Do Human Beings Have Free Will?

By: NATHAN AVIEZER

We begin our discussion of free will by making two obvious statements. First, all human beings feel that they possess free will and they have the ability to make decisions. For example, this morning, I decided to drink coffee for breakfast rather than tea; I decided to say morning prayers, while my atheist friend decided not to pray. The feeling of possessing free will is shared by everyone, including those philosophers who use their free will to staunchly deny its existence.

Second, the possession of free will is essential to understanding the Torah, which states that G-d's commandments obligate us. However, divine commandments can have meaning *only* if we are *able* to perform them, that is, if we have the *free will* to act in accordance with G-d's laws, or, if we so choose, to act contrary to these laws. This idea appears explicitly in the Torah: *I have set before you this day, life and good, and death and evil … you should choose life* (*Devarim* 30:15, 19).

In this article, we shall show that classical physics seems to indicate that free will is an illusion that does not, in fact, exist. We will then explain how quantum physics paves the way towards a resolution of this paradox. Finally, we shall discuss some recent neuroscience experiments which again claim that free will is only an illusion.

Physics

To appreciate the challenge that physics presented to the existence of free will, one must first understand some elements of the history of the scientific enterprise.

In 1687 Isaac Newton published the *Principia*, undoubtedly the most important book of physics ever written. In this work, Newton presented his new discoveries and proclaimed that all physical phenomena can be explained in terms of a few laws of nature—by no means a generally accepted idea at that time. Newton's greatest successes lay in his formulation of the laws of mechanics—his famous three laws of motion—and his discovery of the law of universal gravitation.

Nathan Aviezer is Professor of Physics and former Chairman of the Physics Department of Bar-Ilan University. He is the author of more than 140 scientific articles on solid state physics, was elected as a Fellow of the American Physical Society and is a Research Professor of the Royal Society of London.

The sun, moon, and planets have been the object of continuous stargazing for thousands of years. Nevertheless, explaining the motion of these heavenly bodies had long eluded the best efforts of astronomers. It was not until Newton's discoveries that it finally became possible to explain planetary motion. However, to calculate how the heavenly bodies move across the sky, it was not sufficient to discover *the laws of nature*. New mathematical techniques were required *solve the equations* implied by these laws of nature. This challenge, too, was successfully met by Newton, who developed the mathematics of the calculus, which enabled him to solve the equations that describe the motion of the heavenly bodies.

Because the sun is so very massive (containing 99.86% of the mass of the entire solar system), the primary contribution to the gravitational force acting on each planet is due to the sun. Newton proved that if one ignores the much smaller gravitational forces due to the other planets, then each planet will move around the sun in an elliptical orbit, as had previously been deduced by Kepler in the early 1600s on the basis of astronomical observations. In subsequent years, however, the newly invented telescope permitted much more precise measurements of planetary motion, and these newer data revealed clear deviations from simple elliptical orbits around the sun. The question then arose: Could Newton's theory of gravity also account for these more accurate measurements?

The great practical difficulty in predicting the details of planetary motion stems from the fact that not only the sun, but *every* planet, exerts a gravitational force on every other planet. Although the gravitational forces due to the other planets are relatively small, because the mass of the planets is so much smaller than that of the sun, these forces are not negligible and must be included. This leads to a very complicated set of equations for planetary motion, which are extremely difficult to solve.

The French mathematician Pierre-Simon de Laplace, born a century after Newton, greatly extended Newton's astronomical calculations, and succeeded in explaining all the details of the observed planetary motion. Before the work of Laplace, it was not even known whether the solar system was stable. Even the great Newton had expressed doubts, thinking that the outer planets would eventually drift away from the sun. It was left to Laplace to provide the definitive proof for the stability of the solar system.

The Clockwork Universe

Laplace's lifework is contained in his multi-volume masterpiece *Celestial Mechanics*, summarized in 1796 in his classic *The Exposition of the System of* *the World.* The publication of these two books marked the pinnacle of success in explaining planetary motion. An analogy was often made to a clock. Just as the many parts of a clock—wheels, springs, cogs—work in perfect harmony according to the craft of the clockmaker, in much the same way, the solar system functions according to the laws of nature.

