perrino[1]

Abstract

Results of a critical reading of the "Technical Report on Mirror Bacteria: Feasibility and Risks", December 2024. According to the authors of the Report, mirror bacteria do not exist in nature. Still, they would like to create them to produce chiral mirror molecules that can treat diseases more conveniently and efficiently than those obtained synthetically in the laboratory, such as L-DOPA, which is used to treat subjects affected by Parkinson's. The authors of the Report describe the risks and dangers to which humans and the environment would be exposed if the mirror bacteria were to escape control and justify their disclosure as a preventive action. The analysis of some key statements in the Report seeks to show that the idea of creating mirror bacteria is perhaps more fantasy than reality and that maybe these bacteria already exist, but invisible and harmless because they would have no way and time to interact with life, which, although it remains a mystery, is that thing that allows us to distinguish a dead machine, such as AI (artificial intelligence), from a living one, such as conscious man. The criticisms of the Report's narrative are supported by advanced knowledge, and even if they sometimes appear provocative, they only want to encourage reflection and stimulate discussion on a topic of considerable scientific and public health relevance.

Keywords: *mirror bacteria, life creation, bacterial species, specular life, chirality, consciousness, artificial intelligence, reality and virtuality, duality, and unicity, matter and antimatter, photons and anti-photons, holistic and fractal*.

Riassunto

Risultati di una lettura critica del "Rapporto Tecnico sui Batteri Specchio: Fattibilità e Rischi", dicembre 2024. Secondo gli autori del Rapporto, i batteri specchio non esistono in natura. Tuttavia, vorrebbero crearli per produrre molecole specchio chirali per trattare malattie in modo più conveniente ed efficiente di quelle ottenute sinteticamente in laboratorio, come la L-DOPA impiegata per curare i soggetti affetti da Parkinson. Gli autori del Rapporto descrivono i rischi e i pericoli a cui sarebbero esposti l'uomo e l'ambiente se i batteri specchio sfuggissero al controllo e ne giustificano la divulgazione a scopo preventivo. L'analisi di alcune affermazioni chiave del Rapporto cerca di dimostrare che l'idea di creare batteri specchio è forse più fantascienza che realtà e che forse questi batteri esistono già, ma sarebbero invisibili e innocui perché non avrebbero modo e tempo di interagire con la vita, che, sebbene rimanga un mistero, è quella cosa che ci permette di distinguere una macchina morta, come l'IA (intelligenza artificiale), da una vivente, come l'uomo cosciente. Le critiche alla narrazione del Rapporto sono supportate da conoscenze avanzate e, anche se a volte appaiono provocatorie, vogliono solo invitare alla riflessione e stimolare il dibattito su un tema di notevole rilevanza scientifica e di salute pubblica.

Parole chiave: batteri specchio, creazione della vita, specie batteriche, vita speculare, chiralità, coscienza, intelligenza artificiale, realtà e virtualità, dualità e unicità, materia e antimateria, fotoni e antifotoni, olistico e frattale.

---

[1]Former Research Director of the Germplasm Institute - National Research Council (CNR) Bari. Agronomist and Plant Geneticist, Master of Science in Conservation of Plant Species Threatened by Extinction and Useful in Agriculture. FAO Plant Explorer. Teacher in Biodiversity Conservation and related fields in Italy and Abroad.

Introduction

The authors of the "Technical Report on Mirror Bacteria: Feasibility and Risks," December 2024 (1), describe the technical feasibility of creating mirror bacteria and the potential risks to humans, other animals, plants, and the environment. In a mirror bacterium, hypothesized so far only by some scientists, all the chiral molecules of existing bacteria — proteins, nucleic acids, and metabolites — are replaced by their mirror images.

Before delving into the contents of the Report, it may be useful to recall some general aspects of bacteria and the chirality of biological molecules.

Bacteria. It is useful to know that, due to their microscopic size, omnipresence, and difficulty in studying them, determining the number of bacterial species has always been a struggle. However, recently, mathematics has helped us estimate the existence of a trillion ($1x10^{-12}$) species, of which we know only 0.001%. Conducting a direct census is impossible because the species observable in the laboratory is a tiny fraction of the vast majority that cannot be grown in the laboratory. Experts state that 99.999% of bacterial species have yet to be discovered (2). With this data and information, we could say that any statement about bacteria, including hypothetical mirror bacteria, could be risky, unless it is limited to the known bacterial species, i.e., 0.001%. For example, it would be hazardous to state that mirror bacteria do not exist in nature, and a little less risky to state that they have never been observed among known species.

This discussion about the number of bacterial species makes sense because we must not underestimate the fact that bacteria are polymorphic beings, that is, they change shape depending on the environment in which they live, as demonstrated by the works of Béchamp (3, 4, 5) which were confirmed by the works of Bernard (6, 7) and which together called into question Pasteur's germ theory (8, 9). Perhaps this enormous intraspecific variability should lead us to scale down the number of estimated bacterial species. Even more important, bacterial pleomorphism is also accompanied by genetic changes, useful for the evolution of ecosystems but also very unpredictable, especially in the face of strong environmental changes, whether natural or artificial.

Chirality. Remember that all biological molecules can be split into chiral and achiral molecules. Chiral molecules are those whose mirror images are non-superimposable, a concept often clarified with the example of hands, which are non-superimposable and therefore chiral. This also applies to chiral molecules, also called enantiomers. Achiral molecules, on the other hand, are molecules whose mirror images are superimposable, a concept often clarified with the example of two socks that form a pair of superimposable mirror images. Chiral molecules do not have a plane of symmetry, while achiral molecules do (10, 11).

Still on chirality, it may be useful to remember that: - the enantiomer of a drug can effectively cure a disease, while its mirror image may be ineffective or toxic; - many biological molecules are chiral; - in living organisms, the synthesis of substances occurs through enzymes that act in a stereoselective manner; - the odor of a molecule depends more on its shape than on its functional groups; - all amino acids used in the synthesis of proteins in higher organisms, except glycine, are chiral and left-handed; in lower organisms (bacteria), dextrorotatory and achiral amino acids are also found (12).

In essence, chiral molecules are much more common than achiral ones. Many biologically active molecules are chiral (i.e., like hands), as this property is often linked to their function and activity. Amino acids, monosaccharides, nucleic acids, and lipids are chiral. Many drugs and other bioactive substances are chiral and can be synthesized in the laboratory as pure enantiomers or as racemic mixtures. Achiral molecules are less common in biology, although they can be present in some organic compounds such as noble gases and alkanes (methane, ethane, propane, and butane) (13, 14).

Contents of the Report. After these reminders of the multiplicity of bacterial species, most of which are unknown, and the chirality of biological molecules, which are predominantly chiral, we can approach the topic of mirror bacteria with greater awareness and a crucial question: if mirror bacteria do not exist in nature, at least among those known in the laboratory, why do some scientists want to try to create them? The answer is twofold: scientific and commercial. The first, more optimistic, would represent a challenge that would allow researchers to improve understanding of the secrets of life; the second, more pessimistic, is to satisfy pharmaceutical companies' interest in mirror therapies. If normal protein or nucleic acid-based substances are administered, the human body's digestive enzymes break them down rapidly, sometimes in just minutes, and this can make it very difficult to treat diseases efficiently and cost-effectively. Mirror molecules, on the other hand, would not be recognized by those digestive enzymes, so they would have the potential to act for a much longer time, paving the way for a new class of therapies that would allow the treatment of numerous diseases that are currently difficult to manage.

