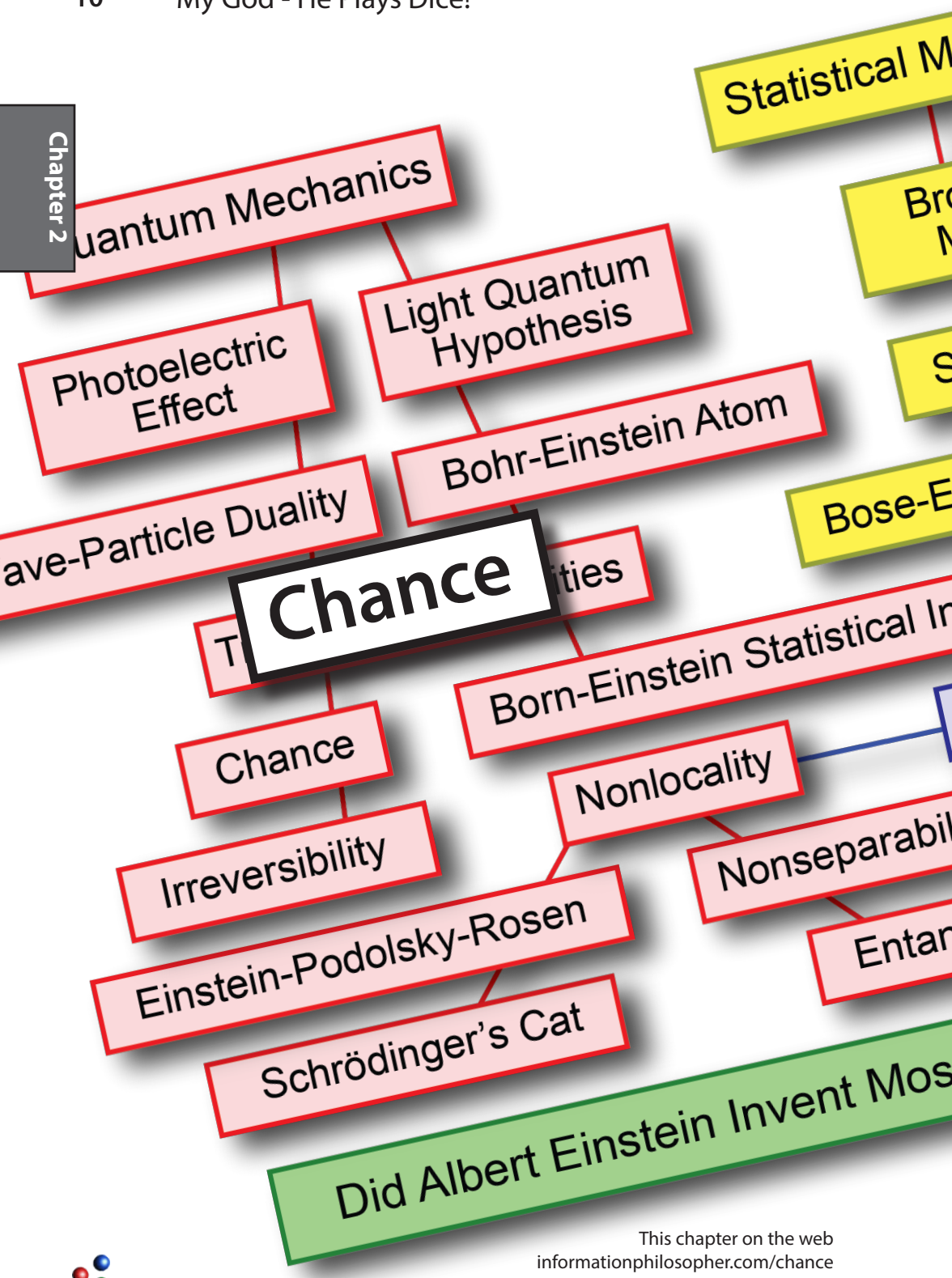

This chapter on the web
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Chance

We hope to develop your ability to *visualize* actual *chance* events and distinguish them clearly from the *continuous* mathematical equations that predict very large numbers of them so perfectly. This will be critical if you are to visualize the quantum wave function and see it the way Einstein saw it.

A continuous "bell curve" is an *ideal* analytic function with values for each of the infinite number of points on the horizontal axis. In the real *material* world of particles, a *discrete* histogram approaches that ideal curve in the limit of large numbers of events. A finite number of particles never gets there.