In the years following Laplace, the scientific enterprise was greatly expanded. The various problems posed by nature all seemed capable of resolution by the concerted efforts of talented scientists. This strengthened the feeling that the laws of nature could provide the explanation for *every* feature of the physical world. It therefore became natural to suggest that the analogy of a clock should not be restricted to the solar system. Perhaps the *entire universe* could be viewed as one gigantic clock, propelled forward by the laws of nature. Thus was born the idea of the "clockwork universe."

One of the most important scientific advances of the 19th century was the discovery that there are *only two* different forces of nature, gravity and electromagnetism. (The two nuclear forces, discovered in the 20th century, do not influence the behavior of macroscopic objects, and therefore are not relevant to our present discussion.) The force of gravity is most evident with regard to massive bodies, such as the planets and the stars. It is this force that restricts us to the surface of the earth, and causes the planets to orbit around the sun.

The electrical and magnetic forces were once thought to be two different forces. However, in 1864, James Clerk Maxwell showed that these were really different aspects of a single force, called electromagnetism, which acts on every particle that possesses an electric charge. Since the most important particles in nature, the electrons and protons, are charged, it follows that electromagnetism is a universal force that acts on every atom.

The two forces of gravity and electromagnetism are responsible for all the numerous diverse phenomena that we observe: light, sound, heat, chemical reactions, magnetism, liquids, gases, electricity, weather, geology, fire, and many more. These myriad phenomena are *not* due to a variety of separate forces and/or different laws of nature, but they can *all* be explained in terms of these two fundamental forces.

An equally important accomplishment of the nineteenth century was the recognition that all materials are composed of submicroscopic particles called atoms. Furthermore, it was discovered that there are relatively few types of atoms, and that the vast number of materials found in nature, despite their very different properties, are all only different combinations of these few basic types of atoms. The electromagnetic force bonds the atoms together to form molecules, and the same force bonds the molecules together to form ceramics, metals, glasses, wood, minerals, and other familiar materials.

Important support for the concept of a clockwork universe came from these two principles: (1) that there exist only two fundamental forces of nature, and (2) that all the materials in the universe are composed of different combinations of a few basic atoms. Therefore, it was not necessary to assume numerous laws of nature to explain the many different phenomena that are observed. The universe seemed to be based on simplicity, as is the mechanism of a clock. Nevertheless, *in practice*, explaining the detailed behavior of the universe is quite a complicated task, because of the many particles that interact with each other. In this respect as well, nature seemed to resemble a gigantic clock. Therefore, the clockwork universe seemed to be the perfect description of nature.

Determinism

An important corollary of the clockwork universe is the concept of determinism, which was first applied to the solar system. Just as the clock mechanism determines where the clock hands will be at all times in the future, the laws of nature determine the future position and motion of all the planets. In other words, the future positions of all heavenly bodies *are already determined* by their present positions and the laws of nature. This is the central principle of determinism: *the present determines the future*.

To summarize: the research of Newton, Laplace and other scientists had shown that the future motion of each planet is completely determined by the planet's present position, and the force of gravity acting on it due to the other heavenly bodies. Subsequently, the principle of determinism was used to explain terrestrial phenomena as well. In fact, Laplace himself had emphasized that if one knew everything about a system at any particular time, then *in principle*, the future behavior of that system could be predicted in complete detail.

In practice, however, it is not possible to predict the future behavior of most systems, because most systems are so complicated that one cannot solve the equations that describe their future motion. But this inability to predict the future is merely a *technical* problem, due to the mathematical difficulties. *But in principle*, determinism seemed to be correct: the future behavior of every physical system is already determined by its present state. The principle of determinism soon became a cornerstone of science.

Determinism and Free Will

The relationship between determinism and free will is easily stated: determinism makes it *impossible* for free will to exist. Determinism states that *the present determines the future*, whereas free will is based on the premise that the present *does not* determine the future. Having free will means that I am now free, *in the present*, to choose what I wish to do *in the future*, because the present *does not* determine the future.

Consider an inanimate object, such as a stone, a planet, a cloud or some water. Each of these objects consists of a very large number of atoms and molecules held together by the two forces of nature: gravity and electromagnetism. The total force that acts on each given object depends on all other objects that interact with it. Thus, the future behavior of each object depends *only* on its present state and the present state of all other objects. This is what is meant by the statement: *the present determines the future*.

