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Chapter 19

Possibility

In the "semantics of possible worlds," necessity and possibility in modal logic are variations of the universal and existential quantifiers of non-modal logic. Necessary truth is defined as "truth in all possible worlds." Possible truth is defined as "truth in some possible worlds." These abstract notions about "worlds" – sets of propositions in universes of discourse – have nothing to do with physical possibility, which depends on the existence of real *contingency*. Propositions in modal logic are required to be true or false. Contingent statements that are neither true or false are not allowed in modal logic. So much for real possibilities!

Historically, the opposition to metaphysical possibility has come from those who claim that the only possible things that can happen are the actual things that do happen. To say that things could have been otherwise is a mistake, say eliminative materialists and determinists. Those other possibilities simply never existed in the past. The only possible past was the actual past.

Similarly, there is only one possible future. Whatever will happen, will happen. The idea that many different things can happen, the reality of modality and words like "may" or "might" are used in everyday conversation, but they have no place in metaphysical reality. The only "actual" events or things are what exists. For "presentists," even the past does not exist. Everything we remember about past events is just a set of "Ideas." And philosophers have always been troubled about the ontological status of Plato's abstract "Forms," entities like the numbers, geometric figures, mythical beasts, and other fictions.

Traditionally, those who deny possibilities in this way have been called "Actualists."

In the last half-century, one might think that metaphysical possibilities have been restored with the development of modal logic. So-called modal operators like "necessarily" and "possibly" have been added to the structurally similar quantification operators "for all" and "for some." The metaphysical literature is full of talk about "possible worlds."

The most popular theory of "possible worlds" is David Lewis's "modal realism," an infinite number of worlds, each of which is just as actual (eliminative materialist and determinist) for its inhabitants as our world.

There are no genuine possibilities in Lewis's "possible worlds"! It comes as a shock to learn that every "possible world" is just as actual, for its inhabitants, as our world is for us. There are no alternative possibilities, no contingency, no things that might have been otherwise, in any of these possible worlds. Every world is as physically deterministic as our own.

Modal logicians now speak of a "rule of necessitation" at work in possible world semantics. The necessarily operator ' □ ' and the possibly operator ' ◊ ' are said to be "duals" - either one can be defined in terms of the other (□ = ~◊~, and ◊ = ~□~), so either can be primitive. But most axiomatic systems of modal logic appear to privilege necessity and de-emphasize possibility. They rarely mention contingency, except to say that the necessity of identity appears to rule out contingent identity statements.

The rule of necessitation is that "if p, then necessarily p," or p ⊃ □p. This gives rise to the idea that if anything exists, it exists necessarily. This is called "necessitism." The idea that if two things are identical, they are necessarily identical, was "proved" by Ruth Barcan Marcus in 1947, by her thesis adviser F.B.Fitch in 1952, and by Willard Van Orman Quine in 1953. David Wiggins in 1965 and Saul Kripke in 1971 repeated the arguments, with little or no reference to the earlier work.

This emphasis on necessitation in possible-world semantics leads to a flawed definition of possibility that has no connection with the ordinary and technical meanings of possibility.

Modal logicians know little if anything about real possibilities and nothing at all about possible physical worlds. Their possible worlds are abstract universes of discourses, sets of propositions that are true or false. Contingent statements, that may be true or false, like statements about the future, are simply not allowed.

The modal operators □ and ◊ are designed to correspond to the universal and existential quantification operators "for all" ∀ and "for some" ∃. But the essential nature of possibility is the conjunction of contingency and necessity. Contingency is not impossible and not necessary (~~◊ ∧ ~□).

Information philosophy proposes the existence of a *metaphysical possibilism* alongside the currently popular notion of necessitism.

"Actual possibilities" exist in minds and in quantum-mechanical "possibility functions" It is what we might call "actual possibilism," the existence in our actual world of possibilities that may never become actualized, but that have a presence as abstract entities that have been embodied as ideas in minds. In addition, we include the many possibilities that occur at the microscopic level when the quantum-mechanical probability-amplitude wave function collapses, making one of its many possibilities actual.

