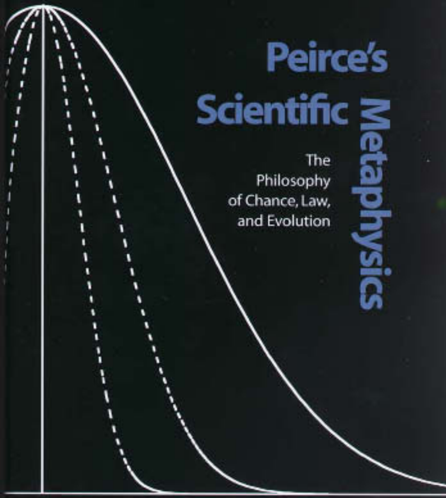
Peirce's Scientific Metaphysics

The Philosophy of Chance, Law, and Evolution



Andrew Reynolds

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The Philosophy of Chance, Law, and Evolution

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To my parents

Contents

Texts and Abbreviations

The following sources of Peirce's writings are referred to throughout the book by the indicated abbreviations.

n.n: *Collected Papers of Charles Sanders Peirce*, edited by C. Hartshorne, P. Weiss (volumes 1–6), and A. Burks (volumes 7–8) (Cambridge, MA: Harvard University Press, 1931–58); numbers in parentheses indicate volume and paragraph number.

C: *The Century Dictionary*, William D. Whitney, chief editor, 10 volumes (New York: The Century Co., 1895).

EP: *The Essential Peirce: Selected Philosophical Writings*, edited by Nathan Houser and Christian Kloesel (volume 1), (Bloomington: Indiana University Press, 1992), and the Peirce Edition Project (volume 2), (Bloomington: Indiana University Press, 1998); followed by volume and page number.

HP: *Historical Perspectives on Peirce's Logic of Science*, edited by Carolyn Eisele, 2 volumes (Berlin: Mouton, 1985); followed by volume and page number.

MS: Microfiche version of the Peirce manuscripts in Houghton Library, Harvard University; numbers indicate those from Richard Robin's *Annotated Catalogue of the Papers of Charles S. Peirce* (Amherst: University of Massachusetts Press, 1967).

N: *Charles Sanders Peirce: Contributions to The Nation*, edited by Kenneth Laine Ketner and James Cook, 4 volumes (Lubbock: Texas Tech University Press, 1975–87); followed by volume and page number.

NEM: *The New Elements of Mathematics by Charles S. Peirce*, edited by Carolyn Eisele, 4 volumes in 5 books (The Hague: Mouton, 1976); followed by volume and page number.

RLT: *Reasoning and the Logic of Things*, edited by Kenneth Laine Ketner, introduction by Ketner and Hilary Putnam (Cambridge, MA: Harvard University Press, 1992).

SS: *Semiotic and Significs: The Correspondence Between Charles S. Peirce and Victoria Lady Welby*, edited by Charles S. Hardwick (Bloomington: Indiana University Press, 1977); followed by page numbers.

W: *Writings of Charles S. Peirce: A Chronological Edition*, edited by Max Fisch, Christian Kloesel, and Nathan Houser et al. (Bloomington: Indiana University Press, 1982–); followed by volume and page number.

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Introduction

> Find a scientific man who proposes to get along without any metaphysics . . . and you have found one whose doctrines are thoroughly vitiated by the crude and uncriticized metaphysics with which they are packed.
>
> —Charles Sanders Peirce [1.129]

Charles Peirce's metaphysical writings, in particular those dealing with his evolutionary cosmology, have not met with the same popular approval as have his contributions to symbolic logic, philosophy of science, and the theory of signs. In fact, Gallie (1952, 215) has referred to the cosmology as the "black sheep" or "white elephant" of Peirce's philosophy. Given the positivistic temper of philosophy throughout the first half of the twentieth century, many people who were impressed by Peirce's researches in formal logic have been shocked to find that the very same figure could have engaged in such a speculative metaphysical venture as his evolutionary cosmology.

Consequently, the task of exposition and analysis of these writings has fallen largely to commentators with a keener interest in his semeiotics (theory of signs) than in his philosophy of science. This has resulted in the literature on Peirce's cosmology—which was to be his *scientific* metaphysics—tending to be rather silent on the more technical issues that are of importance from the standpoint of the history and philosophy of science.[1]

In 1985, Christopher Hookway wrote that "Peirce's cosmology has not received any fully adequate treatment in the secondary literature."[2] Today, seventeen years later, the situation remains arguably unchanged. While I do not presume to say that this book furnishes a "fully adequate treatment," I do hope it plays a significant role toward this end by providing a deeper analysis of Peirce's cosmological writings than has yet been available. Rather than engage in an investigation of the more abstract and broadly philosophical issues, as the available secondary sources specifically concerned with the cosmology have done (cf. Turley, 1977; Esposito, 1980; Hausman, 1993; Sheriff, 1994), I will focus here on the scientific questions and ideas that concerned Peirce and that in turn shaped his cosmological thesis.

Given Peirce's habit of thinking in terms of trios or triads, it is only fitting that this study of his metaphysics is woven together of three main themes that are closely entwined like the overlapping strands of a cable. These are, in no particular order, evolution, statistics, and German *Naturphilosophie*.

Evolution

Peirce's philosophy belongs, as Nicholas Rescher (1996) has recently written, among the class of process philosophies. The types of processes that most intrigued Peirce in nearly every field of inquiry were *irreversible* ones, specifically those with a teleological tendency toward particular ends. Evolution, in a variety of forms, from the development of individuals and communities, increase of complexity and diversity, and intellectual development toward "reasonableness," is the leitmotif throughout Peirce's musings on the universe of mind and matter. The difficulty, as he saw it, was to provide an account of these general patterns of irreversible development or evolution that was consistent with contemporary understanding of the reversible laws of physical science.

Statistics

Recent studies of the "probabilistic revolution," the spread of probabilistic and statistical thinking throughout the nineteenth century, have noted Peirce's pioneering efforts toward the construction of a post-deterministic conception of the world (cf. Porter, 1986; Stigler, 1986; Krüger et al., 1987; Gigerenzer et al., 1989; Hacking 1990). During this time, there occurred a shift in thinking that has been alternatively described as the "erosion of determinism" or the "taming of chance," a shift largely inspired by powerful advances in the theory of probability and statistics and their successful application to a wide variety of problems in the social and natural sciences. Of the studies mentioned above, Hacking (1990) pays the most attention to Peirce's relevance for these developments, devoting the last chapter of his book to Peirce exclusively. Peirce's writings on the subject, however, are rich enough to merit a full book-length treatment of their own. What I have set out to do here is to fill in much of the details regarding Peirce's thinking about the philosophy of chance that are only hinted at in the excellent general studies noted above. In drawing the themes of irreversibility/evolution and statistical thinking together, I show here that Peirce's cosmological theory is modeled on that result of statistics and probability theory known as the law of large numbers. One of the chief objectives of this book is to provide substantial textual evidence for this claim.

Naturphilosophie

Peirce's metaphysical philosophy can be properly understood only when its genealogy within the tradition of German speculative *Naturphilosophie* is duly noted. Peirce's relationship to British empiricism has been well documented for some time. In fact, it has probably been given too much emphasis, for it has blurred the very real differences that exist between the antimetaphysical and agnostic sympathies of the empiricist tradition and Peirce's own rationalist commitment to seek an account of the universe satisfactory in human terms.[3] If the law of large numbers is the architectonic principle that ties together, for Peirce, the phenomena of cosmic evolution and indeterminism and thereby provides an answer to the "riddle of the universe," it is the research tradition of *Naturphilosophie* that compelled him to seek it.

At present, those of Peirce's writings which have found their way into print remain scattered throughout several different edited collections. As a result, it is often difficult to piece together thematically a complete picture of what Peirce thought about any given issue. I have tried to bring together as much of Peirce's own words as was possible to cover the particular themes of irreversibility and evolution in his cosmology. To this end, I have drawn significantly on Peirce's book reviews for *The Nation* and the articles he wrote for the *Century Dictionary*. Much of these writings will be, I believe, unfamiliar to many of the readers of previous books dealing with Peirce's philosophy. I have made a conscientious attempt to spell out some of the technical details of the physics and statistics relevant to Peirce's scientific metaphysics. In short, I have tried to make this the kind of book that I would have found helpful myself when I first began to take a serious interest in Peirce's cosmological metaphysics.

1
Philosophical and Scientific Background

> Behind physics is the more ancient and honorable tradition of attempts to understand where the world came from, where it is going, and why.
>
> P. J. E. Peebles (1993, 3)

Modern cosmology seeks to understand the laws and the historical development of the universe at large. But it is characteristic of the modern approach to cosmology that one concentrates, first and foremost, on inorganic physical structures, only later passing on to organic structures and the necessary conditions for their possibility. To the extent that it is attempted at all, the consideration of mind and mental phenomena is left until the very last. However, if we try to understand Peirce's cosmological writings from this modern perspective, we will almost surely fail to understand him and will find his theory most confusing, for Peirce's approach to the problem of cosmology is entirely opposite to the modern one. He begins with the mind and mental phenomena—the area he called "psychics"—and from there goes on to consider the more familiar topics of physics. Peirce always saw himself primarily as a logician. And logic, as he understood it, is the study of the processes of thought, specifically as this involves different forms of inference.[1] But as we will see, for Peirce, to study logic is also to study the structure of the world at large.

Naturphilosophie, Evolution, and the Law of Large Numbers

It was Peirce's ambition to construct a philosophical system in the tradition of Aristotle, Kant, and Hegel. This systematic account of the most general features of reality would be capable of accommodating all the best scientific theories and results of his time. Because Peirce was a figure of the nineteenth century, it is not surprising that many of that century's most striking ideas occupy a significant place in his philosophy. I have on occasion been asked to describe briefly what Peirce's broader metaphysical philosophy is all about. (Most philosophers at least have a general idea of what his pragmatism is about.) I have searched for a succinct and informative answer to this question, and here is what I think is an interesting encapsulation of Peirce's metaphysical system: It is "*Hegelian dialectical idealism meets Darwinian evolution and statistical thermodynamics.*" That may initially strike one as a hopelessly incongruent assemblage of ideas. The description is, I admit, not entirely accurate, for Peirce was no orthodox Hegelian. He was sympathetic with key aspects of Hegel's philosophy, as we shall see shortly. But he identified his own philosophy much more closely with Hegel's younger colleague, Friedrich Schelling (1775–1854). I mention Hegel (1770–1831) in my description only because he is more familiar than Schelling to most people, and there are obvious similarities in their respective philosophies. Both are important figures in that tradition of German idealism referred to as *Naturphilosophie*. And I will be taking seriously here Peirce's own remark that his philosophy might plausibly be viewed as "Schellingism transformed in the light of modern physics" (6.415). My brief description also mentions Darwin (1809–82) rather than Lamarck (1744–1829). Both were champions of the idea of evolution, though Peirce's own sympathies lay much nearer to Lamarck's teleological account than to Darwin's mechanistic theory of natural selection. Peirce, however, was struck by the essentially statistical nature of Darwin's explanation of how evolution occurs within natural populations. As for statistical thermodynamics, Peirce was duly impressed by all the fruitful applications of statistical method within his time. But Maxwell and Boltzmann's explanation of irreversible phenomena by appeal to the idea that statistical laws can emerge from the "chance" encounter of millions of molecules was for Peirce, I believe, the crowning achievement that brought together all the irreversible trends of development and evolution that composed the common theme of *Naturphilosophie* and evolution theory. It was at once precise and scientific, without being antithetical to the idea of a goal-directed development and evolution of real novelty in the world. Writing at the turn of the last century, the Austrian physicist Ludwig Boltzmann described the preceding hundred years as "Darwin's century."

He did so because the nineteenth century had been characterized by a novel awareness of the concepts of time and change. If there was any *Zeitgeist* characteristic of the nineteenth century, the idea of evolutionary process is certainly one.

It is therefore with the above backdrop in mind that I have chosen to concentrate on the following three philosophical and scientific themes: (1) German idealism and *Naturphilosophie*, particularly as they are found in the works of Kant, Schelling, and Hegel; (2) evolution theory, in both its Darwinian and Lamarckian forms; and (3) the statistical and probabilistic revolution as illustrated by the ideas of such thinkers as Adolphe Quetelet (1796–1874), Henry Thomas Buckle (1821–62), physicists James Clerk Maxwell (1831–79) and Ludwig Boltzmann (1844–1906), and Darwin's first cousin and founder of biometrics, Francis Galton (1822–1911). The key result linking together the last two of our three themes in Peirce's mind is the law of large numbers, also known as the *central limit theorem*. As a precise mathematical illustration of the more metaphysical thesis of the emergence of order from initial chaos, it fits rather naturally with the developmentalist and evolutionary trend of thought characteristic of German idealism and *Naturphilosophie*.

Understanding that these three streams flow beneath the surface of even Peirce's less speculative thought should help us understand how the founder of a method so closely associated with verificationism and positivism could at the same time have ambitions of constructing a metaphysical system to rival those of Aristotle, Kant, and Hegel. Before we discuss exactly how these three strands figure in Peirce's metaphysical thought, however, it is necessary to say a word about some other themes prevalent during the nineteenth century, themes against which Peirce intended his own philosophical methodology to serve as an antidote.

Agnosticism, Necessitarianism, and the Mechanical Philosophy

Peirce was far from alone in attempting to develop a metaphysical system consistent with the important scientific results of the nineteenth century. The Englishman Herbert Spencer (1820–1903) was arguably the most popular and influential philosopher of the Victorian age in the English-speaking world. Spencer's "synthetic philosophy," with its vision of universal evolution following from strictly mechanical laws and forces, enjoyed great popularity among the nineteenth-century consumers of what we would today call popular science and philosophical writing. Spencer based his entire evolutionary system upon the purported a priori truth of the principles of conservation of matter and "force." This quite obviously rankled Peirce's better-trained and better-informed sensibilities. As a career scientist intimately acquainted with the establishment of physical laws and the limitations of experimental results (such as the conservation of energy), Peirce found Spencer's mechanical philosophy of evolution to be nothing more than amateurish scientism.

In an attempt to deal with the problem of keeping science and religion off one another's turf, Spencer invoked the thesis of the "unknowable." Some things are just beyond the ken of human reason, he maintained. On such questions as the ultimate nature of matter and spirit or mind, for instance, we must forever remain agnostic. Spencer did not explicitly use the term *agnostic*. That term was coined by the English naturalist Thomas H. Huxley (1825–95) to refer to the human inability to resolve the question of the existence of an intelligent creator. Huxley also maintained that there are other questions, of a nontheological though equally metaphysical nature, that neither science nor philosophy will ever be able to answer. This sentiment was also expressed by the German physiologist Emil DuBois-Reymond (1818–96) in his famous speech before the Berlin Academy of Sciences in 1880. DuBois-Reymond outlined seven "world riddles," concerning three of which he proclaimed "*Ignoramus, ignorabimus*": "We do not know the answer, nor shall we ever." Included among these unsolvable problems were the nature of force and matter, the origin of motion, and the origin of sensation and consciousness.

But agnosticism as a doctrine directly contradicted what Peirce had concluded from his own research into the logic of scientific method to be the very first rule of inquiry. That rule says: "Do not set up roadblocks in the path of inquiry." An alternative expression of this principle is to say that we should refrain from accepting anything as a brute inexplicable fact, the nature of which we cannot comprehend. The thesis of objective idealism, that the laws of mind and of nature are identical, is a strategy Peirce hoped would be able to overcome such impasses.

The monistic and evolutionary philosophy of Ernst Haeckel (1834–1919) was another important competitor to Peirce's own scientific philosophy. Haeckel's most popular philosophical work, *The Riddle of the Universe* (first published in 1899 in German as *Die Welträtsel*) was an explicit response to DuBois-Reymond's insoluble riddles. A devoted disciple of Darwin (though his own views on biological evolution were more Lamarckian than Darwinian), Haeckel extended the naturalistic logic of Darwin's theory of phyletic history to the case of ontogenetic history. It was Haeckel who popularized the thesis that "ontogeny recapitulates phylogeny." Haeckel was confident that all biological phenomena, including those concerning the mind, would ultimately be reducible to chemistry and physics. The thesis, a metaphysical one, as Peirce pointed out, that all natural phenomena—physical, biological, and mental—must eventually receive their ultimate explanation by reduction to the laws of mechanics and physical chemistry, was known as *mechanicism* or the *mechanical philosophy*. Like Haeckel, Peirce preferred to suppose that mind and matter were but two aspects of a single phenomenon. But unlike Haeckel, Peirce was of the opinion that before the mind could be understood on chemical and physical terms, some major revisions would have to be made in our understanding of the relevant physical laws. In short, the mechanistic interpretation that overlaid them would have to give way and make room for a new interpretation more congenial to the possibility of irreversibility and the emergence of genuine novelty. This is closely linked to the problem of rendering consistent the perceived freedom of the human will with the assumed determinism of mechanical laws. *Necessitarianism*, as Peirce called it, is the thesis that the results of the combination of mechanical laws with initial conditions follow of necessity. Necessitarianism and the mechanical philosophy were intimately related doctrines and composed the accepted background of belief against which Peirce set his own philosophy. And so although Peirce shared Spencer and Haeckel's enthusiasm for speculative evolutionism, he opposed the former for his agnosticism and the both of them for their reliance on purely mechanistic principles.

Despite identifying his own pragmaticistic philosophy as a brand of "prope-positivism," as he called it, Peirce was much more of a realist and much more tolerant of metaphysics than Auguste Comte

(1798–1857), the founder of positivism, and his followers (e.g., W. K. Clifford [1845–79], Karl Pearson [1857–1936], and Ernst Mach [1838–1916]). He was, as already mentioned, a firm opponent of agnosticism (as represented by the likes of Huxley, Spencer, and DuBois-Reymond), and materialism (e.g. Huxley, Haeckel, John Tyndall [1820–93]). All of these doctrines, in one way or another, were, in Peirce's estimation, variants of scientism. They consisted of an overextension beyond available evidence of theoretical and experimental results into dogmatic philosophies. On a more strictly philosophical level, the common enemy that he identified in nearly all his contemporaries was, as he described it, nominalism or Ockhamism. In contrast to this trend of thought, his own philosophy of pragmaticism was descended from the Scholastic realism of the medieval logician John Duns Scotus (1266–1308). Scotus believed in the objective reality of general ideas or universals, whereas his younger contemporary William of Ockham (ca. 1285–1347) restricted them to an exclusively mental existence. In the nineteenth century, positivists such as Mach, Pearson, and the conventionalist Henri Poincaré (1854–1912) claimed that general scientific laws were only convenient fictions, useful for making predictions but nothing more. General laws were something created by the mind. They were not really *in* nature at all. To believe in this, as Peirce saw it, was to assume that our experience of the world was *atomistic*. The raw data of experience would have to be independent and unrelated sensory units, which were somehow woven together by the mind to form a coherent collection of patterns and regularities. Peirce believed, on the contrary, that we actually experience generality, a connectedness or continuity among ideas in the form of patterns and regularities that he called *Thirdness*. It is to the details of Peirce's preferred alternatives to these more popular doctrines that we will now turn.

Synechism, Tychism, and Agapism

The philosophical doctrines of synechism, tychism, and agapism were Peirce's alternatives to the popular positions of, respectively, agnosticism, necessitarianism, and the mechanical philosophy that had become so firmly entrenched in the late nineteenth-century mind-set. In the following sections, we will explore these doctrines in some detail. But by way of a brief introduction, we may say that one important aspect of synechism is that it forbids us to posit brute atomic facts in our attempts to explain the world. Explanations, according to the thesis of synechism, ought to be pursued for each and every fact of experience (*pace* agnosticism). The term *synechism* is derived from the Greek *syneche*, meaning "continuity," or "held together." As a methodological doctrine, synechism exhorts us to attempt to tie together all known facts about the universe, leaving no loose ends. More will be said about the specifics of synechism below (see "Synechism"). *Tychism* (from the Greek *tyche*, meaning "chance") is the hypothesis that the world is essentially indeterministic, that no law of nature is absolutely exact (*pace* the doctrine of necessity). *Agapism* (from the Greek *agape*, meaning "love") posits the reality of final causes in the processes of the world (*pace* mechanicism with its implication that all causation is efficient, blindly mechanical—i.e., governed by Newton's laws of motion—and so, as we shall see, time-reversible). As in the cosmologies of some of the ancient Greeks, love is understood here as a uniting or attractive force that draws all the component parts of the universe into a coherent whole.

These three doctrines represent the more metaphysical aspect of Peirce's mature philosophy of *pragmaticism* (a name invented by Peirce to distinguish his own version of pragmatism from that of William James and others). The chief thesis of pragmaticism is that all concepts (what Peirce called signs) have their origin and intelligibility in practical experience. The meaning of any term or proposition is to be ascertained in its consequences for experience or conduct. This is, as Peirce so often mentioned, a semantic theory extrapolated from the experience of one who has spent much time in a physical or chemical laboratory, hence its association with the theory of operationalism and verificationism in the twentieth century. Its chief distinguishing feature from these schools of thought is its commitment to realism regarding general features of reality (i.e., nonindividuals). The meaning of a proposition, according to pragmaticism, is to be found in the activity or experience that would be undergone should the proposition in question be taken as a guide. To say then, for instance, that a particular coin is fair is to say that repeated tosses of that coin would result (on average and in the long-run limit) in a series having roughly equal proportions of heads and tails. The subjunctive mood of this explication is crucial, for through it, Peirce intended to emphasize the reality of a general law of behavior or propensity that is, or will, or would be displayed by the coin should the suggested experiment be carried out. The propensity is real yet open-ended. It cannot be exhausted by any actual series of tosses. It has a mode of being quite distinct from individual actual outcomes. It is of the nature of a law, for it expresses a regularity, a regularity that is or will be or would be instantiated in actual individual outcomes. That this regularity is or will be or would be displayed shows that it is a reality.

This example of a series of tosses with a fair coin captures very ably, I suggest, the deep significance of the law of large numbers for Peirce's overall philosophy. That a series of tosses displays an emerging pattern or regularity, an irreversible trend (toward a final limit), that becomes more exact and concrete with increasing repetitions illustrates the key features of an evolving and end-directed universal trend toward what Peirce dubbed the cosmological "growth of reasonableness." Pragmaticism as a philosophy concerned with the intelligible meaning of thought expressed through concepts, ideas, and other signs relies on the reality of general regularities and dispositions (like a fair coin's turning up equal proportions of heads and tails in the long run), to which we can coordinate our thinking and behavior so as to attain more successful outcomes in our interactions with the external world.

With the assistance of this pragmatic theory of meaning Peirce hoped to show that "almost every proposition of ontological metaphysics is either meaningless gibberish,—one word being defined by other words, and they still by others, without any real conception ever being reached,—or else is downright absurd" (EP 2, 338 [5.423]). This may strike us as an odd claim coming from someone who has set out to establish an evolutionary metaphysics of the entire universe. I believe the oddity can be dispelled somewhat by noting that the metaphysical hypotheses Peirce himself proposed were supposed to be testable and their adequacy was to be decided by further observation and experiment. The type of "ontological metaphysics" that he considered to be gibberish or absurd I suggest is discussed in the founding essay of pragmatism, "How to Make Our Ideas Clear." There we see Peirce giving a detailed explication of the meaning of the terms *force* and *acceleration* in terms of the laws of analytical mechanics. He considers Gustav Kirchoff's (1824–1887) claim that although we understand precisely the effect of force, we do not understand at all what force itself is (EP 1, 136 [5.404]).

To this Peirce responds, "If we know what the effects of force are, we are acquainted with every fact which is implied in saying that a force exists, and there is nothing more to know" (ibid.). We might suppose that in Peirce's opinion, further employment of the pragmatic method would prove useful in dealing with the remainder of DuBois-Reymond's insoluble riddles.

