Determinism

Determinism is the philosophical view that all events are determined completely by previously existing causes. Deterministic theories throughout the history of philosophy have sprung from diverse and sometimes overlapping motives and considerations. The opposite of determinism is some kind of indeterminism (otherwise called nondeterminism) or randomness. Determinism is often contrasted with free will, although some philosophers claim that the two are compatible.[1][2]

Determinism often is taken to mean *causal determinism*, which in physics is known as cause-and-effect. It is the concept that events within a given paradigm are bound by causality in such a way that any state (of an object or event) is completely determined by prior states. This meaning can be distinguished from other varieties of determinism mentioned below.

Other debates often concern the scope of determined systems, with some maintaining that the entire universe is a single determinate system and others identifying other more limited determinate systems (or multiverse). Numerous historical debates involve many philosophical positions and varieties of determinism. They include debates concerning determinism and free will, technically denoted as compatibilistic (allowing the two to coexist) and incompatibilistic (denying their coexistence is a possibility).

Determinism should not be confused with self-determination of human actions by reasons, motives, and desires. Determinism is about interactions which affect our cognitive processes in our life.[3] It is about the cause and the result of what we have done in our life. Cause and result are always bounded together in our cognitive processes. It assumes that if an observer has sufficient information about an object or human being, that such an observer might be able to predict every consequent move of that object or human being. Determinism rarely requires that perfect prediction be practically possible.

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Varieties

"Determinism" may commonly refer to any of the following viewpoints.

Causal determinism

Causal determinism, sometimes synonymous with **historical determinism** (a sort of path dependence), is "the idea that every event is necessitated by antecedent events and conditions together with the laws of nature."[4] However, it is a broad enough term to consider that:[5]

> ...one's deliberations, choices, and actions will often be necessary links in the causal chain that brings something about. In other words, even though our deliberations, choices, and actions are themselves determined like everything else, it is still the case, according to causal determinism, that the occurrence or existence of yet other things depends upon our deliberating, choosing and acting in a certain way.

Causal determinism proposes that there is an unbroken chain of prior occurrences stretching back to the origin of the universe. The relation between events may not be specified, nor the origin of that universe. Causal determinists believe that there is nothing in the universe that is uncaused or self-caused. Causal determinism has also been considered more generally as the idea that everything that happens or exists is caused by antecedent conditions.[6] In the case of nomological determinism, these conditions are considered events also,

implying that the future is determined completely by preceding events—a combination of prior states of the universe and the laws of nature.[4] Yet they can also be considered metaphysical of origin (such as in the case of theological determinism).[5]

Nomological determinism

Many philosophical theories of determinism frame themselves with the idea that reality follows a sort of predetermined path.

Nomological determinism, generally synonymous with **physical determinism** (its opposite being physical indeterminism), the most common form of causal determinism, is the notion that the past and the present dictate the future entirely and necessarily by rigid natural laws, that every occurrence results inevitably from prior events. Nomological determinism is sometimes illustrated by the thought experiment of Laplace's demon.[7] Nomological determinism is sometimes called *scientific determinism*, although that is a misnomer.

Necessitarianism

Necessitarianism is closely related to the causal determinism described above. It is a metaphysical principle that denies all mere possibility; there is exactly one way for the world to be. Leucippus claimed there were no uncaused events, and that everything occurs for a reason and by necessity.[8]

Predeterminism

Predeterminism is the idea that all events are determined in advance.[9][10] The concept is often argued by invoking causal determinism, implying that there is an unbroken chain of prior occurrences stretching back to the origin of the universe. In the case of predeterminism, this chain of events has been pre-established, and human actions cannot interfere with the outcomes of this pre-established chain.

Predeterminism can be used to mean such pre-established causal determinism, in which case it is categorised as a specific type of determinism.[9][11] It can also be used interchangeably with causal determinism—in the context of its capacity to determine future events.[9][12] Despite this, predeterminism is often considered as independent of causal determinism.[13][14]

Biological determinism

The term *predeterminism* is also frequently used in the context of biology and heredity, in which case it represents a form of biological determinism, sometimes called *genetic determinism*.[15] Biological determinism is the idea that each of human behaviors, beliefs, and desires are fixed by human genetic nature.

Fatalism

Fatalism is normally distinguished from "determinism",[16] as a form of teleological determinism. Fatalism is the idea that everything is fated to happen, so that humans have no control over their future. Fate has arbitrary power, and need not follow any causal or otherwise deterministic laws.[6] Types of fatalism include hard theological determinism and the idea of predestination, where there is a God who determines all that humans will do. This may be accomplished either by knowing their actions in advance, via some form of omniscience[17] or by decreeing their actions in advance.[18]

Theological determinism

Theological determinism is a form of determinism that holds that all events that happen are either preordained (i.e., predestined) to happen by a monotheistic deity, or are destined to occur given its omniscience. Two forms of theological determinism exist, referred to as *strong* and *weak* theological determinism.[19]

Strong theological determinism is based on the concept of a creator deity dictating all events in history: "everything that happens has been predestined to happen by an omniscient, omnipotent divinity."[20]

Weak theological determinism is based on the concept of divine foreknowledge—"because God's omniscience is perfect, what God knows about the future will inevitably happen, which means, consequently, that the future is already fixed."[21] There exist slight variations on this categorisation, however. Some claim either that theological determinism requires predestination of all events and outcomes by the divinity—i.e., they do not classify the weaker version as *theological determinism* unless libertarian free will is assumed to be denied as a consequence—or that the weaker version does not constitute *theological determinism* at all.[22]

