The ANTHROPIC PRINCIPLE

What is it and why is it meaningful to the believing Jew?

By Professor Nathan Aviezer

In recent years, it has become clear to many scientists that the universe appears as if it were specifically designed for the existence and well-being of Man. This phenomenon, which has attracted considerable scientific attention, has become known as the anthropic principle[1,2] from the Greek word *anthropos*, meaning "man." The anthropic principle expresses itself in two ways: 1) very slight changes in the laws of nature would have made it impossible for life to exist, and 2) human life would not have been possible were it not for the occurrence in the past of a large number of highly improbable events. Whereas the secular scientist sees such a sequence of occurrences as mere "lucky accidents," the believing Jew sees in them the guiding hand of the Creator.

Our subject consists of two parts: first, an explanation of exactly what is meant by the anthropic principle, illustrated by a number of examples, and second, a discussion of the importance of the anthropic principle for the believing Jew. The first topic is purely scientific, whereas the second topic deals with religion. This distinction must be kept clear because the words commonly used by secular scientists in discussing the anthropic principle often sound remarkably similar to those used by the rabbis!

The Laws of Nature and the Existence of Life

The anthropic principle refers to the recent discovery of a remarkable connection between the laws of nature and the existence of life. It was previously thought that these two subjects have little in common. One can understand that the principles of biology would be related to the existence of life, but surely not the physical sciences. It is now known that such is not the case. Indeed, recent scientific discoveries have shown that the very existence of living creatures is intimately dependent on the details of the laws of physics, astronomy and cosmology.

Solar Energy

It is not necessary to elaborate on the fact that life on Earth is crucially dependent on the sun, whose heat and light are the primary source of all terrestrial energy (aside from radioactivity, which is not relevant to our discussion). Without solar energy, our planet would be incapable of supporting life. Therefore, we begin our discussion of the anthropic principle by examining the mechanism that produces the sun's energy.

The sun contains only two kinds of atoms: hydrogen and helium. Helium is inert, unconnected to solar energy, and therefore need not concern us further. Our discussion centers on hydrogen, the simplest atom of all, whose nucleus consists of only one particle — a proton. Thus, the sun is basically a vast assemblage of protons. How these protons produce solar energy was first explained in the late 1930s by Professor Hans Bethe, who was awarded the Nobel Prize for his discovery. (Bethe was a German Jew who, like so many others, was dismissed from his university post by the Nazis in 1933. He eventually settled in the United States and joined the physics faculty of Cornell University, where he made his Nobel-prize-winning discovery.)

Because of the extreme conditions present in the interior of the sun, a proton may occasionally transform spontaneously into a neutron — another fundamental particle of nature. The resulting neutron can combine with another proton to form a composite particle known as a deuteron. These deuterons "burn" via a thermonuclear reaction and this "burning" provides the intense heat and brilliant light of the sun. Thus, deuterons constitute the solar fuel that generates the energy of the sun which enables life to exist on Earth.

A very important feature of solar "burning" is that it occurs very gradually. Since neutrons are only rarely formed from protons, a relatively small number of deuterons are produced at any one time, and thus solar fuel (deuterons) constitutes but a tiny fraction of the total material in the sun. This ensures that the sun "burns" slowly, generating solar energy only gradually.

Another possible nuclear reaction that could, in principle, take place is the combination of one proton with another proton. Fortunately for us, however, proton-proton combination does not occur. If one proton would have been able to combine with another proton, then all the protons in the sun would immediately combine with each other, leading to a gigantic explosion of the entire sun.

The possibility of proton-neutron combination and the impossibility of proton-proton combination both depend on the strength of the "nuclear force," one of the fundamental forces in nature (the other fundamental forces include the familiar force of gravity and the electromagnetic force). Detailed calculations[3] of the nuclear force have demonstrated the following results:

