**Demystifying mysteries. How metaphors and analogies extend the reach of the human mind**

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**Abstract**

Some philosophers have argued that, owing to our humble evolutionary origins, some mysteries of the universe will forever remain beyond our ken. But what exactly does it mean to say that humans are ‘cognitively closed’ to some parts of the universe, or that some problems will forever remain ‘mysteries’? First, we distinguish between *representational access* (the ability to develop accurate scientific representations of reality) and *imaginative* *understanding* (immediate, intuitive comprehension of those representations), as well as between different modalities of cognitive limitation. Next, we look at tried-and-tested strategies for overcoming our innate cognitive limitations. In particular, we consider how metaphors and analogies can extend the reach of the human mind, by allowing us to make sense of bizarre and counterintuitive things in terms of more familiar things. Finally, we argue that this collection of mind-extension devices is combinatorial and open-ended, and that therefore pronouncements about cognitive closure and about the limits of human inquiry are premature.

Keywords: new mysterianism; metaphors; analogies; cognitive closure; imaginative understanding; representational access

# Introduction

*“Nature initially arranged things her own way and subsequently so constructed the human intellect as to be able to understand her”* – Galileo Galilei in *Dialogue Concerning the Two Chief World Systems*, 1632

*“And how awkward is the human mind in divining the nature of things, when forsaken by the analogy of what we see and touch directly?”* – Ludwig Boltzmann in *Nature*, 1895[[4]](#footnote-5)

Human brains are the product of blind evolution. They evolved to deal with practical problems impinging upon survival and reproduction, not to unravel the mysteries of the universe. This, remarkably, is what human brains themselves have come to discover, after billions of years of unguided evolution. Are there any limits to what human inquiry might achieve, and if so, what parts of reality must forever lie beyond our ken? In spite of the spectacular successes of modern science, a number of philosophers and scientists have expressed pessimism about our epistemic prospects (Fodor 1983; McGinn 1993; Stich 1990). Given our humble evolutionary origins, they argue, we have no reason to suspect that we will ever penetrate the deepest mysteries of the universe. Some questions are doomed to remain what Noam Chomsky called “mysteries” (Chomsky 1988), a term which has inspired the moniker “new mysterians” for this philosophical school of thought (Flanagan, 1992).[[5]](#footnote-6)

In this chapter, we push back against this epistemic pessimism, introducing a richer conceptual framework for thinking about cognitive limitations. Metaphors and analogies, we shall argue, are among the most successful strategies for extending the reach of our minds. Importantly, metaphors can build on each other, and there is no foreseeable limit to how far analogies and metaphors can extend the reach of the human mind, helping us comprehend abstruse and difficult problems. In the end, we turn the tables on the new mysterians. It is far from clear that there are some mysteries that *must* lie beyond the limit of human understanding, and the burden of proof falls on them to show that science will ever reach an impenetrable limit of understanding. Indeed, we will conclude that the mysterian position, though ostensibly inspired by the virtue of humility and the danger of hubris, is in fact far less modest than it appears.

In section 2, we briefly discuss the mysterian thesis that the biological provenance of human intelligence entails cognitive closure from certain aspects of reality. In section 3, we analyze different forms and modalities of cognitive limitation (representational vs. imaginative, bare brains vs. scaffolded brains, hard limits vs. soft limits). In section 4, we discuss the use of metaphors and analogies as a strategy for overcoming our innate cognitive limitations, using quantum mechanics as a case study.

# The new mysterians

If our minds are biological organs fashioned by evolutionary processes, as indeed they are, they must have certain functional specifications and limitations. This, according to the new mysterians, means that certain thoughts and ideas lie beyond our ken. Just as dogs or pigs will never understand prime numbers, polyphony, the rules of chess, or the properties of electrons, the human brain must be closed off from *some* of the world’s wonders. Most mysterians believe that their thesis is just a straightforward corollary of the evolutionary worldview of modern science. Anyone who accepts the central facts of modern biology, writes Noam Chomsky, must admit that the existence of human cognitive limits is a “truism”. In particular, Chomsky has argued that all human scientific activities are undergirded by a “science forming faculty” (2000, p. 83) – loosely defined as those cognitive capacities that enter into scientific inquiry – which constrains our cognitive reach. It is an inevitable fact of biology that some aspects of the natural world must remain out of our mind’s reach, and hence will always appear mysterious to us.

Steven Pinker (1997) has spelled out the evolutionary reasons for this pessimism in a bit more detail. Evolution by natural selection, explains Pinker, is an opportunistic and short-sighted tinkerer. It tends to produce quick-and-dirty, satisficing solutions to adaptive problems in an organism’s immediate environment, as opposed to optimal and generic solutions that work in every environment. It is also a ruthless economizer. If our ancestors didn’t need to understand the universe at large to spread their genes, it would be uneconomical for natural selection to have given us the brainpower to do so. As Pinker rhetorically asks, “if the mind is a system of organs designed by natural selection, why should we ever have expected it to comprehend all mysteries, to grasp all truths?” (Pinker 1997, p. 563).