One now notes that living creatures are not fundamentally different in the physical sense from inanimate objects; they are merely much more complex. In particular, human beings do not differ from inanimate objects in any way that would invalidate the basic principle of determinism, namely, that *the present determines the future.*

It is true that human beings possess unique mental characteristics, including thought, consciousness, spirituality, self-awareness, and creativity, whose functioning is not presently understood. However, these mental characteristics do not change the fact that each of us is basically an "object" consisting of many atoms and molecules, just like a stone. Therefore, it appears that human beings should be subject to the same laws of nature that apply to stones. Just as the laws of nature decree that stones have no free will, these same laws would seem to imply that people, too, have no free will. There are some philosophers who dispute this statement, claiming that free will *is* consistent with classical science, but it is not difficult to identify the fallacies in these claims.

We are thus faced with a paradox. Human beings certainly *do* possess free will; each of us feels it in our daily lives. However, the laws of science seem to lead to the conclusion that our free will is merely an illusion. How is this paradox to be resolved?

Quantum Theory

The greatest scientific revolution of the twentieth century is known as quantum theory.

The previous theory of how particles move is called Newtonian physics, or classical physics, in contrast to the modern quantum theory. The most astonishing aspect of quantum theory is that it is a *probabilistic* theory of nature. This means that for any physical system, the most that can ever be known are the *probabilities* that certain events might occur in the future. Through the Schroedinger equation, one can calculate the *exact probability* for the occurrence of each possible event. However, *which* of the various possible events will *actually occur* in practice, can *never* be known beforehand.

The probabilistic nature of quantum mechanics leads to an important conclusion that is easily stated: the present *does not* determine the future. This non-determination of the future is called *quantum indeterminacy* and is enshrined in Heisenberg's famous *uncertainty principle*.

It is important to emphasize that quantum indeterminacy of the future is *not* due to lack of knowledge. That is, it is *not* correct to state that the future is already determined but no one is able to predict it. Quantum theory states that the future cannot be known *even in principle*, because *it has not yet been determined*. This can be illustrated as follows. If one performs the same experiment twice, with the two experiments being *absolutely identical* in every respect, one may nevertheless obtain different results in the two cases. In other words, the *same present* (the same experiment being performed twice) has led to *two different futures* (different results in the two cases). This scenario would be quite *impossible* according to classical physics. In fact, this phenomenon violates the very essence of Newtonian physics.

These startling results of quantum mechanics led to the demise of the clockwork universe. The characteristic feature of a clock is that its mechanism determines the future movement of the hands. However, this is no longer the case for the quantum universe.

The reader may be wondering how such a dramatic phenomenon (the present *does not* determine the future) was not noticed earlier by Newton and other great scientists. More to the point, our everyday experience tells us just the opposite; that is, throughout our lives, we observe that the present *does indeed* determine the future. Every soccer player knows that if he kicks the ball in the right direction (the present), in a few seconds (the future) the ball will enter the goal to the roar of the crowd. Why do athletes, as well as all the rest of us, remain unaffected and unaware of quantum theory in our daily lives?

The answer is that the effects of quantum theory are significant *only* for very minute particles. When dealing with macroscopic objects, such as soccer balls, the difference between the quantum prediction and the prediction of classical physics is completely insignificant. (A tiny speck of dust weighing less than a *trillionth of a gram* is considered *large* in this context.) When the soccer ball is kicked in the right direction, classical physics predicts a goal with 100% certainty, whereas the quantum prediction is that the chances of the ball entering the goal are 99.99999999....%, with only an *extremely* small chance of the ball missing the goal. Since the difference between these two predictions is unmeasurably small, an athlete need not be aware of quantum theory to become a soccer star. As long as one is dealing with large objects, the predictions of classical physics are correct.

Whenever one deals with submicroscopic particles, such as electrons and atoms, quantum effects are dominant, and classical physics gives a completely erroneous description of nature. Twentieth-century studies of atomic structure led scientists to question the validity of classical science. These studies showed, among other paradoxes, that according to the *classical* prediction, each atom in the universe should *spontaneously collapse* within a billionth of a second! Since it is obvious that atoms are perfectly stable and do *not* collapse, it was clear that the principles of classical physics are inadequate to describe the universe. Extensive scientific investigations of these paradoxes eventually led to the development of quantum theory.