To gain a better understanding of this aspect, it is important to note that mirror therapies are currently developed by chemically synthesizing mirror molecules and assembling them in the laboratory, atom by atom. This process is long, challenging, expensive, and sometimes even impossible. However, if mirror bacteria were available, it would be possible to produce mirror molecules biologically and in large quantities. According to the authors of the report, this approach could be a more practical and effective solution for mirror therapies.

For example, L-DOPA (L-3,4-dihydroxyphenylalanine) is a chiral molecule used to treat Parkinson's disease. It is produced synthetically in the laboratory and is a precursor of dopamine, a neurotransmitter that is depleted in Parkinson's disease (15). Of course, there are several other examples of chiral molecules, such as Propanolol (16), Simvastatin (17), Omeprazol (18), and the infamous Thalidomide (19), used to treat various human degenerative diseases.

This is the philosophy of Big Pharma, which uses diseases for big business and is careful not to find and/or promote alternative solutions to mirror therapies. Alternatives exist and are more effective, more cost-effective, and less risky, but they are kept hidden, unpublicized, or, worse still, unauthorized, writes Marco Pizzuti (20, 21).

In regard to the risks associated with mirror bacteria, 20 out of the 24 authors of the original report, along with 18 additional scientists, have signed and released a supplementary document that highlights the potential dangers of mirror life (22). This document aims to foster a broader discussion within the global scientific community, including policymakers, research funders, industry representatives, civil society, and the public, to determine an appropriate path forward. The supplementary document, which spans 13 pages and includes 68 citations related to the original report, has 38 authors affiliated with 59 different institutions. The largest number of authors are from the United States (40), followed by China (5), the United Kingdom (4), Singapore (4), Germany (2), Brazil (1), France (1), Japan (1), and India (1).

About the risks, on December 14, 2024, on Rai News.it – Scienza e Tecnologia (23), we read that the 38 scientists also raised an alarm, interpreted by some as a moratorium, in which they ask for a halt to research. It states that "An international group of Nobel laureates and experts warns of a new risk: these synthetic organisms created using mirror images of natural molecules could pose a threat to life on Earth." A very critical and perhaps even somewhat "conspiracy theorist" reader would comment on this announcement by stating that multinationals are making these scientists say whatever they want, through the media. In fact, the authors of the Report (1) write that they are aware that this is threatening news, which should not be made public, but that they are forced to disclose it as a precautionary measure.

It may be worthwhile to examine the viewpoints of some authors of the report, particularly Michael Kay. He is a physician and professor of biochemistry at the Spencer Fox Eccles School of Medicine at the University of Utah, with expertise in mirror pharmaceuticals and the science of mirror life. In an interview with Sophia Friesen, the Director of Communication Sciences at the same university, Kay shared his belief that the concept of mirror life should remain hypothetical (24).

The reactions of two scholars are particularly noteworthy. The first, Geoff Pain, is a scientist who did not sign the Report or the Risk Supplement. He is an expert in analytical chemistry, atmospheric chemistry, nanotechnology, and molecular structure, and has authored several papers on topics such as the dangers of endotoxin in mRNA sera, the potential risks of mRNA vaccines, and the lack of scientific rigor in Australia's response to the COVID pandemic. Pain asserts that experiments involving mirror bacteria should be prohibited (25).

The second scholar, Ruslan Medzhitov, is a Professor of Immunobiology at Yale School of Medicine and one of the authors of both the Report and the Risk Supplement. In an interview with communications expert Isabella Backman (26), he stated, "Our goal is to invite thoughtful and careful discussion. We suggest that research laboratories and funding agencies consider the risks associated with mirror bacteria and collectively decide whether such research should be pursued. This issue is not limited to one country or research institution; it requires a consensus among all parties because the creation of mirror bacteria could potentially lead to devastating consequences that spiral out of our control."

In summary, one affiliated scientist (Michael Kay) states that mirror life remains hypothetical for now, another non-affiliated scientist (Geoff Pain) states that this type of research should not continue, and yet another affiliated scientist (Ruslan Medzhitov) urges caution and a shared choice.

However, even if, based on current knowledge, the idea of creating mirror bacteria seems more of a working hypothesis than a reality, we cannot ignore the fact that sometimes, when fantasy and imagination intertwine, creativity and innovation can arise.

The purpose of this paper is to critically and openly comment on the Report and highlight any critical points regarding the validity of its contents, attempting to understand where the idea of creating mirror bacteria lies between fantasy, imagination, and reality.

Since the Report is quite long (299 pages), for the sake of brevity, the analysis focuses only on eleven key statements of the Report, chosen from those considered fundamental and conceptually reiterated several times in the text, which will be followed by a discussion on the real feasibility of creating a mirror life, the probability of a spontaneous appearance of mirror bacteria and the genesis of the very idea of a laboratory creation.

Key statements and comments

The original eleven key statements and their accompanying comments are provided below.

1. **Statement.** *While creating mirror bacteria is not yet possible or imminent, advances in enabling technologies are expected to make it achievable within the coming decades. (*1, p. iv*).*

Comments. Although the authors of the Report are optimistic about the possibility of creating mirror bacteria in the future, the technologies and approaches they describe do not appear to be sufficient to overcome the fundamental challenges posed by the creation of synthetic life.

2. **Statement.** *It is not yet possible to create a living cell from non-living precursors.* (1, p. 1)

Comments. The problem of synthetic life may not be merely technological, but may also require a deeper understanding of the fundamental principles of biology and the nature of life itself. According to many scientists, life is an emergent property that cannot be understood or recreated through the study of individual elements. At least three Italians: the chemist Corrado Malanga (27), the physicist Federico Faggin (28, 29), and the philosopher Michele Paoletti Paolini (30) explain the limits of classical, reductionist science when it comes to issues concerning the nature of life as we know it, not to mention life outside the body, used as a spy, of Roberto Bartali (31).

3. **Statement.** The authors of the report say that *mirror bacteria could evade many human immunity pathways and potentially cause dangerous infections,* listing *three Key ways* this could happen. (1, p. 2):

First, t*he innate immune response relies upon initial detection of conserved microbial biomolecules, such as bacterial lipopolysaccharides and peptidoglycans, by host pattern recognition receptors. Because these molecules are almost exclusively chiral, immune recognition of mirror bacteria could be substantially impaired.*

Second, *Second, many innate immune mechanisms of pathogen control could be directly compromised; for example, phagocytosis, antimicrobial enzymes, and several complement system pathways rely on stereospecific protein interactions*.

Finally, mirror proteins would resist degradation and other stereospecific mechanisms necessary for antigen processing and presentation by innate immune cells, which would impair the activation of adaptive T and B immune cells and antibody production.

Comments. The immune system is a complex and not fully understood aspect of human biology, and its interactions with other systems, such as the nervous system, are still being explored and understood (32, 33). Therefore, it is difficult to predict how the immune system would respond to a novel threat such as mirror bacteria.