The arguments of Jerry Fodor, another philosopher in the mysterian camp, have a more general scope, and are not tied to specific evolutionary considerations. Every finite cognitive system has a certain “endogenous structure,” according to him, which constrains the kind of representations it can process. Because the human brain is just such a system, there are bound to be “thoughts that we are unequipped to think” (1983, p. 125). For Fodor, cognitive closure is not just a predicament of minds that evolved through biological evolution, but of *any* cognitive system. The notion that some cognitive systems exhibit “epistemic unboundedness” is dismissed by Fodor as “just incoherent” (Fodor 1983, pp. 122-123).

Colin McGinn, finally, has treated the subject of human cognitive limitation most extensively, and he was the one to coin the term “cognitive closure” (1993, 1994). According to him, the human mind is cognitively closed to the answers to certain problems, not because those problems are inherently more difficult than solvable scientific problems, but because the particular structure of our minds obstructs understanding of their answers. In McGinn’s view, our minds can only process representations in combinatorial fashion. He calls this the CALM-conjecture, which stands for ‘Combinatorial Atomism with Lawlike Mappings’. According to the CALM-conjecture, humans understand the world by analyzing it in terms of a set of primitive elements and their ‘lawlike’ interactions. But some problems, McGinn claims, simply cannot be grasped in this fashion. “Conscious states”, in particular, “are not CALM-construable products of brain components” (McGinn 1993, p. 37). McGinn calls his position “transcendental naturalism”, because he thinks that the problems in question “transcend” our cognitive capacities, even though their correct solutions are in fact perfectly natural. It’s just that our minds are not suited to the job.

# Kinds of limits

But what exactly does it mean to be cognitively “closed” or “limited”? There seem to be a number of ambiguities in the position of the mysterians. First, they typically present the question of cognitive limits in stark and black-or-white terms. Either we are capable of solving a problem or the answer will forever elude us. Either we have cognitive access or we are blocked from it. But there are other possibilities. For example, our inquiries into the world may encounter a situation of gradually diminishing returns, without ever quite coming to a full halt. Second, mysterian arguments are focused on the limitations of a single and unaided human brain. But how about a collection of human brains working together, aided by various artefacts and cognitive scaffolds? Third, it is unclear whether the mysterians are claiming that human beings will never possess the true scientific theory of some part of the world, or alternatively, that we may well develop such a theory but we will never *grasp* it? In short, mysterians conflate various sorts and modalities of cognitive limitation. In the following sections, we will treat those points separately, thus developing a richer conceptual framework for thinking about human cognitive limitation.

## Representational and imaginative limits

Arguments about cognitive closure and mysteries often conflate two different predicaments. In one scenario, there is a domain of reality which, because of some insurmountable cognitive or perceptual barrier, we will never be able to probe or penetrate. Other creatures with different cognitive abilities might be capable of developing accurate representations about this part of reality, but for our species, they are inaccessible. In this scenario, we suffer from *representational closure*, which means that we lack *representational access* to a part of the world.

In the second scenario, we do have representational access to a certain domain of reality (possibly with the help of mind extensions, see 3.2), but it is impossible for us to *comprehend* the relevant scientific theory describing that part of reality. No matter how hard we try, we just can’t wrap our minds around it. Because of some species-specific limitation to our imagination, this part of realty will forever bewilder and baffle us. In this scenario we suffer from *imaginative closure*, which means that we lack *imaginative access* to the correct representation of some part of the world (Vlerick and Boudry 2017; Boudry, Vlerick & Edis, 2020).[[6]](#footnote-7)

We need not give an exact definition of “imaginative closure” and “representational closure” to see that we are dealing with two quite different predicaments. Representational access describes a relation between the world and our (scientific) representations of it, whereas imaginative access describes a relationship between certain scientific representations and our minds. By way of illustration, consider a tesseract, which is the four-dimensional equivalent of a cube. Mathematicians have developed accurate formal representations of tesseracts, from which they can derive the number of faces, edges and vertices, and describe other geometric properties, such as various symmetries, intersections with other figures, and projections in two or three dimensions. But this does not mean that mathematicians can *imagine* what a tesseract looks like, in the same way that all of us can visualize a cube before our mind’s eye. Mathematicians clearly have *representational access* to the concept of a tesseract, but one may well doubt if they have *imaginative access*. In a similar way, physicists have representational access to space-time curvature (without it we wouldn’t have functioning GPS devices, which depend on scientific representations about space-time curvature). It is safe to assume, however, that they cannot effortlessly imagine what it is for a 4-dimensional space-time continuum to be curved by a massive object, in the same way they imagine an apple falling from a tree.

In the writings of the new mysterians, however, it is unclear exactly what form of limitation they have in mind, and often the two seem to be conflated.[[7]](#footnote-8) McGinn, for instance, characterizes his thesis as one of “epistemic inaccessibility”, which means that it is impossible to “convert the problem into regular science” (p. 40). About the mind-body problem, McGinn claims that “the correct *theory* is inaccessible to the human intellect” (1994, p. 145, our emphasis). All of this points towards representational closure. But then McGinn proceeds to offer arguments that only bear on the psychological difficulties which we experience when we try to understand the mind-body nexus. We experience a “feeling of intense confusion” when we contemplate the matter, and our “head spins in theoretical disarray” (McGinn 1993, pp. 27-28). In other words, the mind-body nexus is “numbingly difficult to make sense of”. But, as we previously argued, imaginative closure does not entail representational closure. It is perfectly conceivable that we succeed in forming a scientific representation of some aspect of the world, but then fail to achieve an intuitive grasp of our own representations (Vlerick and Boudry 2017).