With respect to free will, "theological determinism is the thesis that God exists and has infallible knowledge of all true propositions including propositions about our future actions," more minimal criteria designed to encapsulate all forms of theological determinism.[23]

Theological determinism can also be seen as a form of causal determinism, in which the antecedent conditions are the nature and will of God.[5] Some have asserted that Augustine of Hippo introduced theological determinism into Christianity in 412 CE, whereas all prior Christian authors supported free will against Stoic and Gnostic determinism.[24] However, there are many Biblical passages that seem to support the idea of some kind of theological determinism including Psalm 115:3 (https://www.biblegateway.com/passage/?search=Psalm+115%3A3&version=NASB), Acts 2:23 (https://www.biblegateway.com/passage/?search=Acts+2%3A23&version=NASB), and Lamentations 2:17 (https://www.biblegateway.com/passage/?search=Lamentations+2%3A17&version=NASB).

Logical determinism

Adequate determinism focuses on the fact that, even without a full understanding of microscopic physics, we can predict the distribution of 1000 coin tosses.

Logical determinism, or **determinateness**, is the notion that all propositions, whether about the past, present, or future, are either true or false. Note that one can support causal determinism without necessarily supporting logical determinism and vice versa (depending on one's views on the nature of time, but also randomness). The problem of free will is especially salient now with logical determinism: how can choices be free, given that propositions about the future already have a truth value in the present (i.e. it is already determined as either true or false)? This is referred to as the problem of future contingents.

Often synonymous with logical determinism are the ideas behind spatio-temporal determinism or eternalism: the view of special relativity. J. J. C. Smart, a proponent of this view, uses the term *tenselessness* to describe the simultaneous existence of past, present, and future. In physics, the "block universe" of Hermann Minkowski and Albert Einstein assumes that time is a fourth dimension (like the three spatial dimensions). In other words, all the other parts of time are real, like the city blocks up and down a street, although the order in which they appear depends on the driver (see Rietdijk–Putnam argument).

Adequate determinism

Adequate determinism is the idea, because of quantum decoherence, that quantum indeterminacy can be ignored for most macroscopic events. Random quantum events "average out" in the limit of large numbers of particles (where the laws of quantum mechanics asymptotically approach the laws of classical mechanics).[25] Stephen Hawking explains a similar idea: he says that the microscopic world of quantum mechanics is one of determined probabilities. That is, quantum effects rarely alter the predictions of classical mechanics, which are quite accurate (albeit still not perfectly certain) at larger scales.[26] Something as large as an animal cell, then, would be "adequately determined" (even in light of quantum indeterminacy).

Many-worlds

The many-worlds interpretation accepts the linear causal sets of sequential events with adequate consistency yet also suggests constant forking of causal chains creating "multiple universes" to account for multiple outcomes from single events.[27] Meaning the causal set of events leading to the present are all valid yet appear as a singular linear time stream within a much broader unseen conic probability field of other outcomes that "split off" from the locally observed timeline. Under this model causal sets are still "consistent" yet not exclusive to singular iterated outcomes.

The interpretation side steps the exclusive retrospective causal chain problem of "could not have done otherwise" by suggesting "the other outcome does exist" in a set of parallel universe time streams that split off when the action occurred. This theory is sometimes described with the example of agent based choices but more involved models argue that recursive causal splitting occurs with all particle wave functions at play.[28] This model is highly contested with multiple objections from the scientific community.

Philosophical varieties

Determinism in nature/nurture controversy

Although some of the above forms of determinism concern human behaviors and cognition, others frame themselves as an answer to the debate on nature and nurture. They will suggest that one factor will entirely determine behavior. As scientific understanding has grown, however, the strongest versions of these theories have been widely rejected as a single-cause fallacy.[29] In other words, the modern deterministic theories attempt to explain how the interaction of both nature *and* nurture is entirely predictable. The concept of heritability has been helpful in making this distinction.

Nature and nurture interact in humans. A scientist looking at a sculpture after some time does not ask whether we are seeing the effects of the starting materials or of environmental influences.

- Biological determinism, sometimes called *genetic determinism*, is the idea that each of human behaviors, beliefs, and desires are fixed by human genetic nature.
- Behaviorism involves the idea that all behavior can be traced to specific causes—either environmental or reflexive. John B. Watson and B. F. Skinner developed this nurture-focused determinism.
- Cultural determinism, along with social determinism, is the nurture-focused theory that the culture in which we are raised determines who we are.

- Environmental determinism, also known as *climatic* or *geographical determinism,* proposes that the physical environment, rather than social conditions, determines culture. Supporters of environmental determinism often also support Behavioral determinism. Key proponents of this notion have included Ellen Churchill Semple, Ellsworth Huntington, Thomas Griffith Taylor and possibly Jared Diamond, although his status as an environmental determinist is debated.[30]

Determinism and prediction

Other 'deterministic' theories actually seek only to highlight the importance of a particular factor in predicting the future. These theories often use the factor as a sort of guide or constraint on the future. They need not suppose that complete knowledge of that one factor would allow us to make perfect predictions.

A technological determinist might suggest that technology like the mobile phone is the greatest factor shaping human civilization.

- Psychological determinism can mean that humans must act according to reason, but it can also be synonymous with some sort of Psychological egoism. The latter is the view that humans will always act according to their perceived best interest.
- Linguistic determinism claims that our language determines (at least limits) the things we can think and say and thus know. The Sapir–Whorf hypothesis argues that individuals experience the world based on the grammatical structures they habitually use.
- Economic determinism attributes primacy to economic structure over politics in the development of human history. It is associated with the dialectical materialism of Karl Marx.
- Technological determinism is a reductionist theory that presumes that a society's technology drives the development of its social structure and cultural values.