Actual Possibles

Although there are no genuine possibilities in Lewis's "possible worlds," we can explain the existence of "actual possibles" in metaphysical terms using the possible world semantics of Kripke, who maintained that his semantics could be used to describe various ways our actual world might have been. Unlike many other "possible world" interpretations, Kripke accepts that empirical facts in the physical world are contingent, that many things might have been otherwise. Kripke's counterfactuals are genuinely different ways the actual world might have been or might become.

> "I will say something briefly about 'possible worlds'. (I hope to elaborate elsewhere.) In the present monograph I argued against those misuses of the concept that regard possible worlds as something like distant planets, like our own surroundings but somehow existing in a different dimension, or that lead to spurious problems of 'transworld identification'. Further, if one wishes to avoid the Weltangst and philosophical confusions that many philosophers have associated with the 'worlds' terminology, I recommended that 'possible state (or history) of the world', or 'counterfactual situation' might be better. One should even remind oneself that the 'worlds' terminology can often be replaced by modal talk—'It is possible that.' ... 'Possible worlds' are total 'ways the world might have been', or states or histories of the entire world." [1]

1 Kripke (1981) *Naming and Necessity*, p. 15, 18

Actualism

Actualism appeals to philosophers who want the world to be determined by physical laws and by theologians who want the world to be the work of an omnipotent, omniscient, and benevolent god.

Some physicists think the future is causally closed under deterministic laws of nature and the "fixed past." If the knowledge that a Laplacian "super-intelligence" has about all the motions at any instant is fixed for all time, then everything today might have been pre-determined from the earliest moments of the physical universe.

The special theory of relativity, for example, describes a four-dimensional "block universe" in which all the possible events of the future already exist alongside those of the past. It makes "fore-knowledge" of the future conceivable.

Diodorus Cronus dazzled his contemporaries in the fourth century BCE with sophisticated logical arguments, especially paradoxes, that "proved" there could be only one possible future.

Diodorus' "master argument" is a set of propositions designed to show that the actual is the only possible and that some true statements about the future imply that the future is already determined. This follows logically from his observation that if something in the future is not going to happen, it must have been that statements in the past that it would not happen must have been true.

Modern day "actualists" include Daniel Dennett, for whom determinism guarantees that the actual outcome is and always was the only possible outcome. The notion that we can change the future is absurd, says Dennett, change it from what to what?

The ancient philosophers debated the distinction between necessity and contingency (between the *a priori* and the *a posteriori*). Necessity includes events or concepts that are logically necessary and physically necessary, contingency those that are logically or physically possible. In the middle ages and the enlightenment, necessity was often contrasted with freedom. In modern times it is often contrasted with mere chance.

Causality is often confused with necessity, as if a causal chain requires a deterministic necessity. But we can imagine chains where the linked causes are statistical, and modern quantum physics tells us that all events are only statistically caused, even if for large macroscopic objects the statistical likelihood approaches near certainty for all practical purposes. The apparent deterministic nature of physical laws is only an "adequate" determinism.

In modern philosophy, modal theorists like David Lewis discuss counterfactuals that might be true in other "possible worlds." Lewis' work at Princeton may have been inspired by the work of Princeton scientist Hugh Everett III. Everett's interpretation of quantum mechanics replaces the "collapse" of the wave function with a "splitting" of this world into multiple worlds existing in parallel universes.

Possibilities in Quantum Mechanics

According to the Schrödinger equation of motion, the time evolution of the wave function describes a "superposition" of possible quantum states. Standard quantum mechanics says that interaction of the quantum system with other objects causes the system to collapse into one of the possible states, with probability given by the square of the "probability amplitude."

One very important kind of interaction is a measurement by an "observer."

In standard quantum theory, when a measurement is made, the quantum system is "projected" or "collapsed" or "reduced" into a single one of the system's allowed states. If the system was "prepared" in one of these "eigenstates," then the measurement will find it in that state with probability one (that is, with certainty).

However, if the system is prepared in an arbitrary state ψ_a, it can be represented as being in a linear combination of the system's basic eigenstates φ_n.

$\psi_a = \Sigma\, c_n \,|\, n >.$

where

$c_n = < \psi_a \,|\, \varphi_n >.$

The system ψ_a is said to be in "superposition" of those basic states φ_n. The probability P_n of its being found in a particular state φ_n is

$P_n = < \psi_a \,|\, \varphi_n >^2 = c_n^{\,2}$.