Noam Chomsky’s account of “mysteries” also wavers between representational and imaginative closure. According to Chomsky, there are certain problems in science that have perfectly natural answers, except those answers will forever remain inaccessible to the “science forming faculty” of our species (Chomsky 2000, p. 82). In other words, no scientific progress whatsoever can be made toward demystifying those mysteries. But, in his latest publication on the subject, Chomsky characterizes mysterianism as dealing with “phenomena that fall beyond human *understanding*” (Chomsky 2014, our emphasis). The possibility that Chomsky overlooks is that of scientific progress leaving behind human comprehension. It is conceivable that we develop an accurate theory of some part of reality without being able to wrap our heads around it.

For example, it is not clear how the mysterian argument applies to quantum mechanics. On the one hand, it is undeniable that scientists have obtained representational access to the quantum world, with current scientific theories about this part of reality leading to extremely accurate predictions. On the other hand, quantum phenomena are notoriously hard to make sense of, even for quantum physicists (see 4.2). Would McGinn and Chomsky claim that humans are “cognitively closed” to the quantum world? If so, this deflates the thesis of mysterianism, since it allows that we may well develop accurate scientific descriptions of domains to which we are allegedly “closed”, such as the mind-body nexus, just as we have already developed accurate scientific theories about the quantum world. If not, then the sense of bewilderment we experience when we contemplate the mind-body problem can only be very weak evidence for cognitive closure, since bewilderment in the face of counterintuitive theories far from everyday experience is nothing new in science.

## Bare senses and bare brains

When mysterians are talking about the cognitive limits of our species, are they referring to the limitations of an isolated human brain, or of human brains with various scaffolds and extensions? To highlight the difference, it is instructive to have a look at the limits of human perception. There are a range of physical processes and phenomena that we cannot detect with our bare senses: UV-light, ultrasound, X-rays, radio waves, CO2 molecules, gravitational waves, and so forth. But of course this is not the end of the story. In order to extend the range of our senses, scientists have developed X-ray film, Geiger counters, radio satellites, spectroscopy, gravitational-wave detectors, and so forth. All this equipment translates physical phenomena into some format that is digestible by our human senses. So are we perceptually ‘closed’ to UV light? It depends on whether we take into account such extension devices.

Just as technology has drastically extended the range of our senses, it has also extended the class of things we can *think*. With the invention of writing, for example, we have vastly expanded the storage capacity of our naked brains.[[8]](#footnote-9) When it comes to representing and understanding the universe, mathematics and statistics have proven to be fantastically successful cognitive scaffolds. For instance, no scientist would be capable of modeling a complex nonlinear system like our planetary climate with their bare brains, but they don’t need to, since they have mathematical models and computers to do the heavy lifting.

Perhaps even more importantly, human minds can also be scaffolded by *other* minds. In cases of mutual scaffolding, a network of human brains can achieve a form of collective understanding that is greater than the sum of its parts. Ronald Giere (2002) called this phenomenon “distributed cognition” and Daniel Dennett (2017) “distributed comprehension”. Many minds working together can understand what none of them would be capable of understanding on its own. Indeed, according to scholars of cultural evolution, this ability to pool our cognitive resources is the secret to our success as a species, since it allowed for the emergence of cumulative cultural design that is smarter than any human agent (Henrich 2015; Richerson and Boyd 2005; Tomasello 2001). While this collaborative intelligence predates science, probably by tens of thousands of years, modern scientific institutions are the most impressive examples of it (Boudry and Pigliucci 2016; Longino 2015). As a group, scientists can understand much more about nature than any of them would be capable of individually (Campbell 1997; Goldman 1999; Thagard 2012). Continuing the metaphor of mind extension, we can say that the mind of a scientist extends both “horizontally” (contemporary academic peers) and “vertically” (scientists of past generations), a point that was expressed forcefully by Isaac Newton: “If I have seen further it is by standing on the shoulders of giants.”[[9]](#footnote-10) The idea that understanding can only be situated at the level of individual reasoners, according to Dennett, is nothing more than a prejudice arising from the cultural ideal of the “intelligent designer, the genius who has it all figured out” (Dennett 2017, p. 324).

The deeply collaborative nature of science shows that the focus of mysterians on the cognitive limits of a single, isolated human brain misses the point. It is probably true that no single scientist understands all the details involved in the discovery of the Higgs boson or gravitational waves. But collectively, the scientific community does possess such an understanding. It is far from clear if there is any limit to what collective human intelligence can achieve. Progress at the cutting edge of science can become increasingly expensive, demanding ever-increasing cognitive, technological and institutional resources. But there is no discrete limit in sight to what we can collectively represent and understand. By continuing to use and develop mind-extension technologies, and by distributing our knowledge across many different people, human beings can expand their cognitive horizon further and further.