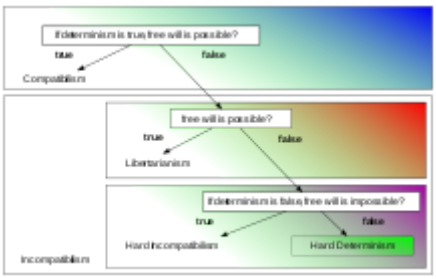
Structural determinism

Philosophy has explored the concept of determinism for thousands of years, which derives from the principle of causality. But philosophers, often, do not clearly distinguish between cosmic nature, human nature, and historical reality. Anthropologists define historical reality as synonymous with culture. The reality of determinism, as an uncontrollable element for human beings, unfolds in the classification of various types of society, after the overcoming of the "society of nature", identifiable with the overcoming of the society without any structure (and, therefore, consistent with the nature of the animal species, endowed with a minimum sociality, and minimal psychic processing). On the contrary, structured societies are based on cultural mechanisms, that is to say on mechanisms other than natural drives, which drives are common to all social animals. Already for some animal species, with less intellectual capacity than homo sapiens, elements of structures can be noted, that is, elements of the societies of the hordes, or of the tribal societies or those with stable social stratifications. These structural elements, insofar as they are artificial, or extraneous to the nature of the specific species in which they emerge, constitute factors of external determination, that is, of upheaval, on the drives, desires, needs, and purposes of the individuals of that particular species.

Contemporary human beings are generally inserted in a social reality equipped with structures, of an organic-stratified type, based on the concept and essence of the state, and therefore definable as structural statual reality, suffer from this reality structural, a decisive influence, which is such as to determine, almost entirely, their character, their thinking, and their behavior. Of this decisive influence, human beings are very little, or not at all, conscious, and can realize such consciousness only through in-depth philosophical studies, and individual reflections. Individually, they can, at least partially, abstract themselves from this decisive influence, only if they self-marginalize themselves from the reality of these same structures, in the specific manifestation

that the latter assumption, in the historical era in which a specific individual finds himself living. This marginalization does not necessarily imply social isolation, which causes it to take refuge in asociality, but to renounce being actively involved in the logic of the specific historical moment in which the individual finds himself living and, therefore, even more, abstracting from the hierarchical logic, based on the principle of authority, which is characteristic of the structural reality, historically determined and, in turn, decisive, on the individuals and peoples.[31]

With free will



A simplified taxonomy of philosophical positions regarding free will and determinism.

Philosophers have debated both the truth of determinism, and the truth of free will. This creates the four possible positions in the figure. Compatibilism refers to the view that free will is, in some sense, compatible with determinism. The three incompatibilist positions, on the other hand, deny this possibility. The hard incompatibilists hold that free will is incompatible with both determinism and indeterminism, the libertarianists that determinism does not hold, and free will might exist, and the hard determinists that determinism does hold and free will does not exist.

The Dutch philosopher Baruch Spinoza was a determinist thinker, and argued that human freedom can be achieved through knowledge of the causes that determine our desire and affections. He defined human servitude as the state of bondage of the man who is aware of his own desires, but ignorant of the causes that determined him. On the other hand, the free or virtuous man becomes capable, through reason and knowledge, to be genuinely free, even as he is being "determined". For the Dutch philosopher, acting out of our own internal necessity is genuine freedom while being driven by exterior determinations is akin to bondage. Spinoza's thoughts on human servitude and liberty are respectively detailed in the fourth[32] and fifth[33] volumes of his work *Ethics*.

The standard argument against free will, according to philosopher J. J. C. Smart, focuses on the implications of determinism for 'free will'.[34] However, he suggests free will is denied whether determinism is true or not. On one hand, if determinism is true, all our actions are predicted and we are assumed not to be free; on the other hand, if determinism is false, our actions are presumed to be random and as such we do not seem free because we had no part in controlling what happened.

With the soul

Some determinists argue that materialism does not present a complete understanding of the universe, because while it can describe determinate interactions among material things, it ignores the minds or souls of conscious beings.

A number of positions can be delineated:

- Immaterial souls are all that exist (idealism).
- Immaterial souls exist and exert a non-deterministic causal influence on bodies (traditional free-will, interactionist dualism).[35][36]
- Immaterial souls exist, but are part of a deterministic framework.
- Immaterial souls exist, but exert no causal influence, free or determined (epiphenomenalism, occasionalism)
- Immaterial souls do not exist – there is no mind-body dichotomy, and there is a materialistic explanation for intuitions to the contrary.

With ethics and morality

Another topic of debate is the implication that Determinism has on morality. Hard determinism (a belief in determinism, and not free will) is particularly criticized for seeming to make traditional moral judgments impossible. Some philosophers find this an acceptable conclusion.

Philosopher and incompatibilist Peter van Inwagen introduces this thesis, when argument that free will is required for moral judgments, as such:[37]

1. The moral judgment that *X* should not have been done implies that something else should have been done instead
2. That something else should have been done instead implies that there was something else to do
3. That there was something else to do implies that something else could have been done
4. That something else could have been done implies that there is free will
5. If there is no free will to have done other than *X* we cannot make the moral judgment that *X* should not have been done.