Chapter 19

Shannon and Quantum Indeterminism

In his development of the mathematical theory of the communication of information, Claude Shannon showed that there can be no new information in a message unless there are multiple possible messages. If only one message is possible, there is no information in that message.

We can simplify this to define a Shannon Principle. No new information can be created in the universe unless there are multiple possibilities, only one of which can become actual.

An alternative statement of the Shannon principle is that in a deterministic system, information is conserved, unchanging with time. Classical mechanics is a conservative system that conserves not only energy and momentum but also conserves the total information. Information is a "constant of the motion" in a determinist world.

Quantum mechanics, by contrast, is *indeterministic*. It involves irreducible ontological chance.

An isolated quantum system is described by a wave function ψ which evolves - deterministically - according to the *unitary* time evolution of the linear Schrödinger equation.

$(ih/2\pi)\ \partial\psi/\partial t = H\psi$

The possibilities of many different outcomes evolve deterministically, but the individual actual outcomes are indeterministic.

This sounds a bit contradictory, but it is not. It is the essence of the highly non-intuitive quantum theory, which combines a deterministic "wave" aspect with an indeterministic "particle" aspect.[2]

In his 1932 *Mathematical Foundations of Quantum Mechanics*, John von Neumann explained that two fundamentally different processes are going on in quantum mechanics (in a temporal sequence for a given particle - not at the same time).

Process 1. A non-causal process, in which the measured electron winds up randomly in one of the possible physical states (eigenstates) of the measuring apparatus plus electron.

2 See chapter 23.

The probability for each eigenstate is given by the square of the coefficients c_n of the expansion of the original system state (wave function ψ) in an infinite set of wave functions φ that represent the eigenfunctions of the measuring apparatus plus electron.

$c_n = < \varphi_n \mid \psi >$

This is as close as we get to a description of the "motion" of the "particle" aspect of a quantum system. According to von Neumann, the particle simply shows up somewhere as a result of a measurement. These measurements are *irreversible,* he said.

Information physics says that the particle shows up whenever a new stable information structure is created, information that can be "observed" by the experimenter.

Process 1b. The information created in Von Neumann's **process 1** will only be stable if an amount of positive entropy greater than the negative entropy in the new information structure is transported away, in order to satisfy the second law of thermodynamics.

Process 2. A causal process, in which the electron wave function ψ evolves deterministically according to Schrödinger's equation of motion for the "wave"aspect. This evolution describes the motion of the probability amplitude wave ψ between measurements. The wave function exhibits interference effects. But interference is destroyed if the particle has a definite position or momentum. The particle path itself can never be observed.

Von Neumann claimed there is another major difference between these two processes. **Process 1** is thermodynamically *irreversible*. **Process 2** is in principle reversible. This confirms the fundamental connection between quantum mechanics and thermodynamics that is explainable by information physics.

Information physics establishes that process 1 may create information. It is always involved when information is created.

Process 2 is deterministic and information preserving.

The first of these processes has come to be called the "collapse of the wave function."

It gave rise to the so-called problem of measurement, because its randomness prevents it from being a part of the deterministic mathematics of **process 2**.

But isolation is an ideal that can only be approximately realized. Because the Schrödinger equation is linear, a wave function $| \psi >$ can be a linear combination (a superposition) of another set of wave functions $| \varphi_n >$,

$| \psi > = \Sigma\, c_n | \varphi_n >$,

where the c_n coefficients squared are the probabilities of finding the system in the possible state $| \varphi_n >$ as the result of an interaction with another quantum system.

$c_n^{\,2} = < \psi | \varphi_n >^2$.

Quantum mechanics introduces real possibilities, each with a calculable probability of becoming an actuality, as a consequence of one quantum system interacting (for example colliding) with another quantum system. These actualizations are *irreversible*.

It is quantum interactions that lead to new information in the universe - both new information structures and information processing systems. But that new information cannot subsist unless a compensating amount of entropy is transferred away from the new information.

Even more important, it is only in cases where information persists long enough for a human being to observe it that we can properly describe the observation as a "measurement" and the human being as an "observer." So, following von Neumann's "process" terminology, we can complete his admittedly unsuccessful attempt at a theory of the measuring process by adding an anthropomorphic

Process 3 - a conscious observer recording new information in a mind. This is only possible if the local reductions in the entropy (the first in the measurement apparatus, the second in the mind) are both balanced by even greater increases in positive entropy that must be transported away from the apparatus and the mind, so the overall change in entropy can satisfy the second law of thermodynamics.