## Hard limits and soft limits

Pronouncements about mysteries and cognitive closure typically evoke the image of suddenly hitting an impenetrable wall, of reaching a discrete limit hard-wired into our biological constitution. We hit upon an ineffable mystery and stare forever in blank incomprehension. But considering the various possible technologies for mind extension, such a hard epistemic limit seems unlikely. In the history of science, we have somehow always seemed to be able to work our way around a mystery, to probe it from different angles, to try to partially understand it by comparing it to something else we already understand.

If there really is a limit to human knowledge (representational or imaginative), it is therefore unlikely that it will feel like slamming up against a wall. Another possibility is that science will gradually slow down, as researchers spend ever-increasing resources against ever-diminishing returns. Max Planck, one of the pioneers of quantum mechanics, envisaged such limits when he wrote that “with every advance [in science] the difficulty of the task is increased; ever larger demands are made on the achievements of researchers, and the need for a suitable division of labour becomes more pressing” (quoted in Rescher 2006, p. 51). Perhaps this division of labour cannot continue indefinitely, but still there is no clear point at which it must come to a halt. Reaching the limits of human knowledge – to use a contrasting metaphor – might be compared to gradually getting bogged down in a swamp rather than slamming into a wall. As you sink deeper, you have to exert more and more effort to keep forging ahead, but there is no discrete point at which further progress becomes impossible.

# Extending our cognitive reach

## A thought experiment

In order to see the danger of drawing premature inferences about cognitive limitations, imagine that extraterrestrial ‘anthropologists’ had visited the earth around 40 000 BCE to write a scientific report about our species and its cognitive prospects.[[10]](#footnote-11) If they had argued along the lines of the new mysterians, this is what their report might have looked like:

Evolution has equipped this upright, walking ape with primitive sense organs to pick up some information that is locally relevant to them, such as vibrations in the air (caused by nearby objects and persons) and electromagnetic waves within the 400-700 nanometer range, as well as certain larger molecules dispersed in their atmosphere. However, these creatures are completely oblivious to anything that falls outside their narrow perceptual range. Moreover, they can’t even see most of the single-cell life forms in their own environment, because these are simply too small for their eyes to detect. Likewise, their brains have evolved to think about the behaviour of medium-sized objects (mostly solid) under conditions of low gravity. None of these earthlings has ever escaped the gravitational field of their planet to experience weightlessness, or been artificially accelerated so as to experience stronger gravitational forces. They can’t even conceive of space-time curvature, since evolution has hard-wired zero-curvature geometry of space into their puny brains. In conclusion, we’re sorry to report that most of the cosmos is simply beyond their ken.

But those extraterrestrial anthropologists would have been dead wrong. Even though our biological constitution did not alter significantly since 40 000 BCE, we did manage to develop scientific theories involving non-Euclidean geometry and space-time curvature, not to mention state vectors in Hilbert spaces. We have succeeded in unraveling the phenomena of modern physics by using various tools and strategies to extend our cognitive capabilities and our perceptual limits, including varying measuring devices, the indefinitely extensible language of mathematics and statistics, and the use of modern computer models.

But how about our imaginative understanding? Bearing in mind that representational access does not entail imaginative understanding, it is still possible for mysterians to retreat to a weaker position. It is one thing to have an accurate scientific theory of the quantum world or the mind-body nexus, but it is another thing altogether to comprehend such a true theory. In the rest of this chapter, we will assume, for the sake of the argument, that there are no hard representational limits to human knowledge. In principle, human scientists could develop accurate scientific representations about every part of reality, given enough time and resources. But will they ever *comprehend* those theories, or will some things forever baffle them? Famously, in Douglas Adams’ science fiction series *The Hitchhiker’s Guide to The Galaxy*, an alien civilization builds a massive supercomputer to calculate the Answer to the Ultimate Question of Life, the Universe and Everything. When the computer finally announces that the answer is “42”, no one has a clue what this means (in fact, they go on to construct an even bigger supercomputer to figure out precisely this). In a similar vein, the physicist P. W. Bridgman has speculated: “The structure of nature may eventually be such that our processes of thought do not correspond to it sufficiently to permit us to think about it at all. … The world fades out and eludes us.” (quoted in Smith, 2003, p. 8 )-

## Optimistic meta-induction

As a first way of softening up the notion of hard imaginative limits, consider that many scientific theories which we are familiar with now also struck people as bizarre and counterintuitive when first proposed. In his book on the counterintuitive nature of science, Robert McCauley has expressed this point forcefully:

When first advanced, the suggestions that the earth moves, that microscopic organisms can kill human beings, and that solid objects are mostly empty space were no less contrary to intuition and common sense than the most counterintuitive consequences of quantum mechanics. (McCauley 2000, pp. 69-70)

Or consider Darwin’s theory of evolution, which conflicts with our intuitive essentialism about species (Gelman, 2003; Gelman & Rhodes, 2012) and with teleological intuitions about functional complexity (De Cruz & De Smedt, 2010a; Dennett, 2009; Kelemen & Rosset, 2009; Reiss, 2009). In this context, Lewis Wolpert has written that he “would almost contend that if something fits with common sense it almost certainly isn't science” (Wolpert, 1992, p. 11).