However, a compatibilist might have an issue with Inwagen's process, because one cannot change the past as their arguments center around. A compatibilist who centers around plans for the future might posit:

- The moral judgment that *X* should not have been done implies that something else could have been done instead
- That something else can be done instead implies that there is something else to do
- That there is something else to do implies that something else can be done
- That something else can be done implies that there is free will for planning future recourse
- If there is free will to do other than *X* the moral judgment can be made that other than *X* should be done, a responsible party for having done *X* while knowing it should not have been done should be punished to help remember to not do *X* in the future.

History

Determinism was developed by the Greek philosophers during the 7th and 6th centuries BC by the Pre-socratic philosophers Heraclitus and Leucippus, later Aristotle, and mainly by the Stoics. Some of the main philosophers who have dealt with this issue are Marcus Aurelius, Omar Khayyám, Thomas Hobbes, Baruch Spinoza, Gottfried Leibniz, David Hume, Baron d'Holbach (Paul Heinrich Dietrich), Pierre-Simon Laplace, Arthur Schopenhauer, William James, Friedrich Nietzsche, Albert Einstein, Niels Bohr, Ralph Waldo Emerson and, more recently, John Searle, Ted Honderich, and Daniel Dennett.

Mecca Chiesa notes that the probabilistic or selectionistic determinism of B. F. Skinner comprised a wholly separate conception of determinism that was not mechanistic at all. Mechanistic determinism assumes that every event has an unbroken chain of prior occurrences, but a selectionistic or probabilistic model does not.[38][39]

Western tradition

In the West, some elements of determinism have been expressed in Greece from the 6th century BC by the Presocratics Heraclitus[40] and Leucippus.[41] The first full-fledged notion of determinism appears to originate with the Stoics, as part of their theory of universal causal determinism.[42] The resulting philosophical debates, which involved the confluence of elements of Aristotelian Ethics with Stoic psychology, led in the 1st-3rd

centuries CE in the works of Alexander of Aphrodisias to the first recorded Western debate over determinism and freedom,[43] an issue that is known in theology as the paradox of free will. The writings of Epictetus as well as middle Platonist and early Christian thought were instrumental in this development.[44] Jewish philosopher Moses Maimonides said of the deterministic implications of an omniscient god:[45] "Does God know or does He not know that a certain individual will be good or bad? If thou sayest 'He knows', then it necessarily follows that [that] man is compelled to act as God knew beforehand he would act, otherwise God's knowledge would be imperfect."[46]

Newtonian mechanics

Determinism in the West is often associated with Newtonian mechanics/physics, which depicts the physical matter of the universe as operating according to a set of fixed, knowable laws. The "billiard ball" hypothesis, a product of Newtonian physics, argues that once the initial conditions of the universe have been established, the rest of the history of the universe follows inevitably. If it were actually possible to have complete knowledge of physical matter and all of the laws governing that matter at any one time, then it would be theoretically possible to compute the time and place of every event that will ever occur (*Laplace's demon*). In this sense, the basic particles of the universe operate in the same fashion as the rolling balls on a billiard table, moving and striking each other in predictable ways to produce predictable results.

Whether or not it is all-encompassing in so doing, Newtonian mechanics deals only with caused events; for example, if an object begins in a known position and is hit dead on by an object with some known velocity, then it will be pushed straight toward another predictable point. If it goes somewhere else, the Newtonians argue, one must question one's measurements of the original position of the object, the exact direction of the striking object, gravitational or other fields that were inadvertently ignored, etc. Then, they maintain, repeated experiments and improvements in accuracy will always bring one's observations closer to the theoretically predicted results. When dealing with situations on an ordinary human scale, Newtonian physics has been so enormously successful that it has no competition. But it fails spectacularly as velocities become some substantial fraction of the speed of light and when interactions at the atomic scale are studied. Before the discovery of quantum effects and other challenges to Newtonian physics, "uncertainty" was always a term that applied to the accuracy of human knowledge about causes and effects, and not to the causes and effects themselves.

Newtonian mechanics, as well as any following physical theories, are results of observations and experiments, and so they describe "how it all works" within a tolerance. However, old western scientists believed if there are any logical connections found between an observed cause and effect, there must be also some absolute natural laws behind. Belief in perfect natural laws driving everything, instead of just describing what we should expect, led to searching for a set of universal simple laws that rule the world. This movement significantly encouraged deterministic views in Western philosophy,[47] as well as the related theological views of classical pantheism.

Eastern tradition

The idea that the entire universe is a deterministic system has been articulated in both Eastern and non-Eastern religion, philosophy, and literature.

In *I Ching* and Philosophical Taoism, the ebb and flow of favorable and unfavorable conditions suggests the path of least resistance is effortless (see Wu wei).

In the philosophical schools of the Indian Subcontinent, the concept of *karma* deals with similar philosophical issues to the western concept of determinism. Karma is understood as a spiritual mechanism which causes the entire cycle of rebirth (i.e. *Saṃsāra*). Karma, either positive or negative, accumulates according to an

individual's actions throughout their life, and at their death determines the nature of their next life in the cycle of Saṃsāra. Most major religions originating in India hold this belief to some degree, most notably Hinduism, Jainism, Sikhism, and Buddhism.

The views on the interaction of karma and free will are numerous, and diverge from each other greatly. For example, in Sikhism, God's grace, gained through worship, can erase one's karmic debts, a belief which reconciles the principle of Karma with a monotheistic God one must freely choose to worship.[48] Jainism, on the other hand, believe in a sort of compatibilism, in which the cycle of Saṃsara is a completely mechanistic process, occurring without any divine intervention. The Jains hold an atomic view of reality, in which particles of karma form the fundamental microscopic building material of the universe, resembling in some ways modern-day atomic theory.