Motivations for a Cosmology

One of the reasons that Peirce wished to construct a cosmology was to provide an explanation of some of the more general observable traits of the universe. Of the chief characteristics of the universe wanting an explanation, Peirce noted the following:

1. Growth and increasing complexity
2. Variety and diversity
3. Regularity (laws of nature)
4. Mind/consciousness/feeling (6.35–65; 6.613)[2]

A second motivation for developing his particular system of philosophy was to provide a guide to future scientific research. Peirce believed that because the human mind and its objects of inquiry had evolved under the same influences, certain ideas particularly useful for scientific inquiry had suggested themselves quite naturally to the human mind. Because the mind is not a supernatural thing but is part of nature, it must have developed according to some of the same principles as other natural phenomena. Certain ideas readily suggest themselves to the mind, therefore, because they are representative of forces that have played an important role in the development of mind. Peirce supposed that their importance in this respect was likely involved with Darwinian natural selection. As an example of such ideas, he mentioned force, space, and time, important elements of the highly successful science of mechanics. But once inquiry begins to delve into phenomena deeper than those that have influenced directly the shaping of the human mind, this natural predilection or intuition for selecting the correct ideas can no longer be relied on. The investigation of the inner constitution of matter—the nature of molecules and atoms—is just such an area of inquiry that goes beyond the natural limits of our intuition, or as Peirce called it after Galileo, il lume naturale (6.10).[3] His evolutionary cosmology, by comprising a natural history of the laws of nature, was to serve as a means of selecting which hypotheses about the constitution of matter were most likely to be on the right track.

Moreover, it was Peirce's opinion that metaphysics could be developed for this purpose as a positive and useful branch of inquiry by fostering the experimental frame of mind that had proved so successful in the exact sciences. In his classification of the theoretical sciences, metaphysics was further divided into religious metaphysics, psychological metaphysics, and finally, cosmology. As Kant had done before him, Peirce considered why it was that metaphysics had managed to make so little progress. Peirce believed that once it had been wrested from the hands of the infallibilistic and dogmatic "seminary" philosophers (such as Hegel and Spencer), metaphysics could be rendered more conducive to the spirit of science. Metaphysics would still attempt to describe reality in its most general features but would follow the experimental lead of science, and not the other way around. The evolutionary cosmology was to be Peirce's own successor to the outdated and ineffective systems of Aristotle, Kant, Schelling, and Hegel.

What Is a Hypothesis?

We have seen now what motivated Peirce to develop his cosmological theory. But Peirce was very sensitive to the fact that the best anyone could do in this direction was "to supply a hypothesis, not devoid of all likelihood, in the general line of growth of scientific ideas, and capable of being verified or refuted by future observers" (1.7). We must therefore consider what he understood a hypothesis to be.

A *hypothesis* is a proposition (or group thereof) meant to provide an explanation of some phenomenon (2.624, 2.636). Hypothesis, as a form of inference, is to be contrasted with the more familiar inferential forms of deduction and induction. The process by which a hypothesis is proposed or entertained Peirce called alternatively *abduction* or *retroduction* (1.68; 1.121; 5.581; 6.470). He often referred to abduction as a guess, highlighting its essentially creative and imaginative role in introducing new ideas into science and problem solving in general (5.171; 6.526; 7.38; 7. 219).

Peirce's characterization of an explanation is a familiar one to students of twentieth-century philosophy of science.

> [Explanations] supply a proposition which, if it had been known to be true before the phenomenon presented itself, would have rendered that phenomenon predictable, if not with certainty, at least as something very likely to occur. It thus renders that phenomenon rational—that is, it makes it a logical consequence, necessary or probable. (7.192)

This statement will be immediately recognizable as containing in essence the covering-law model of explanation.[4] The inclusion in the quote above of probabilistic consequences shows that Peirce was also an early pioneer of Hempel's later inductive-statistical (I-S) model of scientific explanation. The following quotation shows that Peirce was also sensitive to issues of confirmation in relation to explanation:

> A scientific explanation ought to consist in the assertion of some positive matter of fact, other than the fact to be explained, but from which this fact necessarily follows; and if the explanation be hypothetical, the proof of it lies in the experiential verification of predictions deduced from it as necessary consequences. (6.273)

While this passage suggests the familiar hypotheticodeductive (HD) model of confirmation, it should be noted that Peirce published a well-developed theory of statistical inference that goes much beyond the naive HD model of confirmation.[5] As Ian Hacking and Isaac Levi have both shown, Peirce's theory of statistical inference is most similar to Jerzy Neyman and Egon Pearson's theory of confidence intervals and hypothesis testing. Common to Peirce's and the Neyman–Pearson approach is the idea that induction proceeds via a reliable form of behavior or action (a method of population sampling, to be specific), rather than an attempt to incrementally confirm hypotheses by assigning to them probability values on the basis of evidence statements.[6]

A phenomenon is made rational, however, according to Peirce, by showing that it follows, either necessarily or with probability, from an already familiar general law known or assumed to hold in the particular case in question. The act of proposing such an explanation he called *abduction*: "here understanding by abduction any mode or degree of acceptance of a proposition as a truth, because a fact or facts have been ascertained whose occurrence would necessarily or probably result in case that proposition were true" (5.603). The process Peirce called abduction is better known today as "inference to the best explanation."[7] But of chief importance to the topic of Peirce's cosmology is the thesis that a fact is explained, is made rational, by subsumption under a general law. Christopher Hookway (1985, 268) has noted that this would seem to imply an infinite regression in subsuming laws, given that Peirce allows regularities/laws themselves to count as facts. Hookway declares that he is not prepared to say how Peirce proposed to break the regression without supposing that some explanations are simply self-explanatory. But this, he realizes, is inconsistent with an important principle that Peirce calls the first rule of logic or inquiry—that is, that no fact is to be considered brute or inexplicable, for this "blocks the way of inquiry" (1.135, 1.139).[8] Hookway's inability to resolve this problem is a bit curious because Peirce is so explicit about the answer himself. The solution lies in the law of habit and the nature of chance. In Peirce's opinion, it is regularity above all else that requires an explanation. Using a series of coin tosses to make his point, he notes that if we observe no regularity in the outcomes, we feel no need for an explanation. If, however, we observe all heads, we do find this peculiar and seek an explanation. "Law is *par excellence* the thing that wants a reason" (6.12).[9] Conversely, irregularity does not require an explanation, and because Peirce identifies irregularity with chance, the starting point of his explanation of the order and regularity in the universe is chance. But I will save the discussion of Peirce's notions of chance and law for Chapter Six. For now, this will have to suffice as a solution to the problem that Hookway mentions.

The first rule of inquiry requires that no fact be accepted as brute or inexplicable. This, as we saw, led Peirce to require explanations of laws themselves, insofar as laws are real objective regularities and not merely subjective experiences of constant conjunctions or the like. In a word, Peirce was a nomic realist who ceaselessly criticized the nominalist fashions of his time.[10] The requirement that laws themselves be explained, however, has far-reaching consequences for his cosmology.

It is important to note that all four features of the universe that Peirce wished to explain with his hypothesis of tychism (see p. 13) are entirely *general*. By his own admission, it would make little sense to account for some particular object or event by attributing it to an element of uncaused chance (6.63). As he himself said, "from mere non-law nothing necessarily follows, and therefore nothing can be explained; for to explain a fact is to show that it is a necessary or, at least, a probable result from another fact, known or supposed" (6.606). But although no fact about any *particular* object or event follows from the assumption of absolute chance, Peirce believed that he could show that the general features of growth, variety, regularity, and consciousness do.

Although Peirce was trained as a chemist and physicist, and in this respect shared much of the mind-set of British empiricism, his thought on philosophical matters bore the indelible stamp of German influence. This becomes evident in two of the most important features of his cosmology: (1) the principle of synechism and (2) the thesis of objective idealism.

Synechism

Synechism is described by Peirce as "the tendency to regard continuity, in the sense in which I shall define it, as an idea of prime importance in philosophy . . . " (6.103). The principle will be familiar to anyone acquainted with the philosophy of Leibniz. Peirce developed the principle significantly through his mathematical research in set theory and the idea of the continuum. For our purposes, at this point it is not really important how Peirce's mathematical definition of continuity and of a continuum differ from that of his influential contemporary, Georg Cantor.[11] What is more pertinent is that Peirce believed that nature is, in many respects, continuous. Space and time are both continuous. Memory is continuous in time, just as sensation or feeling is continuously extended in space. According to Peirce, laws of nature, too, are continuous in the sense that they involve constants with continuous values. From this, it follows that any determination of physical laws and constants by experimental observation must be prone to some error and imprecision. To discern the exact values of such constants—assuming that they have precise and constant values—would require a degree of precision in experimental measurement beyond any reasonable expectations. As a result, Peirce concludes that it is necessary to assume a stance of fallibilism (1.171–73).

But an even more important consequence of the principle of continuity is that the most important type of explanation is an *evolutionary* one.

> Once you have embraced the principle of continuity no kind of explanation of things will satisfy you except that they *grew*. The infallibilist naturally thinks that everything always was substantially as it is now. Laws at any rate being absolute could not grow. They either always were, or they sprang instantaneously into being by a sudden fiat like the drill of a company of soldiers. This makes the laws of nature absolutely blind and inexplicable. Their why and wherefore can't be asked. This absolutely blocks the road of inquiry. The fallibilist won't do this. (1.175)

It would appear that eventually Peirce became convinced even further of the intimate connection between the idea of evolution and explanation. "Evolution is the postulate of logic, itself; for what is an explanation but the adoption of a simpler supposition to account for a complex state of things" (W4, 547). We see here just some of the reasons why Peirce proposed an evolutionary cosmology.

Objective Idealism

On frequent occasions Peirce described his own intellectual roots in German philosophy:

> The first strictly philosophical books that I read were of the classical German schools; and I became so deeply imbued with many of their ways of thinking that I have never been able to disabuse myself of them. Yet my attitude was always that of a dweller in a laboratory, eager only to learn what I did not yet know, and not that of philosophers bred in theological seminaries, whose ruling impulse is to teach what they hold to be infallibly true. I devoted two hours a day to the study of Kant's *Critic of the Pure Reason* for more than three years, until I almost knew the whole book by heart, and had critically examined every section of it. (1.4)

It is indeed important for our understanding of Peirce to note that he is in many crucial respects a student of Kant.[12] His philosophy is meant to be an architectonic system in the Kantian mold.[13] According to Chapter Three of Kant's *Transcendental Doctrine of Method*, that which raises a mere aggregate of knowledge to the level of a science is an appreciation for a teleological sense of organic unity. To construct a scientific system according to the guidelines of the "architectonic method" requires one to find a suitable idea around which the particular details will be organized.

In further emulation of Kant, Peirce also sought to achieve through an analysis of the possible forms of thought, a list of fundamental or universal categories employed by the mind for representing internal and external experience. Such a list, it is purported, would provide us with the most basic and general features of reality; the concepts contained therein would be applicable to any possible experience or thought.[14] The search for a list of categories began with Aristotle, who listed ten in number. They include such concepts as Substance, Quality, Quantity, and Relation. Kant expanded this list to a total of sixteen, distinguishing three subconcepts under each of the four headings of Quality, Quantity, Relation, and Modality. Aristotle's and Kant's lists of categories are the result of a focus on the end product of thought. They inspected the basic components of any possible proposition or judgment about experience. Peirce, on the other hand, true to his process-oriented philosophy, also brought his attention to bear on the process of thought. His semiotic theory, the theory of signs and of thought as a process of sign interpretation, is thoroughly diachronic, in contrast with the synchronic and substance-oriented approaches of Aristotle and Kant. On this count, Peirce's close affiliation with the philosophical approach of Hegel and Schelling is readily apparent.

Peirce was able to reduce Kant's table down to three. These universal categories he called simply First, Second, and Third. "Chance is First, Law is Second, the tendency to take habits is Third. Mind is first, Matter is Second, Evolution is Third" (6.32). Peirce's discussions of his three categories do not always appear to be consistent, however. Depending on what he was interested in accounting for, Secondness is sometimes said to include the phenomenon of lawful behavior (as in the quote above), or the feature of brute reaction between two things. A common account of the categories provided by Peirce is as follows: Firstness is illustrated by the property of independence, of disconnectedness. Secondness is the feature of brute reaction, of two things coming into contact with one another. Thirdness is the category of relationship, of mediation, and of law and regularity. It is represented by the rendering of formerly discontinuous things into a continuous whole. In general, Peirce's strategy was to show that some feature of experience from the category of thirdness could be used to explain how an apparent divide between an element of firstness and secondness could be continuously bridged. For example, habit-taking (a third) is the explanation of how the universe has evolved from chance (a first) to lawful behavior (a second). Evolution (third) is how the regular and seemingly inert properties of matter (second) have arisen from the spontaneous and free activity of mind-stuff (first). Synechism, in this respect, appears as a program for bridging dualisms.

Peirce even claimed to find the categories within the three distinct forms of inference: First is Hypothesis (also known as Abduction or Retroduction), second is Deduction, and third is Induction.[15] Abduction involves a guess, a free creation of the imagination. Deduction is akin to the activity of mechanical law. Induction illustrates the synthesis of formerly disconnected facts under a new law or continuous conception. These considerations may explain why so much of Peirce's cosmological writings appear to draw as much evidence from psychological reflection on the mind of the logician and mathematician as they do from empirical observations of the physical world. Although he did attempt to follow Kant in deriving the categories from the possible modes of logical judgment, Peirce also employed a phenomenological approach that involved an introspective attention to one's own activities of thought.[16] There are, Peirce claimed, three irreducibly fundamental features of any and all thought or thinking. Corresponding to the first category is what he called the quality of any thought. We might, for instance, concentrate on a red patch. The redness taken all by itself is the quality, detached from any other thought or quality. Yet as soon as we note the redness of our thought content, we invariably find some other element or subject of thought imposing itself on the first thought. This is characteristic of the category of secondness. One thought is always being affected by another. Secondness marks the experience of otherness, of something beyond our own selves or thoughts. It is in the interpretation of thoughts into a reasonable or meaningful experience that the third category is illustrated. By bringing the brute interaction of one thought with another under the relationships of rational concepts, we render experience meaningful beyond the immediate qualities possessed by each thought in isolation.

Now by investigating the processes of thought, we are, on the objective idealist account, at the same time investigating those features of the world that are reasonable. In an 1898 lecture delivered in Cambridge, Massachusetts, Peirce noted that nearly everyone—including the staunchest opponents to metaphysical speculation—thinks of nature as operating according to deductive syllogisms (RLT, 161). The initial conditions of a physical system are commonly conceived as minor premises, the laws of mechanics being the major premises, with the resulting accelerations playing the role of conclusions. And yet, he puzzled, so few are accepting of the proposal that nature also operates in accordance with the forms of induction and retroduction (involving the spontaneous, less-perfectly lawlike activity of chance). But that it does is the direct implication of Peirce's thesis of objective idealism. As Goudge has written, "One sometimes gets the impression that even in the midst of his strictly logical inquiries, Peirce was keeping his weather eye open for their application to his ontology and cosmology" (cf. 3.487).[17]

So that we can grasp adequately this aspect of Peirce's philosophy, more needs to be said about his affinity for the speculative and romantic tradition of *Naturphilosophie*.[18] As Peirce wrote to his close friend William James, "If you were to call my philosophy Schellingism transformed in the light of modern physics, I should not take it hard" (6.415). As Stephen Jay Gould (1977) writes in his study of the history of the recapitulationist thesis, *Naturphilosophie* consisted of two main theses: (1) "An uncompromising developmentalism" (Gould 1977, 36) or a belief in a progressive trend at work in nature; and (2) a belief in the fundamental unity of all natural laws, thereby linking the mental and material worlds into one unified organic system. These ideas are readily apparent in Peirce's evolutionary cosmology. Peirce picks up Schelling's thesis of objective idealism in his attempt to explain matter as effete mind. Mind is the original state of all substance, according to Peirce's hypothesis, while matter is mind that has developed to such a state of regularity, has become so "hide-bound with habit," as he puts it, that it ceases to exhibit the spontaneous qualities that we typically associate with mind (6.25). The thesis of objective idealism then permits the claim that the processes characteristic of reason (including modes of inference) are reflected in the processes of nature itself.[19] And so Peirce writes that "philosophy seeks to explain the universe at large, and to show what there is intelligible or reasonable in it. It is thus committed to the notion (a postulate which however may not be completely true) that the process of nature and the process of thought are alike."[20]

As I have already mentioned, Peirce thought of himself principally as a logician. His broad understanding of the topic of logic included the applied inference forms of various scientific fields. Yet it also involved abstracting from these the most general structure of inference forms. "The first thing to be done therefore is to re-examine the logical process, to dissect it and find its principal elements, with the view of endeavouring to trace these in nature."[21] The result of this study would be the discovery of an objective "logic of events."

A natural objection to objective idealism is to insist that it is simply too anthropomorphic a thesis. Yet Peirce was surprisingly candid on this matter.

> I hear you say: "This smacks too much of an anthropomorphic conception." I reply that every scientific explanation of a natural phenomenon is a hypothesis that there is something in nature to which the human reason is analogous; and that it really is so all the successes of science in its applications to human convenience are witnesses. (1.316)

This reflects not only the extreme rationalist bent of his thought but also his convinced realism. Yet despite these extreme rationalist tendencies, he retained his commitment to the experimentalist attitude, even when considering the role of metaphysics in the general activity of inquiry.[22]

> A metaphysical philosophy, in the sense of that which is to be definitively accepted in advance of scientific inquiry, is, or should be, a system of pigeon holes in which facts are to be filed away. Its first merit is to give a place to every possible fact. Whatever could conceivably be

> settled by experiment, metaphysics should abstain from settling in advance. (N1, 201)

A Summary Statement of the Cosmology

Before we move on to more specific issues, it would be appropriate to look at some particular expression of the cosmology to guide us as we enter into the finer details to be considered in subsequent chapters. Peirce's first public statement of his cosmology was given as a lecture to the "metaphysical club" of Johns Hopkins University in 1884. The object of this lecture, titled "Design and Chance," was to provide an outline of a hypothetical philosophy adequate for explaining the general features of the universe at large. No such explanation would be truly adequate if it left the general lawful behavior of nature unaccounted for. So it was that Peirce went on to explain how he proposed to account for the existence of the laws of nature:

> Now I will suppose that all known laws are due to chance and repose upon others far less rigid themselves due to chance and so on in an infinite regress, the further we go back the more indefinite being the nature of the laws, and in this way we see the possibility of an indefinite approximation toward a complete explanation of nature. (W4, 551–52)

Lawful behavior, in other words, is not something eternal or ultimate. It is the result of a gradual tendency toward increasingly more regular behavior displayed by the basic stuff of nature. This tendency Peirce compares to the formation of habits in an organism. From a letter dated 1891 to his former student Christine Ladd-Franklin we get these further details:

> The state of things in the infinite past is chaos, tohu bohu, the nothingness of which consists in the total absence of regularity. The state of things in the infinite future is death, the nothingness of which consists in the complete triumph of law and absence of all spontaneity. Between these, we have on *our* side a state of things in which there is some absolute spontaneity counter to all law, and some degree of conformity to law, which is constantly on the increase owing to the growth of *habit*. The tendency to form habits or tendency to generalize, is something

> which grows by its own action, by the habit of taking habits itself growing. Its first germs arose from pure chance. (8.317)

Peirce supposes that in the beginning the universe was a disconnected and disorganized assemblage of feeling. There was no personality or consciousness in this early state, however. There was only the potential for responsiveness to stimulation and for development into a higher degree of organization. At this stage, the characteristic feature of the world is what Peirce called Firstness. It is brute feeling. This brute and disconnected mind-stuff gradually becomes more organized and regular through the first seed of a habit-forming tendency. This tendency toward regularity or habit could arise, Peirce proposes, by chance alone. But once it has arisen, the final result ought eventually to be an entirely connected and organized universal "mind." Oddly enough, however, his thesis of objective idealism also implies that in this more evolved state there will be very little mind left, it having all regularized itself into the form of matter. (The suggestion of paradox here is perhaps removed when we consider that as matter the universe will be much more regular in its behavior and so will exhibit more "reasonableness"—that is, less capriciousness—than it did as spontaneous and disorderly mind-stuff.)

The analogy with physiological and psychological development may strike modern readers as slightly fantastic. But such analogies were fairly common within the nineteenth century. Hegel's dialectical idealism is probably the best known example of this, but another can be located in the thought of the founder of positivism, Auguste Comte. Writing of his historical law of three stages in the history of human intellectual development, Comte uses a similar analogy: "This general evolution of human intelligence is easily confirmed, in a very notable though indirect manner, by that of individual intelligence. The starting point in the education of the individual and the principal phases of the individual represent the epochs of the species" (Comte 1975, 21).

There was a general expectation among thinkers of the eighteenth and nineteenth centuries that some parallel pattern of development could be found between the histories of individuals and the organic species to which they belonged.[23] Within biology, the idea that "ontogeny recapitulates phylogeny" is known as the recapitulationist thesis and is commonly associated with the names of Haeckel and Karl Ernst von Baer (1792–1876). (Though Gould warns that it is a mistake to attribute to von Baer the thesis that higher organisms pass through in their embryological development the *adult* stages of lower or more ancient species). Peirce is extending a loose version of this recapitulationist thesis to apply between human mental development and the evolution of the cosmos. The development of the infantile mind from a chaotic and unruly assemblage of feelings and emotions to that of the orderly and rational, rule-following mature mind reflects in essential respects the very evolution of the cosmic-mind system itself. It is the age-old story of order out of chaos. That Peirce would base his hypothesis of the universe's development on the example of the idealist theory of the Absolute is a concrete expression of his confessed sympathy for Schelling's *Naturphilosophie*.

We now have some vague familiarity with Peirce's "Guess at the Riddle" of the universe. In the chapters to follow, we will look more closely at its details.

Summary

In this chapter, we have seen how convictions held by Peirce regarding specific logical and metaphysical principles set constraints on the domain of possible types that he was willing to consider concerning the construction of a cosmology or system of philosophy. As he explained, he was initially drawn to philosophy by interests in psychology and cosmology; his early exposure to Kant and his lifelong studies in logic fundamentally shaped his thought on these subjects. His belief in the real existence of laws of nature and his "first rule of reason" led him to require an explanation of law in general. This ultimately required an evolutionary explanation of laws resulting from the chance-borne germ of a self-organizing tendency that he dubbed the law of habit.

2

Irreversibility in Physics

The aim of this chapter is to outline Peirce's understanding of the physical principles and theories of the nineteenth century, with special attention being paid to his comments on the role of time as it appears in the laws of mechanics and in the principles of energy physics (dynamics). It is important to see that Peirce's dissatisfaction with the popular mechanical philosophy was derived from a deep understanding on his part of the principles of mechanics.

While Peirce is best known today as a philosopher, the bulk of his career was spent as an experimental physicist. For just over thirty years, he was employed by the United States Coast and Geodetic Survey, working mostly in the field of geodesy, the study of the earth's shape, and on problems dealing with finding accurate and reliable standards of measurement (e.g., weight, mass, length). In addition to this work, he also performed several years of astronomical research as an assistant to the supervisor of the Harvard Observatory (a position held for some time by his father, Benjamin Peirce (1809–90), also a Harvard professor of mathematics and astronomy). During this time, he published a monograph entitled *Photometric Researches* (1878) under the auspices of the Harvard Observatory. Within the field of mathematical physics, Peirce contributed many original papers on topics such as gravimetrics and pendulum research, the theory of errors of observations, and the theory of weights and measures. His greatest achievement, in his father's opinion, was his determination of the meter in terms of a wavelength of light. Within the field of geodesy, Peirce earned an international reputation for his original designs of pendulums and their experimental employment in determining the force of gravity at different locations on the earth. Furthermore, he was also a trained chemist who graduated summa cum laude from the Lawrence Scientific School of Harvard, acquiring practical experience as a hired consultant after his career with the Geodetic Survey came to an end.[1] His membership among several prestigious professional scientific organizations included the National Academy of Sciences, the American Academy of Arts and Sciences, the London Mathematical Society, and the New York Mathematical Society. In sum, he was well situated to reflect on the state of natural science in the nineteenth century (a vocation he performed professionally as a reviewer of technical books for periodicals such as *The Nation*).

Nineteenth-Century Physics

It was a common belief among physicists up until the last decade or so of the nineteenth century that all physical phenomena could be accommodated within the framework of Newton's presentation of the science of mechanics. It is apparent from his writing that Peirce shared this opinion to a degree. Although it will become clear that he felt the need to introduce some element other than force to give a complete explanation of the most general features of our experience of the physical world, he defended Newton's system (in terms of the quantities mass, force, space, and time) from the criticisms of Mach and others. His dissatisfaction with the Newtonian framework was not that it was in any way flawed or incorrect but that it was—on its own—insufficient to account for some important phenomena. But more accurately, it was a particular philosophical position drawn by many physicists and philosophers from the physics of the day to which Peirce objected. This position he called alternately "mechanicism" or "necessitarianism."