Because we have grown accustomed to these older theories, they have lost something of their original shock value. This provides reasons for cautious optimism. If we have become better at making sense of empty space, evolution by natural selection and the principle of inertia, we may also become better at comprehending more novel scientific concepts like space-time curvature and non-locality. Indeed, this argument provides grounds for what we may call an “optimistic meta-induction” about the history of science. Ideas and theories that once seemed bizarre and incomprehensible may gradually yield to a more intuitive understanding, not necessarily among lay people, but at least among working scientists. For instance, experts in general relativity today can acquire a more intuitive feel of time dilation, space-time curvature and higher dimensions, after years of exposure to such theoretical notions (Goldberg 1984; Mermin 2009). Of course, this optimistic induction is not a decisive refutation of the existence of imaginational limits to human understanding. Just because now-familiar theories were once regarded as bizarre and dumbfounding does not mean that theories we find bizarre and incomprehensible today will be understood tomorrow.

In the spirit of this volume, we want to argue that metaphors and analogies play an important function in extending the reach of our mind. They are time-tested strategies for overcoming cognitive limitations, and will most likely continue to serve that function in the future, without any clear limit in sight.

## Mind-stretching through metaphors and analogies

Human minds are equipped with a number of cognitive systems, each with their respective domain of application (living organisms, agents, physical objects, quantities, etc.), and each comprising a set of core principles for dealing with the realm of entities in question. For instance, in the case of physical bodies, core principles include cohesion, continuity and contact. Boyer and Barrett (2005) refer to these cognitive templates as ontological categories. Metaphors and analogies are a form of “mapping across domains”, as Carey and Spelke (1994) call it, in which we apply the core principles of one mental category to the set of entities of another. In general, the use of metaphors and reasoning by analogy enables us to apply mental concepts developed in one area to another area, both across ontological or scientific domains and within domains. Metaphors highlight structural similarities between a source domain and a target domain, and transfer understanding from the former to the latter. In this way, we can gain understanding of something alien and unfamiliar in terms of something we already know, thereby enriching or overriding our grasp of the world.

As Lakoff and Johnson (1980; 1999) point out, human languages are filled to the brim with metaphors. These metaphors are not just a matter of occasional rhetorical flourish, but reflect the pervasiveness and importance of analogical reasoning in human thinking. Many of our most abstract concepts are rooted in metaphors and analogies that are in turned based on more basic analogies, all the way down to our most fundamental everyday concepts. Spatial orientation metaphors, for instance, organize entire systems of concepts with respect to one another. More is up, less is down (e.g. numbers go up and down); happy is up, sad is down; good is up, bad is down (e.g. it’s going downhill or it’s going up, he’s rising to the top or tumbling to the bottom); virtue is up, depravity is down (e.g. ‘when they go low, we go high’), and so on. The same goes for front-back, on-off, in-out, centre-periphery, and near-far.

Similarly, scientific thinking has made extensive use of metaphors and analogies, in virtually every domain of inquiry. Metaphors are not just used to get across difficult ideas to a lay audience, but also to enhance and deepen the understanding of experts themselves (Brown 2003). De Cruz & De Smedt have argued that “distant analogies” in particular — where target and source domain are far apart — have often succeeded in bringing about intense conceptual change (De Cruz & De Smedt, 2010b).

In biology, for example, genes have variously been compared to a blueprint, recipe, book, or computer code (Nelkin, 2001), and gene expression (in embryology) has been compared to origami folding (Lewis Wolpert & Skinner, 1993). Each metaphor highlights structural similarities between the source domain and the target domain, while brushing over other features (Boudry & Pigliucci 2013). For instance, the recipe metaphor has the advantage over the blueprint metaphor of highlighting the lack of one-to-one correspondence between genes and phenotypic traits. Just as one cannot identify separate ingredients or instructions in a freshly baked cake, it is meaningless to search for the gene ‘for’ this part of that part of an organism. In other respects, of course, the recipe metaphor has shortcomings too. It can be misleading if taken to suggest that genes contain a step-by-step manual or procedure for ‘making an organism’. Metaphors can be powerful tools for enhancing our understanding, but if ill-chosen or interpreted without due caution, they may also lead us astray (Condit et al., 2002).

When considering the limits of imaginative understanding, it is important to note that metaphors and analogies can be recursive. Not only can we compare anything to anything, but a target domain of one metaphor can become the source domain of a different metaphor. In physics, for instance, Ernest Rutherford’s model of the atom draws on an analogy with our solar system, in which planets (electrons) orbit the sun (nucleus). But the heliocentric model was itself a relatively recent concoction, which was intuitively hard to make sense of when initially proposed. Newton explained how planets can be orbiting the sun by using the thought experiment of a cannonball that is being shot horizontally on top of a large mountain (Newton and Cohen 2004).