Buddhism

Buddhist philosophy contains several concepts which some scholars describe as deterministic to various levels. However, the direct analysis of Buddhist metaphysics through the lens of determinism is difficult, due to the differences between European and Buddhist traditions of thought.

One concept which is argued to support a hard determinism is the idea of dependent origination, which claims that all phenomena (*dharma*) are necessarily caused by some other phenomenon, which it can be said to be *dependent* on, like links in a massive chain. In traditional Buddhist philosophy, this concept is used to explain the functioning of the cycle of *saṃsāra*; all actions exert a karmic force, which will manifest results in future lives. In other words, righteous or unrighteous actions in one life will necessarily cause good or bad responses in another.[49]

Another Buddhist concept which many scholars perceive to be deterministic is the idea of non-self, or *anatta*.[50] In Buddhism, attaining enlightenment involves one realizing that in humans there is no fundamental core of being which can be called the "soul", and that humans are instead made of several constantly changing factors which bind them to the cycle of Saṃsāra.[50]

Some scholars argue that the concept of non-self necessarily disproves the ideas of free will and moral culpability. If there is no autonomous self, in this view, and all events are necessarily and unchangeably caused by others, then no type of autonomy can be said to exist, moral or otherwise. However, other scholars disagree, claiming that the Buddhist conception of the universe allows for a form of compatibilism. Buddhism perceives reality occurring on two different levels, the ultimate reality which can only be truly understood by the enlightened, and the illusory and false material reality. Therefore, Buddhism perceives free will as a notion belonging to material reality, while concepts like non-self and dependent origination belong to the ultimate reality; the transition between the two can be truly understood, Buddhists claim, by one who has attained enlightenment.[51]

Modern scientific perspective

Generative processes

Although it was once thought by scientists that any indeterminism in quantum mechanics occurred at too small a scale to influence biological or neurological systems, there is indication that nervous systems are influenced by quantum indeterminism due to chaos theory. It is unclear what implications this has for the problem of free will given various possible reactions to the problem in the first place.[52] Many biologists do not grant determinism: Christof Koch, for instance, argues against it, and in favour of libertarian free will, by making arguments based on generative processes (emergence).[53] Other proponents of emergentist or generative

philosophy, cognitive sciences, and evolutionary psychology, argue that a certain form of determinism (not necessarily causal) is true.[54][55][56][57] They suggest instead that an illusion of free will is experienced due to the generation of infinite behaviour from the interaction of finite-deterministic set of rules and parameters. Thus the unpredictability of the emerging behaviour from deterministic processes leads to a perception of free will, even though free will as an ontological entity does not exist.[54][55][56][57]

In Conway's Game of Life, the interaction of just four simple rules creates patterns that seem somehow "alive".

As an illustration, the strategy board-games chess and Go have rigorous rules in which no information (such as cards' face-values) is hidden from either player and no random events (such as dice-rolling) happen within the game. Yet, chess and especially Go with its extremely simple deterministic rules, can still have an extremely large number of unpredictable moves. When chess is simplified to 7 or fewer pieces, however, endgame tables are available that dictate which moves to play to achieve a perfect game. This implies that, given a less complex environment (with the original 32 pieces reduced to 7 or fewer pieces), a perfectly predictable game of chess is possible. In this scenario, the winning player can announce that a checkmate will happen within a given number of moves, assuming a perfect defense by the losing player, or fewer moves if the defending player chooses sub-optimal moves as the game progresses into its inevitable, predicted conclusion. By this analogy, it is suggested, the experience of free will emerges from the interaction of finite rules and deterministic parameters that generate nearly infinite and practically unpredictable behavioural responses. In theory, if all these events could be accounted for, and there were a known way to evaluate these events, the seemingly unpredictable behaviour would become predictable.[54][55][56][57] Another hands-on example of generative processes is John Horton Conway's playable Game of Life.[58] Nassim Taleb is wary of such models, and coined the term "ludic fallacy."

Compatibility with the existence of science

Certain philosophers of science argue that, while causal determinism (in which everything including the brain/mind is subject to the laws of causality) is compatible with minds capable of science, fatalism and predestination is not. These philosophers make the distinction that causal determinism means that each step is determined by the step before and therefore allows sensory input from observational data to determine what conclusions the brain reaches, while fatalism in which the steps between do not connect an initial cause to the results would make it impossible for observational data to correct false hypotheses. This is often combined with the argument that if the brain had fixed views and the arguments were mere after-constructs with no causal effect on the conclusions, science would have been impossible and the use of arguments would have been a meaningless waste of energy with no persuasive effect on brains with fixed views.[59]

Mathematical models

Many mathematical models of physical systems are deterministic. This is true of most models involving differential equations (notably, those measuring rate of change over time). Mathematical models that are not deterministic because they involve randomness are called stochastic. Because of sensitive dependence on initial conditions, some deterministic models may appear to behave non-deterministically; in such cases, a deterministic interpretation of the model may not be useful due to numerical instability and a finite amount of precision in measurement. Such considerations can motivate the consideration of a stochastic model even though the underlying system is governed by deterministic equations.[60][61][62]

Quantum and classical mechanics

Day-to-day physics

Since the beginning of the 20th century, quantum mechanics—the physics of the extremely small—has revealed previously concealed aspects of events. Before that, Newtonian physics—the physics of everyday life—dominated. Taken in isolation (rather than as an approximation to quantum mechanics), Newtonian physics depicts a universe in which objects move in perfectly determined ways. At the scale where humans exist and interact with the universe, Newtonian mechanics remain useful, and make relatively accurate predictions (e.g. calculating the trajectory of a bullet). But whereas in theory, absolute knowledge of the forces accelerating a bullet would produce an absolutely accurate prediction of its path, modern quantum mechanics casts reasonable doubt on this main thesis of determinism.