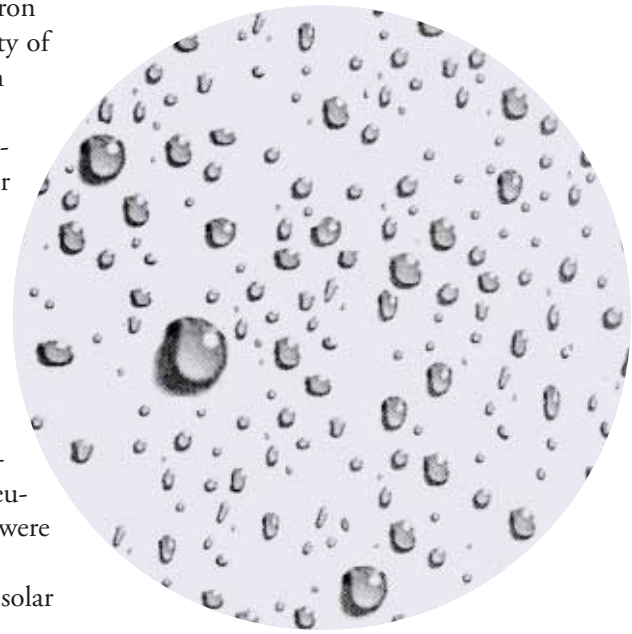
1. If the nuclear force were only a few percent weaker, then a proton could not combine with a neutron to form a deuteron. If this were the case, no deuterons would be formed in the sun and hence no solar fuel would exist. As a result, the sun would not shine ("burn"), but would merely be a cold ball of inert gas — precluding the possibility of life on Earth.
2. If the nuclear force were only a few percent stronger, then each proton would rapidly combine with another proton with explosive results. If this were the case, the sun would soon explode and thus cease to "burn," once again precluding the possibility of life on Earth.

It is an extraordinary fact that the strength of the nuclear force just happens to lie in the narrow range in which neither of these two catastrophes occurs. This is our first example of the anthropic principle.

Water and Air on Our Planet

It is not necessary to elaborate on the necessity of water and air for the existence of life. The Earth is blessed with an abundant supply of both, permitting life to flourish here, whereas our two neighboring planets, Venus and Mars, are both devoid of water and air, and hence devoid of life, as the space program has established. These facts may not seem particularly noteworthy, but we shall see just how remarkable they really are.

It was recently discovered that, shortly after they were formed, all three planets (Earth, Venus and Mars) had large amounts of surface water.



The deep channels that are observed today on the surface of Mars were carved out long ago by the copious fast-flowing Martian primordial surface waters.[4] Similarly, Venus was once covered by deep oceans which contained the equivalent of a layer of water three kilometers deep over its entire surface.[5] However, in the course of time, all surface waters on Mars and Venus disappeared. How did the Earth escape this catastrophe?

The answer is that the Earth escaped this catastrophe by sheer "accident!" The Earth just happens to be sufficiently distant from the sun that our surface water neither evaporated nor decomposed, as happened on Venus. Moreover, the Earth just happens to be sufficiently near the sun that the temperature remains high enough to prevent all the oceans from freezing permanently, as happened on Mars. Therefore, the Earth alone, among the planets of the solar system, is capable of supporting life.

Similar remarks apply to the atmosphere. Recent studies of the carbonate-silicate geochemical cycle have shown that the planetary atmosphere is controlled by a very delicate balance, involving the subtle interplay of many factors.[6] This balance is so delicate that if the Earth were only a few percent closer to the sun, surface temperatures would be far higher than the boiling point of water, precluding all possibility of a life-sustaining atmosphere. Similarly, if the Earth were only a few percent farther from the sun, the concentration of carbon dioxide in the atmosphere would become so high that "the atmosphere would not be breathable by human beings."[7] Fortunately, the orbit of the planet Earth just happens to lie at the crucial distance from the sun that permits the formation of a life-sustaining atmosphere. ("Life could appear in this extremely narrow zone."[8])

This remarkably fortunate coincidence is known among scientists as "the Goldilocks problem of climatology." Recall the children's story in which Goldilocks found the various items of Baby Bear to be "not too hot and not too cold, not too hard and not too soft, but just right." In that vein, scientists refer to the existence of water and air on Earth as another example of the anthropic principle.

Physics and Astronomy

The above two examples of the anthropic principle are taken from among the many that could be brought from the physical sciences. Indeed, the examples are so numerous and so dramatic that many scientists have commented on the severe restraints that the existence of life places on the laws of nature. Particularly perceptive are the impressions of Professor Freeman J. Dyson[9] of the Institute for Advanced Study in Princeton, one the world's leading mathematical physicists, whose words capture the essence of the anthropic principle:

As we look out into the universe and identify the many peculiarities of physics and astronomy that have worked together for our benefit, it almost seems as if the universe must in some sense have known that we were coming.