4. **Statement.** *While mirror bacteria would lack functional virulence factors that facilitate invasion, transient bacteremias caused by environmental bacteria are common, suggesting that exposure to mirror bacteria through inhalation, ingestion, microabrasions, or wounds could result in passive translocation across epithelial barriers.* (1, p. 2)

Comments. The authors propose that exposure to mirror bacteria through inhalation, ingestion, or other routes could lead to their passive translocation across epithelial barriers, potentially resulting in transient bacteremia. However, this hypothesis is speculative and lacks supporting evidence. While it is true that environmental bacteria can cause transient bacteremia, the characteristics and behaviors of mirror bacteria are still unknown. Therefore, it remains unclear if they can produce similar effects in the human body. It is crucial to critically assess such speculative claims and carefully evaluate the available evidence before reaching any definitive conclusions.

5. **Statement.** *Once inside, mirror versions of common bacteria such as Escherichia coli would be able to grow on achiral nutrients such as glycerol and, with suitable engineering, on glucose and other common chiral nutrients. Impaired immunity would likely permit extensive replication within the bloodstream. The exact clinical presentation of a mirror bacterial infection is unclear, but absent an effective immune response, a lethal outcome appears highly plausible.* (1, p. 2).

Comments. The authors' claims introduce several concerns and seem to rely on assumptions that are not well-supported by evidence. First, the assertion that mirror-image versions of common bacteria, such as Escherichia coli, can grow on achiral nutrients—and potentially on certain chiral nutrients with appropriate genetic modifications—is speculative and requires further experimental validation. Second, while the hypothesis that a compromised immune system may allow for widespread replication of these mirror-image bacteria in the bloodstream is plausible, the actual extent of this occurrence remains uncertain due to the unique properties of these bacteria. Finally, the suggestion that genetic engineering would be necessary for mirror-image bacteria to cause a lethal infection is also speculative and lacks robust evidence. Overall, while the authors' ideas are intriguing and stimulating, it is essential to approach them with a degree of skepticism and to acknowledge the necessity for further research and validation before reaching definitive conclusions.

6. **Statement** *Most antibiotics interact stereospecifically with their microbial targets, so existing stocks would be restricted to a few achiral or racemic antibiotics. As an emerging infectious disease, there would be no pre-existing vaccine. It should be possible to develop novel antimirror compounds and conjugate vaccines; nevertheless, as with a new pandemic, the practical challenges to developing such measures quickly and at scale would be considerable.* (1, p.2)

Comments. The claim is exaggerated and alarming, and it is unusual for the authors to rely solely on vaccines as a solution. This is especially noteworthy given the concerns raised about the pharmaceutical industry's role in responding to pandemics. While it is often assumed that vaccines are effective, a pandemic caused by resistant bacteria would leave insufficient time to develop them. This indicates that the scientists mentioned in the report view vaccines as either a cure-all or a central strategy for potential pandemics. However, many researchers and experts worldwide have long expressed skepticism about vaccines. Numerous arguments suggest that vaccines can be both ineffective and potentially harmful. This skepticism dates back to Alfred Russel Wallace's paper on smallpox vaccinations published in 1889 (34). Consequently, we currently possess only theoretical hypotheses about incurable pandemics that lack solid evidence, similar to claims made during the COVID-19 pandemic, which has been attributed to the SARS-CoV-2 virus. It is now evident that many individuals have experienced serious adverse effects or have died due to vaccines rather than the virus itself. While artificial intelligence (AI) states that COVID vaccines are safe, it also acknowledges that it could be unsafe. It admits that uncertainty exists, although it asserts that the likelihood of being incorrect is low, as developers continually update its information.

7. **Statement.** *Mirror bacteria could potentially infect many other animals and plants and colonize some external environments, causing irreversible ecological disruption. Other multicellular organisms may be similarly vulnerable to mirror bacterial infection. Vertebrates share broadly similar immune systems and would likely suffer from equivalent defects to humans. Invertebrate immune systems are more variable and less thoroughly characterized, but may be similarly ineffective. For example, the model insect Drosophila melanogaster relies on peptidoglycan recognition to initiate antibacterial immune mechanisms, and so is unlikely to recognize mirror bacteria. The model nematode Caenorhabditis elegans does not appear to rely on the recognition of pathogen-associated molecules, but instead on pathogen avoidance and the recognition of host damage; the latter may or may not permit nematodes to survive a mirror bacterial infection. The consumption of tissues from an infected organism by a predator or scavenger could lead to infection, causing mirror bacteria to spread through the food web.* (1, p.3).

Comments. Assuming everything is scientifically correct, information on the immune systems of vertebrates and invertebrates is used to hazard hypotheses about what might happen. The immune system of an insect, such as Drosophila melanogaster, against bacteria relies on the recognition of peptidoglycan and is therefore unlikely to recognize the mirror bacterium as a pathogen. However, in the case of a nematode, such as Caenorhabditis elegans, it would not rely on the recognition of molecules associated with the pathogen, but would exclude any recognition at all and would rely on the food web to cause damage, as the nematode, by consuming infected tissue, would cause the spread of the mirror bacteria. Both scenarios present potential risks associated with the hypotheses. In the *Drosophila melanogaster* model, we overlook other molecules that could potentially interact with the mirror bacterium. Similarly, in the case of *Caenorhabditis elegans* model, we fail to consider the mechanisms the nematode might employ to avoid feeding on infected tissue. While both models are hypothetical and require further investigation, this poses challenges, as mirror bacteria do not exist in nature.

8. **Statement.** *Plant immune systems also rely on the detection of conserved pathogen biomolecules. Almost all known immune receptors in plants recognize chiral ligands, and thus would be unlikely to recognize mirror bacteria. Although mirror bacteria would not by default possess specific adaptations to invade and colonize plants, both plant roots and leaf stomata could allow for passive translocation of mirror bacteria from the environment. Whether mirror bacteria could spread through vasculature is unclear and may vary for different types of plants, but if systemic infections did occur they might be fatal. Key crops could probably be engineered to be resistant, but protecting wild plants and their associated ecosystems would be infeasible.* (1, p. 3)

Comments. In the plant immune system, attention is drawn to the recognition of chiral ligands of conserved pathogenic biomolecules, suggesting that recognition by mirror bacteria is unlikely. Mirror bacteria do not possess specific adaptations by default to invade and colonize plants, however, both plant roots and leaf stomata could allow passive translocation of mirror bacteria from the environment. Although it is unclear whether mirror bacteria have the ability to spread through the vascular system, which could vary depending on the plant species, it is suggested that if this were possible, we would expect fatal systemic infections. Humans would need to engineer crops that are resistant to certain threats, but it would be impossible to engineer wild plants to have the same resistance. This scenario raises concerns and could justify research projects focused on creating and studying so-called "mirror bacteria." Since there is virtually no chance that mirror bacteria will emerge naturally, we should anticipate that an ambitious scientist may successfully create them in the laboratory. This could lead to significant investment in research, which, in addition to facing funding challenges, might inadvertently create a real health issue. Therefore, it seems that these projections are based on hypothetical models that lack a solid foundation.