The "binomial coefficients" in figure 1.1 were arranged by Blaise Pascal in what is known as Pascal's triangle. Each number is the sum of the two numbers above, giving us the *number of ways* from the top to reach each point in the lower rows.

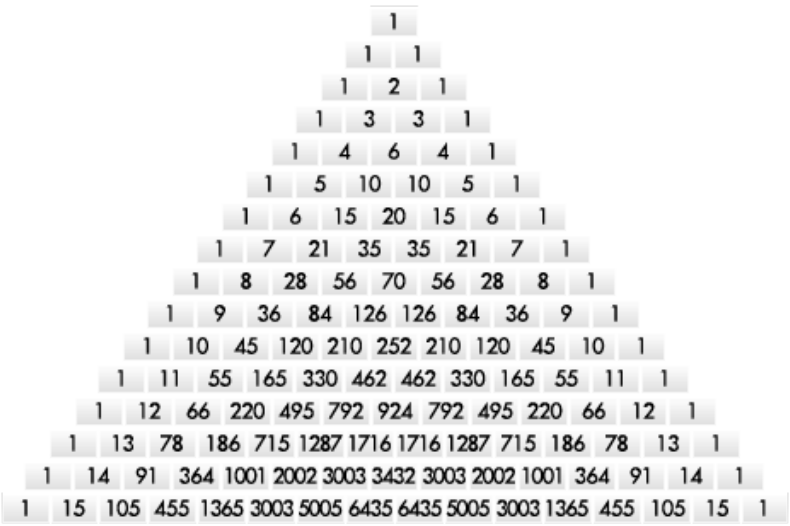

Figure 2-1. Pascal's triangle. Plotting the numbers in the bottom row would show how sharp and peaked the normal distribution is for 16 coin flips.

To illustrate *physically* how random events approach the normal distribution in the limit of large numbers, the sociologist and statistician Francis Galton designed a *probability machine*, with balls bouncing randomly left or right in an array of pins.

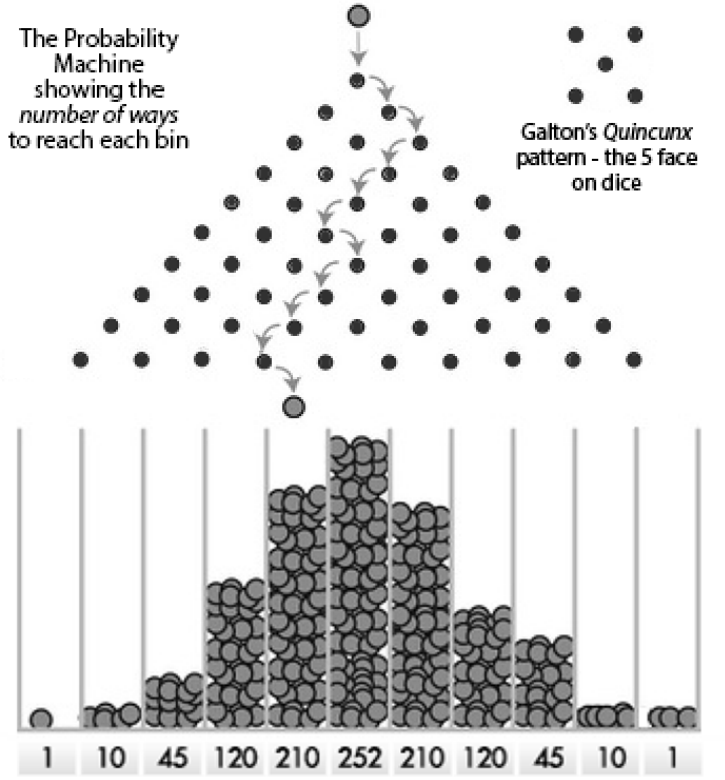

Figure 2-2. Galton's "Quincunx." The number of ways to a bin in the bottom row is the binomial coefficient.

The *probability* of reaching a bin is the *number of ways* to the bin divided by the total number of ways, $2^{10} = 1024$.

Generalizing now to the cases of shuffling decks of cards, or throwing pairs of dice, the most probable outcomes are those that can be accomplished in the largest *number of ways*.

Now we test your physical understanding of probability. Do you consider each bounce of a ball above as random? As really random? Or is it *determined* by the laws of nature, by the laws of classical mechanics?

Is the use of probability just because we cannot know the exact details of the initial conditions, as the proponents of deterministic chaos maintain? Is the randomness only human ignorance, thus subjective and epistemological? Or is it objective and ontological?