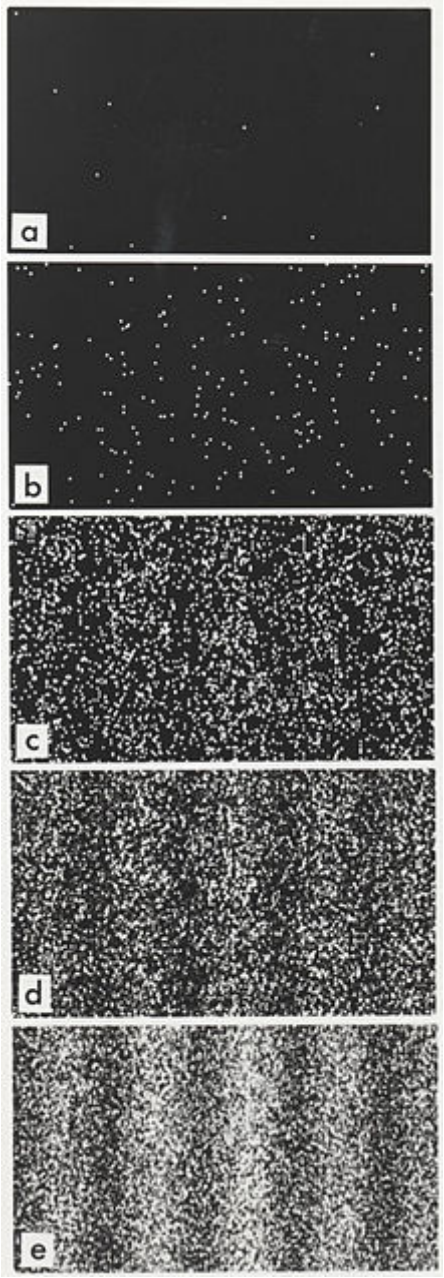
Relevant is the fact that certainty is never absolute in practice (and not just because of David Hume's problem of induction). The equations of Newtonian mechanics can exhibit sensitive dependence on initial conditions. This is an example of the butterfly effect, which is one of the subjects of chaos theory. The idea is that something even as small as a butterfly could cause a chain reaction leading to a hurricane years later. Consequently, even a very small error in knowledge of initial conditions can result in arbitrarily large deviations from predicted behavior. Chaos theory thus explains why it may be practically impossible to predict real life, whether determinism is true or false. On the other hand, the issue may not be so much about human abilities to *predict* or attain *certainty* as much as it is the nature of reality itself. For that, a closer, scientific look at nature is necessary.

Quantum realm

Quantum physics works differently in many ways from Newtonian physics. Physicist Aaron D. O'Connell explains that understanding our universe, at such small scales as atoms, requires a different logic than day-to-day life does. O'Connell does not deny that it is all interconnected: the scale of human existence ultimately does emerge from the quantum scale. O'Connell argues that we must simply use different models and constructs when dealing with the quantum world.[63] Quantum mechanics is the product of a careful application of the scientific method, logic and empiricism. The Heisenberg uncertainty principle is frequently confused with the observer effect. The uncertainty principle actually describes how precisely we may measure the position and momentum of a particle at the same time – if we increase the accuracy in measuring one quantity, we are forced to lose accuracy in measuring the other. "These uncertainty relations give us that measure of freedom from the limitations of classical concepts which is necessary for a consistent description of atomic processes."[64]

This is where statistical mechanics come into play, and where physicists begin to require rather unintuitive mental models: A particle's path simply cannot be exactly specified in its full quantum description. "Path" is a classical, practical attribute in our everyday life, but one that quantum particles do not meaningfully possess. The probabilities discovered in quantum mechanics do nevertheless arise from measurement (of the perceived path of the particle). As Stephen Hawking explains, the result is not traditional determinism, but rather determined probabilities.[65] In some cases, a quantum particle may indeed trace an exact path, and the probability of finding the particles in that path is one (certain to be true). In fact, as far as prediction goes, the quantum development is at least as predictable as the classical motion, but the key is that it describes wave functions that cannot be easily expressed in ordinary language. As far as the thesis of determinism is concerned, these probabilities, at least, are quite determined. These findings from quantum mechanics have found many applications, and allow us to build transistors and lasers. Put another way: personal computers, Blu-ray players and the Internet all work because humankind discovered the determined probabilities of the quantum world.[66] None of that should be taken to imply that other aspects of quantum mechanics are not still up for debate.

On the topic of predictable probabilities, the double-slit experiments are a popular example. Photons are fired one-by-one through a double-slit apparatus at a distant screen. They do not arrive at any single point, nor even the two points lined up with the slits (the way it might be expected of bullets fired by a fixed gun at a distant target). Instead, the light arrives in varying concentrations at widely separated points, and the distribution of its collisions with the target can be calculated reliably. In that sense the behavior of light in this apparatus is deterministic, but there is no way to predict where in the resulting interference pattern any individual photon will make its contribution (although, there may be ways to use weak measurement to acquire more information without violating the uncertainty principle).



Although it is not possible to predict the trajectory of any one particle, they all obey determined probabilities which do permit some prediction

Some (including Albert Einstein) argue that our inability to predict any more than probabilities is simply due to ignorance.[67] The idea is that, beyond the conditions and laws we can observe or deduce, there are also hidden factors or "hidden variables" that determine *absolutely* in which order photons reach the detector screen. They argue that the course of the universe is absolutely determined, but that humans are screened from knowledge of the determinative factors. So, they say, it only appears that things proceed in a merely probabilistically determinative way. In actuality, they proceed in an absolutely deterministic way.