9. **Statement.** Mirror bacteria may directly drive vulnerable plant and animal species to extinction, and the loss of vulnerable "keystone species" could indirectly trigger severe ecological disruptions. Very large mirror bacterial populations, especially autotrophic mirror bacteria, may disrupt nutrient cycling in many ecosystems, and could impact the global carbon cycle. Ecological countermeasures such as the synthesis and release of mirror phages that target the invasive mirror bacteria could reduce their maximum population size, but would have little realistic prospect of averting these large and irreversible harms. (1, p. 3)

Comments. The apocalyptic scenario outlined in the report suggests that numerous plant and animal species may face extinction, leading to significant disruptions in nutrient cycling and the global carbon cycle. To address this issue, the authors propose potential countermeasures, such as the synthesis and release of mirror bacteriophages (or mirror viruses) to combat invasive mirror bacteria, which could help reduce their populations. However, even with these measures in place, the likelihood of avoiding extensive and irreversible damage remains low. This situation resembles a science fiction scenario.

10. **Statement.** *Despite being exactly as versatile as natural-chirality proteins, mirror proteins cannot be made by natural living organisms and do not exist in nature.* (1, p. 5)

Comments. Mirror proteins created in laboratories by humans are as versatile as natural chiral proteins; however, they do not exist in nature and cannot be produced by any living entity. According to the authors of the report and their representatives, they propose that mirror bacteria produce these mirror proteins. This raises the question: if their concerns about the risks associated with mirror bacteria are valid, should we take that risk solely for the sake of developing mirror therapies? One might question the logic behind this approach. More diplomatically, we could argue that, while the scientific exploration of mirror bacteria is intriguing, the potential risks involved might outweigh the benefits, especially since alternative methods for producing mirror proteins already exist.

11. **Statement.** *Why is mirror life absent in nature? (Box 1.3).*
The risks from mirror bacteria arise because reversed-chirality confers significant advantages through immune evasion and predation resistance. If reversed-chirality could be so advantageous, why does mirror life appear to be absent from nature?
Evolution is a stepwise process involving the gradual accumulation of advantageous mutations. If it was possible to invert the chirality of one surface molecule at a time, each of which would confer some resistance, then we might see such changes in natural organisms. But inverted chirality appears to be all-or-nothing: either a cell can make mirror proteins, and therefore other mirror macromolecules, or it cannot. There is simply no plausible series of stepwise changes through which a natural-chirality cell could build functional mirror proteins without severely damaging its ability to make normal proteins. Even small alterations to the genetic code alter the structure of all existing proteins, likely causing numerous fatal changes (Crick, 1968). As a result, the genetic code has remained remarkably conserved across living organisms (Ambrogelly et al., 2007; Koonin & Novozhilov, 2017). Modifying an existing cell into a mirror cell would require many steps of similar or greater complexity to the incorporation of a novel amino acid, and therefore appears to be essentially impossible.
In principle, mirror life could arise independently of existing life, but there is also no compelling reason to think that mirror life would have arisen independently of ordinary life. Opinion varies as to whether the origin of life was an extremely rare event, almost inevitable, or something in between; the very limited evidence available does not allow strong conclusions to be drawn on this matter (Spiegel&Turner,2012). If abiogenesis is rare, it would have been very unlikely for life to have arisen twice, and so mirror life probably never arose on Earth. Even if abiogenesis happened more than once on the early Earth, it is not

clear that other living organisms would have had a close resemblance to modern life, mirrored or otherwise.

It thus appears most likely that nothing similar to a mirror bacterium ever existed on Earth. The absence of mirror life from nature provides no cause for reassurance with respect to synthetic mirror life. (1, p 22, Box 1.3).

Comments. Mirror life does not exist in nature because inverted chirality enables these organisms to evade immunity and predation. Despite these advantages, mirror life has never developed by itself. According to the authors of the Report, evolution is a gradual process, and thus, inverted chirality should emerge slowly over time. However, this seems implausible because chirality is an "all-or-nothing" trait: a cell can either produce mirror proteins and, consequently, other mirror macromolecules, or it cannot produce them at all. Based on this reasoning, the authors conclude that mirror life most likely never existed on Earth. They also mention that this does not rule out the possibility of creating such life forms through synthetic engineering. In other words, the Report suggests that while mirror life did not arise through natural evolution, it might still be possible to engineer these organisms using synthetic biology. This approach could circumvent the gradual evolutionary process that makes the development of mirror traits highly unlikely. However, achieving this goal would still pose significant challenges, and the feasibility of creating synthetic mirror life remains uncertain: a statement difficult to accept or digest.

Insights and discussion.

Based on the information provided in the introduction and the comments on the statements, at least three key aspects emerge that warrant exploration and discussion before drawing any conclusion: the feasibility of creating mirror bacteria about the meaning of life, the likelihood of their spontaneous emergence, and the origins of the concept of mirror life, along with other relevant working hypotheses.

Feasibility of creating mirror bacteria about the meaning of life

The feasibility of creating mirror bacteria, along with the associated risks and dangers, is the central part of this discussion. The authors of the Report emphasize that mirror bacteria do not exist in nature; however, they plan to attempt to create them in the laboratory to produce chiral mirror molecules, which could potentially be used to treat various degenerative diseases in humans. The authors assert that, sooner or later, scientists will succeed in creating life in a lab setting. This raises a crucial question: Is there evidence to suggest that scientists will be able to construct life in the laboratory, including mirror bacteria? To answer this, we must first consider what defines life, as one cannot create something without understanding its fundamental nature—unless the creator is directly involved.

Humans have successfully created various types and models of machines, including what we refer to as Artificial Intelligence (AI). However, it is worth noting that AI does not represent true intelligence; it functions primarily as an advanced calculator. While AI can be a useful tool, its effectiveness depends on ongoing support and updates from human developers. Unlike mechanical, reductionist, and deterministic machines such as AI, humans are more than just machines; we are living beings. AI is essentially a lifeless machine because it cannot reproduce, whereas humans are living organisms capable of reproduction and performing many other functions. Therefore, scientists must understand what endows machines or matter with life. With this knowledge, they might eventually be able to create living beings that can reproduce, similar to all known organisms, including those that are sterile but manage to reproduce through various methods such as parasitism, cloning, or vegetative propagation.

To put it simply, currently, in the world we humans know, there are roughly two distinct groups of scientists: a larger group continues to think in a classical, reductionist, mechanistic way, and a much smaller group continually tries to understand what humans have behind machines, including AI. This second group of scientists, although it has not yet clearly defined what it is that humans have more than AI, has called this thing Consciousness. This second group of scientists is always growing qualitatively and quantitatively, because the demonstrations and proofs that support the existence of Consciousness, upstream of all things and not as an epiphenomenon, therefore not downstream, increase every day thanks also to developments in knowledge of the physics of living organisms (35), quantum physics (27, 28, 29) and immortality (36).

The distinction between the two groups arises primarily because the first group remains focused on classical Newtonian physics, or, at most, on relativistic Einsteinian physics. In contrast, the second group does not reject these traditional theories but integrates them with modern quantum physics. This newer framework effectively explains several phenomena that the first two fail to address adequately. Unfortunately, this division is evident across various fields, including biology. In this domain, the first group of scientists attempts to tackle human health issues using classical genetics, which views an individual's DNA as stable and separate from environmental factors. This perspective overlooks the significant insights gained from studying the interactions between DNA and the environment, particularly through research on the human genome (37).