Moreover, new scientific inventions and technologies may themselves become the source domain of fresh metaphors. For instance, the development of functionalism in philosophy of mind was inspired by the invention of digital computers, with their distinction between hardware and software. In biology, the invention of steam engines inspired 19th-century theorizing about the working of the human mind (with Sigmund Freud as a notable example), and earlier the invention of various mechanical contraptions inspired the notion of a ‘clockwork universe’ and the conception of living organisms as machines, such as in Harvey’s model of the heart as a pump and, more radically, in La Mettrie’s famous work *L'Homme Machine* (Shanks, 2004). It is plausible that future inventions will provide us with a batch of fresh metaphors to draw from.

In order to see how far a metaphorical understanding may carry us toward an understanding of ‘mysteries’, we will now briefly sketch the case of quantum mechanics, which has perhaps the most daunting reputation when it comes to incomprehensibility.

## A case study: quantum mechanics

### The counterintuitive nature of the quantum world

While it is hard to comprehend a curved 3+1-dimensional spacetime continuum, general relativity is still a classical theory. Physicists learn to think about general relativity while remaining anchored in the easily visualizable background of classical mechanics. Classical states can be described as a list of physical variables, or a point in an appropriate phase space—hence even at a high level of abstraction, classical physics retains a connection with intuitively available pictures such as projectile motion. Quantum mechanics, by contrast, is much further removed from everyday physical intuitions—as expressed by Richard Feynman’s remark that “I think I can safely say that nobody understands quantum mechanics” (2017, p. 129).[[11]](#footnote-12)

Some of the difficulties in intuitively understanding quantum mechanics are due to features such as superposition and the fundamental role of randomness. The most common approach to quantum mechanics describes states as “wave functions” or, more generally, vectors in a Hilbert space. State vectors are superpositions of eigenvectors of mathematical operators corresponding to physical observables. A typical quantum state, therefore, represents multiple possible measurable results; indeed, quantum mechanics only predicts probability distributions for experimental outcomes. This inherent randomness is conceptually challenging, and probabilistic thinking is already intuitively difficult for most people, including physics students (Bao and Redish 2002). But the difficulties run deeper. The components of quantum state vectors—the coefficients multiplying the appropriate eigenvectors—are complex rather than real numbers. The magnitude squared of these complex numbers give the probabilities, while the relative phases produce the notoriously counterintuitive quantum interference phenomena. Quantum states, therefore, represent not probabilities but *probability amplitudes*, a counterintuitive concept that is unique to quantum mechanics. Conceptually, quantum states are far removed from pictures – such as those of projectiles – that are rooted in folk physics.

Moreover, our understanding of quantum mechanics very heavily depends on mathematics, and the mathematical degrees of freedom in describing the quantum realm are such that even the fundamental objects representing physical states are not completely settled. For example, it is possible to do quantum mechanics without state vectors, and hence without probability amplitudes. The same information can be represented through real-valued functions in classical phase space known as “Wigner functions”, which are conceptually closer to probability distributions except that they can take on negative values (Zachos, Fairlie et al. 2005). Physicists do not even attempt to reach agreement on a “true” picture of a quantum state; our representations function pragmatically as mathematical devices to generate the probability distributions subject to experimental tests. So, every available way to do quantum mechanics is far removed from folk physics and associated notions of imaginative access.

In that case, how much progress can we make toward understanding quantum mechanics on an intuitive level? To address this question, let us look at how quantum physicists have exploited metaphors and analogies to extend their imaginative reach.

### Making sense of the quantum world through metaphors

Quantum physicists have extensively relied on metaphors to make sense of what has seemed incomprehensible at first. Max Planck’s notion of a “quantum” uses our everyday experience with discrete bundles or packages of matter. J. J. Thomson’s model of the structure of the atom uses the image of a plum pudding, with negative electrons distributed in a positively charged atom “pudding”, while Ernest Rutherford’s model draws an analogy with the structure of the solar system, with electrons going around the nucleus in orbit (Brown 2003, pp. 74-99). In current versions of quantum mechanics, these analogies have been superseded, but metaphors drawn from everyday experience continue to recruit the intuitive imagination of physicists and lay people alike. The central concept of quantum “superposition” is a metaphor exploiting our spatial imagination, which invites us to think of quantum states as discrete entities stacked on top of each other. Quantum “entanglement” draws an analogy with strands or ropes that are inextricably intertwined with each other.

Physics education at all levels draws heavily on such metaphors. Some are only used for scaffolding: students learn about the planetary model of atoms, but later they will confront its failures, moving on to Bohr’s variation on the planetary model, and then examining the Bohr model’s failures in order to motivate a proper quantum approach. Some metaphors continue to guide the way physicists work. For instance, the standard Hilbert space formulation of quantum mechanics draws on physicists’ experience with waves and vectors in many other areas of physics, even though infinite dimensional complex vector spaces can harbor mathematical oddities that cannot be anticipated through familiarity with the three-dimensional vectors of introductory courses. Such metaphors also help develop physical intuitions—as they advance, students acquire intuitions about quantum phenomena, though they will never be able to dispense with the mathematics. A beginner has to trust the math, and carefully calculate to obtain even trivial results. More seasoned physicists are often able to perceive – even if they can’t always articulate how – that something feels wrong about an erroneous conclusion. Such experts will develop insight into quantum physics to a degree where they often, by doing back-of-the envelope calculations and drawing on analogies with other domains of physics and mathematics, know what sort of result should be expected even before a detailed calculation is carried out. Indeed, such developed intuitions are vital for exploring physics beyond fully solvable textbook examples. Much of the research in physics pedagogy concerning quantum mechanics addresses ways to develop improved intuitions in students (Singh, Belloni et al. 2006).