An Information Interpretation of Quantum Mechanics

Our emphasis on the importance of information suggests an "information interpretation" of quantum mechanics that eliminates the need for a conscious observer as in the "standard orthodox" Copenhagen Interpretation. An information interpretation dispenses with the need for a separate "classical" measuring apparatus.

There is only one world, the quantum world.

It is ontologically indeterministic, but epistemically deterministic, because of human ignorance. It *appears* to be deterministic.

Information physics claims there is only one world, the quantum world, and the "quantum to classical transition" occurs for any large macroscopic object with mass m that contains a large number of atoms. In this case, independent quantum events are "averaged over," the uncertainty in position and momentum of the object becomes less than the observational accuracy as

$\Delta v \, \Delta x > h / m$ and as h / m goes to zero.

The classical laws of motion, with their implicit determinism and strict causality emerge when microscopic events can be ignored.

Information philosophy interprets the wave function ψ as a "possibilities" function. With this simple change in terminology, the mysterious process of a wave function "collapsing" becomes a much more intuitive discussion of possibilities, with mathematically calculable probabilities, turning into a single actuality, faster than the speed of light.

Information physics is standard quantum physics. It accepts the Schrödinger equation of motion, the *principle of superposition*, the *axiom of measurement* (including the actual information "bits" measured), and, most important, the *projection postulate* of standard quantum mechanics (the "collapse" so many interpretations deny).

A conscious observer is not required for a projection, for the wave-function to "collapse", for one of the possibilities to become an actuality. What projection does require is an interaction between (quantum) systems that creates *irreversible* information.

In less than two decades of the mid-twentieth century, the word information was transformed from a synonym for knowledge into a mathematical, physical, and biological quantity that can be measured and studied scientifically.

In 1929, Leo Szilard connected an increase in thermodynamic (Boltzmann) entropy with any increase in information that results from a measurement, solving the problem of "Maxwell's Demon," a thought experiment suggested by James Clerk Maxwell, in which a local reduction in entropy is possible when an intelligent being interacts with a thermodynamic system.

In the early 1940s, digital computers were invented by von Neumann, Shannon, Alan Turing, and others. Their machines run a stored program to manipulate stored data, processing information, as biological organisms have been doing for billions of years.

Then in the late 1940s, the problem of communicating digital data signals in the presence of noise was first explored by Shannon, who developed the modern mathematical theory of the communication of information. Norbert Wiener wrote in his 1948 book Cybernetics that "information is the negative of the quantity usually defined as entropy," and in 1949 Leon Brillouin coined the term "negentropy."

Finally, in the early 1950s, inheritable characteristics were shown by Francis Crick, James Watson, and George Gamow to be transmitted from generation to generation by information in a digital code.

Possible Worlds

In ancient times, Lucretius commented on possible worlds:

> "for which of these causes holds in our world it is difficult to say for certain ; but what may be done and is done through the whole universe in the various worlds made in various ways, that is what I teach, proceeding to set forth several causes which may account for the movements of the stars throughout the whole universe; one of which, however, must be that which gives force to the movement of the signs in our world also ; but which may be the true one," [3]

The sixteenth-century philosopher Giordano Bruno speculated about an infinite universe, with room for unlimited numbers of other stars and their own planets.

3 Lucretius. *De Rerum Natura*, Book V, lines 526-533

"**Philotheo**. This is indeed what I had to add; for, having pronounced that the universe must itself be infinite because of the capacity and aptness of infinite space; on account also of the possibility and convenience of accepting the existence of innumerable worlds like to our own; it remaineth still to prove it.

I say that the universe is entirely infinite because it hath neither edge, limit, nor surfaces. But I say that the universe is not all-comprehensive infinity because each of the parts thereof that we can examine is finite and each of the innumerable worlds contained therein is finite.

Theophilo. For the solution that you seek you must realize Firstly, that since the universe is infinite and immobile, there is no need to seek the motive power thereof, Secondly, the worlds contained therein such as earths, fires and other species of body named stars are infinite in number, and all move by the internal principle which is their own soul, as we have shewn elsewhere;" [4]

Gottfried Leibniz famously introduced his idea of possible worlds as a proposed solution to the problem of evil.