John S. Bell criticized Einstein's work in his famous Bell's theorem, which proved that quantum mechanics can make statistical predictions that would be violated if local hidden variables really existed. A number of experiments have tried to verify such predictions, and so far they do not appear to be violated. Current experiments continue to verify the result, including the 2015 "Loophole Free Test" that plugged all known sources of error and the 2017 "Cosmic Bell Test" experiment that used cosmic data streaming from different directions toward the Earth, precluding the possibility the sources of data could have had prior interactions. However, it is possible to augment quantum mechanics with non-local hidden variables to achieve a deterministic theory that is in agreement with experiment.[68] An example is the Bohm interpretation of quantum mechanics. Bohm's Interpretation, though, violates special relativity and it is highly controversial whether or not it can be reconciled without giving up on determinism.

More advanced variations on these arguments include Quantum contextuality, by Bell, Simon B. Kochen and Ernst Specker, which argues that hidden variable theories cannot be "sensible," meaning that the values of the hidden variables inherently depend on the devices used to measure them.

This debate is relevant because it is easy to imagine specific situations in which the arrival of an electron at a screen at a certain point and time would trigger one event, whereas its arrival at another point would trigger an entirely different event (e.g. see Schrödinger's cat - a thought experiment used as part of a deeper debate).

Thus, quantum physics casts reasonable doubt on the traditional determinism of classical, Newtonian physics in so far as reality does not seem to be absolutely determined. This was the subject of the famous Bohr–Einstein debates between Einstein and Niels Bohr and there is still no consensus.[69][70]

Adequate determinism (see Varieties, above) is the reason that Stephen Hawking calls Libertarian free will "just an illusion".[65]

Other matters of quantum determinism

Chaotic radioactivity is the next explanatory challenge for physicists supporting determinism.

All uranium found on earth is thought to have been synthesized during a supernova explosion that occurred roughly 5 billion years ago. Even before the laws of quantum mechanics were developed to their present level, the radioactivity of such elements has posed a challenge to determinism due to its unpredictability. One gram of uranium-238, a commonly occurring radioactive substance, contains some 2.5 x 10^{21} atoms. Each of these atoms are identical and indistinguishable according to all tests known to modern science. Yet about 12600 times a second, one of the atoms in that gram will decay, giving off an alpha particle. The challenge for determinism is to explain why and when decay occurs, since it does not seem to depend on external stimulus. Indeed, no extant theory of physics makes testable predictions of exactly when any given atom will decay. At best scientists can discover determined probabilities in the form of the element's half life.

The time dependent Schrödinger equation gives the first time derivative of the quantum state. That is, it explicitly and uniquely predicts the development of the wave function with time.

$$i\hbar\frac{\partial\psi(x,t)}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial^2\psi(x,t)}{\partial x^2} + V(x)\psi$$

So if the wave function itself is reality (rather than probability of classical coordinates), then the unitary evolution of the wave function in quantum mechanics, can be said to be deterministic. But the unitary evolution of the wave function is not the entirety of quantum mechanics.

Asserting that quantum mechanics is deterministic by treating the wave function itself as reality might be thought to imply a single wave function for the entire universe, starting at the origin of the universe. Such a "wave function of everything" would carry the probabilities of not just the world we know, but every other possible world that could have evolved. For example, large voids in the distributions of galaxies are believed by many cosmologists to have originated in quantum fluctuations during the big bang. (*See* cosmic inflation, primordial fluctuations and large-scale structure of the cosmos.)

However, neither the posited reality nor the proven and extraordinary accuracy of the wave function and quantum mechanics at small scales can imply or reasonably suggest the existence of a single wave function for the entire universe. Quantum mechanics breaks down wherever gravity becomes significant, because nothing in the wave function, or in quantum mechanics, predicts anything at all about gravity. And this is obviously of great importance on larger scales.

Gravity is thought of as a large-scale force, with a longer reach than any other. But gravity becomes significant even at masses that are tiny compared to the mass of the universe.

A wave function the size of the universe might successfully model a universe with no gravity. Our universe, with gravity, is vastly different from what quantum mechanics alone predicts. To forget this is a colossal error.

Objective collapse theories, which involve a dynamic (and non-deterministic) collapse of the wave function (e.g. Ghirardi–Rimini–Weber theory, Penrose interpretation, or causal fermion systems) avoid these absurdities. The theory of causal fermion systems for example, is able to unify quantum mechanics, general relativity and quantum field theory, via a more fundamental theory that is non-linear, but gives rise to the linear

behaviour of the wave function and also gives rise to the non-linear, non-deterministic, wave-function collapse. These theories suggest that a deeper understanding of the theory underlying quantum mechanics shows the universe is indeed non-deterministic at a fundamental level.