The Hilbert space formulation of quantum mechanics is dominant partly because of its richness in providing metaphors that exploit connections with non-quantum physics. Its apparatus of linear algebra and partial differential equations are familiar to students in many different physical contexts, and the easily visualized waves of everyday experience often provide direct insight into the behavior of quantum wave functions. Quantum scattering phenomena, for example, are very similar to ordinary wave scattering. The famous Heisenberg uncertainty principle can be approached at first as a property of waves, without anything especially ‘quantum’ about it.[[12]](#footnote-13) This avoids much of the mystification about the uncertainty principle that has taken root outside of the culture of physics. Physicists do not just learn quantum mechanics as an abstract formalism; they develop a toolkit of metaphors and concrete visualizations that help with developing approximations and avoiding blind alleys in research.

Alternative mathematical formulations of quantum mechanics, such as working with Wigner functions rather than vectors in Hilbert space, can further help develop this understanding. Few physicists learn about Wigner functions, and almost never at an undergraduate level, because the mathematical apparatus to deal with Wigner functions is not shared between many different domains of physics. But once mastered, the phase space formalism can be an anchor for developing fresh metaphors. Even though the predicted probability distributions remain the same, and therefore the different formulations are identical in physical substance, they provide different conceptual anchors and motivate varying intuitive approaches to problems. Varying mathematical approaches support different metaphorical scaffoldings to help physicists establish a feel for quantum mechanics.

Naturally, no analogy is perfect. Atoms are only superficially like our solar system, and different physical states are not literally stacked on top of each other. But different analogies and metaphors can be used to overcome each other’s limitations, or function as temporary scaffolds to attain a higher level of understanding. For our argument, we need not assume that any given metaphor provides a perfect understanding of quantum phenomena. It suffices that some metaphors allow us to get *some* intuitive purchase on otherwise incomprehensible phenomena. Even experienced physicists who teach quantum mechanics to others may never develop a complete intuitive understanding of quantum phenomena, forming only approximate images and partial mental representations. Nonetheless, they can improve their imaginative understanding as they go along.

### Holistic understanding?

The picture of mind extensions through metaphors and analogies is very different from how mysterians conceive of the human mind. McGinn, for example, conceives of his CALM-principles (“Combinatorial Atomism with Lawlike Mappings”) as an inescapable prison of human understanding. No matter how hard we try, we will always be confined to thinking along CALM-lines (McGinn, 1993, p. 18). In this conception, a more holistic mode of understanding of nature would be ruled out. But this is exactly what quantum physicists have learned to do. Instead of analyzing every entity in terms of its constituents and their relations, as per CALM-like principles, they have learned to think in holistic, spread-out, all-at-once, different-things-together terms. As Norton put it, quantum holism is an approach to quantum phenomena according to which “the state of the whole is not constituted by states of parts” (Healey, 1999).

To the extent that quantum physicists are approaching an imaginative limit of the human mind, it seems that such limits have a more swamp-like than wall-like nature. It’s not that they find it *impossible* to make sense of some things. Rather, they encounter difficulties and obstacles, and are trying out various ways to overcome them, to try to make inroads into the alleged ‘mystery’. In many cases they will become better with practice, as they gradually develop an intuitive feel for these strange notions, with some of course being more successful than others. But there does not seem to be a single hard limit that all of them run up against. Naturally, it remains possible that in the future only a few people, and eventually no-one at all, will be able to wrap their heads around some scientific theories, but it is also possible that we will just become better and better at wading through the swamp. In any event, the notion of a hard cognitive limit such as envisaged by the mysterians begins to look like be an implausible assumption, and this is all we need to soften up the radical thesis of cognitive (imaginative) closure.

# Discussion

## Epistemic modesty?

Mysterians often present their arguments as displaying appropriate modesty in the face of the cosmos and its mysteries. Would it not be the height of hubris to imagine that the human brain, a product of biological evolution just like any other organ, can unravel all mysteries and understand everything there is to understand about the cosmos? On closer inspection, however, their position is far less modest than it appears. Take McGinn’s confident pronouncement that the mind-body problem is “an ultimate mystery […] that human intelligence will never unravel” (McGinn 2000, p. 5). In order to secure this conclusion, McGinn needs knowledge about three different things: the nature of consciousness, the constitution of the human mind, and the reasons for the mismatch between the two.[[13]](#footnote-14) In particular, following our framework, mysterians have to demonstrate that no possible combination of mind extensions (including all possible mind extensions which could be developed in the future) will bring science any closer to an understanding of consciousness. Not only is this a taller order than mysterians have acknowledged, but it also leads them into a paradox. In his pronouncement about the mystery of consciousness, McGinn is assuming more knowledge about consciousness than his own transcendental naturalism allows.