It will be helpful for our understanding of Peirce's comments concerning physics if we first look at his classification and definition of its several branches. Luckily such definitions are easily obtained, as he wrote all the definitions concerning the topic of mechanics (as well as those of logic, metaphysics, mathematics, astronomy, and weights and measures) for the *Century Dictionary* (ca. 1889). There we find Peirce defining *physics* as "the science of the principles operative in nature; the science of forces or forms of energy." This discipline was divided by him into the branches of

1. Mechanics or dynamics, the science of force in general, with extensive mathematical developments
2. The science of gravitation
3. Molecular physics, the study of the constitution of matter, and of the forces within and between its molecules, including elasticity and heat (an indivisible subject), cohesion, and chemical forces
4. The physics of the ether, being the study of light or radiation, electricity, and magnetism

It was within the third branch, molecular physics, that Peirce saw the greatest need for guidance from the kind of logicometaphysical project that he envisioned his system to be.

The Laws of Motion

One of the more common complaints we find Peirce making is that the laws of mechanics make no distinction between the "forward" and "backward" flow of time—that is, they are time-reversal invariant. At the foundation of mechanics or dynamics are Newton's three laws of motion. If we change the sign for time, t, as it appears in the second law of motion [$F = m(d^2s/dt^2)$] with its negative, $-t$ (which is in effect to reverse the "flow of time"), we may still retain solutions consistent with the law. The explanation of this is sometimes said by Peirce to be due to the fact that time enters into the second law as a squared quantity, and the square of a negative quantity is positive. But this is inaccurate, the real reason being a bit more complex and having to do with the features of the rules of calculus.[2] Acceleration, (the rate of change of velocity, or the rate of change of the rate of change of spatial position), is expressed as a second order differential equation like so: $d^2s/dt^2=F/m$, where F is an external force and m the mass of the object whose motion is under consideration. To solve such an equation is to find the changed spatial position of the object, and requires integrating the above equation twice. (We must also know how the force in question acts as a result of change in position and/or time). Each integration results in the placement of a negative sign at the front of the solution, and so ultimately the two negative signs cancel one another out. Hence, to "reverse the flow of time" by changing the sign for the time in the original second order differential equestion from 't' to '$-t$,' leaves the final solution unchanged, that is, $d^2s/dt^2=d^2s/d(-t)^2$. So in effect taking the second derivative restores any changes made in the value of the sign of the independent variable that stands for time. This invariance would hold so long as the derivative of the acceleration was of an even power. That accelerations are in fact represented by second derivatives is not explained by Newtonian mechanics, it appears to be a rather arbitrary feature of the theory. And as we will see in later chapters, that it remains thus arbitrary is a defect of the mechanical philosophy in Peirce's opinion. In any case, that time only "flows" in one direction (more accurately, that many physical processes occur in just one distinct sequence of events only), is a fact that cannot be accounted for by appeal to the laws of motion alone.

It is most common though to see Peirce attributing the "reversibility of time" to the principle of energy conservation. However, he can also be found describing it as a consequence of the laws of motion and the law of *vis viva*. It is possible to reconstruct his understanding of the connections among these three separate principles and the condition of reversibility, I believe, in the following way.

Beginning with the most general of the three principles, Peirce wrote that Newton's three laws of motion are more akin to formal principles for talking about motion in terms of forces in general than they are statements about any specific forces and specific motions.

> But the laws of dynamics stand on quite a different footing from the laws of gravitation, elasticity, electricity, and the like. The laws of dynamics are very much like logical principles, if they are not precisely that. They only say how bodies will move after you have said what the forces are. They permit any forces, and therefore any motions. (1.347)

The laws of motion, then, on this account, make no distinction concerning the "direction of time" because of their extreme generality and formal nature. As we are about to see, without any specification about whether the forces involved rely on the time or the velocities, the result is that the equations of motion are reversible.

The Law of Vis Viva

Next in order of specificity is the law of vis viva. This quantity was originally defined by Leibniz as being equal to the product of the mass and the square of the velocity of a particle (mv^2) or the sum thereof of a group of particles. Leibniz and Huyghens found that for collisions between rigid bodies, this quantity is conserved. Eventually the vis viva (or force of motion) would be defined as one half the above quantity (by Coriolis in 1829) and renamed the *kinetic* energy (so popularized by Thomson and Tait's 1867 *Treatise on Natural Philosophy*, following Rankine). The law of vis viva is also known as the law of the conservation of vis viva, or conservation of mechanical energy. Peirce described it as "the principle that, when only positional forces are considered, any changes in the vis viva of a system depend only on the initial and final situations of the particles" (C, 6768). A force is positional if it is solely a function of the relative positions of the bodies involved. Nonpositional forces are functions of either the time or the velocities, examples being friction and viscosity.

For a system involving positional forces exclusively, the quantity known as the vis viva is conserved—that is, in allowing the particles to move about relative to one another, we do not affect the value of the vis viva for the system. To express this slightly differently, if we measure the value of the vis viva for such a system—which is to determine its sum of particle masses and velocities—and then allow its particles to move about, interacting with one another through collisions, the vis viva of the individual particles will change as a result of changes in the velocities (we assume that particle masses remain constant), but if we bring all the particles back to their original positions, thereby obtaining the initial configuration for which we took the value of the system's vis viva, we will find the initial and final values to agree. The restriction to positional forces is crucial because, were any forces to depend on either the time (duration) or the velocity, simply bringing the particles back to their original positions alone would not guarantee getting the same value for the vis viva.

Because positional forces have this property of conserving the quantity of vis viva, they were known as "conservative forces."

Peirce's entry in the *Century Dictionary* for the term *force* included the following description of *conservative force*:

> An attraction or repulsion depending upon the relative position of the pair of bodies concerned. All fundamental forces are believed to be conservative or fixed. *Whatever motion takes place under the influence of conservative forces alone might take place under the same forces in precisely the reverse order, the velocities being the same, but opposite in direction.* (C, 2319; italics mine)

So it is that the law of vis viva implies that those systems to which it applies are reversible.

In an unfinished manuscript intended as a text book on mechanics, "The Principles of Mechanics" (ca. 1878), Peirce wrote that "the fundamental law of mechanics is as follows. *All material effects consist in accelerations (which are compounded by geometrical addition) and which are functions of the relative positions of the bodies*" (W3, 202–07). This is equivalent to saying that all accelerations are the result of conservative forces of attraction and repulsion between pairs of particles.

We note, too, that the law of vis viva, or conservation of mechanical energy, falls within the scope of that branch of physics called mechanics. Peirce had defined *mechanics* as "the mathematical doctrine of the motions and tendencies to motion of particles and systems under the influence of forces and constraints; in a narrower sense, this doctrine as applied to systems of rigid bodies" (C, 3679). Now, it should be noted that it was far from clear that all systems and physical phenomena (e.g., fluids, gases, light, electricity, magnetism, heat) could be immediately reduced to and treated as mere congeries of particles or rigid bodies; mechanics, in other words, was originally a fairly restricted discipline. The motivation for the mechanical theory of heat and the kinetic theory of matter (including gases and liquids) was to extend the principles of mechanics to a broader range of physical phenomena. But prior to the establishment of these two programs, the scope of the principle of vis viva was restricted to clearly mechanical systems of rigid bodies. It was part of Helmholtz's accomplishment in his landmark paper *Über die Erhaltung der Kraft* (1847) to extend the principle of vis viva to all physical systems by arguing that all of nature's fundamental forces are positional (i.e., conservative), interacting between pairs of material points.

The Conservation of Energy Principle

Now, as was mentioned above, Peirce most frequently attributed the time-reversibility of physical systems to the law of the conservation of energy. This law is intended to be more inclusive than either the general laws of motion or the law of vis viva in terms of stating what kinds of forces are to be found in physical systems. Whereas the laws of motion permit any forces whatever—so long as they abide by Newton's three guidelines—the mechanical principle of vis viva made a more specific appeal to a particular type of force, namely, positional. What the principle of energy conservation did was to make the older principle of mechanics (the law of vis viva) a general principle of physics with universal application to all physical systems. It did so, as we have said, through Helmholtz, by claiming that all of nature's fundamental forces are positional or conservative. And because the law of vis viva implies that those systems to which it applies are reversible, it is for this reason that Peirce so often cites the principle of energy conservation as being responsible for the implication of reversibility. To say that the universe as a whole is a conservative system is to say, on this reading, that it is a reversible system.

Perhaps because he was so familiar with all of these results and developments Peirce's discussions of these issues is rather difficult to follow, for he seldom spells out clearly some of the more subtle distinctions, only hinting at them. For example, we sometimes see him making an apparent distinction between what he called "the law of energy" and the "law of vis viva." The law of energy is described, after first defining the term *energy*, in the following manner:

> In *physics*: (a) Half the sum of the masses of the particles of a system each multiplied by the square of its velocity; half the vis viva . . . (b) Half the greatest value to which the sum of the masses of all the particles of a given system each multiplied by the square of its velocity, could attain except for friction, viscosity, and other forces dependent on the velocities of the particles; otherwise, the amount of work . . . which a given system could perform were it not for resistance depen-

> dent on the velocities. *The law of energy is precisely the principle that these two definitions are equivalent.* (C, 1927; italics mine)

To say that these two definitions are equivalent is to say, it would seem, that energy is dissipated only by means of friction, viscosity, and so on. According to the kinetic theory of heat, energy dissipated in these forms remains kinetic, but as the motion of the constituent parts of molecules and atoms. The implication is that while energy may be dissipated, it is not destroyed, and hence is conserved.[3] This expression of the "law of energy" appears quite different from the law of vis viva. Yet Peirce offers another interesting account:

> Another equivalent version of the law of energy is as follows: Suppose a system of bodies were moving under the influence of those positional forces to which the law exclusively applies, and suppose that at any one instant all the particles were to strike squarely against elastic surfaces so as to have the directions of their motions reversed, but their velocities otherwise unaltered; then the whole series of motions would be performed backward, so that the particles would again pass through the same positions they had already passed through, and in the same intervals of time, but in the reverse order. Thus, a squarely rebounding cannon-ball in vacuo would move backward over the same trajectory, and with the same velocities, as in its forward motion, plunging into the mouth of the cannon again with exactly the velocity with which it had issued. (C, 1927)

This expression of the law of energy is at least equivalent to the law of vis viva with respect to the consequence of reversibility. There is yet further reason to suppose that Peirce intended the two to be equivalent if not identical. After explaining how the introduction of a potential function into the mechanical principle of vis viva results in the sum of the potential and kinetic functions (the total energy) being conserved, Peirce goes on to write that "the corresponding general principle of physics is that the total energy of the physical universe is constant; this is the principle of the *persistence* or *conservation of energy*." Later, he again describes the "law of the conservation of energy or force" as "the law that, fundamentally speaking, there are no forces in nature to which the law of energy does not apply." Here again, it looks as though the law of vis viva and the law of energy are equivalent expressions, for as we have said, the conservation of energy can also be seen as a generalization of the law of vis viva. A final and perhaps more direct argument for identifying the two is to note that Peirce defined energy, in mechanics, as one half the vis viva. We should be able, then, to substitute *vis viva* for *energy* in the *law of energy*. Having said all this, however, we must note that at times, Peirce clearly uses the phrase *law of energy* to mean the law of the conservation of energy. As this should not create any difficulties for the present discussion, it will suffice to mention this tendency toward ambiguity in Peirce's vocabulary.

Perhaps one of the plainest statements of Peirce's construal of the relationship between the principles of vis viva and conservation of energy is the following:

> It may also be argued that, according to the law of the conservation of energy, there is nothing in the physical universe corresponding to our idea that the previous determines the subsequent in any way in which the subsequent does not determine the previous. For, according to that law, all that happens in the physical universe consists in the exchange of just so much *vis viva* $\frac{1}{2}m(ds/dt)^2$ for so much displacement. Now the square of a negative quantity being positive, it follows that if all the velocities were reversed at any instant, everything would go on just the same, only time going backward as it were. Everything that had happened would happen again in reverse order. (SS, 27)[4]

Note that the same argument could be made with respect to the laws of motion alone, thereby locating the source of the reversibility condition at the very root of the mechanical treatment of observed phenomena. In fact, Peirce does make this point elsewhere.

> I, personally, believe that the two directions of Time are as alike as the two directions along a line. For the law of the conservation of energy is that the *vis viva*, and consequently also the forces, of the particles depends upon nothing mutable except the relative positions of the particles. Now the differential of the time enters into the analytical expression of the *vis viva*, $\frac{1}{2}m(ds/dt)^2$, as well as into that of force, $m\,d^2s/(dt)^2$, only as squared. Whence, the square of a negative quantity being equal to that of the corresponding positive quantity, the two directions of time are indifferent as far as the action of the law of the conservation of energy goes. (NEM II, 481)

We saw earlier that Peirce also made the remark that the laws of motion are much more like formal principles than they are physical principles involving specific kinds of forces. Given this assumption, one might have hoped that the principle of vis viva, in being more specific about the nature of the forces involved, would have established some sort of irreversibility consistent with our observations of the world about us. But in fact, as we have seen, it does not; everything remains as reversible as before. And while the principle of energy conservation was surely an important and revolutionary achievement, it, too, failed to provide any explanation of observed irreversibility. In fact, worse than that, by its extension into a universal principle, it implies that the entire physical universe should consist entirely of reversible actions.

This suffices to show, I hope, that my reconstruction of Peirce's understanding of these principles and their relationship to the condition of reversibility is correct. To repeat, the laws of motion fail to pick out a distinct direction in the sequence of physical events because of their extremely abstract and general nature; moreover, reversibility follows from the mechanical law of vis viva but is restricted to those systems involving only positional forces. The conservation of energy principle extends this result to all physical systems in general through the claim that all fundamental forces are positional/conservative. The world is then said to be a "conservative" system. In Peirce's estimation, this was equivalent to the claim that if in fact there is no element responsible for all material effects other than the interactions of positional/conservative forces acting between bodies, then all observable physical phenomena should exhibit nothing but reversible actions.

For this reason, he was critical of popular expressions of the law of the conservation of energy that obscured what he considered to be its true content. In particular, he was critical of formulations that endorsed the notion that energy was somehow conserved in a way analogous to the conservation of matter. Peirce faulted P. G. Tait (1831–1901) for encouraging this reading (6.601).[5] To correct this misunderstanding, Peirce restated the law of energy conservation thusly:

> The true substance of the law is that the accelerations, or rates of change, of the motions of the particles at any instant depend solely on

> their relative positions at those instants. The equation which expresses the law under this form is a differential equation of the second order; that is, it involves the rates of change of the rates of change of positions, together with the positions themselves. (6.601)

He then goes on to note that the expression for the acceleration ($D_t^2 s$) may be rewritten in an equivalent form as

$$D_t^2 s = {}^1\!/_2 D_s (D_t s)^2$$

which upon integration introduces a function of position equal to the kinetic energy *plus* an arbitrary constant, C. The arbitrary constant is required, he writes, because of the fact that forces determine accelerations and not velocities. The arbitrary constant C appears in our solution of the equation as an artifact of the calculus. In effect, when we integrate the above equation, our solution describes not a specific result but a whole family of results all sharing certain general features (i.e., we are working with an indefinite integral). Now the value of C is known, he says, once the velocity at any instant is known. And this quantity exists independently of time and is therefore "conserved" regardless of whether the forces involved are positional (i.e., conservative) or not. Moreover, it is this constant plus another, "which is absolutely indeterminable, being merely supposed large enough to make the sum positive," that gives the energy (6.601).[6]

> Thus, the law of energy does not prescribe that the total amount of energy shall remain constant; for this would be so in any case by virtue of the second law of motion[7]; but what it prescribes is that the total energy diminished by the living force shall give a remainder which depends upon the relative positions of the particles and not upon the time or velocities. It is also to be noticed that the energy has no particular magnitude, or quantity. Furthermore, in transformations of kinetical energy into positional energy, and the reverse, the different portions of energy do not retain their identity, any more than, in bookkeeping, the identity of the amounts of different items is preserved. In short, the conservation of energy . . . is a mere result of algebra. (6.601)[8]

Having said this, Peirce reemphasizes what he takes to be the real content of the law, namely:

> to say that the law of the conservation of energy makes the total amount of energy constant is to attribute to this law a phenomenon really due to another law [Newton's second law of motion], and to overlook what this law really does determine, namely, *that the total energy less the kinetic energy gives a remainder which is exclusively positional.* (6.601)

So to reiterate, all accelerations are the result of central forces emanating from relative *spatial* positions—and, as Peirce points out, it is difficult to see how a preferred direction *in time* is to be derived from a feature of relative spatial position. It is this difficulty inherent in the combination of the law of energy conservation with temporal irreversibility that Peirce wished to bring to people's attention.

The Doctrine of the Conservation of Energy

Peirce referred to the extension of the conservation of energy principle to the universe at large as the "doctrine" of the conservation of energy. Consider his definition of "conservative system" in the *Century Dictionary*:

> in *mech*., a system which always performs or consumes the same amount of work in passing from one given configuration to another, by whatever path or with whatever velocities it passes from one to the other. *The doctrine of the conservation of energy is that the universe is a conservative system*. (C, 1207; italics mine)

The same doctrine is also mentioned by Peirce in the *Century Dictionary* under the label of *dynamism*: "(d) to the widely current doctrine that the universe contains nothing not explicable by means of the doctrine of energy." (C, 1809)

Because Peirce interpreted the law of the conservation of energy in the way he did, his objection to its elevation to the status of a doctrine should be obvious. Such an assumption about the physical world implies that all actions within it should be reversible, but obviously they are not. Peirce saw that physics was, for this reason, faced with a difficulty. The conservation of energy result was an extremely important one of revolutionary proportions, yet the number of instances of irreversible phenomena were overwhelming. It is clear that Peirce himself was torn at times on this issue. He evidently had the highest respect for the conservation of energy law, yet he required some way of explaining the irreversibility of well-known phenomena. Furthermore, as a careful experimentalist and logician, he was unwilling to overextend physical results into areas in which their applicability was still unfounded—especially results requiring such precise measurement as did the conservation of energy.

We see his high regard for the result in the following passages:

> The discovery of this law [of the conservation of energy] is the greatest that science has ever made, and nothing that can be discovered hereafter (unless it be of a supernatural kind) can equal it in importance. (W5, 402)

> We may begin with dynamics—field in our day of perhaps the grandest conquest human science has ever made—I mean the law of the conservation of energy. (6.10)

> The sublime discovery of the conservation of energy by Helmholtz in 1847, and that of the mechanical theory of heat by Clausius and by Rankine . . . had decidedly overawed all those who might have been inclined to sneer at physical science. (6.297)

On the other hand, we can also see his hesitation to extend it into an overblown doctrine:

> The discovery of the conservation of energy may well be considered as the greatest achievement of natural philosophy. Yet, after all, we know nothing about it except what experience teaches us; and the experiential verifications of it, except in a few simple cases, do not attain any extraordinary degree of precision; while in regard to muscular work and brain activity there is little but analogy to lead us to think it so much as a close approximation to the truth. Every physical determination of a continuous quantity has its "probable error"; and the probable error of the equation which expresses the conservation of energy is large in comparison with those which express, for example, the three laws of motion. Nevertheless, we often find the "scientists" treating the law of the conservation of energy, in its extremest applications, the most remote from anything we can measure, as something it would be absurd to doubt. (N1,176)[9]

This attitude of caution toward extending the conservation law is further justified by Peirce on the grounds of sound scientific methodology:

> We said nothing about the law of the conservation of energy, which is the grandest discovery of science. Still, as a scientific generalization, it can only be a probable approximate statement, open to future possible correction. In its application to the ordinary transformations of forces, it has been pretty exactly verified. But as to what takes place within organized bodies, the positive evidence is unsatisfactory, and, in connection with the question of free will, we cannot feel sure the principle holds good without assuming a partisan position which would be unwise and unscientific. (N2, 115)

Another chief target of Peirce's criticism was necessitarianism, the doctrine that the laws of nature are rigidly exact principles that determine their outcomes with exact necessity. This leaves no room for real *absolute* chance or novelty in the world. We will be discussing this a bit later on.

Conditions for Reversibility

So far we have seen Peirce claim that all of the following are reversible: systems, forces, laws, actions. Given that these are drastically different kinds of things, we must get clearer about what the claim that they are reversible might mean in each case. To this end, I will follow the classification of criteria for reversibility given by Hollinger and Zenzen (1985).

Hollinger and Zenzen note that discussions concerning irreversibility have traditionally conflated the reversibility of equations (time-reversal invariance) with the reversibility of physical processes. To draw out the differences between these two distinct conditions, they consider three separate criteria for reversibility, namely:

C1: A process is reversible if it occurs so close to equilibrium that it can be reversed quickly by changing the external influences.
C2: A process is reversible if it can be reversed (conceptually in

time) by reversing the motion variables. Or we may say that the process is reversible if it can be reversed by reversing time.

C3: A process is reversible if the process and its reverse both occur naturally.

Here C1 and C3 are relevant to the reversibility of physical processes, while C2 captures the idea behind the time-reversal invariance of equations. C1 captures the sense of reversibility that so often comes up in discussions of Carnot cycles and equilibrium thermodynamics. This C1 does not, however, appear to be a sense relevant to Peirce's claims. Hollinger and Zenzen note that all mechanical processes are reversible in the sense of C2, but not all are reversible in the sense of C3.

It is clear that Peirce is appealing to some unformulated notion of reversibility involving both C2 and C3. It also seems safe to say that Peirce, like most writers of the nineteenth century, was often less than careful to make explicit the distinction between the reversibility of equations or physicomechanical laws and the reversibility of physical processes.

The claim that the laws of mechanics and dynamics are reversible amounts to the claim that they are time-reversal invariant, which is an appeal to C2. Peirce, as we have seen, often noted that reversing the sign of the time and the velocity leaves the equation describing the law of vis viva unchanged. The same holds for the law of the conservation of energy. His illustration of the time-reversal invariance of the equations, however, often appeals to a visualization of physical particles retracing their paths.

> It is, indeed, a mathematical consequence of the doctrine of conservation that if the velocities of all the particles were at any instant precisely reversed, all those particles would move back over their former paths with precisely the same, though reversed, velocities as before. Thus, the laws of motion do not favor one determinate direction in an entire course of change, rather than the reverse direction. (8.187)

So the equations and laws of mechanics and dynamics are reversible in the sense we have just seen—time-reversal invariant à la C2. The reason that this creates a problem, however, is because the vast majority of actual processes we see in the world are irreversible in the sense that they fail to meet the condition set out by C3. And this raises a problem for those who would like to explain such actions by appeal to the doctrine of energy alone.

> Almost all the phenomena of bodies here on earth which attract our familiar notice are non-conservative, that is, are inexplicable by means of the Law of the Conservation of Energy. For they are actions which cannot be reversed. In the language of physics they are irreversible. Such for instance is birth, growth, life . . . all motion resisted by friction or by the viscosity of fluids . . . the conduction of heat, combustion, capillarity, diffusion of fluids . . . the thunder bolt, the production of high colors by a prism, the flow of rivers, the formations of bars at their mouths, the wearing of their channels, in short substantially everything that ordinary experience reveals . . . (RLT, 203)

In the next section, we will see how this problem was resolved by some physicists and how Peirce incorporated their arguments into his own thinking.

The Second Law of Thermodynamics, the Kinetic Theory of Gases, and the Law of Large Numbers

Any adequate theory of the universe has, at the very least, to be sensitive to those features of the universe we find to be generally characteristic of it. And as Peirce fully noticed,

> The physical universe is full of changes regularly taking place in determinate directions; —so full that this might almost be said to be the predominant character of nature. (8.187)

Peirce surely was not the first to emphasize this point.[10] Within nineteenth-century physics alone, the attention of researchers like Sadi Carnot (1796–1832), Rudolf Clausius (1822–88), and William Thomson (later Lord Kelvin) (1824–1907) had turned to the irreversible processes connected with heat phenomena, the outcome of which was the science of thermodynamics. It was Carnot's studies of ideal reversible steam engines that kicked off this new discipline. What was originally known as Carnot's principle—a description of the irreversible flow of heat from warm bodies to cool—eventually became, via the kinetic theory of gases, the Second Law of Thermodynamics. Kelvin was an early advocate of the idea that the chief object of thermodynamics was the study of irreversible processes.[11] His 1852 paper "On a Universal Tendency in Nature to the Dissipation of Mechanical Energy" was followed up by Clausius's prophetic statements that:

1. The energy of the universe is constant, and
2. The entropy of the universe tends to a maximum.

More than anything else, the second law of thermodynamics, interpreted as the increase of entropy (equivalently, the dissipation of energy), established a direction to the "flow" of time on a universal scale. We can understand, then, Peirce's dismay at the decision of Spencer and others to use the first law of thermodynamics as the fundamental principle for explaining the evolution of the universe.