The Human Genome Project (HGP) was an international scientific research initiative aimed at determining the complete sequence of the human genome (37). It began in 1990 and officially concluded in 2003, although further analysis and improvements to the sequence continued afterward. The total cost of the project was approximately $3 billion, funded by both public and private sources. Key stakeholders included the National Human Genome Research Institute (NHGRI), the United States Department of Energy, and various research institutions from other countries, such as the United Kingdom, Japan, and Germany.

Although many researchers were involved in the HGP and were enthusiastic about its potential, some expressed criticism or disappointment regarding its results. For instance, Michael Meaney, a neurobiologist and professor at McGill University, voiced his dissatisfaction with the project's outcomes, claiming that it "didn't change medical practice." Similarly, Stuart Newman, a professor of cell biology and anatomy at New York Medical College, criticized the project for its reductionist approach and for overlooking the complexity of biological systems. Additionally, the biochemist and researcher Mae-Wan Ho, not directly involved in the project, labeled it as misleading and risky, arguing that the results did not support the exaggerated claims made about its potential benefits (38).

The disappointments and failures of the HGP can be attributed to the fact that the scientists involved in the research were primarily from the first group of scientists rather than the second. Additionally, many geneticists and biologists are heavily grounded in classical genetics, often overlooking the significance of environmental factors and what the second group of scientists refers to as Consciousness.

This reasoning leads us to conclude that the probability of creating life in a laboratory, specifically producing mirror bacteria, is either zero or extremely close to zero. Consequently, this suggests that the risks and dangers outlined in the eleven statements and elsewhere in the Report are unlikely to occur.

Probability of spontaneous appearance of mirror bacteria

I asked AI about the likelihood of mirror bacteria appearing spontaneously. The response was as follows: "*The likelihood of bacteria spontaneously transforming into mirror-image versions, known as 'mirror bacteria,' is highly unlikely. While it is theoretically possible for living organisms to exist with chiral molecules in the mirror-image configuration, the spontaneous transformation of bacteria into this form would require a significant shift in the fundamental chemistry of life as we know it. This shift would involve not just reversing the chirality of a single molecule, but rather of every chiral molecule in the bacterial cellular machinery, including proteins, sugars, and nucleic acids. Because these molecules have been selected and optimized over billions of years of evolution to function in their current chiral configuration, it is incredibly unlikely that a bacterium could spontaneously undergo this transformation and still retain its ability to live and reproduce*."

In practice, the AI response almost certainly implies that mirror bacteria have no chance of appearing through mutation of natural or known bacteria.

Genesis of the idea of mirror bacteria: real and virtual world

One might wonder what leads scientists to consider the possibility of creating or synthesizing mirror bacteria in the laboratory. What inspired the authors of the Report to explore this idea? What scientific knowledge contributed to the development of their thinking on creating mirror bacteria? If these bacteria have never been found in nature, what basis do the authors have for suggesting that they could be artificially produced?

The idea that mirror bacteria could be synthesized may arise from the desire to create mirror molecules. It also reflects the understanding that we live in a world characterized by duality, where every concept has an opposite. However, is our world truly dualistic? Historically, there have been two primary philosophical viewpoints on this matter: monism and dualism. (39).

Do the vast majority of people, including many scientists and the authors of the Report, perceive the world through the lens of duality? Physically, duality is represented in the human brain with two hemispheres: the left hemisphere, which is often associated with masculine traits, and the right hemisphere, associated with feminine traits (especially in right-handed individuals, who constitute the majority). Rationality and irrationality constantly strive to coexist and ultimately unite to form a single entity: the synthesis of opposites. In this context, the thesis and antithesis generate a synthesis (40). As the awareness of Consciousness increases, it will choose to abandon duality for monism, which regulates and harmonizes everything, giving calm and quiet to the soul exhausted by the search and the eternal struggle between good and evil (41). Every duality has unity as its foundation. To achieve true balance, one must transcend duality, moving beyond good and evil. (42). Only by reaching the essence of being will duality cease to be a sort of gymnasium in which opposites alternate, becoming a harmonious sequence of complementary polarities moved by the eternal and ancient Tao (43). What happens to de Broglie's wave-particle dualism (44) and Bohm's reality, which postulates a physical reality made up of waves and particles, so that the universe is non-local, holographic, and fractal? (45, 46, 47). According to quantum physics, Schrödinger's cat is alive and dead simultaneously (48, 49).

Combining all this knowledge, the studies of Pribram (50, 51, 52, 53, 54), and others, we conclude that the world we live in is dual, but virtual and constantly evolving, while the real world is unique and stationary. We are, therefore, alive and dead simultaneously; it's as if we were constantly switching on and off at an interval of time equal to 5.39×10^{-44} seconds, a time so short that we don't realize that while we live, we are also dead. Few people still have this awareness, even though it increases every day due to the second law of thermodynamics and therefore the increase in symmetry and entropy of the universe. In any case, even those who are aware have difficulty living as if they were in a real world. Awareness, as a measure of human consciousness, increases continuously because the entropy of the universe increases continuously, thus every day our world becomes less dual and more real, moving towards uniqueness. This phenomenon is clearly explained by Malanga (55).

In light of this latest knowledge, particularly in quantum physics, we should ask ourselves whether the idea of creating mirror bacteria still makes sense. We should ask ourselves whether mirror bacteria already exist, given that they exist in the minds of some scientists, but we (or they) struggle to observe them. We might also think they exist, but they are ephemeral and therefore cannot cause harm because they would not have the time to interact, manifest themselves, be noticed, and produce mirror molecules.

At the atomic level, we should not overlook the fact that the polarity (positive charge of the nucleus and negative charge of the electron cloud) can reverse for fractions of a billionth of a second (56, 57, 58, 59). The same thing can therefore also happen for the chirality of molecules, but we cannot be certain because it is tough to demonstrate it experimentally (60, 61, 62, 63). If this were true and could be demonstrated, one might speculate that bacteria could also exist in a mirror state for some time. Therefore, we could suggest that mirror versions of bacteria are present among us; however, the conditions required for them to survive in a mirror state for an extended period are not present.

If this is the case, then it's clear that we can explain why we don't observe mirror bacteria in nature and why they can't be created, because the conditions in this universe aren't right for their mirror-like lifespan to last long enough. When asked about this, the AI responded: "*Overall, your (my) conclusion is thoughtful and well-reasoned, because it takes into account the complex and dynamic nature of biological systems, as well as the limitations of our current knowledge and technology*."

Mirror bacteria can be viewed from a different perspective, particularly by those who believe that our consciousness (soul, mind, spirit) created the universe along with all creatures that evolve continuously and naturally. According to Corrado Malanga (27), consciousness did this to understand the one thing it did not know: itself. In this process, it splits into two, creating a virtual universe that mirrors a real universe that remains still and inactive. If this were true, we should consider why consciousness has not also created mirror bacteria, assuming they do not already exist somewhere in the universe. From a naturalistic perspective, the most logical explanation is that they were neither necessary nor functional. If this argument holds on a logical or rational level, it suggests that the idea of creating mirror bacteria arises solely from a dualistic view. However, this creation cannot be realized until the creator, or consciousness, decides it is so. This further means that everything man creates artificially, such as machines, is unconscious, or as we often say, inanimate or lifeless. Continuing to reason along these lines, perhaps man could create an artificial bacterium, a microscopic robot capable of synthesizing mirror molecules, the true goal of pharmaceutical companies. At this point, however, a question arises: would mirror molecules be stable? And if so, for how long? At what temperature? Under what environmental conditions? However, in my humble opinion, soon, man will be more likely to create a little robot capable of creating mirror molecules than to create mirror bacteria.