The Origin of Life

The branch of science dealing with the origin of life is called molecular biology. There has been enormous progress in the past few decades. Scientists have unraveled the structure of DNA (the long, thread-like molecules that form the genetic material found in each cell of every living creature) — the famous double helix. The genetic code has been deciphered. The hundreds of complex chemical reactions that take place within the cell are now understood. From all this scientific progress, one could easily form the impression that the "riddle of life" has been solved, i.e., that scientists have succeeded in explaining all the steps by which inanimate material became transformed into the complex biological systems that we call "life." However, such a conclusion would be completely erroneous.

After half a century of intensive research into molecular biology, scientists have come to appreciate just how extremely improbable and incredible appears the transformation of inanimate material into living cells. This was the central theme of a recent *Scientific American* article,[10] appropriately entitled, "In the Beginning..." (I love that title!). This article describes, in detail, the enormous difficulties encountered by all current scientific proposals to explain the origin of life, quoting leading experts in the field.

Professor Harold Klein,[11] chairman of the U.S. National Academy of Sciences Committee that reviewed origin-of-life research, is quoted by *Scientific American* as follows: *The simplest bacterium is so damn complicated that it is almost impossible to imagine how it happened.*

Professor Francis Crick,[12] who shared the Nobel Prize for discovering the structure of DNA, is also quoted as using picturesque language: *The origin of life appears to be almost a miracle, so many are the conditions which would have had to be satisfied to get it going.*

If this Nobel laureate, known as a man completely devoid of any religious feeling, sees fit to use the words "almost a miracle" to describe the origin of life, it is clear that quite an incredible series of unlikely events must have occurred.

Highly Improbable Events and Human Beings

The Destruction of the Dinosaurs

So far, we have been discussing the many unlikely events that were necessary to make possible the existence of life itself. But our main concern, of course, is with human life. Therefore, we ask: Did any extremely unusual events have to occur to permit the existence of human beings? As we shall see, the scientists' answer is a resounding "Yes!" This is the very heart of the

anthropic principle.

We begin our analysis of the highly improbable events that culminated in human life with a discussion of the dinosaurs, those terrible monsters of the past. The dinosaurs were one of the most successful groups of animals that ever lived — the largest, strongest, fastest and fiercest animals of all time. The dinosaurs (and their close relatives) inhabited every continent, the air (flying dinosaurs) and the oceans (marine dinosaurs). Other animals lived in constant fear of being devoured or destroyed by these gigantic reptiles. Because the dinosaurs were the dominant form of animal life, this geological era is commonly referred to as the Age of Reptiles.

After being the undisputed masters of our planet, all the dinosaurs worldwide suddenly became extinct. This sudden destruction of all the dinosaurs, together with most other animal species, is the most famous of the mass extinctions that have occurred periodically in the history of our planet, each time abruptly wiping out the majority of animal species. The cause of this mass extinction had baffled scientists for many years. What could have caused the abrupt demise of these extremely successfully animals after they had enjoyed such a long period of dominance? What occurred to suddenly wipe out the dinosaurs?

After years of debate, the riddle of what caused the sudden and total destruction of the dinosaurs was finally solved in 1980 by Nobel laureate Luis Alvarez and his son Walter, who showed that a giant meteor from outer space had collided with the Earth to cause this worldwide catastrophe.[13] This explanation for the mass extinctions — the impact of meteors or comets colliding with the Earth — has become known as the "impact theory." The scientific evidence in favor of the impact theory accumulated rapidly, and by 1987, Professor Alvarez could point to 15 different pieces of scientific data that supported the theory.[14]

The point of central importance to our discussion is that the collision between the meteor and the Earth was a matter of sheer luck. This has been repeatedly stressed by the leading paleontologists. For example, Professor David Raup, past president of the American Paleontological Society, has taken precisely this point as the central theme of his famous article (since expanded into a book with same title), *Extinctions: Bad Genes or Bad Luck?* In his article, Raup[15] emphasizes the role played by "luck" in mass extinctions: *The extinction of a given species or higher group is more bad luck than bad genes. Pure chance would favor some biologic groups over others.*

The important role played by luck in mass extinctions has also been emphasized by Professor Stephen J. Gould[16] of Harvard University, one of the world's leading authorities on evolutionary biology: *If extinctions can demolish more than 90% of all species, then we must be losing groups forever by pure bad luck.*

> *Our main concern, of course, is with human life.*

Professor George Yule[17] of the University of Oxford puts it in the following way:
The species exterminated were not killed out because of any inherent defects, but simply because they had the ill-luck to stand in the way of the cataclysm.