In an attempt to give a mechanical account of such irreversible processes as are described by the second law, Clausius, Maxwell, Boltzmann and others developed the kinetic theory of gases, in which the theory of probability and the principles of mechanics are combined to give a statistical account of the motions of myriad gas particles. The statistical treatment was considered necessary mainly because of the vast number of molecules supposed to make up a gas.

To take a specific example, the reason, according to this approach, that gases are always observed to diffuse irreversibly in such a way as to fill the volume of a container is that, while it is theoretically possible, the chance that all the gas molecules will condense into a volume smaller than the total volume available is exceptionally less than the chance that they will spread themselves out so as to occupy the whole container. Chance appears here in two separate guises. First of all, because the number of molecules is so great and their movements are so swift, we have to assume that interactions between molecules is essentially left to chance (i.e., there is no way to tell beforehand which molecules will be colliding with one another at any instant).[12] Second, to say that the chances are greater that the molecules will spread themselves out is to say that of all possible microconfigurations of the molecules, a far greater number will correspond to the macroscopic condition of diffusion than to the macroscopic condition where the gas remains tightly huddled in a corner of the container. In order that the likelihoods of these two macrostates can be compared, it is assumed that each possible microconfiguration of molecules in phase space (in which the molecular velocities are represented) is as likely as any other. This is sometimes called the assumption of equiprobability.

The kinetic theory of gases attempted to explain the irreversibility of thermodynamic processes while at the same time admitting the reversibility of the motion of each molecule. Although such processes are in theory reversible, the odds are against any such reversal because of the large numbers of molecules involved. Boltzmann explained this in the following terms:

> If in a gas a large number of molecules happen to be moving toward the same point at the same time, a sudden increase in density must occur there. However, we observe none of this, *and the reason why this is so is nothing other than the law of large numbers.*[13] (1886; italics mine)

While Maxwell and Boltzmann et al. spoke of "chance" interactions among the molecules of the gas, it is reasonably clear that they did not intend to reject the assumption of determinism with respect to mechanical systems. As we shall later see, the introduction of the notion of "absolute" chance by Peirce separated him more than he admitted from the mainstream of kinetic theorists. Yet Peirce was quite happy to adopt their way out of the difficulty between the observational evidence of irreversible phenomena and the implications of reversibility of the conservation of energy law. This strategy allowed him to accommodate both within his general metaphysical framework.

> As to those explanations which the physicists propose for irreversible phenomena by means of the doctrine of chances as applied to trillions of molecules, I accept them fully as one of the finest achievements of science. (RLT, 220)

It is also this statistical explanation that accounts for his constant description of irreversible actions as *apparent* violations of the law of energy.

Owing to the consequence of reversibility, Peirce often referred to irreversible phenomena as being "nonconservative." Nonconservative actions tend to work, he wrote, irreversibly toward some final end.[14] As an example of such a final end, which—as we shall see—he equated with final causes, he offered the case of thermal equilibrium. The progression toward thermal equilibrium is an almost inevitable consequence because of the chance interactions of the vast numbers of molecules involved in thermodynamic systems. Peirce often referred to this type of irreversible process as following from "the law of high numbers," or what is more familiarly known as Bernoulli's law of large numbers.

> It was found that the kinetical theory would account, in a remarkably satisfactory way, for non-conservative phenomena. It accounts for these phenomena . . . by representing that they are results of chance; or, if you please, of the law of high numbers; for it is remarkable that chance operates in one way and not in the opposite way. (7.221)

There was obviously, in Peirce's mind, an intimate connection between the kinetic theory of gases and what he called the law of high numbers. But it should be pointed out that what is called Bernoulli's law of large numbers is a purely formal mathematical result, while the result that Peirce refers to as the law of high numbers, while obviously related, is an empirical conjecture about actual physical systems.[15] It would seem that this ambiguity has its roots historically in Poisson's statement of his own law of large numbers.[16]

The apparent incompatibility between the implications of the conservation law and the organic phenomena of biology were particularly striking:

> The law of the conservation of energy is equivalent to the proposition that all operations governed by mechanical laws are reversible; so that an immediate corollary from it is that growth is not explicable by those laws, even if they be not violated in the process of growth. (6.14)

To resolve this tension Peirce extended the application of the large numbers argument from gas theory to all phases of matter (i.e., to liquids and solids), so as to include organic matter and phenomena.

> Those uniformities of nature which present phenomena of irreversible actions—such as friction and other resistances, the conduction of heat

> and the phenomena of the second law of thermodynamics in general, chemical reactions, *the growth and development of organic forms, etc.*—cannot . . . result from the laws of force alone, but are to be accounted as statistical uniformities, due to vast numbers of fortuitously moving molecules.[17] (C, 1927; italics mine)

One might object that this extension of the kinetic theory to liquids and solids is problematic because the applicability of the large numbers argument in the case of gases involves an assumption of molecular chaos or *Stosszahlansatz* (assumption about the numbers of collisions occurring among molecules of specific velocities). It is not obvious that a similar or equivalent assumption of molecular chaos is legitimate for the cases of liquids and solids.[18] The statistical assumptions that Boltzmann was forced to employ in addition to the laws of dynamics to provide a proof of his H-theorem, the theorem that predicts the irreversible temporal evolution to equilibrium, met with strong criticism. But in fact it would seem that the applicability of the law of large numbers is independent of the assumption of molecular chaos. The role played by some version of the large numbers argument has appeared less objectionable than the assumption of molecular chaos.[19] The understanding now seems to be that macroscopic irreversibility emerges from microreversible laws of motion merely due to the extreme unlikelihood of reattaining the exact initial conditions necessary to have a complex system retrace its trajectory.[20] Hence, the statistical assumption required for irreversibility need not invoke the notion of random or chaotic molecular motion.

But what exactly *is* the relationship between the law of large numbers and the kinetic theory of gases? Richard von Mises (1981, 115) expresses Bernoulli's law of large numbers informally as "the relative frequencies of certain events or attributes in indefinitely prolonged sequences of observations tend to constant limiting values."[21] Now compare this with the Ehrenfest's statement concerning the probabilistic assumptions of kinetic theory: "In the motion of molecules, which is too complicated to be observed, certain regularities are described in terms of statements about the relative frequency of various configurations and motions of the molecules."[22]

By combining these two statements, we get a hint of how certain properties of the individual gas molecules (e.g., the distribution of molecular velocities) will produce an average velocity that tends to a constant.[23] In the case of a gas in an equilibrium state, the velocities will be described by the Maxwell–Boltzmann distribution, this being consistent with the state of a gas at uniform temperature.[24]

This tendency for large numbers of independent and diverse individual qualities to result in an overall uniformity made a great impression on Peirce. "But it is the law of high numbers that extreme complication with a great multitude of independent similars results in a new simplicity" (1.351). It became part of his Kantian logico-metaphysical project to trace out this phenomenon in all its multifarious forms, as this note for a lecture plan of (1883) attests:

> **Lecture XXX**
>
> The law of high numbers. Important consequences of certain numbers being large in different branches of science; such as political economy, theory of gases, physiology, doctrine of natural selection, and wherever there is a tendency toward an end. (NEM III, ii, 1096; W4, 488)

We get a hint here of the teleological thought that would later become the doctrine of "agapism" espoused in the essay "Evolutionary Love." We will have occasion to note in subsequent chapters how Peirce's opinion on final causation developed over the years. In his early period of cosmological speculation, final causes are exhibited by the rather blind action of chance, of which the above-mentioned instances of the law of large numbers are choice examples. Peirce's reason for classifying these phenomena as examples of final causation is that they do not exhibit their characteristic property of tending toward specific ends as a result of mechanical force. While force is an undeniable component, for instance in the approach of a gas to thermodynamic equilibrium, the chief factor responsible for the irreversible behavior is none other than the chance encounters among the molecules involved. Force is merely a matter of blind mechanical reaction, of secondness, in the terminology of Peirce's categories (NEM IV, 66), and is, in any case, reversible. But chance, because of its role in bringing forth order from chaos, results in thirdness, which is the category of habit, lawfulness, and reasonableness.

Surprisingly enough, Peirce had very little to say about Boltzmann's probabilistic interpretation of the entropy function. In fact, the only discussion by Peirce that I have been able to find of the term *entropy* makes no mention of the probabilistic approach. Rather, Peirce restricts himself to the older definition of Clausius:

> ENTROPY . . . 1. As originally used by Clausius, that part of the energy of a system which cannot be converted into mechanical work without communication of heat to some other body or change of volume. 2. As used by Tait (who wrote for the purpose of discrediting Clausius) the available energy, that part of the energy which is not included under the entropy, as properly used.[25]

Equally as puzzling, there appears to be no direct mention in his vast extant writings of Poincaré's recurrence theorem. Both Poincaré and, after him, Ernst Zermelo used the recurrence theorem as an objection to the physical reality of Boltzmann's H-theorem.[26] There are some very brief and vague remarks mentioning both Boltzmann and Poincaré that indicate they are concerned with the debate surrounding the H-theorem (cf. NEM IV, 37). Otherwise, Peirce restricts his comments to his agreement with Boltzmann (against Poincaré) on the former's adoption of the atomic hypothesis.[27]

Summary

In summary, then, we see that the solution adopted by Peirce to the problem of reversibility involves the ascription of an objective feature of chance to the physical world. It is an objective feature of chance just in the sense that it is an irreducible component of the explanation of natural phenomena. This is an important element of the thesis of tychism. Yet there is also an important distinction here which must be carefully noted. Ever since Sir Arthur Eddington, who followed the lead of Boltzmann, it has been fashionable to refer to the second law of thermodynamics (or the "law of entropy") as the "arrow of time." Once the Newtonian conception of an absolute and universal time is dispensed with, it becomes practical to think of time as nothing more than a relation among physical events, and if the universe is the only truly closed system, then the perceived anisotropy of time readily suggests itself as the result of the universal increase of entropy. Now, to begin with, Peirce was throughout his life, it seems, a Newtonian of sorts when it came to understanding time (but not space). Time was, in his opinion, something absolute and real (but again, space was not).[28] More importantly, we should notice that he does not appear to ascribe the asymmetry of time itself to the chance actions of vast numbers of molecules; it is only the nonreversibility of certain physical processes that he wishes to account for in this way. For instance, he writes that "*a determinate order among phenomena* is . . . never due to the action of forces, but is a result of probabilities" (C, 2319; emphasis added), and that "those uniformities of nature which present *phenomena of irreversible actions* . . . are to be accounted as statistical uniformities, due to the vast numbers of fortuitously moving molecules" (C, 1927; emphasis added). For Peirce, therefore, time would appear to be something distinct from physical events. And so the "arrow" of time will have to be accounted for in some other way. What that account is will be the subject of the next chapter.

3
Irreversibility in Psychics

The last chapter detailed how Peirce proposed to explain the irreversibility of natural processes by appeal to the statistical principles of the kinetic theory of matter. We concluded, however, that he did not attribute the asymmetry of *time itself*, with respect to the difference between past and future, to any such considerations. It should be noted that some see the problem of the direction of time itself, understood as a phenomenon distinct from the direction of processes *in* or *with respect to* time, as a nonstarter.[1] It would seem, however, that Peirce was not among them. Peirce appears to conceive time to be something more than just a relation among events. Time, as he speaks of it, is an entity or substance with its own intrinsic properties or structure (RLT, 225–26; 6.506), chief among them being its continuity and flow. While Peirce was interested in the physical aspects of time, he was also concerned with it as an object of experience and consciousness. In this chapter, we shall focus on his explanation of the basis of the distinction between past and future by appeal to the "Law of Mind" and shall consider its relationship to causation, teleology, irreversible processes and, once again, the law of large numbers.

The Law of Mind

In the 1892 *Monist* essay "The Law of Mind," Peirce wrote that "there is but one law of mind, namely, that ideas tend to spread continuously and to affect certain others which stand to them in a peculiar relation of affectibility. In this spreading they lose intensity, and especially the power of affecting others, but gain generality and become welded with other ideas" (6.104).

One of the most important features of this law, we are told, is that it "makes time to have a definite direction of flow from past to future" (6.127). How does it do this? Peirce's exposition of this "peculiar relation of affectibility" involves the characterization of ideas in terms of states of feeling.[2] Given any particular state of feeling, we find that all others may be grouped into two separate classes: those that affect the state in question (or have a *tendency* to do so) and those others that are affected by it. The class of feelings, therefore, under the ordering relation of affectibility makes up a transitive and asymmetric series with a condition of simultaneity defined for two or more states absolutely unaffectible by one another. In adopting this essentially causal theory of time, Peirce is following in the tradition of Kant and Leibniz.[3] The consequence of this condition of affectibility is that "the present is affectible by the past but not by the future" (6.128). The section of "The Law of Mind" entitled "Analysis of Time" finishes with the claim that "these propositions involve a definition of time and of its flow" (6.131).

With this analysis, Peirce believed that he had shown how the law of mind accomplished what the physical laws of force could not—namely, how to establish a preferred direction in the flow of time. But how exactly, we may ask, does it do this? There seems to be nothing intrinsic to the relation of affectibility that would forbid its time reversal. For if we have a temporal series of ideas (or states of feelings), *A, B, C, D* . . ., under the relation of affectibility, what is to stop us from reversing (conceptually) the order under a time transformation to get the series . . . *D, C, B, A*? It would seem, in fact, that any ordering we may be aware of that involves the affectibility relation must be a contingent or de facto one sensitive to personal experiences (although there are certain general relations to be considered such, as were noted by Kant).[4] To attribute the distinction between past and future to the relation of affectibility therefore seems suspect. It may be the case that as a matter of historical accident, idea *A* affects idea *B*, but there appears to be no good reason why *B* could not (or in the future will not) affect *A*.[5] The law of mind, on this account, is no less reversible than the law of vis viva—that is, it is merely irreversible in the sense of Hollinger and Zenzen's criterion C3.

Any given serial ordering of ideas, then, will be insufficient to provide an explanation of why there exists a preferred direction in the flow of time or of the basis for the distinction between "past" and "future." Although this is a valid objection, I believe it misses the point somewhat. To understand why Peirce believed that the law of mind provided the answer to the question concerning the direction of time's flow, we must consider what he saw to be the alternative. Recall that according to dynamics and the principle of energy conservation, which, under the authority of Helmholtz, is based on central forces, the only real changes in the external world are due to the accelerations of particles, and these accelerations are the direct result of nothing more than the relative positions of the particles themselves. Try as one might, there is nothing in the idea of the relative spatial positions of particles that suggests a preferred direction in time. This, by the way, should explain why Peirce was so adamant about stating the law of energy so as to make the centrality of positional forces explicit. So long as the law is stated in such a way that emphasis is placed on the conservation of energy, rather than on the important role given to central forces, the consequence of reversibility is masked. In contrast, the relation of affectibility—with its obvious connections with the notion of causation—certainly does suggest an intrinsically asymmetric relation in time. So, despite the failure of any particular de facto chain of ideas to explain the unidirectionality of time, the one essential relation operating on ideas, because it is inherently asymmetric, does pick out a preferred direction. On the other hand, Peirce does not offer any explanation of the asymmetry of the affectibility relation, and this is surely a shortcoming.

The law of mind is essentially Peirce's expression of the eighteenth-century English school of associationist psychology developed by Gay, Hartley, Berkeley, and Hume. Peirce frequently expressed praise for this approach over more modern theories, such as those of Herbart (1776–1841), and even his friend William James (1842–1910).[6] In fact, Peirce often spoke of the law of mind and the law of association as equivalent expressions of the same principle. It is through the association of individual ideas that general ideas are created, and, furthermore, it is through these general ideas that the formation of habits are made possible. "Habit is that specialization of the law of mind whereby a general idea gains the power of exciting reactions" (6.145). The category of habit plays an important role in Peirce's conception of the world in that all regularities, whether social, mental, or material, are construed as habits acquired by the systems in question in accordance with the fundamental principle of universal evolution. This latter principle was also called by Peirce the "law of habit," "law of habit-taking," and the "law of generalization." In keeping with his thesis of objective idealism, physical laws are assumed to be inveterate habits exhibited by matter; correlatively, matter is mind that has become "hidebound" with habit:

> Instead of supposing mind to be governed by blind mechanical law, [Peirce's theory] supposes the one original law to be the recognized law of mind, the law of association, of which the laws of matter are regarded as mere special results. (6.277)

> Hence . . . the laws of the universe have been formed under a universal tendency of all things toward generalization and habit-taking. (7.515; RLT, 241)

We see here that he considers not only the laws of mind and association to be equivalent expressions but also the law of habit. "Now the generalizing tendency is the great law of mind, the law of association, the law of habit-taking" (7.510). *Habit* is for Peirce just another expression for *generalization*, which appears within the realm of mental phenomena as the association or "welding" of ideas. But furthermore, "this action of habit is nothing but generalization, and generalization is nothing but the spreading of feelings" (6.268).

Taking this equivalence of the law of mind and law of habit into consideration, we can understand even better why Peirce saw the law of mind as providing the key to the direction of time's flow. Consider the following passage:

> The one primary and fundamental law of mental action consists in a tendency to generalization. Feeling tends to spread; connections between feelings awaken feelings; neighbouring feelings become assimilated; ideas are apt to reproduce themselves. These are so many formulations of the one law of the growth of mind. (6.21)

What this passage describes, as the last line attests, is the growth or development of mind. It may be taken to provide a sufficiently accurate account of the type of change that goes on in the mind of an infant as it experiences the world and develops into an adult who views the world through the lenses of rational categories. Just as we could recognize that a film was being played backward if what it showed was a disorganized spread of glass shards leaping from the floor onto a table to form a drinking glass, so is it plausible that were it possible for us to view some kind of "recording" of thoughts, which proceeded from a coherent, sensible, and unified system to a disconnected and unorganized one, we could recognize this as the reversal of a normal development. "The law of mind is that feelings and ideas attach themselves in thought so as to form systems" (7.467). Humans tend to acquire habits as a result of experience and education. As Peirce so often noted, the process of becoming rational, of learning to act in accordance with the guidance of logic, is a process of developing useful habits. Indeed, forms of inference themselves (e.g., deduction, induction, abduction) are, according to him, forms of habit. As outlined in his earlier essays "The Fixation of Belief" and "How to Make Our Ideas Clear," the stimulus to inquiry is a problematic situation that none of our current beliefs (habits) can adequately accommodate. This results in a state of doubt, the removal of which is the whole purpose of inquiry. Through the process of inquiry, the problematic state of doubt is replaced with a new belief or habit that, in the future, will allow us to deal with similar situations. Through inquiry, then, our actions become increasingly guided by habit and we become more orderly and regular in our conduct, acting more in accordance with the edicts of reason, just as the universe does as it evolves toward its limit point of perfect lawfulness and reasonableness. When expressed in terms of the spreading of feelings, the parallel between the dissipation of energy principle and the law of mind becomes apparent. "That there is analogy between spreading of motion through a gas by viscosity and association of ideas need not be denied" (N1, 85). Yet despite the analogy, Peirce did not appear to wish to make much of it.

In essence, a habit is just a tendency to behave on future occasions as on similar past ones. But another aspect of habit is its directedness toward the achievement of specific goals. In keeping with the thesis of objective idealism, Peirce encourages us to recognize this feature of the law of habit at work in the physical realm in such examples as the approach of substances and gases to thermal equilibrium, the wearing of beds by streams, and the neurophysiological development of protoplasm. It is largely as a result of this generalization of the notion of habit that Peirce claims that "while every physical process can be reversed without violation of the law of mechanics, the law of habit forbids such reversal" (8.318).[7] As we saw in Chapter Two, what keeps those systems which "violate" the law of energy from reversing themselves is chance and probability. Mind, on the other hand, Peirce seems to suggest, is essentially nonreversible.

However, this does not mean that the law of mind is perfectly exact or deterministic. It, too, is essentially stochastic in nature:

> The law of mind only makes a given feeling *more likely* to arise. It thus resembles the "non-conservative" forces of physics, such as viscosity and the like, which are due to statistical uniformities in the chance encounters of trillions of molecules. (6.23)

Why is the law of mind not reversible (in principle at least) like the laws of physics, if it is only a probabilistic dispositional regularity? Many stochastic processes are reversible (with a recurrence time inversely proportional to the number of items involved) because of the independence of the events or trials in question.[8] The law of mind, though—in this instance, better thought of as the law of habit—does not meet the condition of independence. Certain of the events or trials in question have a tendency to influence certain others. Equivalently, we could say that the law of mind sets up certain correlations among ideas. And it is because of the asymmetric nature of this relation of correlation and influence that the law of mind/habit—although a statistical one—is nonreversible. I will have more to say about this, however, in Chapter Six.

Causation and Mental Activity

Peirce's analysis of time's direction so far is plausible only because of its appeal to the notions of cause and effect. We certainly do say that causes precede their effects and not vice versa, but still, Peirce's account of the relations among ideas does little to provide anything like an explanation of this fact. We find that by the time of the 1898 Cambridge lectures (RLT), Peirce has ceased referring to the "law of mind" and prefers to talk instead in terms of causational versus conservative action. The former disjunct he wishes to identify with nonconservative and irreversible actions; the latter, with reversible actions. The split is also drawn along the lines of the psychical–physical distinction. The notion of cause is, he notes, a peculiarly mental one and is to be contrasted with the dynamical notion of force. But given that all known laws of physics are reversible, why is it that we still prefer temporally asymmetric explanations of events in terms of causes and effects?

What Peirce wished to draw people's attention to were the difficulties in any attempt to reduce mental phenomena to properties of matter (i.e., the difficulties inherent in materialism). Some of the more pressing problems he claimed are endemic to materialism are as follows: (1) The mental notion of causation is quite dissimilar to the dynamical notion of force. (2) The law of mental activity is intrinsically time asymmetric (nonconservative/causational), while the laws of physical force are reversible. (3) How can one make plausible the thesis that "blind" matter is capable of feeling or of sensation?

The first point is, in many ways, the most interesting and perhaps original. In his 1898 Cambridge lectures, Peirce considers how people typically characterize the notion of a cause. First, he notes that the idea has evolved since the time of the ancient Greeks and Aristotle and until the present. Yet people typically assume that modern physics has settled on Aristotle's efficient cause and has dropped the rest. But this is, in fact, not so. An efficient cause for Aristotle, he notes, was often a person or thing and not an event, as is the modern conception.

The popular doctrine of causation involves these claims: (1) "that the state of things at any one instant is completely and exactly determined by the state of things at *one* other instant"; (2) "that the cause, or determining state of things, precedes the effect or determined state of things in time"; and (3) "that no fact determines a fact *preceding* it in time in the same sense in which it determines a fact *following* it in time" (RLT, 199). Now, according to Newton's second law of motion, forces are responsible for the production not of velocities but of accelerations. And, as Peirce explains, an acceleration involves the relation of the position of a body or bodies not to the position at one other instant but to the positions at a second and third instant. This is because an acceleration, as a second derivative, is the rate of change of the rate of change of spatial displacement and requires the comparison of three points at three separate instants. This is inconsistent with the first proposition of the popular conception of causation. Second, because the effect of a force, an acceleration, is, according to the doctrine of the conservation of energy, produced by the relative positions of the bodies involved, the second proposition is also confuted,[9] for the order of events is not that there is first a configuration of bodies and *then* an acceleration but that the acceleration and relative positions are entirely simultaneous. Finally, we have the familiar argument that in accordance with the conservation of energy principle, past events are determined by the future in exactly the same sense as future events are determined by the past.[10] Everyone will agree, though, that only the past can affect the future and not the reverse.

For these reasons, Peirce claims that the commonsense notion of cause is not to be confused with the dynamical notion of force. But if physics really makes no use of the familiar notion of causation, where is it applicable? The answer is: in the realm of mental action, not in physics but in psychics. When we turn to the consideration of mental processes, we find the notion of cause entirely natural and appropriate. For we do believe, on evidence of introspection and the law of association, that one idea suffices to suggest another; and that the suggesting idea precedes in time, however slightly, the idea suggested; nor do we suppose that we can influence the past with any thought from the present or future. Here, then, in the mental realm, in the domain of ideas, the notion of cause seems tailor-made.