You may be surprised to learn that many physicists, and perhaps most philosophers of science, think physics is deterministic, despite the evidence for quantum indeterminism, following centuries of tradition which were deep beliefs of Albert Einstein.

To deny ontological chance is to commit to just one possible future and to the belief that if we could reverse the velocities and directions of all material particles from their current positions, Newton's laws say that all the particles would retrace their paths back in time to the beginning of the universe.

The History of Chance

For most of the history of philosophy and physics, ontological chance has been strictly denied. Leucippus (440 B.C.E.) stated the first dogma of determinism, an absolute necessity.

> "Nothing occurs by chance (*maton*), but there is a reason (*logos*) and necessity (*ananke*) for everything."[1]

Chance is regarded as inconsistent with reasons and causes.

The first thinker to suggest a physical explanation for chance in the universe was Epicurus. Epicurus was influenced strongly by Aristotle, who regarded chance as a possible fifth cause. Epicurus said there must be cases in which the normally straight paths of atoms in the universe occasionally bend a little and the atoms "swerve" to prevent the universe and ourselves from being completely determined by the mechanical laws of Democritus.

For Epicurus, the chance in his atomic swerve was simply a means to deny the fatalistic future implied by determinism. As the Epicurean Roman Lucretius explained the idea,

> "...if all motion is always one long chain, and new motion arises out of the old in order invariable, and if the first-beginnings do not make by swerving a beginning of motion such as to break the decrees of fate, that cause may not follow cause from infinity, whence comes this freedom in living creatures all over the earth."[2]

Epicurus did not say the swerve was directly involved in decisions so as to make them random. His critics, ancient and

1 Fragment 569 - from Fr. 2 *Actius* I, 25, 4

2 *De Rerum Natura*, Book 2, lines 251-256

modern, have claimed mistakenly that Epicurus did assume "one swerve - one decision." Some recent philosophers call this the "traditional interpretation" of Epicurean free will.

On the contrary, following Aristotle, Epicurus thought human agents have an autonomous ability to transcend the necessity and chance of some events. This special ability makes us morally *responsible* for our actions.

Epicurus, clearly following Aristotle, finds a *tertium quid*, beyond the other two options, necessity (Democritus' and Leucippus' determinism) and chance (Epicurus' swerve).

The *tertium quid* is agent autonomy. Epicurus wrote:

> "...some things happen of necessity (ἀνάγκη), others by chance (τύχη), others through our own agency (παρ' ήμᾶς)...necessity destroys responsibility and chance is uncertain; whereas our own actions are autonomous, and it is to them that praise and blame naturally attach."[3]

Despite abundant evidence, many philosophers deny that real chance exists. If a single event is determined by chance, then indeterminism would be true, they say, undermining the very possibility of reasoning to certain knowledge. Some go to the extreme of saying that chance makes the state of the world totally independent of any earlier states, which is nonsense, but it shows how anxious they are about chance.

The Stoic Chrysippus (200 B.C.E.) said a single uncaused cause could destroy the universe (*cosmos*), a concern shared by some modern philosophers, for whom reason itself would fail. He wrote:

> "Everything that happens is followed by something else which depends on it by causal necessity. Likewise, everything that happens is preceded by something with which it is causally connected. For nothing exists or has come into being in the cosmos without a cause. The universe will be disrupted and disintegrate into pieces and cease to be a unity functioning as a single system, if any uncaused movement is introduced into it." [4]

The core idea of chance and indeterminism is closely related to the idea of *causality*. Indeterminism for some is simply an event without a cause, an uncaused cause or *causa sui* that starts

3 *Letter to Menoeceus*, §133

4 Plutarch, *Stoic. Rep.*, 34, 1050A

a new causal chain. If we admit some uncaused causes, we can have an adequate causality without the physical necessity of strict determinism - which implies complete predictability of events and only one possible future.

An example of an event that is not strictly caused is one that depends on chance, like the flip of a coin. If the outcome is only probable, not certain, then the event can be said to have been caused by the coin flip, but the head or tails result itself was not predictable. So this "soft" causality, which recognizes prior uncaused events as causes, is undetermined and to some extent the result of chance.