Finally, we quote Professor David Jablonski[18] of the University of Chicago, a world authority on the subject of mass extinctions: *When a mass extinction strikes, it is not the "most fit" species that survive; it is the most fortunate. Species that had been barely hanging on...inherit the earth.*

These leading paleontologists are emphasizing that if a giant meteor suddenly falls from the sky and wipes out some species, while permitting other species to survive and ultimately to flourish, then the latter species were blessed with good luck — the occurrence of an extremely improbable and totally unexpected event. The Darwinian principle of "the survival of the fittest" is irrelevant in such a process.

The Dinosaurs and Man

Why is the sudden destruction of all the dinosaurs worldwide a dramatic example of the anthropic principle? As long as the dinosaurs dominated the Earth, there was no possibility for large mammals to exist. Only after the dinosaurs were wiped out could the mammals flourish and become the dominant fauna.

This intimate connection between human beings and the dinosaurs was emphasized by Professor Alvarez,[19] who ends his article about the abrupt destruction of all the world's dinosaurs due to the impact of a gigantic meteor, with the following stirring words: *From our human point of view, that impact was one of the most important single events in the history of our planet. Had it not taken place, the largest mammals alive today might still resemble the rat-like creatures that were then scurrying around trying to avoid being devoured by dinosaurs.*

But there is even more to the story. For human beings to exist today, it was not sufficient merely that such an impact with the meteor occurred. The impact had to have occurred with just the right strength. As Professor Alvarez explains:[20] *If the impact had been weaker, no species would have become extinct; the mammals would still be subordinate to the dinosaurs, and I [Alvarez] wouldn't be writing this article. If the impact had been stronger, all life on this planet would have ceased, and again, I wouldn't be writing this*

article. That tells me that the impact must have been of just the right strength [to ensure that] the mammals survived, while the dinosaurs didn't.

Wonderful Life *by S. J. Gould*

It has recently become clear to scientists that the sudden destruction of all the world's dinosaurs was just one of a long series of completely unexpected, highly improbable events whose occurrence was necessary for human beings to exist — and all these events just happened to occur in precisely the required sequence. Indeed, this is a major theme in the recent book, entitled *Wonderful Life*, by Professor Gould. Again and again, Gould emphasizes how amazing it is that human beings exist at all, because, [21] *we are an improbable and fragile entity...the result of a staggeringly improbable series of events, utterly unpredictable and quite unrepeatable.* His 320-page book abounds with examples of the anthropic principle. For example:[22] *It fills us with a kind of amazement (because of its improbability) that human beings exist at all. Replay the tape[of life] a million times from the same beginning, and I doubt that* Homo sapiens *would ever appear again. It is, indeed, a wonderful life.*

Calculating Probabilities

Now that we have described in detail the scientific meaning of the anthropic principle, we turn to the second part of the discussion and ask: What are its implications?

In particular, what are the implications for the Torah Jew? I would like to begin this part of the discussion on a personal note. A few years ago, I wrote a book on Biblical creation and science, titled *In the Beginning*, showing that current scientific evidence is in remarkable agreement with the Biblical account of the origin and development of the universe. My book has enjoyed a measure of success, and has been reprinted ten times and translated into Hebrew, Russian, French, Spanish, Portuguese and Norwegian.

However, the book was not to everyone's taste. Professor Raphael Falk, a geneticist at the Hebrew University and a militant secularist, was so outraged by my book that he published a ten-page article[23] devoted solely to attacking both my book and me personally ("fundamentalist," "commits scientific rape," "writes pseudo-science," "manipulates facts," etc.). In particular, Falk[24] ridiculed my discussion of the anthropic principle by means of the following counter-argument: *Aviezer places particular emphasis on the "remarkable coincidences" which characterize the universe. The point of this claim is that such remarkable events could not have occurred through chance, but rather are the result of a guiding hand. Superficially, this claim appears convincing, but a little thought shows that that it is without foundation. According to Aviezer's logic, the probability that I am writing these lines with a dull yellow pencil, using my left hand, sitting at my kitchen table, on the third floor of a specific Jerusalem address — this probability is completely negligible. Nevertheless, all these events happened and they clearly mean nothing.*

It is important to explain what is wrong with Falk's argument, because his error is not immediately obvious and, in fact, has been repeated by many other writers. For example, this same error appears in an article on the anthropic principle,[25] written by a distinguished philosopher who is also an observant Jew. This author brings the following example: "I pull a $1 note from my wallet and observe its serial number to be G65538608D...[probability for occurrence] was less than one in ten billion. Thus, undeniably, I am faced here with an *extremely rare event*...but I am not surprised. What is essential is to make the crucial distinction between *improbable events that are genuinely surprising* and those that are not." (italics added)

I have italicized the two erroneous statements. The first italicized statement is simply wrong. We shall soon see why we are not faced with a rare event. The second italicized statement is meaningless, because all improbable events are surprising. Indeed, that is what is normally meant by the word "surprising."