Quantum Theory and Free Will

Let us recall the paradox we posed earlier concerning free will. According to classical physics, the present determines the future and, therefore, free will cannot exist. Quantum theory asserts that the present does *not* determine the future, and so it would seem that the paradox has been resolved. However, matters are not that simple. Human beings are clearly large objects, and we have explained that classical physics is completely adequate to deal with large objects. If quantum theory is not necessary to describe the human body, the paradox remains unresolved. The paradox would disappear only if quantum theory were *essential* to describing *thought processes*.

The exercise of free will does not require the functioning of the human body as a whole. Free will is determined by our thoughts, and the organ that controls our thinking is the brain. There has been much recent progress in our understanding of how the brain functions. Neuro-physiological research has shown that every mental process contains at least one crucial step that occurs through the activity of only a very small number of atoms working in concert.

The most widely used description of mental processes is based on the model of neural networks, developed in the 1980s in a series of pioneering articles by Professor John Hopfield of Princeton University. There are crucial steps in the functioning of the neural network that involve the activity of only a few atoms working together.

We have previously explained that the behavior of individual atoms lies within the quantum realm. Thus, quantum theory may indeed play an essential role in thought processes. How the workings of the brain are translated into the sensations and thoughts of the conscious mind is still shrouded in deep mystery. Nevertheless, it appears that the process of thinking cannot be described within the framework of classical physics, and quantum theory may have to be invoked. This is sufficient to disprove Laplace's claim of the scientific impossibility of free will.

Libet's Experiment

In the 1980s, a new challenge to free will was raised by Professor Benjamin Libet of the University of California at San Francisco. Libet performed a series of neuroscience experiments that seemed to demonstrate the absence of free will. However, we will see that these experiments are not relevant to the Torah assertion that human beings possess free will.

Description of the Experiment. There are several versions of Libet's experiment. In one version, the subject of the experiment has electrodes attached to his head that measure EEG (electroencephalogram) signals that are related to brain activity. A change in the EEG signal of brain activity indicates that the person is about to carry out a task.

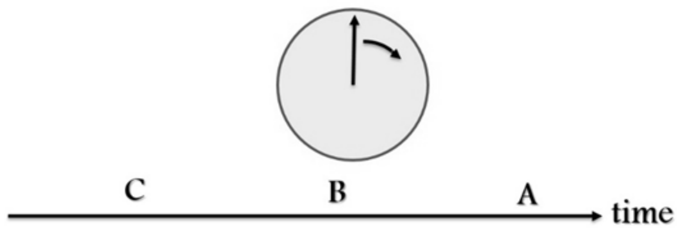
The subject is shown a clock with a single hand that rotates around the clock face (see figure below). The rotating hand can be stopped by pushing a certain button. The subject is asked to decide, at his leisure, when to push this button and thus stop the rotating clock hand.

Results of the Experiment. The results of the experiment are given by the time line in the figure under the clock. Say that the clock hand stops rotating at Time A. One knows that the subject's reaction time is about 0.3 seconds. Therefore, the subject's *decision* to push the button occurred at Time B, which is about 0.3 seconds before the rotating hand stopped at Time A.

However, *and this is the main point*, the EEG electrodes show that brain activity occurred at 0.7 seconds *earlier*, at Time C. In other words, the electrodes show that the brain had "ordered" the subject to carry out the task of pushing the button (at Time A), *before* the subject made his decision (at Time B) to push the button. Thus, it was the "decision" of the brain (at time C) to push the button, and not the decision of the subject, *which occurred later* (at Time B).

In summary, brain activity caused the subject to push the button before the subject made his decision. One concludes this from the fact that the EEG signal occurred (at Time C) before the subject made his decision to push the button (at later Time B).

LIBET EXPERIMENT



Time A: Button pressed and hand stopped
Time B: Subject made decision to press button (0.3 sec. before Time A)
Time C: Brain activity begins (0.7 seconds before Time A)

Other Examples of Acting Without Free Will

In fact, there is nothing unique about the Libet experiment. There are many examples of human activities that are carried out without the person exercising free will.

Driving a Car. When I drive my car, occasionally another car will cut right in front of me and I slam on the brakes to avoid an accident. However, I do not exercise any free will in my sudden braking, but rather, I act by instinct. Slamming on the brakes by using free will would mean that after recognizing the danger, I use my free will to decide to shift my foot from the gas pedal to the brake pedal, and then again use my free will to decide to press hard on the brake pedal. By that time, I would already be dead.