Even mathematical theorists of games of chance found ways to argue that the chance they described was somehow necessary and chance outcomes were actually determined. The greatest of these, Pierre-Simon Laplace, preferred to call his theory the "calculus of probabilities." With its connotation of approbation, probability was a more respectable term than chance, with its associations of gambling and lawlessness. For Laplace, the random outcomes were not predictable only because we lack the detailed information to predict. As did the ancient Stoics, Laplace explained the appearance of chance as the result of human ignorance. He said,

> "The word 'chance,' then expresses only our ignorance of the causes of the phenomena that we observe to occur and to succeed one another in no apparent order." [5]

As we have seen, decades before Laplace, Abraham de Moivre discovered the normal distribution (the bell curve) of outcomes for ideal random processes, like the flip of a coin or throw of dice. But despite this de Moivre did not believe in chance. It implies events that God can not know. De Moivre labeled it *atheistic*.

> Chance, in atheistical writings or discourse, is a sound utterly insignificant: It imports no determination to any mode of existence; nor indeed to existence itself, more than to non existence; it can neither be defined nor understood...it is a mere word. [6]

We have seen that random processes produce a regular distribution pattern for many trials (the law of large numbers). Inexplicably, the discovery of these regularities in various social phenomena led Laplace and others to conclude that the phenomena are *determined*, not random. They simply denied chance in the world.

5 *Memoires de l'Academie des Sciences* 1783, p. 424.

6 *The Doctrine of Chances*, 1756, p.253.

A major achievement of the Ages of Reason and Enlightenment was to banish absolute chance as unintelligible and atheistic. Newton's Laws provided a powerful example of deterministic laws governing the motions of everything. Surely Leucippus' and Democritus' original insights had been confirmed.

As early as 1784, Immanuel Kant had argued that the regularities in social events from year to year showed that they must be determined.

> "Thus marriages, the consequent births and the deaths, since the free will seems to have such a great influence on them, do not seem to be subject to any law according to which one could calculate their number beforehand. Yet the annual (statistical) tables about them in the major countries show that they occur according to stable natural laws." [7]

In the early 1800's, the social statisticians Adolphe Quételet and Henry Thomas Buckle argued that these regularities in social physics proved that individual acts like marriage and suicide are determined by natural law. Quételet and Buckle thought they had established an absolute deterministic law behind all statistical laws. Buckle went so far as to claim it established the lack of free will.

The argument for determinism of Quételet and Buckle is quite illogical. It appears to go something like this:

- As we saw above, random, unpredictable individual events (like the throw of dice in games of chance or balls in a probability machine) have a normal distribution that becomes more and more certain with more events (the law of large numbers).
- Human events are normally distributed.
- Therefore, human events are determined.

They might more reasonably have concluded that individual human events are unpredictable and random. Were they in fact determined, the events might show a non-random pattern, perhaps a signature of the Determiner?

In the next chapter, we shall see that Quételet and Buckle had a major influence on the development of statistical physics.

In the nineteenth century in America, Charles Sanders Peirce coined the term "tychism" for his idea that absolute chance is the first step in three steps to "synechism" or continuity.

7 *Idea for a Universal History*, introduction

Peirce was influenced by Buckle and Quételet, by the French philosophers Charles Renouvier and Alfred Fouillee, who also argued for some absolute chance, but most importantly Peirce was influenced by Kant and Georg W. F. Hegel, who saw things arranged in the triads that Peirce so loved.

Renouvier and Fouillee introduced chance or indeterminism simply to contrast it with determinism, and to discover some way, usually a dialectical argument like that of Hegel, to reconcile the opposites. Renouvier argues for human freedom, but nowhere explains exactly how chance might contribute to that freedom, other than negating determinism.

Peirce does not explain much with his tychism, and with his triadic view that adds continuity, then evolutionary love, which is supreme, he may have had doubts about the importance of chance. Peirce did not propose chance as directly or indirectly providing free will. He never mentions the ancient criticisms that we cannot accept responsibility for chance decisions. He does not really care for chance as the origin of species, preferring a more deterministic and continuous lawful development, under the guidance of evolutionary love. Peirce called Darwinism "greedy." But he does say clearly that the observational evidence simply does not establish determinism.

It remained for William James, Peirce's close friend, to assert that chance can provide random unpredictable alternatives from which the will can choose or determine one alternative. James was the first thinker to enunciate clearly a two-stage decision process, with chance in a present time generating random alternatives, leading to a choice which selects one alternative and transforms an equivocal ambiguous future into an unalterable determined past. There are free and undetermined alternatives followed by adequately determined choices made by the will.

Chance allows alternative futures. The deep question is how the one *actual* present is realized from *potential* alternative futures.

Claude Shannon, creator of the mathematical theory of the communication of information, said the information in a message depends on the number of possibilities. If there is only one possibility, there can be no new information. If information in the universe is a conserved constant quantity, like matter and energy, there is only one possible future.