See also

- *Amor fati*
- Calvinism
- Digital physics
- False necessity
- Fractal
- Game theory
- Ilya Prigogine
- Interpretations of quantum mechanics
- Lazy reason
- *Notes from Underground*
- Open theism
- Philosophical interpretation of classical physics
- Radical behaviorism
- Superdeterminism
- Voluntarism
- Wheeler–Feynman absorber theory

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63. "Struggling with quantum logic: Q&A with Aaron O'Connell (http://blog.ted.com/2011/06/02/struggling-with-quantum-logic-qa-with-aaron-oconnell/)
64. Heisenberg, Werner (1949). *Physikalische Prinzipien der Quantentheorie* (https://books.google.com/books?id=NzMBh4ZxKJsC&pg=PA4) [*Physical Principles of Quantum Theory*]. Leipzig: Hirzel/University of Chicago Press. p. 4. ISBN 9780486601137.
65. Grand Design (2010), page 32: *"the molecular basis of biology shows that biological processes are governed by the laws of physics and chemistry and therefore are as determined as the orbits of the planets...so it seems that we are no more than biological machines and that free will is just an illusion"*, and page 72: *"Quantum physics might seem to undermine the idea that nature is governed by laws, but that is not the case. Instead it leads us to accept a new form of determinism: Given the state of a system at some time, the laws of nature determine the probabilities of various futures and pasts rather than determining the future and past with certainty."* (discussing a Many worlds interpretation)
66. Scientific American, "What is Quantum Mechanics Good For?" (http://www.scientificamerican.com/article.cfm?id=everyday-quantum-physics)
67. Albert Einstein insisted that, "I am convinced God does not play dice" in a private letter to Max Born, 4 December 1926, Albert Einstein Archives (http://www.alberteinstein.info/db/ViewDetails.do?DocumentID=38009) Archived (https://web.archive.org/web/20100819045822/http://www.alberteinstein.info/db/ViewDetails.do?DocumentID=38009) 19 August 2010 at the Wayback Machine reel 8, item 180
68. Jabs, Arthur (2016). "A conjecture concerning determinism, reduction, and measurement in quantum mechanics". *Quantum Studies: Mathematics and Foundations*. **3** (4): 279–292. arXiv:1204.0614 (https://arxiv.org/abs/1204.0614). doi:10.1007/s40509-016-0077-7 (https://doi.org/10.1007%2Fs40509-016-0077-7). S2CID 32523066 (https://api.semanticscholar.org/CorpusID:32523066).

69. Bishop, Robert C. (2011). "Chaos, Indeterminism, and Free Will" (https://books.google.com/books?id=kzcFDsWg0GEC&pg=PA90). In Kane, Robert (ed.). *The Oxford Handbook of Free Will* (Second ed.). Oxford, New York: Oxford University Press. p. 90. ISBN 9780195399691. OCLC 653483691 (https://www.worldcat.org/oclc/653483691). "The key question is whether to understand the nature of this probability as epistemic or ontic. Along epistemic lines, one possibility is that there is some additional factor (i.e., a hidden mechanism) such that once we discover and understand this factor, we would be able to predict the observed behavior of the quantum stoplight with certainty (physicists call this approach a "hidden variable theory"; see, e.g., Bell 1987, 1–13, 29–39; Bohm 1952a, 1952b; Bohm and Hiley 1993; Bub 1997, 40–114, Holland 1993; see also the preceding essay in this volume by Hodgson). Or perhaps there is an interaction with the broader environment (e.g., neighboring buildings, trees) that we have not taken into account in our observations that explains how these probabilities arise (physicists call this approach decoherence or consistent histories[15]). Under either of these approaches, we would interpret the observed indeterminism in the behavior of stoplights as an expression of our ignorance about the actual workings. Under an ignorance interpretation, indeterminism would not be a fundamental feature of quantum stoplights, but merely epistemic in nature due to our lack of knowledge about the system. Quantum stoplights would turn to be deterministic after all."
70. Baggott, Jim E. (2004). "Complementarity and Entanglement" (https://books.google.com/books?id=uVdjwsqrgz8C&q=scientific+consensus+determinism+bell+theorem&pg=PA203). *Beyond Measure: Modern Physics, Philosophy, and the Meaning of Quantum Theory*. Oxford, New York: Oxford University Press. p. 203. ISBN 978-0-19-852536-3. OCLC 52486237 (https://www.worldcat.org/oclc/52486237). "So, was Einstein wrong? In the sense that the EPR paper argued in favour of an objective reality for each quantum particle in an entangled pair independent of the other and of the measuring device, the answer must be yes. But if we take a wider view and ask instead if Einstein was wrong to hold to the realist's belief that the physics of the universe should be objective and deterministic, we must acknowledge that we cannot answer such a question. It is in the nature of theoretical science that there can be no such thing as certainty. A theory is only 'true' for as long as the majority of the scientific community maintain a consensus view that the theory is the one best able to explain the observations. And the story of quantum theory is not over yet."

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Further reading

- George Musser, "Is the Cosmos Random? (Einstein's assertion that God does not play dice with the universe has been misinterpreted)", *Scientific American*, vol. 313, no. 3 (September 2015), pp. 88–93.

External links

- Stanford Encyclopedia of Philosophy entry on Causal Determinism (http://plato.stanford.edu/entries/determinism-causal/)
- Determinism in History (https://web.archive.org/web/20050404080900/http://etext.lib.virginia.edu/cgi-local/DHI/dhi.cgi?id=dv2-02) from the *Dictionary of the History of Ideas*
- Philosopher Ted Honderich's Determinism web resource (http://www.ucl.ac.uk/~uctytho/dfwIntroIndex.htm)
- Determinism on Information Philosopher (http://www.informationphilosopher.com/freedom/determinism.html)
- The Society of Natural Science (http://www.determinism.com)
- Determinism and Free Will in Judaism (http://www.chabad.org/article.asp?AID=3017)
- Snooker, Pool, and Determinism (http://www.jottings.ca/john/cogitations.html)
- Game of life:-Life is a game, how to play it (https://www.thefactssite.com/2020/05/life-is-game-game-of-life.html)