Conclusions

The first important and clear thing that emerges from reading the Report is that scientists are currently unable to create life, much less mirror bacteria, in the laboratory. The second, equally clear, thing is that the authors of the Report will attempt to create mirror bacteria because pharmaceutical companies are interested in producing mirror molecules for mirror therapies.

Now that we understand the rationale behind creating mirror bacteria, it seems likely that we won't need to pursue this goal. In the future of medicine, there will be little to no place for mirror therapies. The emerging field known as quantum medicine, or frequency medicine (64), is already beginning to shape healthcare. Unfortunately, this innovative approach has not gained acceptance from those currently in power, who significantly influence our healthcare system.

Many physicists hypothesize the existence of parallel worlds or two half-universes. Essentially, we inhabit a world that seems dual to us; however, according to quantum physics—the most modern and accurate framework compared to Newton's mechanical physics and Einstein's relativistic physics—this world is not truly dual. The reality we experience is dynamic and capable of change, which does not imply that it is fake. Instead, it suggests that it is fluid and ever-evolving. This contrasts with a "real" reality that is fixed, immobile, unchanging, and devoid of space, time, and energy.

Consciousness, as represented by humanity, may have created this dualistic world to explore the nature of existence. Therefore, every phenomenon has its opposite. For example, every cell divides into two, never into three. Chemical reactions occur between two molecules, never between three. Malanga often states after decades of research that every chemical reaction always occurs between two molecules, never between three molecules (27, 55).

The evolution of thought is moving towards uniqueness, an increase in entropy and in awareness, which is a measure of Consciousness, towards an increase in the symmetry of the universe. Many scientists in recent times are successfully demonstrating the idea that awareness is increasing and that we are moving towards uniqueness, calling into question the second law of thermodynamics (27, 55). This is also in line with what Federico Faggin states in his latest book "Beyond the Invisible" which shows the fundamental role of Consciousness and the substantial, incontestable and unequivocal difference between the machine and man, respectively without and with consciousness (28, 29).

In a virtual, inherently dual world, we can only imagine mirror bacteria and compare them to antimatter, which exists but remains unseen. If this perspective is accurate, we might conclude that the idea of creating mirror bacteria is neither entirely wrong nor completely right. It isn't wrong because, in theory, these bacteria could be created; however, the environmental conditions necessary to sustain, observe, and interact with them do not currently exist. On the other hand, it isn't right because mirror bacteria may already be present, and it would be sufficient to search for them, much like the ongoing efforts to locate antimatter. (65, 66, 67).

Based on these considerations, if one of the research issues were funding, perhaps the funds earmarked for projects to create or study mirror bacteria could be allocated to projects more useful for the future of humanity. Unfortunately, we know that funding is a non-issue, since central banks create and print as much money as they want since there is no requirement for a corresponding gold reserve (68, 69, 70). Therefore, any research is fine, but ultimately, let science, not AI scientism, decide how to use the results.

By the way, are we really sure that mirror bacteria are needed to produce mirror molecules? During my research, I had the opportunity to read at least one scientific publication from 2022 (71) that demonstrates the possibility of synthesizing a chirally inverted ribosome with the aim of building mirror-like biological systems, by preparing one-kilobase-long mirror-like ribosomal RNAs, which constitute the structural and catalytic core and approximately two-thirds of the molecular mass of the mirror-like ribosome. In this case, the authors chemically synthesized a 100-kilodalton mirror-like T7 RNA polymerase, which allowed efficient and faithful transcription of full-length 5S, 16S and 23S mirror-like ribosomal RNAs, starting from enzymatically assembled long mirror-like genes. They then exploited the versatile mirror-image T7 transcription system for practical applications, such as the biostable mirror-image riboswitch sensor, long-term storage of one-kilobase-long unprotected l-RNA in water, and l-ribozyme-catalyzed l-RNA polymerization, to serve as a model system for basic RNA research. This and similar publications, both recent and older (72, 73, 74), leave no doubt that mirror-image molecules can be obtained in the laboratory with relative ease without necessarily having to create mirror bacteria.

It's unlikely that we'll ever encounter mirror bacteria in our lifetime. We can therefore conclude that in our universe they will likely remain a concept, a hypothesis, rather than a reality.

End of writing in English: September 12, 2025.

Acknowledgements

I would like to thank Chiara Madaro and Marco Tiberti for inviting me to read the Report and share my observations, but who also unconsciously inspired me to write the present manuscript. I would also like to thank my wife, Eleonora Rosanna Greco, who listened to me and supported me as I studied and wrote. Finally, thanks also go to the authors of the Report and especially to those I contacted to learn more about their thoughts.

Bibliografy

1. Katarzyna P. Adamala et al., 2024. Technical Report on Mirror Bacteria: Feasibility and Risks, December 2024. https://stacks.stanford.edu/file/druid:cv716pj4036/Technical%20Report%20on%20Mirror%20Bacteria%20Feasibility%20and%20Risks.pdf
2. Kenneth J. Loceya and Jay T. Lennona, 2016. Scaling laws predict global microbial diversity. PNAS, May 24, 2016, vol. 113, no. 2: 5970–5975. https://www.pnas.org/doi/pdf/10.1073/pnas.15212911133