As an illustration of the distinct natures of explanations in terms of dynamical force and the commonsense notion of cause, Peirce showed, with the use of a physical example, how the two approaches diverge.[11] Consider a coupled system consisting of two equal pendulums allowed to swing freely in the same line of action, both suspended from a common flexible support (a cable) between two rigid stands. If one pendulum is put into motion, it will eventually lose oscillations, while the other formerly stationary pendulum will begin to move with about the same amplitude as had the first.

Once this second pendulum has come to rest, the first will start up again, and so on. The natural explanation that comes to mind is that the motion of the first pendulum is transferred via the cable to the second pendulum and then back again. We say, for this reason, that the motion of the first is the cause of the motion of the second, and so on. But Peirce notes that the equations of analytical mechanics describing this system may be written in such a way that the two pendulums are treated as separate and independent systems having no influence on one another. Such a system is called an integrable or free-body system. Despite the fact that this approach is mathematically correct and provides the proper empirical results, Peirce notes that it goes against the grain of our natural intuitions. This he takes to be further support that the law of mental activity is causational and not conservational.

Teleology and the Action of Mind

It is one of the most distinctive characters of mind (whatever the mind may ultimately turn out to be) that the mind works toward the fulfillment of specific goals or ends. This constitutes a further similarity between the action of mind and the nonconservative forces of physics, for as was mentioned earlier, these forces exhibit an irreversible tendency toward ends. But what exactly does this mean?

> By a tendency to an end, I mean that a certain result will be brought about, or approached, and in such a way that if, within limits, its being brought about by one line of mechanical causation be prevented, it will be brought about, or approached, by an independent line of mechanical causation. (NEM 4, 65–6)

For example:

> The phenomenon of diffusion is a tendency toward an end; it works one way, and not the opposite way, and if hindered, within limits, it will, when freed, recommence in such a way as it can. (ibid.)

In his analysis of this behavior, Peirce identified the influence of a kind of final cause. His interpretation, though, differs in an important way from the Aristotelian notion:

> . . . We must understand by final causation that mode of bringing facts about according to which a general description of result is made to come about, quite irrespective of any compulsion for it to come about in this or that particular way . . . (1.211)

For Peirce, then, a final cause is not necessarily a purpose that compels a particular result to obtain.[12] While the description of final causation in terms of purposes may be appropriate in the case of the human mind, it need not hold for final causes in general. "A purpose is merely that form of final cause which is most familiar to our experience" (1.211). In the parlance of mathematical dynamics, such end states as Peirce had in mind are known as "attractors."[13] Equilibrium states, either thermal, chemical, or mechanical, are familiar examples. But in the more recent study of nonequilibrium thermodynamics and nonlinear dynamics, it has been shown that sufficiently complicated systems may be "attracted" toward states exhibiting very novel and interesting spatial and temporal order. It would appear, then, that there may be some ground for Peirce's claim that final causation—properly construed—can be found in physical systems.

For Peirce, what makes final causation distinct from efficient causation is that "final causation does not determine in what particular way [a fact] is to be brought about, but only that the result shall have a certain general character" (1.211). For instance, if we ask why an isolated gas system should assume a configuration consistent with thermal equilibrium, an account given in terms of all the specific molecular positions and all the individual collisions and intermolecular forces of repulsion and attraction that were involved in the tracing out of the actual trajectory would be too specific. The description we desire does not specify the unique actual trajectory of the system at all. What it tells us is that given such and such parameters, a general type of result will almost surely obtain. And what is perhaps even more interesting, as Peirce pointed out, is that in such cases as diffusion and other thermal phenomena, mechanical force has really very little to do with the explanation of the general nature of the result (NEM, IV, 66). For example, it is the "random" nature of the interactions among a large number of molecules that is more significant for the general description of the fact in question (e.g., an average value such as temperature) than are the particular forces involved. This is borne out by the need for some form of ergodic hypothesis in such cases.[14] Furthermore, as the example of Maxwell's demon illustrates, lawlike phenomena such as are described by the second law of thermodynamics are only statistical regularities. There must, therefore, be some important factor involved over and above deterministic mechanical force. The research of "statists" such as Quetelet and Buckle had made popular the idea that statistical uniformities emerge from the uncorrelated behavior of individuals within large populations. Peirce, following the lead of these writers, not to mention Maxwell and Boltzmann, identified this extra ingredient with chance.[15] In Peirce's universe, chance, in cooperation with the law of habit, is responsible for the evolution of systems toward those attractor states which result in increased complexity and regularity.[16] Nobel-winning chemist Ilya Prigogine has credited Peirce on this point for foreseeing the possibility of "dissipative" structures.[17]

The Problem of Mind–Matter Reductionism

In Peirce's time, the thesis of Cartesian dualism had waned in popularity, giving way to some form or other of monism. Two basic options then present themselves: materialism or idealism.

> Wherein do materialistic monism and idealistic monism differ? Only in this, that the former makes the laws of mind a special result of the laws of matter, while the latter makes the laws of matter a special result of the laws of mind. (N1, 200)

Now, the materialist must overcome the following difficulty:

> The laws of matter are entirely blind, or non-teleological, only prescribing that in given relative positions the motions of particles shall have given accelerations: now, mind does not act blindly, but pursues purposes; therefore the problem is how teleological or purposed action can be a secondary effect of non-teleological action. (ibid.)

It would be unfair perhaps to expect the materialist to derive all the characteristics of mind directly from the laws of mechanics alone, but it must be admitted that any other principles invoked in a materialist reduction will have to be restricted to those describing nothing beyond material principles. Any principles of chemistry, biology, physiology, and psychology employed will have to be compatible with the laws of motion and restrict themselves to features of matter. One does get the distinct impression, however, that Peirce is actually challenging the materialist to provide a strict deduction of the principles of mind and sensation from Newton's laws. Owing to the relatively primitive state of organic chemistry and neurophysiology at the time, it was Peirce's opinion that materialism could not look to these fields for much help in reducing mind *completely* to properties of matter. Although he did not believe the materialist reduction would work, he did agree that "mind is to be regarded as a chemical genus of extreme complexity and instability" (6.101). The next chapter will take up his statisticokinetic theory of protoplasm and his attempt to bridge the (apparent) gap between the worlds of physics and psychics.

The materialist's best response to Peirce's challenge (to explain how the mind's teleological behavior could be the result of blind mechanical law) came from Darwin's theory of natural selection, according to which fortuitous variations in biological forms are selected for and against by the natural circumstances of the environment. In this way, the materialist could argue, those organisms which happened upon behaviors that secured for them a reproductive advantage over their competitors would tend to leave more offspring. Those organisms that did not stumble upon adaptive strategies would be outcompeted and consequently diminish in number. It may be allowed, Peirce conceded, that the action of natural selection is of the nature of a mechanical law. But, he asks, can the diversification that results from fortuitous variation be likewise accounted for? This move on Peirce's part changes the subject slightly, for the issue is now made to center on the generation of novel forms rather than on teleology. However, let us follow his lead. It is presumed to be of the essence of mechanical law that it is inviolate and perfectly exact. Consequently, he argues, mechanical law cannot account for the diversification of novel forms that results from fortuitous variation, for under like antecedents, mechanical law must produce like consequents:

> It would seem as if there were an increase in variety, would it not? And yet mechanical law, which the scientific infallibilist tells us is the only

> agency of nature, mechanical law can never produce diversification. That is a mathematical truth—a proposition of analytical mechanics; and anybody can see without any algebraical apparatus that mechanical law out of like antecedents can only produce like consequents. It is the very idea of law. So if observed facts point to real growth, they point to another agency, to spontaneity for which infallibilism provides no pigeon-hole. (1.174)

There must be a source of novelty, of freedom from the monotony of exact regularity, and for this reason he supposed there must occur real violations of mechanical law. There must be room in the world for real chance, that is, not just a mere subjective measure of our own ignorance. On this point, Peirce diverged from Darwin himself, who considered the talk of chance or fortuitous variations nothing more than a *façon de parler*.[18] But aside from this, Peirce noted that the phenomena of fortuitous variation, on any account, is in fact described by a kind of law quite distinct from that of mechanical law. It is, however, by that account an idea no less exact, as this extraordinary passage attests:

> The conception of fortuitous variation is so exact that it can be expressed by a mathematical equation. In fact, it is expressed by the formula which expresses the conduction of heat, the action of viscosity, and the diffusion of gases. All these phenomena are explained by physicists as results of Bernoulli's law of high numbers, where the same idea of multitude reappears which is directly involved in the Darwinian hypothesis. The same formula shows itself in the doctrine of chances, in the theory of errors of observations, and in the logic of inductive reasoning. As well as we can make it out, the law of mental association, which is at least strongly analogous to induction, is probably of the same form. All these things seem to be connected. (N2, 200–01)

The phenomenon of diversification, which is the result of these fortuitous variations in heritable traits, cannot, he argues, be the result of mechanical law alone. Consequently, the materialist cannot appeal to Darwin's theory of evolution without thereby bringing in nonmechanical principles. Furthermore, as the above list of related phenomena was meant to illustrate, the type of law on which Darwin's theory relies shows up again in phenomena of a distinctly mental nature.[19] One might wish to object that this could be read as weakening the case for idealism rather than strengthening it, as Peirce seems to think, for it appears to offer hope that the properties of mind may in fact be explicable without having to assume them as primitive. Moreover, the need for an objective element of chance in our explanations of natural phenomena, if in fact such a need is genuine, is not in itself an argument against materialism, for Peirce seems to be confusing the positions of materialism and necessitarianism (determinism). A real need for objective chance would be a problem for the latter doctrine but not necessarily for the former. In Peirce's mind, the two are clearly related, though under the broader doctrine of the mechanical philosophy. In the final analysis, his objection to materialism is really that it cannot account for the properties of sensation, feeling, or consciousness. His idealism attempts to get around this problem simply by taking these properties as primitive and supposing them to be ubiquitous throughout the universe.

But why should we assume the features of mind to be primitive? In fact, does it not violate Peirce's own first rule of inquiry that nothing be supposed inexplicable from the outset? His response is rather ingenious and consistent with his methodology, if implausible from our own modern perspective. Remember that for Peirce chance is the one thing that requires no explanation. By identifying feeling, an important feature of mind, with chance, he attempts to sidestep this objection. "Chance is but the outward aspect of that which within itself is feeling" (6.265), so that insofar as matter is yet capable of experiencing chance fluctuations and has not yet become perfectly governed by habit, then it is still capable of feeling. Obviously what we understand to be an individual mind is more than just feeling; personality is an important part. Peirce, realizing this, wrote that personality is a coordination of ideas or feelings, a teleological harmony in ideas (6.613). Such organized aggregates of feeling are possible, he explained, because general ideas themselves are composed of individual feelings. General ideas, you will recall, through the law of mind/law of habit, influence future activity. And viewed from this perspective, what we mean when we say of someone that they have a mind is that they portray certain general habits that guide their behavior. For Peirce, the important thing is that these general habits guide our actions in a teleological way. Our conduct in the present is influenced by an idea we have of some thing or situation that we hope to bring about in the future. And as has already been mentioned, these final causes at which our conduct aims influence us only in a general way; that is, they do not determine the exact sequence of events that we will play out but only ensure that some general type of result will be the final outcome.

This, then, is what it means for Peirce to say that someone has a mind. He distinctly rejects the mind–brain identity thesis, even though he will admit the importance of healthy brain functions for mental activities. But for Peirce, an understanding of what it is to be a rational individual with a mind has more to do with semeiotics (the theory of signs) than with neurophysiology. According to his semeiotic approach to psychology, we humans are essentially sign-readers. In fact, as a result of our social interactions with one another, each of us stands to the other as a sign. He defines a sign as "something, A, which denotes some fact or object, B, to some interpretant thought, C" (1.346). Because the interpretant of a sign by the mind involves the establishment of an observable mode of external behavior (which is just what the thesis of pragmatism tells us), and all thought is in signs (1.538; 5.251; 5.265), it follows that thought is not confined to the brain. "Accordingly, just as we say that a body is in motion, and not that motion is in a body we ought to say that we are in thought and not that thoughts are in us" (5.289). Although this is a woefully brief treatment of such an important feature of Peirce's philosophy as is his semeiotics, I wish to return now to the connection between chance and feeling.

Every belief is a form of habit, it is a guide to action. Without habits, we act randomly, as by chance. Now, one of the consequences of obtaining a habit is that we are thereby able to perform an action without having to concentrate on it; we come to perform the act automatically and without consciousness of doing so. The result is that through habit, feeling subsides; this is nothing more than a restatement of the law of mind. "According to that law, consciousness subsides as habit becomes established, and is excited again at the breaking up of habit" (6.613). A habit involves the development of a general idea, and the process of generalization involves the spreading of ideas and feeling. In this way, disconnected feelings and ideas become welded into coherent systems of activity and belief. It is fitting that an idealistic and evolutionary cosmology should have the universe starting off as an unruly chaos of feeling that gradually becomes more orderly and regulated so as to exhibit rational conduct.

A helpful illustration of Peirce's understanding of an individual mind as an integrated system of feelings can be drawn from the modern theory of neural networks. A neural network is essentially a directed graph composed of nodes and vectors used to model a neurophysiological system.[20] Peirce identifies three essential features of mind (corresponding to the categories, of course). First is feeling, second is energy of action (i.e., "affectibility,") and third is habit or connection. Consider each node in a neural network to be possessed with the capacity for feeling. This of course corresponds to the property of sensation in a neuron. Each node we suppose has also the ability to affect neighboring nodes. This is made possible through some connection or continuity existing among them. Now, as we begin to link up neurons in a random fashion, we first obtain simple connections between neurons corresponding to the affectibility of one idea on another, but as we continue to link up nodes at random, we will eventually build up complex connections among neurons that correspond to general ideas. These general ideas will themselves have the property of feeling, but with the important difference that they are more than simple connections between immediate neighbors. Stuart Kaufmann has used such cellular automata models to describe the emergence of complex systems.[21]

There is, as we have seen, a similarity between the causal-teleological activity of mind and the nonconservative action of certain irreversible physical systems. And the key to understanding these directed physical processes is probability and chance. It was Peirce's strategy to attempt an explanation of the mind's capacity for teleological behavior by appealing to probability and statistical principles. "The laws of cerebration and particularly of habit could be accounted for by the principles of probability" (MS, 875). This will be taken up next in Chapter Four. But first we will turn to the topic of time itself and ask how it is related to the mind.

What Is Time?

So far, we have covered a lot of ground concerning Peirce's theory of the mind and the temporally irreversible law that describes its function and development. But what was Peirce's opinion of the nature of time itself?

> I, personally, believe that the two directions of Time are as alike as the two directions along a line. For the law of the conservation of energy is that the *vis viva*, and consequently also the forces, of particles depends upon nothing mutable except the relative positions of the particles. Now the differential of the time enters into the analytical expression of the *vis viva*, $\frac{1}{2}m(ds/dt)^2$, as well as into that of force, only as squared. Whence, the square of a negative quantity being equal to that of the corresponding positive quantity, the two directions of time are indifferent as far as the action of the law of conservation of energy goes. This seems to me to indicate that the difference of the two directions through time consists in a peculiar property of *psychical* events, and not to purely *physical* events, and *a fortiori* not to pure Time itself.[22] (NEM, II, 481)

Accordingly, pure Time in itself is a symmetric one-dimensional continuum with no intrinsic preference being given by the fundamental laws of physics for one direction over the other. Peirce suggests in this passage that the symmetry is broken by some feature of the mind. But what *is* time in relation to the mind; that is, what is time as an object or feature of our experience? Here are three separate expressions of one response he offers:

> What is time? It is our form of intuiting logical connections. (MS, 446)

> . . . Time is the image of a logical sequence . . . (NEM, III, 891)

> [Time] is the form under which logic [specifically, the relation of logical dependence] presents itself to intuition. (RLT, 217)

The Kantian flavor of these statements should come as no surprise in light of Peirce's early study of and respect for that philosophy.[23] In what follows, I will attempt to reconstruct Peirce's answer to the question concerning the connection between probability and the above definitions of time as involving the logical form of intuition. It should be noted that in the *Monist* series of 1890–93 in which his cosmology was mostly laid out, his explanation of how the law of mind prevents reversibility centers entirely on the asymmetric relation of "affectibility." This relation introduces a temporal asymmetry, we saw, in that an idea being affected stands as an effect, and hence comes later than an idea doing the affecting, which stands as cause and comes earlier. But later, in the 1898 Cambridge lectures (RLT), Peirce offered another, more interesting, account that resembles more closely the statistical mechanical treatment of irreversibility. It is this account that I wish to reconstruct now.

In the very significant passage quoted on page 61 above, we saw how Peirce wished to connect the teleological action of mind with the irreversible processes resulting from nonconservative forces. Physics explains such actions, he wrote, as following from Bernoulli's law of "high" numbers. Now, there are two important elements involved in that law: (1) a sequence of independent trials or events and (2) a fortuitous (symmetric) variation of individual values around an emergent mean value. Peirce was very familiar with the fact that the mind exhibits such a trend, for his work with the Coast Survey frequently involved the law of errors of observation, and, moreover, he also published the results of an original experimental study of that phenomenon that he conducted while teaching at Johns Hopkins.[24] For any study requiring a large number of independent observations—such as observational astronomy, a field in which Peirce worked and published a monograph[25]—the law of errors states that the observations, taken collectively, will tend to exhibit a pattern of dispersion approximating the normal or bell-shaped curve (see Figure 3.1).

Here we have one of the elements involved in Bernoulli's law, a normal distribution. Yet the law of observational errors is, according to Peirce, demonstrative of a much more general and important feature of the human mental faculties. This feature is our propensity to make errors in reasoning and judgment. "*Errare est Humanum,*" he repeats (RLT, 217). But far from counting this a de-

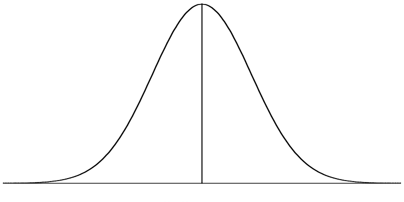


Figure 3.1. Normal distribution curve.

fect, Peirce says that we owe to it wholly our ability to learn, for the law of habit, which relies on our ability to learn from experience through hypothesis, induction, and deduction, must not be inflexible. Were it the case that the mind took on inflexible habits, its growth and development would come to a screeching halt. It is of the essence of the law of mind that it should be flexible, subject to violation and revision, and not mechanical like the laws of dead matter.[26] We return now to the other element required by Bernoulli's law. Peirce asked himself how chance results in irreversibility in the first place. How, that is, does chance manage to bring about specific states irreversibly?

> When we ask why chance produces permanent effects, the natural answer which escapes from our lips is that it is because of the independence of different instants of time. A change having been made there is no particular reason why it should ever be unmade. (RLT, 216)[27]

Instants of time are made independent, he writes, by the peculiar nature of the present instant (ibid.). The present instant neither is precisely determined by the past nor exerts a complete and determinative influence on future instants infinitesimally near to it. The present is, in other words, of the category of firstness; it is a spontaneous source of novelty.

With both pieces now in hand, Peirce claims that our "tendency to error when you put it under the microscope of reflection is seen to consist of fortuitous variations of our actions in time" (ibid., 217). The error curve is hereby made to support a great deal of weight indeed. Aside from not giving any evidence for the claim that errors in reasoning are normally distributed, it is unclear (without specification of the kind of random variable concerned and how a mean value is to be calculated) what such a claim amounts to. He does not make his intent quite explicit here, but presumably what he has in mind is that our attempts to draw correct inferences about the true state of affairs are normally distributed with respect to their deviation from the truth. This would match nicely his thesis that the truth (about any given matter) is what the community of inquirers would converge to in the long run.[28]

The argument, then, is this: Peirce is maintaining that time, as it concerns the mind, is the form under which logical relations present themselves to the mind, but because our attempts to reason properly are subject to error (falling into the pattern of a normal distribution), and these errors being rendered independent by the present instant, which constitutes a point of rupture in the continuum of time, our mind follows the pattern of the law of large numbers, leading, as it does in physical systems, to the experience of an irreversible process. It is in this way that the symmetry of time is broken.[29]

It is worth asking why Peirce would assume that errors in reasoning would, like errors in observation, follow the pattern of a normal curve. One would assume that as proficiency in reasoning is attained, errors would occur less frequently and, more importantly, in a more systematic or less haphazard fashion. With time and practice, should there not arise a bias or skewedness in our personal equation of error? The answer can be found, I believe, in the fact that for Peirce all knowledge is inferential and provisional. He rejected the traditional foundationalist epistemologies, both the sensationalism of the British empiricists and the Cartesian model of knowledge, and replaced them with his own theory of inquiry in which all reasoning is classified into the modes of deduction, induction, and abduction. Because he rejected the existence of any knowledge obtained through immediate sensory data, every observation must also involve an inference. But more importantly, these observational inferences are beyond our control and hence beyond logical correction. This permits, therefore, a permanent and ineliminable source of random error.

It was as a result of experiments conducted in the psychology of sensation that Peirce came to the conclusion that the mind's operation on raw sensory data is beyond logical criticism.[30] Murphey (1993, 360) notes that Peirce's 1891 review of James's *Principles of Psychology* gives an affirmative response to the question "Is perception unconscious inference?" and that by 1893 Peirce had made the identification of unconscious inference with the involuntary psychological processes of association. In "The Law of Mind," he outlines how the three types of inference correspond to psychological operations of association: "In deduction the mind is under the dominion of a habit or association by virtue of which a general idea suggests in each case a corresponding reaction" (6.144), whereas "by induction, a number of sensations followed by one reaction become united under one general idea followed by the same reaction. . ." (6.146). Finally, "by the hypothetic process, a number of reactions called for by one occasion get united in a general idea which is called out by the same occasion" (ibid.).

When we move from the unconscious to the conscious level, the careful and controlled application of the inference forms becomes a live possibility once again. Of the three forms of inference, only deduction is capable of providing certain results, and that only under ideal conditions in which personal and systematic error is avoided. Abduction is of the nature of an educated guess, and no quantitative estimate of its accuracy is forthcoming, Peirce insists. But Peirce's theory of induction—or equivalently, probable inference—*is* quantitative and modeled on the experimental method of sampling from a population. Moreover, Peirce was one of the first writers on the subject to emphasize the importance of introducing techniques of randomization into the sampling process.[31] It is of some significance, then, that he saw the process by which ideas become associated (via the law of habit) and the randomization of sample trials as analogous. In a note for a series of lectures, for instance, he wrote: "Chance and the law of high numbers. The process of stirring up a bag of beans preparatory to taking out a sample handful analogous to the welding of ideas" (NEM 4, 376).[32] Recall again from the quote on page 61 dealing with Bernoulli's law that he wrote, "As well as we can make it out, the law of mental association, which is at least strongly analogous to induction, is probably of the same form." If the inductive method is to have the self-corrective feature that Peirce claimed of it, it is crucial that it be based on the solid foundations of the mathematical theory of probability, in that way we may expect, in the long run at least, that our application of "the scientific method" will secure for us the convergence on truth and the merger of opinion results of the large number theorems.[33]

Traditionally, induction has been portrayed as the discovery of general laws from the observation of particular instances. This picture is retained by Peirce's analysis of induction as a statistical sampling method if we consider that by observing particular events or instances we are sampling from a vast population stretched out in time. If the instants of time can be assumed to be independent of one another, as a result of the disruptive influence of the present moment, and our ideas about the world become welded together into a system in a way sufficient to ensure that they provide a representative and undistorted sample of that same world (i.e., at random), then we may expect our beliefs about any given issue eventually to converge upon the truth. In fact, Peirce's theory of inquiry as a convergence or settling down of opinion within certain limits is clearly meant to mirror his theory of truth and reality. The activity of inquiry tracks the evolution of the world itself as it settles down to a convergence of regular behavior. In a wonderful kind of metaconvergence theorem, Peirce has the corresponding error bars of our beliefs and of the developing laws of nature converging in the limit of the infinitely distant future.[34] It is not likely just coincidence that there is this striking similarity between the monotonicity of Bernoulli's law and the irreversibility of Peirce's evolutionary cosmology.[35]

Having resolved to his satisfaction the relationship of the independence of instants of time to chance's ability to produce permanent effects, Peirce mused (RLT, 217) that "perhaps all fortuitous distribution originates from a fortuitous distribution of events in time. . . ." The crucial question here is does he mean to refer to the time of conscious experience or to pure objective time itself? If the former, then we only get a subjective explanation of irreversibility; that is, irreversibility would be merely an illusion created by an individual mind. There is some evidence to support this interpretation. For instance, on reflection of the reversibility of mechanical laws, he wrote, "Thus, in respect to the direction of its flow, time seems to be, if not purely a psychological affair, at any rate not purely a dynamical affair" (6.387). But given the need for some kind of objective temporal series for his irreversible evolutionary cosmogony to make sense, this does not seem a very satisfactory reading. His proposal might then be construed as stating that fortuitous distributions result from a fortuitous distribution of events in time, with time being understood as an objective dimension of the external world. But if we have an explanation of the irreversibility of time construed as an objective phenomena, what need have we for the extra account of irreversibility as a subjective experience due to errors in reasoning and judgment? There would appear to be a redundancy in explanation here. One or the other should be sufficient. How is this problem to be resolved?