My experience in driving a car enables me to act immediately by instinct. Only after the danger was averted and I calmed down, do I realize that my sharp reflexes had saved my life. I had exercised my free will earlier when I decide to drive carefully and to be primed for any emergency that might occur while driving. This priming activated the "readiness potential" in my brain which permits actions to be carried out instinctively.

The "readiness potential" can be detected by a change in the EEG signal.

Playing Baseball. When I play baseball and my team is in the field, a batter will occasionally hit a sharp line drive near my position in the infield. I lunge for the ball and often manage to catch it. However, I do not exercise my free will in my sudden lunging for the ball, but rather, I act by instinct. Acting by using free will would mean that after seeing that the ball was heading my direction, I use my free will to decide to move in the direction of the ball and then again use my free will to decide to stretch out my hand toward the ball. By that time, the ball would already be far past me, deep in the outfield.

My experience in playing baseball enables me to act immediately by instinct. Only after I have caught the ball, do I realize that my sharp reflexes had enabled me to make the catch. I had exercised my free will earlier when I become alert at my position and primed myself to be ready to catch any ball that might come my way. This alertness activated the "readiness potential" in my brain which permits actions to be carried out instinctively. The "readiness potential" can be detected by a change in the EEG signal.

Libet Experiment. The Libet experiment works in the same way. The subject is instructed under which circumstances he should push the button to stop the rotating hand. However, when the subject suddenly pushes the button, he is not exercising his free will. The subject exercised his free will earlier when he agreed to be primed to suddenly push the button, thus activating the "readiness potential," as measured by a change in the EEG signal.

Motor System. Such processes are continually performed by our neural motor system. We are surrounded by objects whose sight automatically activates those motor schemas in the brain that would normally be employed to interact with these objects. These actions are prompted by the features of the objects. It has even been shown that simply observing pictures of these objects activates a sub-region of the medial frontal cortex, called SMA (supplementary motor area), even when there is no requirement to actually act on these stimuli. These stimulus-driven activations are rapid, involuntary, and unconscious.

Summary. In all three examples brought here, namely, the subject of the Libet experiment, the driver of the car and the baseball player, the person indeed acts without free will. In fact, one acts automatically, without exercising free will, in many daily activities, including walking, driving a car, signing one's name, chewing food, and tying one's shoes.

The Words of the Torah

However, none of these examples relates to the following words of the Torah: *I have set before you this day, life and good, and death and evil … you should choose life* (*Devorim* 30:15, 19). The Torah is speaking of deliberate acts that a person carries out, not sudden acts that are determined by instinct.

These deliberate acts are determined by free will. Examples of such deliberate free-will acts include: (i) praying to G-d, (ii) giving charity, (iii) eating pork, and (iv) robbing a bank. In each case, the person exercises his free will long before he carries out the physical act.

The Torah commands us to do good deeds. G-d gives every human being the intellectual capability to decide, *without His interference*, whether or not to obey His commandments. This is the essence of free will.

Summary

Questions regarding the existence of free will are not new. Paradoxes concerning free will have furnished grist for the mills of philosophers throughout the centuries. There are, of course, many more aspects of these complex questions than could be dealt with here. We have chosen to restrict the discussion to those points that can be formulated in terms of science. In particular, both quantum theory and neuroscience play a role in discussions of free will. We have attempted to show that modern science has something of value to contribute to the ancient conundrum of whether or not human beings choose their actions on the basis of free will.

Kavana: Beyond Free Will

Before ending this discussion, I would like to point out that in addition to exercising one's free will in carrying out G-d's commandments, there is an additional requirement: *kavana*, meaning *intent*. Unfortunately, it is all too common for one to rattle through prayers without *intent*, that is, without giving much thought to the meaning of the prayers or to the fact that prayer is a unique opportunity given to us to communicate with G-d. We may exercise our free will to sit in the *succah*, to shake the *lulav*, to hear the *shofar*, and to say a *brachah* before and after eating. But, in addition, we should also be aware that when performing these acts, we are standing in the divine presence and carrying out G-d's will. Lack of intent does not disqualify the *mitzvah* (*Shulchan Aruch*, *Orech Haim* 60, Mishna Berura 10), but this is certainly not the ideal manner of performing *mitzvot*.

May we all be blessed with the understanding that we come closer to G-d by performing the commandments with proper *kavana*.