3. Béchamp, A. (1864). Recherches sur le développement des voies urinaires et génitales des vertébrés. Paris: De Boccard.
4. Béchamp, A. (1866). Recherches sur la nature, les fonctions et les produits des microzymas. Paris: De Boccard.
5. Béchamp, A. (1883). The Third Element of the Blood. London: Trubner & Co.
6. Bernard, C. (1865). Introduction à l'étude de la médecine expérimentale. Paris: J.B. Baillière.
7. Bernard, C. (1878). Leçons sur les phénomènes de la vie communs aux animaux et aux végétaux. Paris: J.B. Baillière.
8. Pasteur, L. (1858). Mémoire sur la fermentation appelée lactique.
9. Pasteur, L. (1861). Recherches sur la putréfaction [Research on putrefaction]. Comptes rendus de l'Académie des Sciences, 52, 1260-1264.
10. Stereochimica – Chiralità. 2025. https://moodle2.units.it/pluginfile.php/336131/mod_resource/content/2/5_Stereochimica.pdf
11. Chiralità, 2025. https://www.people.uniurb.it/GiovanniPiersanti/organica2/Lectures/03Chirality.pdf
12. Salvatore Caccamese, 2025. La Chiralità dalla Chimica all'Arte e alla Natura: osservazioni personali†. https://www.gioenia.unict.it/bollettino/bollettino2018/Full_Papers/La%20Chiralit%C3%A0%20dalla%20Chimica%20all%E2%80%99Arte%20e%20alla%20Natura.pdf
13. Definizione di Chiralità, 2025. https://stem.elearning.unipd.it/pluginfile.php/498614/mod_resource/content/1/04_stereogenicit%C3%A0.pdf
14. Eric Francotte and Wolfgang Linder, 2006. Chirality in Drug Research Edited. Wiley/VCH, Weinheim, Germany. 2006. xix + 351 pp. 17 Ã— 24 cm. ISBN 978-3-527-31076-0. $175.00. by Kirk Kenneth L. Y1 - 2007/05/01. doi: 10.1021/jm0780088 - Journal of Medicinal Chemistry. VL – 50.
15. Chen, J.J. et al. (2007). L-DOPA Pharmacology and Therapeutic Use in Parkinson's Disease. Frontiers in Pharmacology, 4, 29.
16. Black, J. W., & Crowther, A. F. (1971). Beta-adrenergic blocking agents. British Medical Bulletin, 27(3), 249-254.
17. Endo, A. (1985). Compactin (ML-236B) and related compounds as potential cholesterol-lowering agents that inhibit HMG-CoA reductase. Journal of Medicinal Chemistry, 28(4), 401-405.
18. Lindberg, P., Brändström, A., Wallmark, B., Mattsson, H., Rikner, L., & Hoffmann, K. J. (1990). Omeprazole: the first proton pump inhibitor. Medicinal Research Reviews, 10(1), 1-54.
19. Vargesson, N. (2015). Thalidomide-induced teratogenesis: history and mechanisms. Birth Defects Research Part C Embryo Today, 105(2), 140-156.
20. Marco Pizzuti, 2014. Scoperte Mediche non Autorizzate. Le cureproibite osteggiate dale multinazionali del farmaco. Pagine 443. Edizioni il Punto D'Incontro.
21. Marco Pizzuti, 2015. Scelte Alimentari non Autorizzate. Dai cibi di distruzione di massa a una nuova coscienza agroalimentare. Pagine 391. Edizioni il Punto D'Incontro.
22. Katarzyna P. Adamala, 2024. Confronting risks of mirror life Broad discussion is needed to chart a path forward. Science 12 Dec 2024, Vol 386, Issue 6728, pp. 1351-1353. DOI: 10.1126/science.ads9158; https://www.science.org/doi/10.1126/science.ads9158
23. Rai News.it 14/12/2024 https://www.rainews.it/articoli/2024/12/batteri-specchio-cosa-sono-e-perche-38-scienziati-chiedono-di-fermare-la-ricerca-6d11a2ba-68ab-4a22-b3df-8154b77c196f.html
24. Sophia Friesen, 2024. "Mirror Life" is Still a Hypothetical. Here's Why it Should Probably Stay That Way. University of Utah Healt, Dec. 12 2024. https://healthcare.utah.edu/newsroom/news/2024/12/mirror-life-still-hypothetical-heres-why-it-should-probably-stay-way
25. Geoff Pain, 2024. Endotoxin from Mirror Bacteria could be the most Lethal yet devised by Madmen. https://geoffpain.substack.com/p/endotoxin-from-mirror-bacteria-could
26. Isabella Backman, 2024. Q&A: How 'Mirror Bacteria' Could Take a Devastating Toll on Humanity. An Interview to Ruslan Medzhitov, PhD, Sterling Professor of Immunobiology at Yale School of Medicine (YSM), December 19, 2024. https://medicine.yale.edu/news-article/qanda-how-mirror-bacteria-could-take-a-devastating-toll-on-humanity/
27. Corrado Malanga, 2021. Trilogia della Coscienza – Genesi/Evideon/La Geometria Sacra in Evideon. Edizioni Spazio Interiore, Roma.
28. Federico Faggin, 2022. Irriducibile - la coscienza, la vita, i computer e la nostra natura. Libro, pp 330. Oscar Mondadori Editore.
29. Federico Faggin, 2024. Oltre L'invisibile, Dove scienza e spiritualità si uniscono. Libro pp 304. Mondadori Editore.
30. Paolini Paoletti, Michele, 2024. Life is Strongly Emergent in RATIO; 37(4); Oxford, Wiley-Blackwell; pp. 297 - 312 (ISSN: 1467-9329) 01.01 Articolo in Rivista » scheda U-PAD.
31. Roberto Bartali, 2024. La CIA come ci spia? Visione a distanza e obe nei documenti segreti dell'intelligence USA. Tra le righe libri, pp 482.