The key to understanding this topic can be found in the words of Nobel laureate Richard Feynman, one of the most brilliant physicists of the 20th Century. In his marvelous, popular book on quantum electrodynamics (in which he explains this most complex of theories simply and without the use of a single equation!), Feynman[26]

> *The same rare event can either be wondrous or meaningless.*

emphasizes: *In order to calculate correctly the probability of an event, one must be very careful to define the event clearly.*

Following Feynman's advice, we shall clearly define the event described above, which immediately leads to the conclusion that there is a probability of 100% that the dollar note pulled from the wallet has G65538608D for its serial number! Why? Because this number was chosen by looking at the serial number on the $1 note. In other words, one was simply asking, "What is the probability that the serial number on the note is the serial number on the note?" And the answer to this question, clearly, is 100%. Since the event was not improbable at all — but

certain — there is no reason whatever to be surprised by its occurrence.

One may now apply the same logic to invalidate Falk's argument. What was the probability that Falk wrote his article on his kitchen table, using a dull yellow pencil held in his left hand, on the third floor of a specific Jerusalem address? The answer is: 100%! Why? Because Falk chose these unusual conditions on the basis on what he already knew to have happened. In other words, he simply asked, "What is the probability that what I know to have happened, really did happen?" The answer is clearly 100% — by definition.

A rare, extremely improbable event occurs if one defines the conditions before knowing what will happen. For example, if one chooses a serial number before pulling the $1 note from the wallet, and then finds that the number chosen is exactly the same as the number on the note, we would all be absolutely astonished — and with good reason! Similarly, if Falk had guessed correctly all the conditions under which someone else had written an article, then we would all be flabbergasted — and rightly so.

Events in Context - Playing the Lotto

We now turn to the second important aspect of Feynman's statement — events must be defined in context. An example will illustrate this point.

Among the popular national lotteries in Israel is "Lotto." Say, for example, that one million people buy a Lotto ticket each week. If I am informed that this week's winner is Chaim Cohen from Afula, I will certainly not get very excited about it. But why not? The chances that Chaim Cohen would be the winner were only one in a million — and it happened! The reason for my lack of excitement is the following. I could not care less if the Lotto winner is Chaim Cohen from Afula, Sarah Levi from Be'er Sheva or Shmerel Berel from Ramat Gan. In other words, each of the one million Lotto players is completely equivalent in my eyes to Chaim Cohen from Afula (the technical term for this in statistics is "equivalent microstates"). Although the chances were only one in a million that the winner would be Chaim Cohen from Afula, there exist one million "equivalent" Chaim Cohens. Therefore, the substance of what I heard is that someone won the Lotto this week. And the chances for that event happening — someone winning — are 100%. Hence, I have no reason to be surprised.

Now consider the following week. If I were informed that Chaim Cohen *again* won the Lotto, I would most certainly be amazed, and so would everyone else. But why? The chances of Chaim Cohen winning the Lotto the second week were exactly the same as his chances of winning the first week. The answer is that the context is entirely different. In the first week, Chaim Cohen was just one out of a million equivalent Lotto players. But in the second week, he has become a unique individual — the fellow who won last week. In other words, in the second week, there exists only one Chaim Cohen — only one previous week's winner — and the chances of this unique individual winning the Lotto again are therefore truly one in a million. When such a rare event occurs, we are all genuinely surprised.

Finally, we turn to the third week. If we were to learn that Chaim Cohen from Afula had again won the Lotto, for the third consecutive week, it is clear that suspicion, not surprise, would be the natural reaction. Indeed, there is little doubt that the fraud division of the police department would soon be paying Chaim Cohen a visit to discuss with him just how it happened that Chaim won the Lotto for three consecutive weeks. But why? The chances of Chaim Cohen winning the Lotto in the third week were exactly the same as his chances of winning the first week. The answer again lies in the context of the event. In the third week, Chaim Cohen is an extremely unusual individual — the fellow who has already won the Lotto for two weeks running. The chances that this same person will win the Lotto once again are easily shown to be only one in a million millions. Such events are so rare that they simply do not occur. Therefore, the police department correctly suspects that a guiding hand was behind Chaim Cohen's triple win. A guiding hand in the creation of the universe means the intercession of the Almighty, but a guiding hand in the determination of the Lotto winner means five years in Ramla Prison!