We might begin to address this difficulty by recalling that according to Peirce's objective idealism, mind and the universe are assumed to function by the same principles, so we may suppose that conclusions drawn concerning the mind of an individual may also be extended, provisionally at least, to the universe at large insofar as it is appropriate to think of it as a supersystemic mind in development. If the individual human mind proceeds by logical inference, therefore, then so, too, the universe. Consequently, Peirce proposed that the evolution of the universe proceeds by principles analogous to logical inference. In this we saw his affinity with Hegel's metaphysical project of absolute idealism, through which the absolute becomes self-conscious. But whereas Hegel supposed that the development of the absolute proceeds by a deductive logic of internal compulsion alone, Peirce suggested that it also makes inductions and abductions (RLT, 161).[36]

Here we get at a crucial difference between the two systems; while both are teleological, Peirce's is a developmental teleology that allows for the growth and development of the end goal itself. For this to be the case, there must be a source of novelty and spontaneity in the development of the universe; otherwise, it runs, as it were, along steel rails that must have been laid out from the beginning. Peirce's "objective logic of events" expands the Hegelian system so as to permit inductive and abductive moods in addition to that of deduction.[37]

Reflecting back on the development of the individual mind, we must ask ourselves how this spontaneous novelty fits in. " . . . The signification of the discontinuity at the actual instant [the present] is that here new premises not logically derived by Firsts are introduced" (RLT, 217). The independence of the present instant—as it relates to the objective evolutionary development of the universe—thereby allows for the novelty and arbitrary specificity that Peirce identified with the variety of the world, a variety that could not be deduced from general laws or principles. Why, for instance, should there be in this world just the particular kinds of physical and biological forms that there are? Because no rational explanation is possible—that is, a deduction neither necessary nor probabilistic—the actuality of the forms that do obtain must be relegated to the category of firstness—that is, to chance, spontaneity, and variety.

Returning from our digression on the differences between the Hegelian and Peircean systems of objective logic, let us ask again how it is that Peirce's story of how the symmetry of time gets broken manages to be more than just a subjectivistic account. We should note that for Peirce, anything that we can reasonably call a reality must be a possible object of experience. And if it is to be experienceable for us, then it must have something of the mental in its nature. A reality for Peirce is something that would impinge itself on our experience regardless of what any of us may think or do about it. A reality is something that is the way it is independently of our will; it is something that exerts a brute force on us; it partakes of the category of secondness.[38] Hence, to say of something that its nature is of the mental is not equivalent to saying that it is merely something subjective. So just because Peirce explains the asymmetry of time as arising from a peculiar feature of mental events, it does not follow that the asymmetry is merely a subjective illusion. It is beyond our control and an objective feature of experience, which is to say, by Peirce's understanding, that it is real. This would still seem to leave open the question whether there are a multitude of separate but parallel experiences of irreversibility or whether there is just one such system, of which all individual minds share a similar experience. Speaking for myself, I cannot see that any obvious answer to this question is forthcoming from Peirce's writings. There appears to be an ineliminable redundancy in explanations of temporal irreversibility offered by Peirce. On the one hand, irreversibility is the result of the objective logic of events in the world "external" to our minds, and on the other hand, irreversibility is a psychological impression resulting from our mind's processing of events in the objective external world. That there is another closely related redundancy in Peirce's cosmological system will be discussed in Chapter Six.

Let us consider now once more the law of mind and its relation of "affectability." Peirce wrote near the end of "The Law of Mind," after discussing the association of ideas, that "we can now see what the affection of one idea by another consists in. It is that the affected idea is attached as a logical predicate to the affecting idea as subject" (6.142). Viewed from the perspective of cause and effect, this says that a cause and its effect are welded together by association as a subject and predicate. (In fact, according to Peirce, the relation of cause and effect is to be explained in terms of the relation of association and not the other way around.) It is clear that Peirce would want to see a connection linking the logical relations between ideas and the teleological mode of explanation, for teleology is the basic modus operandi of the mind, but if it is to have any validity, any assurance from the theory of logic and inquiry, then the teleological associations between ideas must at root also follow logical associations. "The mind works by final causation, and final causation is logical causation" (1.250).

How are we to understand this claim that "final causation is logical causation"? Causation, he writes (6.67), is a relation involving not events but facts. Now, facts are not themselves events, although they may be about events. While events are essentially examples of brute existence (i.e., secondness), facts, about causes and effects, have an aspect of rationality about them and partake of the category of thirdness. The cause of an event B is not, therefore, just another event A preceding it in time, for as we saw under "Teleology and the Action of Mind" above, the notion of cause is a mental one, or, to put it more accurately, causation is a rational relation involving the category of thirdness. Hence, a cause cannot be just an event or state of affairs, A, preceding some other event or state of affairs, B, in time; it is, instead, a rational abstraction from the entire state of affairs that preexisted the effect in question (6.93). Peirce is here pointing to the difficulty of identifying the notion of a cause with the physical notion of a configuration of a system as used in mechanics.[39] We do not say, for instance, that the cause of the ink bottle's overturning is the entire configuration of the universe at the instant just preceding the spill. Nor do we even attempt to restrict the relevant system down to the room within which the spill occurs, for this still allows too many irrelevant conditions, such as the color of the drapes, and so on. When we ask for the cause of an event, we are after a very specific and abstracted feature of the entire set of conditions in existence just prior to the event in question. And because the thing we are after is so abstracted from the set of physical conditions, it must clearly be something mental. Moreover, because we seek causes in order to understand circumstances and events, causal explanations must also be rational.

Now I believe we are in a better position to understand Peirce's statement that "the mind works by final causation, and final causation is logical causation." The mind seeks particular kinds of ends, causal explanations for instance. And causal explanations must stand up to certain tests of logical rigor. Not just any causal story will do if science as an enterprise is to fulfill its duties of prediction and control.[40] But what does this say about mechanical and dynamical explanations in terms of force and energy? Are we to understand that Peirce would have us assume the "intentional stance" toward inanimate material systems? I do not believe that Peirce meant anything like this at all. For one thing, the approaches of mechanics and dynamics deal with mind hidebound with habit—that is, mind so regular that it appears to us not as mind but as matter. There is no—or at any rate, very little—spontaneity left in the things traditionally identified as inanimate material objects. Consequently, our understanding of them need not involve teleology in any sense beyond what was explained above concerning the rationality of the notion of causation. However, when we are dealing with mental phenomena—with one another, for instance—then we naturally turn to final causes. And insofar as the universe has not yet become completely regularized (habituated) into dead matter, to the extent that it has some evolution and development left to go, then we may attempt to understand it in terms of final causation, too. In this way, Peirce hoped, scientists might be able to anticipate which of the infinity of possible hypotheses about such things as molecules and atoms are most likely to be worth putting to the test.[41]

Summary

I have attempted to fill in the details of Peirce's argument regarding how the law of mind results in an irreversible "flow of time." We saw that there are two quite distinct arguments to this end. The first relied on our intuitive prejudice that a cause must precede its effect. The least that can be said in its behalf is that it presents a more satisfactory explanation of temporal asymmetry than does the philosophy of mechanism with its reliance on the fundamental laws of physics, for those laws provide no explanation of temporal asymmetry at all. The second argument was more complicated and more interesting. It incorporated the law of large numbers directly into our mental framework, combining elements of probability theory and phenomenology. This second argument, however, proved to be rather obscure in its details. We have seen, so far, the law of large numbers show up in physics and in psychics. In the next chapter, we will see it again in the field of biology and, more specifically, in physiology, where Peirce attempts to use it to explain how protoplasm exhibits the rudimentary features of mind and especially habit. So far, we are lacking any convincing connection between the stochastic telos of the law of large numbers (exemplified by attractor states such as thermal equilibrium) and the more full-blown animistic telos expected of the mind. The importance of the molecular theory of protoplasm is that it attempts to draw these two strains together. It attempts to do this in a way consistent with Peirce's own neo-Lamarckian theory of evolution, whereby the driving force of evolution is not merely the blind force of chance but the force of habit and striving to achieve ends. Agapasm, the name given to this theory by Peirce (from the Greek word for "love"), retains yet that statistical element of Darwin's original theory which Peirce associated with Bernoulli's law of large numbers, but it is combined with an element of purpose and rationality, the desire to aid in the rationalization of the universe, to fulfill one's duty toward the evolution of "concrete reasonableness." To achieve this, Peirce must show how elements such as ideas (and submolecules!) can be attracted to one another not just as a result of chance but because of a striving each has for the other in virtue of the kind of elements that they are.

4

Irreversibility in Physiology and Evolution

> I know scarcely anything so apt to impress the imagination as the wonderful form of cosmic order expressed by the "Law of Frequency of Error." The law would have been personified by the Greeks and deified, if they had known of it. . . . The huger the mob, and the greater the apparent anarchy, the more perfect is its sway . . .
>
> Francis Galton 1886[1]

This chapter consists of two main sections. In the first, Peirce's molecular theory of protoplasm will be the focus of attention. In particular, we will be looking to see whether he manages to provide a convincing story of how the strong notion of final causation associated with conscious goal-seeking behavior can arise from the much weaker notion of final cause obtained from the blind action of chance (that phenomenon of irreversibility which derives ultimately from the averaging effect described by the law of large numbers). This discussion will be almost exclusively contained within the confines of physiology and the kinetic theory of matter. The second section will deal with the theories of biological evolution popular in the nineteenth century. Here we will also be concerned with Peirce's own *agapastic* theory of evolution. The goal is to get a clear picture of how this account of evolution contrasts with Darwin's theory of natural selection and Lamarck's theory involving the inheritance of acquired traits. Ultimately, the object is to understand how Agapasticism, taken as a general theory of evolution, incorporates both the stochastic elements of Darwin's theory and the Lamarckian-inspired thesis that evolution occurs through the exercise and adaptation of novel traits for the attainment of a specific purpose or final cause. As we shall see, this latter element becomes, in Peirce's cosmology, the engine whereby the universe's own teleological striving for systemic orderliness is achieved (the process otherwise called by

Peirce “the development of concrete reasonableness” or the “crystallization of mind”).

Physiology

The Molecular Theory of Protoplasm

The widespread manufacture and regular employment of microscopes in the 1820s and 1830s brought to the attention of physiologists the existence of the sticky “life-slime” material found in the cells of all living organisms, both plant and animal. This material was given the name “protoplasm” by Johannes Purkinje (1787-1869) and Hugo von Mohl (1805-1872) (Mayr 1982, 654). This substance is now known to consist of the cytoplasmic fluid and various organelles found outside of the cell nucleus. “What the nineteenth-century investigators had called protoplasm and had considered to be the basic substance of life turned out to be a highly complex system of intracellular organelles with various functions. Most of them are membrane systems which serve as the ‘habitat’ of specific macromolecules” (Mayr 1982, 124).

The *Century Dictionary* defined protoplasm as

> An albuminoid substance, ordinarily resembling the white of an egg, consisting of carbon, oxygen, nitrogen, and hydrogen in extremely complex and unstable molecular combination, and capable, under proper conditions, of manifesting certain vital phenomena, as spontaneous motion, sensation, assimilation, and reproduction, thus constituting the physical basis of all plants and animals. (C v.6, 4799)

Although this definition would not have been written by Peirce himself, it would have been one familiar to him and representative of scientists’ understanding at the time. Indeed, in 1868 T. H. Huxley had popularized the idea of protoplasm in his controversial lecture, “On the Physical Basis of Life” (Huxley, 1968, 130–65).

The extreme complexity of the protoplasm molecule allowed Peirce to speculate about how to apply to it the principles of the kinetic theory of matter. Richard Tursman, in a brief footnote in a paper dealing with Peirce’s theory of mind, lays out in a clear way Peirce’s motivation and strategy for dealing with the molecular structure of protoplasm.[2] Tursman writes that

> Peirce held that thought was a non-conservative system (CP 7.501, 6.600) and that all such systems could be explained by the laws of chance (CP 6.73). The main such law is Bernoulli's law of large numbers which is given today as the first half of the central limit theorem. Peirce found the large numbers required for the law to apply to thought in the complexities of protoplasm (CP 7.503).[3]

The rest of this section will be devoted to filling in this brief outline. In doing so, we will be required to look at Peirce's opinions about the structure of molecules and atoms and about the physiology of the primitive slime molds and other amoeboid creatures.

The key reference paper on this topic is Peirce's fourth installment of his metaphysical series published in the *Monist* in 1892, the essay "Man's Glassy Essence" (6.238–71). In the second paragraph of that paper, Peirce states the need to look at the current understanding of the constitution of matter if we are to understand the mental aspects of the most rudimentary form of life, protoplasm. This may seem strange coming from an idealist, but it must be recalled from the last chapter that Peirce's approach to the mind is materialist at least in the sense that he identifies mental functions and states with neurophysiological events and conditions. His ultimate preference for idealism will not be compromised by this, because in the end matter will be cashed out as mind "hidebound" with habit. And so we find him writing that "all physicists are rightly agreed the evidence is overwhelming which shows all sensible matter is composed of molecules in swift motion and exerting enormous mutual attractions, and perhaps repulsions, too" (6.240). This is followed by a summary of the most important results of and evidence for the molecular theory, with specific mention made of the mechanical theory of heat, the principles of the doctrine of energy, and the kinetic theory of gases, liquids, and solids. Of crucial importance for Peirce's own interests here is the nature of the motions of molecules when aggregated in the different forms of matter (i.e., gas, liquid, solid). He states the evidence for the hypothesis that gas molecules move in rectilinear paths and then asserts that "liquids must clearly be bodies in which the molecules wander in curvilinear paths, while in solids they move in orbits or quasi-orbits" (6.241). On the question of atoms, Peirce was, throughout most of his career, fondest of the Boscovichian conception of atoms as immaterial point centers of force (6.82, 6.242, 7.483), only later following Kelvin in his vortex theory (8.60, 8.168). As Murray Murphey has noted, the Boscovichian theory of immaterial centers of force lent itself well to Peirce's idealism (Murphey, 390). Kelvin speculated that atoms were akin to swirling vortices in an underlying continuous ether medium (cf. Harman, 1993). This vortex theory was attractive to Peirce, Murphey suggests (390–91), because of its assumption of a continuous and universal medium (naturally congenial to the thesis of synechism). But I would add further that Peirce was likely to find Kelvin's theory attractive for the reason that vortices involve nonconservative forces of viscosity. Consequently, an explanation of why most processes are irreversible follows from the fundamental ontology more readily than from a corpuscularian theory. As for the nature of molecules, Peirce appears at the time of the "Man's Glassy Essence" article (1892) to have envisaged them on the model of tiny solar systems (6.283).

For reasons that should by now be obvious, Peirce was quite willing to see the methods of the kinetic theory of gases extended to the other forms of matter as well. In 1909, he would write:

> We find that the kinetical theory of gases, now extended to liquids and solids, has veritably transformed pure physics already, and, being nearly coëxtensive, as it is, with the physics of nonreversible actions, such as the diffusion of matter, the conduction of heat, and the action of viscosity and other varieties of friction, it seems not unlikely in the future still more fundamentally to revolutionize physics, until instead of such actions being regarded as exceptional, it may be that it will be the reversible processes such as motion under gravity, the action of the dynamo etc., which will in future appear so. Now this all important theory is the direct offspring of the calculus of probabilities. (NEM 3, i, 150)

This reflects his earlier conviction that the presence of probability and chance within physics would prove to be no temporary aberration. As early as 1883, he was willing to speculate that the scope of the statistical approach would only increase with time:

> Certain laws of nature, laws of Boyle and Charles, the Second law of thermodynamics, and some others are known to be results of chance,—

> statistical facts so to say. Molecules are so inconceivably numerous, their encounters so inconceivably frequent, that chance with them is omnipotent. I cannot help believing that more of the molecular laws—the principles of chemistry for example—will be found to involve the same element, especially as almost all these laws present the peculiarity of not being rigidly exact. (W4, 551)

It was the opinion of the majority of scientists, however, that chance and probability were only practical requirements, imposed on researchers because of the relatively gross size of our sensory organs in comparison with the size of molecules and atoms, not to mention the inconceivably large numbers of them involved.

But Peirce saw in the new statistical approach much richer potential—for instance, the potential to explain the existence of nature's laws and diversity. But that was not all. He also believed that from the assumption that there was absolute chance in the world, he could explain many of the significant properties of mind and life. And that no such explanation appeared possible on the alternative assumption of mechanism only recommended it to him that much more strongly.

> Protoplasm certainly does feel; and unless we are to accept a weak dualism, the property must be shown to arise from some peculiarity of the mechanical system. Yet the attempt to deduce it from the three laws of mechanics, applied to never so ingenious a mechanical contrivance, would obviously be futile. It can never be explained, unless we admit that physical events are but degraded or undeveloped forms of psychical events. (6.264)

(As an aside, it is interesting to note the extent to which Peirce resembles here the Schrödinger of the *What Is Life?* and the *Mind and Matter* lectures. In fact, both were concerned with the very same problem, and both approached it with the tools of statistical physics.[4] Ultimately, they appear to agree that some form of idealism is needed to resolve the problem of mind-matter interaction).

The ingenuity of Peirce's metaphysical theory of the universe consists of its attempt to cope with a wide variety of phenomena with such an economy of principles. Again, the three categories provide the key. "Chance is First, Law is Second, the tendency to take habits is Third. Mind is First, Matter is Second, Evolution is Third"

(6.32). The regulative principle of synechism states that discontinuities should not be introduced into phenomena where experience does not suggest they are necessary. For this reason, Peirce preferred the idealist hypothesis that the universe begins as a rudimentary form of mental substance and slowly evolves into matter under the influence of a "generalizing tendency." But where should we look to verify that any such tendency is in fact still active in nature? If matter is mind already dulled by habit, then there can be little use of looking for it there. So

> We must search for this generalizing tendency rather in such departments of nature where we find plasticity and evolution still at work. The most plastic of all things is the human mind, and next after that comes the organic world, the world of protoplasm. . . . We . . . find in all active protoplasm a tendency to take habits. (7.515)

Now, we have seen several times that Peirce drew a connection between the probability calculus and the processes of thought. In the 1883 "Design and Chance" lecture, he told his audience of Johns Hopkins colleagues that "I have several times shown to my classes how some of the main laws of cerebration and particularly the formation of habits could be accounted for by the principles of probability" (W4, 553). What remains to be seen is how he proposed to do this in a way that captures the goal-directed aspect of reasoning.

Protoplasm, Habit, and Nutrition

It will pay to give a brief recap here of the main features of mind and reason that Peirce is concerned with. To exhibit reason, we recall, is to follow a method or a rule. Our primitive or immature tendency to deal with a problem is to attack it randomly. The process of becoming rational is a process of establishing logical habits of conduct. In becoming habitually rational, we free our conscious attention from the labor of having to oversee remedial tasks. Finding the right habit to deal with a particular type of problem situation is a matter of coordinating our ideas and responses toward that problem type into a generalized idea. Such habituated ideas Peirce identifies with beliefs. Consciousness sinks in generalization because we no longer need to concentrate on the task at hand. In becoming rational, we become mechanical and efficient, so establishment of general ideas (beliefs) is the ultimate aim of thoughtful inquiry.

The immediate task at hand is to show that in fact protoplasm exhibits the more important features of mind. In "A Guess at the Riddle" (1887–88), Peirce noted that traditionally, three chief psychological faculties characteristic of mind have been identified: feeling, knowing, and willing. To develop this division in more depth, Peirce sought to trace these capacities back to more basic physiological properties. The corresponding properties within the nervous system he suggested are (1) excitation of nerve cells, (2) transfer of excitation over nerve fibers, and (3) the fixing of definite tendencies under the influence of habit. These are clearly meant to reflect the triad of categories. Recall that Peirce often explicated Firstness as feeling or quality, Secondness as action and reaction, and Thirdness as synthesis, continuity, growth, generality, or habit taking. With respect to protoplasm, we again spot these three features, now appearing as (1) the capacity for an active and a passive state (sensibility), (2) transferal of the active state from one part of the protoplasm to another (motion), and (3) growth. Growth occurs within protoplasm, Peirce conjectured, by the absorption of food material and its subsequent conversion into protoplasm material. It is with this stage of growth and nutrition that Peirce will identify the capacity for habit taking.

But before looking in detail at his explanation of the habit-taking capacity in protoplasm, we should first highlight that Peirce considered protoplasm in general to be a complex and unstable molecular system. For instance, its capacity for sensation, which is exhibited when it is pricked by an instrument,

> Is without any doubt dependent upon the extreme complexity of the protoplasmic molecule, if the word molecule can be applied to so intricate, unstable, and ununified a system. But it is the law of high numbers that extreme complication with a great multitude of independent similars results in a new simplicity. (1.351)[5]

His training in chemistry must have been an advantage to Peirce here, allowing him to recognize the wide gulf separating what was then understood of protoplasm from what was known of the most complex of the inorganic compounds. After mentioning that at least two chemical theories of protoplasm had been attempted, he wrote that "as for what a physicist would understand by a molecular explanation of protoplasm, such a thing seems hardly to have been thought of; yet I cannot see that it is any more difficult than the constitution of inorganic matter" (1.393). It is apparent that by applying the tools of the statistical approach in physics Peirce hoped to resolve the problems surrounding the orderly, complex, and nonreversible behavior of living, conscious organisms in a way similar to the successful explanation of other (inorganic) thermodynamic systems.

Because Peirce's doubt-belief theory of inquiry maintains that beliefs are just a special kind of habit, we should expect to find some connection between the establishment of habits and the formation of beliefs. And indeed we do, according to Peirce: "General conceptions arise upon the formation of habits in the nerve-matter, which are molecular changes consequent upon its activity and probably connected with its nutrition" (6.22). It is this last remark involving the role of nutrition that will hold the key to understanding Peirce's theory of how protoplasm is capable of taking on habits.

But what has nutrition got to do with the formation of habits at the molecular level of neurophysiology? Let us consider first Peirce's thoughts about how the nervous system functions:

> When a group of nerves are stimulated, it is certain that the ganglions with which the group is most intimately connected on the whole are thrown into an active state. This in its turn usually occasions movements of the body. Those movements are often intelligent; that is to say, what is to be accomplished determines what is done. Now, as all mechanical action is determined by the conditions at the instant, the question arises how is the tendency of nervous reactions towards ends to be accounted for. Suppose, then, that in the beginning, the reflex movements were not intelligent. In that case, the stimulation continuing, the irritation would spread from ganglion to ganglion, while increasing in intensity. Meantime, the ganglions first excited would begin to be fatigued, and their action would flag; and thus for a double reason the bodily activity would be of a changing kind. This would happen again and again, until at last some motion would remove the stimulus; and as soon as this was withdrawn, the excitement would quickly subside. (6.278)

Here we glimpse Peirce's doubt-belief theory of inquiry at the level of the nervous system. When stimulated by an irritating source of doubt, the system responds by attempting to fashion a coordinated response that shall remove the irritant. In the early stages, the responses may be entirely blind and at random, but eventually the nervous system will hit upon a sequence of reactions that removes the irritation. That response of coordinated ganglionic nervous signals which proves successful in this regard will become habitual if its repetition is called for often enough. With repeated stimulus, in other words, a "groove" becomes worn in a particular neurophysiological pathway. In becoming a habitual response to a certain type of stimulus or situation, it functions, on the cognitive level, as a belief.[6] (It is worth noting that there is a hint of Darwinian natural selection on random "trials" in Peirce's account.)