Indeed, as mysterians succeed in spelling out exactly what it is about the human mind that makes knowledge of certain mysteries inaccessible, they risk being hoisted by their own petard. As Dennett writes:

As soon as you frame a question that you claim we will never be able to answer, you set in motion the very process that might well prove you wrong: you raise a topic of investigation. (Dennett 2017, p. 374)

In any event, to claim from the outset that human brains will *never* understand some problem, when scientific inquiry into that problem has only just begun, is far removed from the ideal of epistemic modesty championed by mysterians.

## Conclusion

By distinguishing between different forms and modalities of cognitive limits, and exploring some strategies for overcoming them, we have arrived at a more optimistic assessment of the epistemic prospects of humanity. First, mysterians often talk about the limitations of a single, isolated brain, but such limits miss the point, since humans are a tool-making species, which includes the use of countless cognitive tools. Second, imaginative closure does not entail representational closure. It is conceivable that human beings succeed in accurately *representing* some aspects of the world, but then prove unable to grasp these theories on an intuitive level. Third, mysterian arguments typically evoke the image of hitting a hard wall of knowledge, but there are other more plausible options. Given the flexibility of the human mind, as well as the myriad possibilities for mind extensions, it is more likely that we will encounter a scenario of diminishing cognitive returns. Reaching the end of scientific inquiry may feel less like slamming into a brick wall than getting bogged down in a swamp.

In this chapter, we explored analogies and metaphors as an important strategy for overcoming imaginative limitations, thus threatening even the weaker version of mysterianism. Not only is there no good reason to suppose that some parts of the universe will forever lie beyond the reach of science, but there is also no good reason to suppose that we will never *comprehend* some of these scientific achievements. Though captivating, the idea of a true scientific theory with a 42-like quality (see above) – perfectly accurate but perfectly incomprehensible – is hard to make sense of. Even when it comes to imaginative access, our prospects are not as bleak as suggested by the new mysterians. By bending, twisting, stretching, and pumping up our imagination – all metaphors in their own right, naturally – we may develop a more intuitive understanding even of those things our minds have not evolved to understand.

It is of course true that no-one can rule out altogether the possibility that human inquiry will one day come to an abrupt end, or that our scientific advances will become completely unmoored from intuitive understanding by even the smartest scientists. To assume otherwise would be epistemic hubris indeed. But in light of our remarkable past successes, and the myriad and open-ended possibilities for mind extension, any such pessimistic pronouncements remain premature.

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4. This chapter is based on an earlier paper published in *Biology & Philosophy*: Boudry, M., Vlerick, M., & Edis, T. (2020). The end of science? On human cognitive limitations and how to overcome them. *Biology & Philosophy, 35*(1), 1-16. [↑](#footnote-ref-5)
5. To a large extent, the epistemic pessimism of the new mysterians recapitulates arguments developed by German *naturphilosophen* and Victorian scientists in the 19th century, in particular during the so-called Ignorabimusstreit (Tennant, 2007). [↑](#footnote-ref-6)
6. In our previous work (Vlerick and Boudry 2017) we called these predicaments, respectively, “representational closure” and “psychological closure”. We have now decided to opt for a slightly different terminology, because the adjective “psychological” was too broad for our purposes. [↑](#footnote-ref-7)
7. In his original formulation, McGinn wrote that “A type of mind M is cognitively closed with respect to a property P (or theory T) if and only if the concept-forming procedures at M’s disposal cannot extend to a grasp of P (or an understanding of T)?” (McGinn, 1989, p. 350). By adding these parenthetical asides, McGinn suggests some rough equivalence, or a mere terminological difference. But there is a crucial difference between the claim that we cannot form a representation of some property P, and the claim that we cannot understand or grasp the representation itself. [↑](#footnote-ref-8)
8. According to the “extended mind” hypothesis in philosophy of mind (Clark and Chalmers 1998), the human mind literally extends beyond the skin/skull boundary, encompassing notebooks, computer screens, maps, file drawers, and so forth. But one does not need to embrace this radical philosophical view to appreciate how artefacts “extend” the reach of our minds. [↑](#footnote-ref-9)
9. Letter to Robert Hooke, February 5, 1675: https://bit.ly/2hIzhIe [↑](#footnote-ref-10)
10. This thought experiment was earlier used in an essay for *The Conversation* (Boudry 2019). [↑](#footnote-ref-11)
11. It is curious that mysterians have not explored quantum mechanics as a possible example of a domain to which we are cognitively closed. This might perhaps be attributed to the fact that quantum mechanics is notoriously demanding, to the extent that even confidence about its status as a mystery might be hard to come by. [↑](#footnote-ref-12)
12. Δ*x*Δ*p* ≥ ℏ/2 is really Δ*x*Δ*k* ≥ ½ for waves in general, combined with the de Broglie relationship of *p* = ℏ*k*. [↑](#footnote-ref-13)
13. In this respect, a more consistent (and radical) form of mysterianism can be found in Kriegel (2003), who maintains a strict second-order ignorance about the reasons for our sense of mystery. [↑](#footnote-ref-14)