"Metaphysical considerations also are brought up against my explanation of the moral cause of moral evil; but they will trouble me less since I have dismissed the objections derived from moral reasons, which were more impressive. These metaphysical considerations concern the nature of the possible and of the necessary; they go against my fundamental assumption that God has chosen the best of all possible worlds. There are philosophers who have maintained that there is nothing possible except that which actually happens. These are those same people who thought or could have thought that all is necessary unconditionally. Some were of this opinion because they admitted a brute and blind necessity in the cause of the existence of things: and it is these I have most reason for opposing. But there are others who are mistaken only because they misuse terms. They confuse moral necessity with metaphysical necessity: they imagine that since God cannot help acting for the best he is thus deprived of freedom, and things are endued with that necessity which philosophers and theologians endeavour to avoid." [5]

4 Bruno. *On the Infinite Universe and Worlds*, First Dialogue

5 Leibniz. *Theodicy*, § 168

As we have seen, the logician and philosopher Saul Kripke described various universes of discourse, collections of true and false propositions, as various "ways the world might be."

But most talk about possible worlds is the work of the analytic language philosopher David Lewis. He developed the philosophical methodology known as "modal realism" based on his claims that

> Possible worlds exist and are just as real as our world.
>
> Possible worlds are the same sort of things as our world – they differ in content, not in kind.
>
> Possible worlds cannot be reduced to something more basic – they are irreducible entities in their own right.
>
> Actuality is indexical. When we distinguish our world from other possible worlds by claiming that it alone is actual, we mean only that it is our world.
>
> Possible worlds are unified by the spatiotemporal interrelations of their parts; every world is spatiotemporally isolated from every other world.
>
> Possible worlds are causally isolated from each other.[6]

Lewis's "modal realism" implies the existence of infinitely many parallel universes, an idea similar to the many-world interpretation of quantum mechanics.

Possible worlds and modal reasoning made "counterfactual" arguments extremely popular in current philosophy. Possible worlds, especially the idea of "nearby worlds" that differ only slightly from the actual world, are used to examine the validity of modal notions such as necessity and contingency, possibility and impossibility, truth and falsity.

Lewis appears to have believed that the truth of his counterfactuals was a result of believing that for every non-contradictory statement there is a possible world in which that statement is true.

- True propositions are those that are true in the actual world.
- False propositions are those that are false in the actual world.
- Necessarily true propositions are those that are true in all possible worlds.
- Contingent propositions are those that are true in some possible worlds and false in others.

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6 Wikipedia article on Modal Realism, accessed 11/11/2016

- Possible propositions are those that are true in at least one possible world.
- Impossible propositions are those that are true in no possible world .

Unfortunately, the modern defender of "modally real" possible worlds is a determinist who does not believe that alternative possibilities are real. Ironically, Lewis is an actualist, in every "possible" world.

And apart from his extravagant and outlandish claim that there are an infinite number of inaccessible "possible" worlds, he is also the creator of another absurd set of infinities. According to his theory of temporal parts, sometimes called four-dimensionalism, Lewis argues that at every instant of time, every individual disappears, ceases to exist, to be replaced by a very similar new entity.

He proposes temporal parts as a solution to the metaphysical problem of persistence.[7] He calls his solution "perdurance," which he distinguishes from "endurance."

Perdurance is a variation of an Academic Skeptic argument about growth, that even the smallest material change destroys an entity and another entity appears. There is no physical or metaphysical reason for this wild assumption. Nevertheless, Lewis's "counterfactual" thinking is highly popular among modern metaphysicians.

Other Possible Worlds

Hugh Everett III's many-worlds interpretation of quantum mechanics is an attempt to deny the random "collapse" of the wave function and preserve determinism in quantum mechanics. Everett claims that every time an experimenter makes a quantum measurement with two possible outcomes, the entire universe splits into two new universes, each with the same material content as the original, but each with a different outcome. It violates the conservation of mass/energy in the most extreme way.

The scientist David Layzer argues that since the universe is infinite there are places in the universe where any possible thing is being realized. This is a cosmologist's version of David Lewis's "possible worlds." Layzer argues that free will is a consequence of not knowing which of the many possible worlds that we are in.

7 See chapter 18.