But what, we must ask, is happening at the molecular level throughout this process of groove-wearing?

> Such a molecule [that of protoplasm] must be excessively unstable; and I believe that in the excited condition a considerable percentage of the molecules of protoplasm are partially decomposed. The peripheral stimulus deranges one or more molecules (which must be imagined as something like little solar systems, only vastly more complex) and an errant fragment from one of these enters another such system and perturbs that. But after the stimulus is removed they gradually settle down again, some molecules being destroyed, but others being recomposed with groups of atoms coming from food, while still others take up fragments which had been thrown off from neighbouring molecules. I think it is pretty clear that the new portions thus taken in would be a very long time in acquiring the ideally stable places in the molecule; and until they did so they would be more likely to be thrown out than other portions of the same molecules; and so a new excitation would be likely to repeat approximately the phenomena of the previous one; and the spreading of the disturbance would be likely to take the same course as before. (6.283)

This is a remarkable application of celestial mechanics and perturbation theory to physiology. Here we also see Peirce applying the principles of the kinetic theory of matter. While these submolecular fragments are being thrown out of their regular orbits to wander about freely, the protoplasm enters into a liquid state. In this state, the material may be seen to move by the extension of pseudopods. Eventually there will occur an averaging of the kinetic energy of the particles and a cooling down of the protoplasmic material. When this happens, the protoplasm returns to its original solid state (6.257).

Up to this point, Peirce has only told us how a series of responses might get repeated when the protoplasm meets with the same stimulus again. What he has not yet shown is how the protoplasm "recalls" that this is the correct response to a particular stimulus, once a length of time has passed sufficient to allow the molecular systems to settle down into stable orbits. The problem is, in other words, how the protoplasm is capable of storing a "memory" of proper responses to particular stimuli, so that it can truly be said to perform a certain action *because* that is the response called for by that stimulus. I think there is a suitable response to this objection open to Peirce. It may be said that protoplasm is too primitive to be capable of any complicated form of memory. If, after the establishment of a habit, a period of time passes sufficient for the molecular systems to settle back down into stable orbits, then this will correspond to what Peirce described as fatigue. When a series of responses is not used for some time, the habit is lost. And if this is the case with complex creatures like ourselves, then it should be no surprise that it happens that much more readily in protoplasm. That having been said, we have yet to understand how protoplasm is capable of performing a specific action because that action was called for by the stimulus. We have yet to see, that is, how protoplasm is capable of *intelligent* action, as Peirce promised.[7] To get to this, we must look further at the process of nutrition.

While in the liquid state, and only then, according to Peirce, will the protoplasm be able to incorporate any available food particles that may be in solution. This will occur by diffusion, during which both the protoplasm and food molecules will be largely dissociated (6.258). Through the process of nutrition, the protoplasm is able to restore lost particles and deranged molecular structure resulting from perturbations. But for nutrition to occur—that is, for the food particle to be taken in as a part of an orbital system of the protoplasm's molecular structure—Peirce proposed that the food particle would have to be at the right place at the right time. Moreover, it will be those particles of a specific vis viva and subject to just the right force of attraction which will be drawn into a particular orbital system; for in doing so they will be replacing particles of a similar kind previously thrown out by a disturbance (1.394; 6.260).

It is in this way that Peirce supposes the protoplasmic material to be capable of *selecting* the right kind of particles for its nutritive needs and for being capable of establishing habits:

> Thus, when a partial liquefaction of the protoplasm takes place many times to about the same extent, it will, each time, be pretty nearly the same molecules that were last drawn in that are now thrown out. They will be thrown out, too, in about the same way, as to position, direction of motion, and velocity, in which they were drawn in; and this will be in about the same course that the ones last before them were thrown out. Not exactly, however; for the very cause of their being thrown off so easily is their not having fulfilled precisely the conditions of stable retention. Thus, the law of habit is accounted for, and with it its peculiar characteristic of not acting with exactitude. (6.260)

This is meant to show that when reparation of molecules is to begin, not just any particles will do. But it is a bit quick yet for Peirce to be declaring that the law of habit has been accounted for. Even if he has successfully shown that protoplasm is capable of performing some form of selective operation on types of particles, the connection between this and the selection of types of response activities is still missing. Why, that is, should the requirement that the particles present themselves under conditions similar to those under which the molecules were deranged lead to the repetition of past behavior at the level of the organism as a whole?

Nutrition is crucial, obviously, for the maintenance of any living organism. It is through nutrition that a living system far from equilibrium resists the attractive pull toward the ultimate state of thermal and biological death.[8] Nutrition restores the damage done by exertion and exercise. And it is on account of this close relationship between waste and nutrition that Peirce locates there the capacity for habit taking:

> Habits appear to be formed in the human organism as a part of the process of nutrition. We are continually being "born again" by nutrition, and in being "born again" we are born into a second nature. Nutrition itself probably takes place only when waste takes place in the

> course of exercise; and that is why it is that the second nature which we acquire in nutrition is a natural tendency to act as we have acted before, as we were acting in the exercise which made the waste that nutrition repairs. In this way habits are formed by exercise. (NEM IV, 142)

(As we shall soon see, Peirce made this relation between exercise and habit a fundamental element of his Lamarckian-inspired theory of evolution). But let us try again to understand this relation between waste and habit.

In our endeavors to achieve some goal, we will inevitably deplete our resources of some important chemical substance—call it *X*. Our body makes us aware of this deficiency in the supply of *X* by causing us to experience the sensation of hunger, thirst, or fatigue. Our natural response to this irritating sensation is to seek out a source of *X* or some suitable alternative. What is strange in Peirce's hypothesis is that our need to replenish our store of *X* is supposed to require us to act as we have in the past, particularly in a way similar to how we were acting when we used up our supply of *X*. For according to his molecular theory of protoplasm, the repair of deranged molecules will be successful only if the right food particles are presented under the right conditions. And those conditions are, he proposes, precisely the conditions under which the molecules themselves were first deranged. But, to repeat, the crucial problem is in finding a suitable mapping from conditions at the molecular level (involving kinetic energy, position, forces of attraction, etc.) and conditions at the molar (multimolecular) level involving bodily activity, such that bringing about the same molecular conditions will result in the repetition of the same bodily activities. The difficulty may become more explicit if we consider the following example: If I expend energy performing jumping jacks, I will have to replenish my energy by consuming food. But when I eat the food, I do not have to do jumping jacks again to bring about the right conditions for the food particles to be assimilated into the molecular structure of my body; in fact, that would obviously be counterproductive, for I would thereby be expending just as much energy again. But neither does the process of nutrition *cause* me to act in a way similar to my past actions, for it is not the case that while nutrition is going on I am somehow compelled to perform jumping jacks again.

Hence, the crucial link between the molecular conditions and molar activity does not obtain; there is no suitable mapping between the two. And for this reason, Peirce's molecular theory of habit falls short of the mark.

Why might he have thought that his molecular theory of habit was adequate to the task? That is, why might he have thought that he had found an adequate mapping from the molecular level to the level of physical behavior? Given that Peirce was thinking in terms of the kinetic theory of gases, he may have been implicitly supposing that the relevant macroscopic "states" of organic matter were supervenient on the underlying microscopic states. For example, each time an isolated gas system assumes a particular microscopic condition of such and such a mean kinetic energy, the macrosystem will exhibit a specific measurable temperature. Similar illustrations could be given using such state properties as pressure and volume. Peirce may have been led by this to suppose—subconsciously and mistakenly—that large-scale physical behavior is analogously supervenient on the underlying molecular conditions. Although merely conjectural, this explanation certainly has some degree of plausibility to recommend it.

Ultimately, then, Peirce has not yet successfully shown how habits in large-scale behavior arise at the molecular level. But at this point, it may be more helpful to remind ourselves why Peirce would have wanted to show this in the first place. Think back for a moment to the topic of the last chapter, irreversibility in psychics. There we saw Peirce concerned with the two fundamental types of action: "conservative" and "causational." As we would expect, protoplasm according to Peirce follows the formula of (irreversible) causational action. It is worth reminding ourselves once more why that is:

> There can hardly be a doubt that the peculiar properties of protoplasm depend upon the enormous complexity of its molecules, and upon those molecules being frequently broken up and reunited in new connections, and upon the circumstance that in the quiescent state the molecules are in stationary motion, while in the active state they are partly broken up and the fragments are wandering. *Now all this may be summarized by saying that its properties depend upon Bernoulli's law of high numbers, and every action depending upon that law is, so far as it is so dependent, purely causational and not conservative.* (RLT, 237; italics mine)

This solution to the problem of how primitive life forms are capable of teleological activity involves nothing more than an appeal to the "blind" tendency of stochastic systems to drift away from positions of nonequilibrium back to an equilibrium or mean value. Although he has suggested a link between the "irreversibility" of blind random walks and the irreversibility of conscious teleological behavior, Peirce has still not come up with an adequate account of how the latter can arise from the former, for the statistical averaging effect implicit in the law of large numbers does not *choose* to converge to a particular end state or value because it *desires* that particular state. The task Peirce had to accomplish was to show how living systems are capable of selecting and pursuing particular ends *for the sake of* those particular ends. The ends must be sought after because they hold an attraction for the mind, and not just a blind attraction of the kind we see in state space diagrams in which the trajectories of systems are traced; the mind must *strive* to achieve these particular end states, not just find itself pulled toward them. At most the irreversibility of stochastic systems might be a necessary condition for purposeful goal-pursuing behavior, but it can hardly be considered sufficient. It is precisely for this reason, I believe, that we see Peirce in these discussions of nutrition desperately attempting to sneak in some semblance of the selection of particles *because* of their possessing specific mechanical properties of vis viva and so on.

Now, Peirce did sketch out some speculations in the direction of supplying the missing link between the molecular and behavioral levels. Of his molecular theory of protoplasm he wrote:

> If this theory be true, different modes of spreading might differ greatly in regard to the amount of nutrition that would accompany them; and since the recomposed molecules would be the ones most likely to be deranged, those habits would be most likely to be formed which would result in the greatest nutritive gain. Thus, the animal would appear to exhibit a preference for modes of action involving the formation of new molecules of protoplasm. (6.284)

So far there is little new here apart from the proposal that certain types of habits would be selected for as a consequence of their securing greater nutritive dividends. But in the next line, Peirce proposes a striking mechanism for teleological activity:

> Were there a feeling of pain at every breaking of a molecule, and a pleasure at every recomposition of such a system, the animal would have a preference for pleasurable actions, and it would seem to him as if this pleasure, or the anticipation of it, were the cause of his acting in one way rather than in another. (ibid.)

Could this provide Peirce with the missing link necessary to explain why, on account of the process of nutrition, we are impelled to act as we have before? Whether it could hold up to real scrutiny or not, it seems a moot point, for Peirce himself was dissatisfied with it. His objection is based on the grounds that it requires of us to suppose blind matter capable of feeling and sensation (6.285). I must confess myself that this supposition hardly seems any less difficult to swallow than that all matter is really just mind grown regular under the influence of a primordial law of habit taking. In any case, Peirce does not attempt any further development of this proposal. Perhaps he had further reason to abandon it because the hedonistic pursuit of pleasure did not jibe well with the much more normative and aesthetically charged direction that his cosmical eschatology was beginning to take.

So while it must be admitted that his proposal is ultimately unsuccessful, it must also be conceded that it is an ingenious attempt to explain a very complex phenomenon with a minimal amount of conceptual equipment. We should not be too surprised, perhaps, that Peirce's theory is not entirely convincing, for he was attempting to solve a tremendously complex puzzle that to this day remains little understood. A question more to the point would ask whether Peirce accomplished what he had specifically set out to do. Let us be clear, then, about what the point of the molecular theory of protoplasm was. The opening paragraph of "Man's Glassy Essence" informs us that its purpose is "to elucidate, from the point of view chosen, the relation between the psychical and physical aspects of a substance" (6.238).[9] The "brick and mortar" of the point of view in question are the ideas of absolute chance, continuity, and the law of mind. By the end of the paper, Peirce would add another instrument to his tool box, this one being the thesis of objective idealism. But before arriving at the conclusion that a thesis of objective idealism was necessary to account for the facts (sensation, to be specific), Peirce stopped to consider another question.

Given that he had just laid out a purely mechanical theory of the habit-taking qualities of protoplasm, he noted that “it may fairly be urged that since the phenomena of habit may thus result from a purely mechanical arrangement, it is unnecessary to suppose that habit-taking is a primordial principle of the universe” (6.262). Of course he rejects this proposal, for reasons we will consider shortly, but the important clue to be drawn from this passage is that Peirce did not intend his molecular theory of protoplasm to be a complete explanation of how the human mind, in all of its complexity, is capable of goal-directed behavior. Rather, his objective was to identify some semblance of the primordial habit-taking tendency, and so of teleology, at a rudimentary level of nature. Recall that it was precisely because the activity of matter is already so hidebound with habit and regularity that Peirce turned to the more plastic activity of mind and protoplasm in the first place. Here there remains an element of spontaneity and chance. A full explanation of the human mind and its rich array of teleological behavior would require a more complex story, for what makes an individual mind special, Peirce wrote, is that it portrays a *developmental* teleology (6.156). A developmental teleology is one in which the goals pursued may themselves evolve and develop over time; it is this feature, this complicated coordination of ideas, that makes up a personality, for “were the ends of a person already explicit, there would be no room for development, for growth, for life; and consequently there would be no personality. The mere carrying out of predetermined purposes is mechanical” (6.157).

In light of this, it should now become evident why it would be off the mark to object that Peirce has failed because he has not shown that systems of all kinds converge toward points of attraction because they *desire* to do so. It was his objective to show not that all systems exhibit the developmental teleology possessed by conscious organisms but merely that a tendency toward ends is much more common among physical systems than is reversible or cyclical behavior. What he wished to make explicit to his peers, especially those advocating the mechanical philosophy, was that final causation, properly understood, was much more prevalent than in just the human sphere alone. To do this, he had to exorcise people of their prejudicial identification of final causes with purposes. “A purpose is merely that form of final cause which is most familiar to our experience" (1.211). Once he had made plausible the claim that final causation is all around us, the next step was to show how it could be explained via the law of habit taking. To the objection that the mechanical theory of protoplasm obviates the need for positing a primordial law of habit, Peirce responded that even if habit can be explained completely in mechanical terms, still there is at least one phenomenon that resists any such treatment.[10] That there should ever have come about such a massive aggregation of trillions of molecules as we see in the world about us can never, he insists, be explained as solely the result of conservative forces.

Why is this, exactly? Earlier (6.262) he had claimed that conservative forces cannot leave an object in a state of stable equilibrium, for when an object reaches a position of stable equilibrium, he writes, its momentum will be at a maximum, and it would constitute a violation of the law of energy for conservative forces to leave an object at rest in such a state. This would appear to be untrue in general. But we can understand better what he has in mind here, I would suggest, if we think of a pendulum swinging *in vacuo* (such an example would be natural for someone who swung pendulums for a living). As it passes through the lowest point in its path, which point corresponds to the point of stable equilibrium, the bob will be moving with its greatest kinetic energy. Without the resisting forces of air friction and other nonconservative forces, the pendulum will not come to rest at its stable equilibrium point but will continue to oscillate back and forth indefinitely. So if matter does tend to aggregate into systems in stable equilibrium, this cannot be explained in terms of conservative forces alone.

We are now in a better position to make sense of Peirce's objection. How are we to explain the peculiar aggregation of molecules that makes possible the world as we know it? First, we must note that physics does not attempt to give any explanation for the initial conditions of the systems it considers, and consequently neither can the philosophy of mechanism. Both must simply take the initial conditions (e.g., the concentration of matter into galactic clusters, solar systems, planets, and terrestrial objects) as given and quite arbitrary.[11] Epicurus at least attempted to explain why there should be a clumping together of atoms so as to form a world, using his hypothesis of the spontaneous swerving of atoms in the void (the *clinamen*). If the dynamical account of irreversible physical processes is to get off the ground at all, a couple of assumptions about the initial setup of the universe must be made. First, it must be assumed that there exists a multitude of similar particles, similar in respect of having equal masses and exhibiting identical behavior under the influence of particular forces (we will consider this assumption presently). Second, it must be assumed that the molecular energies (of the system under consideration) have not yet attained a normal or Maxwellian distribution—for if the system is already at equilibrium, one may have to wait many lifetimes of the universe (depending on the number of particles involved) for any noticeable chance departure from equilibrium to occur at all.

Hence it is with these initial conditions in mind that Peirce wrote that

> One fact remains unexplained mechanically, which concerns not only the facts of habit, but all cases of actions apparently violating the law of energy; it is that all these phenomena depend upon aggregations of trillions of molecules in one and the same condition and neighborhood; and it is by no means clear how they could have all been brought and left in the same place and state by any conservative forces. But let the mechanical explanation be as perfect as it may, the state of things which it supposes presents evidence of a primordial habit-taking tendency. For it shows us like things acting in like ways because they are alike. (6.262)

I believe that Peirce is asking, first, the Epicurean question “How did all the molecules and atoms come together to form a world?” And second, he is raising, in the last sentence, a distinct question about the properties of atoms and molecules. With respect to this second question, in what way does the (statistical) mechanical account rely on the assumption of “like things acting in like ways because they are alike”? Peirce is referring here to the fact that the atoms or molecules in question must be supposed to have similar mechanical properties. This is especially true of the early kinetic theory of Clausius, Maxwell, and Boltzmann, in which the gas models employed are of ideal and homogenous (either all monatomic or all diatomic) gases. It is also quite likely though that Peirce has in mind Maxwell’s *Encyclopaedia Britannica* (ninth edition, 1875) article on atoms. There we find Maxwell writing that

> A theory of evolution . . . cannot be applied to the case of molecules, for the individual molecules neither are born nor die, they have neither parents nor offspring, and so far from being modified by their environment, we find that two molecules of the same kind, say of hydrogen, have the same properties, though one has been compounded with carbon and buried in the earth as coal for untold ages, while the other has been "occluded" in the iron of a meteorite, and after unknown wanderings in the heavens has at last fallen into the hands of some terrestrial chemist.[12]

Maxwell's argument against an evolutionary account of atoms and molecules relies on the lack of any discernible variety among atoms and molecules of the same chemical element. Darwin and Wallace's theory of evolution by natural selection relies on the existence of variation (heritable and adaptive) among individuals of a species for the natural environment to select from. Without any such variation among the individual particles of the different chemical "species," Maxwell correctly pointed out, a Darwinian evolutionary explanation for the existence of these different chemical species cannot get off the ground. Yet Peirce did hope to supply an evolutionary explanation of molecules and their attractive influence on one another. It is, however, a Lamarckian kind of evolutionary mechanism, not a Darwinian one, and so is not subject to Maxwell's quite excellent objection. In unpublished manuscript notes, one sees that Peirce spent considerable effort in trying to work out how the preponderance of attractive forces in nature could have arisen from the primordial law of habit. For instance:

> Now it is clear that the tendency to generalization being a tendency to bring about repetition of similar events, in general, will tend to bring about stationary motion [i.e., motion such that of a system of bodies, none is carried to an indefinite distance nor acquires an indefinitely great velocity.] Hence, it will not permit bodies to repel one another, in general and on the whole, and since its ultimate effect is to render forces alike, it will ultimately destroy repulsive forces. The principal forces therefore developed under the tendency to generalization will be attractions. (MS, 965, 30–31)

It is not entirely clear why he claims that the tendency toward generalization will result in attractive rather than repulsive forces.

Perhaps what he has in mind is that a preponderance of repulsive forces would result not in a coherent system or world but in a disaggregated bunch of atoms spread uniformly throughout space. The law of generalization, it would seem, is supposed to act in a way analogous to Newton's force of universal gravitation.

But though we may grant that the law of habit or generalization will work toward the establishment of attractive laws, this in no way explains how the various chemical elements became segregated into their respective "species." Peirce does not, to my knowledge, ever deal with the question of material evolution to this level of detail.

Although this part of the argument is unclear, it is clear that Peirce, unlike the mechanists, was not content to accept the initial conditions of the universe, as we find it, as brute facts.[13] And consistent with his general cosmogonical strategy, his attempt to account for these initial conditions involved his law of habit taking. What Peirce saw to be lacking in all the discussions by contemporary physicists was any means for accounting for the presence of *novelty*, of the emergence of new forms—in a word, of *evolution*.[14] All the physicists' models of dynamic change supposed a fixed number of elements (atoms, molecules) and their properties—the novelty they allowed for was purely *combinatorial*. Peirce wanted to work genuine novelty into the picture—a novelty that was *qualitatively* new, not just combinatorial.

In other words, Peirce wished to *Darwinize* physics—to biologize it, to challenge the dogma of the fixity of atomic and molecular "species." To do so, he had to bring in the activity of some spontaneous force—"sports"—the truly fresh, new, and unprecedented. This represented the importance of Darwinian biology for the topics of physics, chemistry, and science in general. The law of generalization, of habit taking, incorporates both the agency of chance and the directedness of teleological development. We saw above Maxwell's resistance to the idea of evolution being applied to the chemical elements. Maxwell had objected:

> I do not think, however, that the perfect identity which we observe between different portions of the same kind of matter can be explained on the statistical principle of the stability of the averages of large numbers of quantities each of which may differ from the mean. . . . We must

> admit that the equality which we assert to exist between the molecules of hydrogen applies to each individual molecule, and not merely to the average of groups of millions of molecules. (Maxwell 1888, 329)

Peirce's response, we can easily imagine, would be that experience can never provide us with grounds for an absolute certainty of an absolute identity of all molecules. Nor did he agree with Maxwell, who agreed with Sir John Herschel, that atoms and molecules are best considered as the "manufactured articles" of a divine creator (Maxwell 1986, 153, 214–15). Eventually Sir Norman Lockyer (1836–1920), in his book *Inorganic Evolution* (1900), gave an explanation of the formation of chemical elements in the interiors of stars by employing an analogy of organic evolution. Lockyer was preceded in this direction by the physicist Sir William Crookes (1832–1919), who raised the issue of elemental evolution in his 1886 presidential address to the chemistry section of the meeting of the British Association for the Advancement of Science.[15]

Before leaving this section, I want to say one last thing about the relation between nutrition and the aggregation of molecules into cohesive systems. Nutrition, as we have seen, is important for growth. Growth is a form of aggregation of matter. But as Peirce pointed out, living systems achieve growth in a special way:

> Crystals also grow; their growth, however, consists merely in attracting matter like their own from the circumambient fluid. To suppose the growth of protoplasm of the same nature would be to suppose this substance to be spontaneously generated in copious supplies wherever food is in solution. . . . It is more consonant with the facts of observation to suppose that assimilated protoplasm is formed at the instant of assimilation, under the influence of the protoplasm already present. (6.250)[16]

The important feature of protoplasmic growth, then, is that it "grows by chemically transforming other substances into its own chemical kind" (6.283). This, as it turns out, is a nice bit of foreshadowing, for as the next section will show, this process of taking in a foreign substance and incorporating it into a larger system is an important theme in Peirce's evolutionary philosophy of agapasm.[17] But this is also the way that an individual mind grows and develops. As the feelings that are associated with ideas spread, they may become generalized and coordinated with one another in accordance with a plan for the attainment of some desired outcome. This type of development is analogous to that followed by protoplasm. And like protoplasm, the development does not consist merely in the accretion of external matter to some internal core. Rather, the process involves the transformation of external substance—in this case, ideas—so as to become adapted to the purpose sought after by the mind. The Lamarckian theme here is quite conspicuous.

Evolution

The Influence of Darwin

Even though he did not agree entirely with Darwin's theory, Peirce was very much impressed with it, enough so, in fact, to say of his own system of philosophy that "indeed, my opinion is only Darwinism analyzed, generalized, and brought into the realm of Ontology" (W5, 552). Why should Peirce be so fond of this particular theory of evolution? Why speak so highly of it when ultimately he preferred a theory more reminiscent of Lamarck's? The element of Lamarck's theory that was attractive to Peirce has already been briefly mentioned. But what was special about Darwin's theory was its association with a certain statistical principle:

> In biology, that tremendous upheaval caused in 1860 by Darwin's theory of fortuitous variations was but the consequence of a theorem in probabilities, namely, the theorem that very many similar things constituting one class are subject to very many slight fortuitous variations, as much in one direction as in the opposite direction, which when they aggregate a sufficient effect upon any one of those things in one direction must eliminate it from nature, while there is no corresponding effect of an aggregation of variations in the other direction, the result must, in the long run, be to produce a change of the average characters of that class of things in the latter direction. (NEM III, i, 150–51)[18]

This passage is significant for a number of reasons. First, we see here that some of the irreversible phenomena Peirce had in mind do not involve the nonreversible motion of tangible objects, such as projectiles being fired from the mouths of cannons, but that he was also thinking about changes in character of things, these changes being "observable" only over long periods of time or by mapping the variation within some sort of abstract geometric space.