32. Gilberto Corbellini, 2004. La seconda rivoluzione scientifica: scienze biologiche e medicina. Dall'immunità al sistema immunitario. Treccani. https://www.treccani.it/enciclopedia/la-seconda-rivoluzione-scientifica-scienze-biologiche-e-medicina-dall-immunita-al-sistema-immunitario_(Storia-della-Scienza)/
33. Mark Davis, PhD, illuminates the "black box" of the human immune system. Stanford Medicine, Medical Center Development. https://medicalgiving.stanford.edu/biomedical-innovation/mark-davis.html
34. Alfred Russel Wallace, 1889. Forty-five years of registration statistics, proving vaccination to be both useless and dangerous. 43 pages. https://wellcomecollection.org/works/ek7m65dt/items
35. Mae-Wan Ho, 2008. The Rainbow and Worm: The Physics of Organisms (3rd Edition), pp 410. World Publishing Co.Pte. Ltd.
36. Stéphane Allix, 2024. La morte non esiste. Un'inchiesta scientifica, Un viaggio spirituale. Le prove della vita oltre la vita. Libro, pp 349. Harper Collins Italia S.p.A.
37. Human Genome Project. (2003). Initial sequencing and analysis of the human genome. Nature, 409(6822), 860-921. https://doi.org/10.1038/35057062
38. Mae-Wan Ho, 2004. The Human Genome Map, the Death of Genetic Determinism and Beyond. Biosafety Information Centre. https://biosafety-info.net/articles/biosafety-science/genomicsgenetics/the-human-genome-map-the-death-of-genetic-determinism-and-beyond/
39. Lorenzo Masciandaro. La via conciliante tra monismo e dualismo nel pensiero di alcuni teologi del XX secolo. Dialegesthai. Rivista telematica di filosofia [in linea], anno 22 (2020) [pubblicato: 31/12/2020], disponibile su World Wide Web: https://purl.org/mdd/lorenzo-masciandaro-01, ISSN 1128-5478.
40. Fabio Duranti, 2023. La dualità: tra il bene e il male https://ilprogressonline.it/lifestyle/la-dualita-quale-substrato-della-realta/#:~:text=1.3K-,La%20dualit%C3%A0%3A%20tra%20il%20bene%20e%20il%20male,-.
41. Fabio Duranti, 2022. Dalla dualità al monismo, un tuffo nella spiritualità. https://ilprogressonline.it/cultura/storia/dalla-dualita-al-monismo/#:~:text=Dalla%20dualit%C3%A0%20al%20monismo%3A%20un%20tuffo%20nella%20spiritualit%C3%A0
42. Simone Zanello, 2024. Il dualismo in Nietzsche: il caso della Nascita della Tragedia. https://www.academia.edu/41562186/Il_dualismo_in_Nietzsche_il_caso_della_Nascita_della_Tragedia
43. Fabio Duranti, 2019. La legge della dualità simmetrica. https://ilprogressonline.it/lifestyle/la-legge-della-dualita-simmetrica/#:~:text=Lifestyle-,La%20legge%20della%20dualit%C3%A0%20simmetrica,-La%20legge%20naturale
44. Louis De Broglie, Recherches sur la théorie des Quanta, in Annales de Physique, vol. 10, n. 3, 1925, pp. 22-128, https://doi.org/10.1051/anphys/192510030022
45. David Bohm, A Suggested Interpretation of the Quantum Theory in Terms of "Hidden" Variables. I, in Physics Review, vol. 85, 1952, pp. 166-179.
46. David Bohm, A Suggested Interpretation of the Quantum Theory in Terms of "Hidden" Variables. II, in Physics Review, vol. 85, 1952, pp. 180-193.
47. David Bohm, Universo, mente e materia, Rea, 1996. Traduzione di: Wholeness and the Implicate Order, London: Routledge, ISBN 0-7100-0971-2, Ark paperback: ISBN 0-7448-0000-5, 2002 paperback: ISBN 0-415-28979-3-
48. Lorenzo Maccone, 2014. Il Gatto di Schrödinger. Dipartimento di Fisica "A. Volta" & INFN Sezione di Pavia
49. Schrödinger, Erwin (November 1935). "Die gegenwärtige Situation in der Quantenmechanik (The present situation in quantum mechanics)". Naturwissenschaften. 23 (48): 807–812. Pribram, K.H. (1971) Languages of the brain: experimental paradoxes and principles in neuropychology. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.
50. Pribram, K.H. (1985) 'Holism' could close the cognition era. APA Monitor, 16, pp. 5-6.
51. Pribram, K.H. (1986) The Cognitive Revolution and Mind/Brain Issues. American Psychologist. 41(5): 507-520.
52. Pribram, K.H. (1991) Brain and Perception Lawrence Erlbaum Associates, Publishers, Hillsdale, New Jersey.
53. Pribram, K. H. (1993) Rethinking Neural networks: Quantum Fields and Biological Data. Proceedings of the first Appalachian Conference on Behavioral Neurodynamics. Lawrence Erlbaum Associates, Publishers, Hillsdale, New Jersey.
54. Comparison between Karl Pribram's "Holographic Brain Theory" and more conventional models of neuronal computation.
55. Corrado Malanga, 2025 (disponibile in rete). Mondi Reali e Mondi Virtuali. Efficace e facile per capire i concetti reale e virtuale. https://ia904605.us.archive.org/33/items/CorradoMalanga/Italian/2003-12-30-Malanga-MondiRealiEMondiVirtuali.pdf
56. Bohr, N. The Quantum Postulate and the Recent Development of Atomic Theory. Nature 121, 580–590 (1928). https://doi.org/10.1038/121580a0Niels . Bohr: "The electron may be said to be in a state of continual fluctuation between all possible positions and momenta."

57. Richard Feynman, 1949. The Theory of Positrons. Physics. Physical Review, 76, 749-759.) "The electron is constantly fluctuating between a particle and a wave." file:///C:/Users/HP/Downloads/FEYpr49b.pdf
58. Dirac Paul Adrien Maurice, 1931. Quantised singularities in the electromagnetic field, Proc. R. Soc. Lond. Royal Society A133, 60–72 http://doi.org/10.1098/rspa.1931.0130 . "The laws of physics are such that the states of negative energy are completely filled up, except perhaps for one or two holes, and it is these holes which appear to us as positrons." file:///C:/Users/HP/Downloads/dirac-1997-quantised-singularities-in-the-electromagnetic-field.pdf
59. Erwin Schrödinger, 1935. The Present Situation in Quantum Mechanics. Naturwissenschaften, 23, 807-812. "The wave function is not a physical object but a mathematical tool for calculating the probability of events."
60. Kim, H. et al. (2012). Reversal of the optical chirality of a gold nanoparticle trimer. Nature, 492, 81-85.
61. Shao, J. et al. (2016). Dynamic Reversal of Chirality in Artificial Molecular Motors. Journal of the American Chemical Society, 138, 14276-14279.
62. Chen, J. et al. (2017). Controlling Chirality Reversal and Helicity Inversion in Assembled Supramolecular Fibers through Host-Guest Interactions. Angewandte Chemie International Edition, 56, 12649-12653.
63. Sun, Q. et al. (2019). Interfacial Chirality and Its Dynamic Reversal at the Gold-Selenium Interface. Journal of the American Chemical Society, 141, 8827-8834.
64. Piergiorgio Spaggiari e Caterina Tribbia, 2016. Medicina Quantistica – La medicina attraverso la fisica dei quanti. III Edizione, pp 220. Nuove Tecniche Edizioni.
65. Frank Close, 2010. Antimatter. Libro pp 176. Oxford University Press.
66. Frank Close, 2013. Antimatter. PDF 12 slides. https://www.iop.org/sites/default/files/2019-06/Antimatter%202013_0.pdf
67. Beatriz Gato-Rivera, 2024. Antimatter. Instituto de Física Fundamental, CSIC, Serrano 123, 28006 Madrid, Spain. file:///C:/Users/HP/Downloads/REFIngles%20(1).pdf
68. Bernanke, Ben S. (2010). "Quantitative Easing: An Additional Monetary Policy Tool for Economic Recovery." Speech at the Annual Meeting of the Rhode Island Public Expenditure Council.
69. Joyce, Michael, et al. (2012). "Quantitative Easing and Unconventional Monetary Policy: An Introduction." Bank of England Quarterly Bulletin, 52(4), pp. 275-285.
70. Kuttner, Kenneth N. (2018). "Outside the Box: Unconventional Monetary Policy in the Great Recession and Beyond." Brookings Papers on Economic Activity, 2018(1), pp. 333-402.
71. Xu Y, Zhu TF. Mirror-image T7 transcription of chirally inverted ribosomal and functional RNAs. Science. 2022 Oct 28;378(6618):405-412. doi: 10.1126/science.abm0646. Epub 2022 Oct 27. PMID: 36302022.
72. Lewicki BT, Margus T, Remme J, Nierhaus KH. Coupling of rRNA transcription and ribosomal assembly in vivo. Formation of active ribosomal subunits in Escherichia coli requires transcription of rRNA genes by host RNA polymerase which cannot be replaced by bacteriophage T7 RNA polymerase. J Mol Biol. 1993 Jun 5;231(3):581-93. doi: 10.1006/jmbi.1993.1311. PMID: 8515441.
73. Ree HK, Zimmermann RA. Organization and expression of the 16S, 23S and 5S ribosomal RNA genes from the archaebacterium Thermoplasma acidophilum. Nucleic Acids Res. 1990 Aug 11;18(15):4471-8. doi: 10.1093/nar/18.15.4471. PMID: 1697064; PMCID: PMC331267.
74. Ling JJ, Fan C, Qin H, Wang M, Chen J, Wittung-Stafshede P, Zhu TF. Mirror-Image 5S Ribonucleoprotein Complexes. Angew Chem Int Ed Engl. 2020 Feb 24;59(9):3724-3731. doi: 10.1002/anie.201914799. Epub 2020 Jan 21. PMID: 31841243; PMCID: PMC7217020.