Events in Context — Playing Cards

We next consider card games, beginning our discussion with the game of poker (in particular, five-card poker without a draw). In this game, each player is dealt five cards from the deck, and these cards form a combination (such as a pair, three-of-a-kind, a flush, etc.). Each combination has an agreed ranking, and the game is won by the player whose cards form the highest ranking combination.

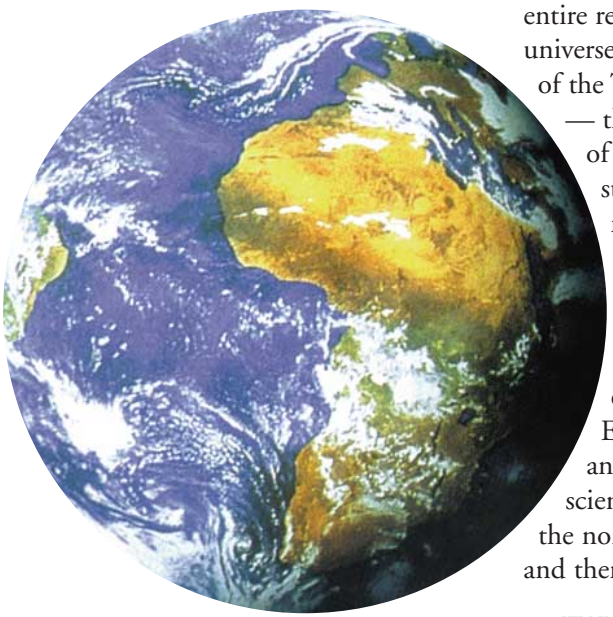
The highest ranking combination of cards in poker is the straight flush (it is not necessary to know what a straight flush is). A straight flush is so rare that

one can play poker all day, every day of his life, and never see one. And if a poker player should ever get a straight flush, he will never forget it. It's the dream of every poker player!

We now turn to a different card game: bridge. In this game, each player is dealt thirteen cards, but we will consider only the first five cards to enable us to make a comparison with poker. If a bridge player's first five cards were to be the combination that constitutes a straight flush in poker, he would probably not even be aware of it because, in bridge, a "straight flush" has no value or meaning whatever. This combination of cards is not even defined in bridge, hence I put quotation marks around the words "straight flush." Thus, we see that the exact same combination of cards is considered a wondrous combination in poker because of its rarity and value, but is considered a meaningless combination in bridge, despite its rarity, because it has no value.

The Anthropic Principle and the Believing Jew

The preceding examples and discussion pave the way for the answer to our central question: What conclusions may one draw from the anthropic principle? The answer depends on one's views regarding the significance of human beings. In our example about poker and bridge, we explained why the extremely rare straight flush is a wondrous event in a poker game, but a meaningless event in a bridge game. In other words, the same rare event can be either wondrous or meaningless: it all depends on the importance that one attributes to the event itself.



Returning to the subject of our article — human beings — we saw that many extremely unlikely events ("a staggeringly improbable series of events...quite unrepeatable"[27]) had to "occur" to make possible the appearance of human beings on Earth. Thus, the extreme rarity of the events leading to human existence is well established. Indeed, that is the scientific content of the anthropic principle. But before we can decide on the meaning of these events, we must first decide on the meaning of the end product — human beings.

If humans are assumed to be just another species in the Animal Kingdom (as the secularists believe), not more important than any other of the approximately two million species discovered so far, then the anthropic principle has no meaning. We have seen that rarity by itself is not significant. It is a "straight flush" in bridge, rare and interesting, but without any meaning. If, however, one believes that human beings are the most important species in the world and that mankind is the entire reason for the creation of the universe — as the Torah and the Sages of the Talmud repeatedly emphasize — then the anthropic principle is of the utmost significance. It is a straight flush in poker, the most meaningful of occurrences.

In summary, the scientists have discovered that, in the existence of human beings, the universe has dealt out the extremely rare straight flush. Everyone agrees with that; the anthropic principle has become a scientifically established fact. But the non-believer is "playing bridge" and therefore the anthropic principle means nothing to him. By contrast, the believing Jew is "playing poker" and therefore the anthropic principle is yet another example of the harmony that exists between modern science and words of the Torah. JA

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