The passage also shows that Peirce realized that the type of irreversibility attained by stochastic systems requires an extra element, either in the form of a constraint or of peculiar initial conditions.[19] In the above passage, what Peirce is describing is a system performing a random walk in one dimension with an absorbing barrier at one end. Once that particular end state has been reached, there is no leaving from it (the point representing the system's motion is "absorbed" by the wall or barrier). The organism or species will then be annihilated.

But the real significance of this passage is that it indicates a failure on Peirce's part to recognize the importance assigned by Darwin's theory to the selective pressures imposed on an organism by the environment in which it is located. The only mechanism of "selection" mentioned in Peirce's expression of Darwinian evolution is internal to the organisms. Cumulative variations in one "direction" are said to lead to death of the organism, while the accumulation of variations in the "opposite" direction does not result in any detrimental effect. Peirce was so impressed with the statistical aspect of Darwin's theory that he failed to recognize the crucial role assigned by it to the nonrandom influence of selection. This influence expresses itself in terms of the differential reproductive success of those organisms having adaptive traits. Failure to appreciate this important feature of Darwin's theory is to leave out one of its most distinctive elements: the mechanism of natural selection.

In his book *Full House*,[20] Stephen J. Gould gives an illustration of a similar random process as one more episode in his long-standing critique of the idea of evolutionary "progress." Gould uses the example of a "drunkard's walk," in which an inebriate starting from a pub wall embarks on a journey, each step of which is taken at random, staggering to and fro (in one dimension) until the drunkard eventually winds up in the gutter. For Gould, the point of this example is to illustrate that although natural selection may work to make organisms better adapted to their local environments, there is no progress in the sense of movement toward an ultimate and predetermined point transcending all environments, such as increased complexity. A macroevolutionary pattern of increasing complexity, for example, may well be due to such a random walk (on the part of organismal morphology) against a wall of minimal complexity (living organisms can be only so simple, but there appears to be no constraints on how complex they may be). For Peirce, the example of a random walk apparently serves as an illustration of what he took to be the purely random nature of Darwinian natural selection. But this is a confusion on Peirce's part, for Darwinian natural selection does not function in any such random fashion. Individuals with adaptive traits, relative to the local environment within which they find themselves, are said to be a better "fit" to that environment and are more likely to enjoy a greater reproductive success than those individuals lacking the adaptive trait. The only sense in which Darwin posited an element of chance or randomness to be at work in his theory of "descent with modification" was that the *occurrence* of a particular variation was supposed to be completely independent of whether it would be adaptive. Variation, in other words, is not "aiming" at any specific result.

In failing to recognize the proper respects in which Darwinian selection is not random, Peirce exaggerated the extent to which it is. There is small wonder, then, that he ultimately rejected the "Darwinian" theory for his neo-Lamarckian account. He could not take Darwin's theory seriously as an adequate account of the development of species, let alone mind and the universe, because of his mistaken belief that according to that theory, progress is really nothing more than a chance-driven random walk.[21]

Evolution was an extremely popular and controversial topic throughout the nineteenth century. Even before Darwin's *Origin of Species* appeared in 1859, the English philosopher Herbert Spencer was promoting an evolutionary philosophy of the physical and social universe at large.[22] According to Peirce, "evolution means nothing but *growth* in the widest sense of that word" (1.174). And what do we mean by *growth*? "Spencer says it is the passage from the homogeneous to the heterogeneous—or, if we prefer English to Spencerese—diversification" (ibid.).[23] As may be expected, Peirce's understanding of evolution was unapologetically teleological: ". . . evolution is nothing more than the working out of a definite end" (1.204). The end toward which evolution tends is a composite process of diversification and subsequent generalization or adaptation. This process of adaptation or generalization appeared within Chapter Three as the mind's propensity for systematization. Restricting the notion to biology, evolution meant, for Peirce, as it did for Darwin and Wallace, the adaptation of organisms to their environment. The peculiar element of Darwin's theory that Peirce found so commendable was, of course, its implicit reliance on statistics and the doctrine of chances:

> The Darwinian controversy is, in large part, a question of logic. Mr. Darwin proposed to apply the statistical method to biology. The same thing had been done in a widely different branch of science, the theory of gases. . . . Darwin, while unable to say what the operation of variation and natural selection in any individual case will be, demonstrates that in the long run they will adapt animals to their circumstances. (5.364)

Given his tendency for generalizing fruitful results into broader principles (a tendency that is recognizably enshrined in his thesis of synechism), Peirce drew from this construal of Darwin a general principle of generic evolution:

> This Darwinian principle is plainly capable of great generalization. Wherever there are large numbers of objects having a tendency to retain certain characters unaltered, however, not being absolute but giving room for chance variations . . . there will be a gradual tendency to change in directions of departure from them. (6.15)

Peirce set out to illustrate this generalized notion of evolution with the example of a gambling casino (what statisticians today call a Monte Carlo model). Peirce describes a large number of gamblers, each starting with equivalent cash sums, placing bets on the outcomes of a fair gambling scenario (an odd or even outcome of the rolling of a die). Players losing their last dollar are removed from the game. Using the mathematical theory of probability to predict the effects of repeated bets on the players' fortunes, Peirce notes that both the reduction in the number of gamblers after each play, and the increase in fortunes of those remaining, will roughly follow a precise law of probability. And in this way, he says, it can be seen that the effect of chance is to increase the "adaptiveness" of those players remaining (1.395–99).[24]

This generalization of Peirce's has met with much criticism and disbelief.[25] One of the most serious flaws in the gambling analogy

Peirce describes is that it includes no proper analogue of fitness or adaptation. Wealth, which he assumes to have the appropriate features, is in fact a conserved quantity in his scenario; it is not increased, contrary to adaptiveness in Darwin's theory, but is merely redistributed among an ever-diminishing number of players. Nor does the example provide any noncircular definition of fitness. The "fittest" individuals (i.e., the wealthiest) can be identified only by virtue of their having survived the last chance event. No player becomes richer because he or she is a better (i.e., fitter) gambler. Chance decides the whole issue. It is a mere matter of chance which players get lucky on each bet. But in the biological scenario, it is the organisms that possess traits conferring an advantage within that specific environmental context that tend to flourish over their competitors.

That Peirce was unconvinced of the sufficiency of natural selection as a mechanism to explain the phenomenon of evolution is not surprising. For as Bowler (1983) describes so well, Darwin's theory of natural selection was eclipsed in the latter part of the nineteenth century by the greater popularity of neo-Lamarckian mechanisms. In fact, one can easily see by reading through the sixth edition of the *Origin of Species* just how much Darwin himself had come to doubt its sufficiency. But of course Peirce was not interested in a narrowly biological notion of evolution. He was out to bag much bigger and more exotic game (the evolution of mind, matter, and the laws of nature). Compound this with the fact that his interpretation of Darwin's theory emphasizes (perhaps overly much) its reliance on ideas of statistics and probability, and it becomes even less surprising that Peirce felt the need for a more reliably teleological mechanism. Peirce showed very little interest, in fact, in the specific problems of organic evolution or biology. What interested him in Darwin's theory was its concern with development and change, and so its applicability to the problem of cosmology, and especially its employment of statistical thinking. As applied to the big question of cosmic evolution, it provided Peirce with an alternative to Herbert Spencer's mechanistic model that was more compatible with his own indeterministic (i.e., tychistic) sympathies.

But if Peirce's proposed explanation of the universe appears highly speculative, let us consider the alternatives being proffered at the time. Spencer's evolutionary philosophy was arguably the most popular and influential account during the nineteenth century. Peirce disapproved of Spencer's purported explanation of evolution by deduction from the "law of the persistence of force" (the conservation of energy principle). This approach is clearly too mechanistic to win Peirce's approval, for as we have had occasion to see over and over again, the greatest difficulty that Peirce identified in this entire area was the explanation of nonreversible behavior from reversible mechanical law.[26] But the inadequacy of Spencer's approach was only one instance of what Peirce saw to be a larger deficiency of the popular mechanistic philosophy as a whole. One of the chief virtues of Darwin's theory, in his opinion, was the positive influence it had on the scientific and philosophical communities' conception of the universe at large.

> It would seem . . . that through biological studies science may be led to modify the existing mechanical theory of the universe, which is not at all requisite to its progress, but is merely the coloring which scientific thought acquired during the period beginning with Galileo and ending with Helmholtz's great dynamical memoir, when mechanics and allied branches of physics were the chief subjects of thought, and which in the new period that opened with Darwin is already beginning to be corrected. Many biologists are pleading to-day for the admission of genuine spontaneity. (N1, 176)

Because of the blatant lack of fit between the principle of energy conservation (and its implication of reversibility) and the ubiquitous irreversibility of everything from physical motions to the teleological activity of the mind, Peirce referred to the widespread and unqualified acceptance of the energy principle as the "pet *petitio principii* of our time" (N2, 70). Proposals to integrate the phenomena of life with the doctrine of energy he found no less puzzling. For instance, of the suggestion that life is a special kind of energy, he wrote that it is "a doctrine whose attractiveness is inversely as one's knowledge of dynamics" (N1, 89).

Peirce especially commended the Darwinian theory for its use of statistical principles because in doing so, it brought the study of organic phenomena, which is distinctly marked by its irreversible nature, in line with cutting-edge research into irreversible physical phenomena:

> Besides, the law of *vis viva* is plainly violated in the phenomena of growth, since this is not a reversible process. To explain such actions . . . physicists resort to the consideration of the chance encounters between trillions of molecules, and it is an admirable scientific feature of the Darwinian hypothesis that, in order to account for a similar irreversible operation, that of growth, it equally resorts to the doctrine of chances in its fortuitous variations. (N2, 113)

Peirce had conjectured, on first reading the *Origin*, that Darwin had been influenced by economists Malthus and Ricardo and their work on the competition for limited resources within populations (7.66). This point is also raised in an essay entitled "Why should the Doctrine of Chances raise Science to a higher Plane?" (NEM, III, i, 150–58), in which he muses on the reason for the great success reaped from applying probability and statistics to scientific inquiry. His suggestion bears out his commitment to a realism about objective chance; the application of probability to nature works so well, he writes, because of the fact that "that concept which man had evolved from games of his own invention,—the concept of probability,—was already embodied in God's material creation" (ibid., 155).

Perhaps a word should be said here concerning the apparent tension between the second law of thermodynamics and the process of evolution. During the 1870s, Boltzmann gave a definition of the entropy function in terms of the relative probability of the state of a system. Entropy, S, is defined as being equal to the (natural) logarithm of the probability of the macroscopic state of a system, $S = k \log W$, where k is a constant, named after Boltzmann, and W is a measure of the relative frequency of a particular macroscopic configuration of a system's molecular energies, and so forth, with respect to all possible microscopic configurations. The entropy of a system at thermal equilibrium hereby turns out to be the most probable one in the sense that the greatest proportion of possible microconfigurations (of molecular energies within phase space) correspond to that particular macroscopic state. By dividing up the continuous phase space into discrete cells so as to represent the possible configurations from which a value for W is calculated, one can see that a condition of high entropy is one in which the representative points within phase space are scattered in a disorderly way among the cells. Conversely, a state of low entropy, being one from which a correspondingly greater amount of free energy may be drawn, will have its representative points concentrated in relatively few of the available cells (or degrees of freedom). Hence, the notion of order associated with a state of low entropy is not to be confused with considerations of visual spatial symmetry but with concentration or confinement to a relatively small number of the available cells or degrees of freedom. It eventually became standard to say that the content of the second law of thermodynamics is that systems naturally tend to drift toward states of greater probability. People began to worry about how this reflected on the process of biological evolution in which the trend appears to be toward ever more orderly arrangements.[27] However, this aspect of Boltzmann's work did not become immediately well known, and even among the select few physicists who paid it any attention, the nature of the link between probability and disorder was not immediately made perspicuous.[28] It may be for this reason that Peirce did not himself worry about the supposed tension between the two trends. In fact, any expression of the second law given by Peirce (that I have seen) is always in terms of the dissipation of energy; never is any mention made of disorder or its increase.[29] The only actual discussion of the term *entropy* that I have been able to find by Peirce is also in terms of the availability of energy; again, no mention is made of the notions of order, disorder, or randomness.[30]

In his time, there were some speculations that living organisms must violate somehow the second law of thermodynamics, not because they constitute more "orderly" or complex systems but because they appear capable of deriving more work from their environments than seems possible by considerations of the second law. For instance, in 1894 Peirce reviewed a book by early aeronautics pioneer Simon Langley entitled *Internal Work of the Wind* (N2, 33), in which the author maintained that the ability of birds to fly upon the air is the result of their taking advantage of differential distributions of heat through selectively inclining their wings at the appropriate moments. Peirce agreed with Langley that this ability to transfer momentum from thermal currents (consisting of largely "random" or dissipated molecular energy) to their own bodies *appears* to be a violation of the second law. But later that same year

Peirce reviewed another book, this one by an engineer by the name of Robert Henry Thurston (N2, 64), in which it was claimed that all living organisms constitute continual violations of the second law. In this review, it becomes clear that Peirce preferred to explain certain experimental results conducted on animal respiration (research now known as "energetics") as evidence that the first law of thermodynamics—the conservation of energy principle—fails to apply to living things. It is worth noting here that Peirce would rather suspend faith in the theoretical law of energy conservation than in the phenomenological Law of Carnot, which states simply that "heat flows from hot bodies to cold, as water runs downhill." The Law of Carnot is, obviously, a variant of the second law of thermodynamics. But it is also apparent from this particular review that Peirce considered the statistical mechanical expression of the second law of thermodynamics as the relevant physical principle, rather than the statement in terms of Carnot's law. Does this mean, then, that the second law has some kind of fundamental priority over the first law or principle of energy conservation in his estimation? If so, I would argue, its priority does not derive from his attaching to it any a priori fundamental status. Rather, as an expression of the second law provided by Peirce in 1905 shows, its priority derives from its statistical nature: "This law, as Maxwell first showed and as is now universally acknowledged, merely provides that nothing shall interfere with certain chance distributions . . ." (N3, 200). Peirce supposed, therefore, that living organisms do not fall under the purview of the conservation of energy principle, at least not entirely. But then it remains somewhat curious that he still insisted that an understanding of them in physical terms required applying to them the second law of thermodynamics, along with its statistical interpretation. For if the law of energy conservation does not strictly apply to them, then the problem of reversibility does not arise and there is no need to get around that apparent tension by invoking the statistical interpretation of the second law. Perhaps he was unwilling to push the thesis that living organisms are excluded from the conservation of energy principle, because to do so would be to suggest the need for vitalistic assumptions and to place biology outside the reaches of physical science altogether. The most likely explanation is that Peirce was suspending judgment on whether and to what degree the energy conservation principle applied to life until better experimental results could be attained. This reading best fits his generally cautious attitude toward experimental results. The following passage attests to this nicely:

> To one who is behind the scenes, and knows that the most refined comparisons of masses, lengths, and angles, far surpassing in precision all other measurements, yet fall behind the accuracy of bank accounts, and that the ordinary determinations of physical constants, such as appear from month to month in the journals, are about on a par with an upholsterer's measurements of carpets and curtains, the idea of mathematical exactitude being demonstrated in the laboratory will appear simply ridiculous. There is a recognized method of estimating the probable magnitudes of errors in physics—the method of least squares. It is universally admitted that this method makes the errors smaller than they really are . . . (6.44)

Peirce's Classification of Evolutionary Philosophies

Peirce noted that in his time there were three chief contending theories of organic evolution. These were (1) Darwin's gradualist theory of natural selection, (2) Lamarck's theory of the inheritance of acquired characteristics arising from effort and exercise, and (3) Clarence King's theory (similar in some superficial respects to Gould and Eldredge's theory of punctuated equilibrium) that evolution chiefly takes place subsequent to events of cataclysmal environmental changes.[31] But taking "growth" in a broad sense as the phenomenon to be explained by evolutionary theories, Peirce listed three alternative mechanisms of how the process of growth and variation might occur. Peirce felt it likely that all three mechanisms were at work to some degree, but ultimately he preferred his own agapastic synthesis of all three.[32] The first general theory he labeled *tychasticism*, meaning that the direction of evolution proceeds by chance alone. The second he called *anancasticism*, the doctrine that evolution is driven by a blind mechanical necessity, again without any consideration of the ultimate end obtained. This is best illustrated, I suggest, by the orthogenetic theories of the German *Naturphilosophen*, Schelling and Hegel. The third option Peirce called *agapasticism*—that is, evolution occurs as the result of a striving for specific ends (*agape* coming from the Greek word for "love"). Lamarckism is an instance of this type of mechanism. Variation may still arise by chance, as in the tychastic theory of Darwin, but these will be selected for on the basis of how well they serve the attainment of particular ends sought. Those variations which prove beneficial in this way are developed through effort and exercise. *Agapasm*, therefore, stands for "evolution by creative love" (6.302).[33]

We get a clearer picture of how these three mechanisms differ by looking at how Peirce applied them to the processes of thought:

> The tychastic development of thought . . . will consist in slight departures from habitual ideas in different directions indifferently, quite purposeless and quite unconstrained whether by outward circumstances or by force of logic. . . . The anancastic development of thought will consist of new ideas adopted without foreseeing whither they tend, but having a character determined by causes either external to the mind, . . . or internal to the mind as logical developments of ideas already accepted, such as generalizations. The agapastic development of thought is the adoption of certain mental tendencies, not altogether heedlessly, as in tychasm, nor quite blindly by the mere force of circumstances of logic, as in anancasm, but by an immediate attraction for the idea itself, whose nature is divined before the mind possesses it, by the power of sympathy, that is, by virtue of the continuity of mind. (6.307)

Darwin's theory is deemed the best example of a tychastic theory; for examples of anancasticism, Peirce singled out Spencer and Hegel; and finally, Peirce's own general theory of evolution, inspired chiefly by Lamarck, is an instance of agapasm.

Remembering the objective idealist thesis that the processes of mind and of nature are identical, we are ready to prepare ourselves for the big picture to come. Speculating on the purpose of life itself, Peirce insisted that

> The purpose of vitality should be discoverable by considering what growth in general, or the process of vitality, accomplishes. Certainly growth is not mainly an operation upon something outside; it is a development of the organism itself. Whatever be its formula, it is this that describes the great struggle of the universe, and it is this that the great myths seek to embody. (N1, 178)

Keeping this view of the purpose of growth and the Lamarckian thesis of agapasm in the forefront, consider now Peirce's statement that "growth by exercise takes place also in the mind. Indeed, that is what it is to *learn*" (6.301). As we strive to make ourselves better prepared to deal with the challenges that constantly face us from day to day, so, too, does the universal mind strive to achieve a systematic regularity; a regularity that involves taming the constant spontaneous divergences from laws already established, bringing them into harmony with the ideal of a perfectly generalized system which shall only emerge as the ideal limit of this cosmic struggle.

Summary

It was crucial for Peirce's project that some link be found between the tychistic form of telos featured in the theories of Darwin, Maxwell, and Boltzmann and the stronger form of teleology associated with Lamarck's theory of evolution and our traditional understanding of mental activity. Both Darwinian evolution and statistical thermodynamics provide examples of tychastic evolution. While both describe the gradual drift of systems toward a final state, in neither case is the end obtained selected because of any intrinsic worth or attraction it may possess. Peirce's recognition of the need for something more may in fact be directly related to his later project of founding logic on ethics, and ethics in turn on aesthetics. Logic (in the sense of general inquiry) can only tell us how we ought to proceed given that we desire to achieve certain goals (1.611*ff*.; 2.198). It is the job of ethics to tell us what types of ultimate ends we ought to desire. But this task itself requires that we have a theory of aesthetics that assists us in recognizing what types of things are intrinsically valuable and suitable to be pursued as ultimate ends (1.191; 1.612*ff*.; 2.199).

We begin to see here a problem with two strands of Peirce's philosophy. According to his objective idealism, the processes of the development of mind and the processes of the development of the universe are assumed to be identical. But as Murphey has pointed out (1993, 356–57), while the ultimate goal of the universal mind is an aesthetic ideal acting as a final cause (a state of perfect symmetry, beauty, and regularity), that of the individual mind is the less grandiose purpose of removing an irritating doubt, with the doubt acting as an efficient cause. We see, then, that the same problem of coordinating the "blind" processes of tychism with the prophetic and aesthetic processes of agapism turns up once again.

It was Peirce's proximate aim to bridge the gap between tychism and agapism through his molecular theory of protoplasm. The crucial linchpin there, we saw, was the activity of growth and how that is achieved by living organisms through the process of nutrition. Nutrition involves a principle of selection that is neither entirely tychistic nor anancistic. If an organism is to remove itself from an irritating stimulus, its responses must be intelligent—that is, it must hit on a general plan of action that resolves that particular problem and all similar types of problems that may arise in the future. In order, however, for these appropriate forms of habit to be established, there must occur the right molecular conditions for the reparation of protoplasmic structure disturbed by the exertion and exercise invoked by the irritating stimulus. Nutrition is thereby shown to be a specialized form of growth, and, as Peirce attempts to show, a similar process of growth (by exercise) occurs within the mind. Mental growth is merely the deliberate attempt to develop habits of a particular kind. Because matter is only mind strictly governed by habit, it follows that the entire universe undergoes a similar kind of evolution. Exactly how that process is instantiated within the universe as a whole is the subject of cosmology, and it is to that branch of Peirce's metaphysics that we turn next.

5

Cosmology and Synechism

> Metaphorically speaking, our universe is animated by a *life urge*. Initially it had exactly the right conditions to produce organization, complexity, and ultimately life. Throughout its history, the urge has done just that.
>
> Hubert Reeves (1991, 6)

In the last chapter, we were concerned with seeing whether Peirce had managed to reconcile the purposeless but directed behavior of stochastic systems with his neo-Lamarckian theory of evolution (agapasm). We saw how he attempted to trace a kind of selective principle at the molecular level of protoplasm, which would allow him to identify nutrition with the agapistic idea that growth or evolution occurs through the development of the organism from within, by the incorporation of material from without. We also noted Murphey's reservations about the divergence that had opened up between the immediate goal of inquiry and the ultimate goal of the universal mind. Individual organisms and minds must, if they are to survive, adapt themselves to their environments. It is really, then, the environment that determines the direction of evolution, not the mind or organism.[1] What Peirce needed was some assurance that the universe was developing in a specific direction and according to its own purposes.

Murphey (Flower and Murphey, 1977, 616) points out that interpreting the cosmology along Lamarckian lines does not help at all, because even according to the Lamarckian theory—despite its teleological bent—it is still the environment that really determines the direction of evolution. On this account, organisms merely take the initiative to adapt themselves, rather than allow the environment to select which of them will survive (as the Darwinian theory maintains). And in what sense, Murphey asks (1993, 350), can we talk about the environment of the entire universe?[2] Whatever it is that is driving the development of the universal mind must be internal to it. The universe as a whole does not occupy an environment in the same way as an organism does. But because the development of the universal mind and the development of individual minds are supposed to be the same (i.e., both follow the processes of inquiry), if we can identify the intrinsic goal of inquiry we will have also identified the intrinsic goal of evolution. At the same time, Murphey writes (1993, 361f), Peirce began to see the need for more than a merely descriptive and psychologistic theory of logic, so that around the turn of the nineteenth century he began to develop the thesis that logic is based on ethics, and ethics in turn on aesthetics.

Logic may tell us how to proceed on the assumption that we want to discover truth. But it cannot tell us why we *ought* to pursue truth. For that, we must turn to ethics. But ethics, according to Peirce, is the science of directing behavior toward goals in general (1.611*ff*., 2.198, 5.130*ff*.). Because ethics is concerned only with goal-directed behavior in general, it cannot tell us which goals we ought to pursue. Discernment of which goals we ought to pursue requires a study of those things which have inherent value and desirability. This, for Peirce, is the domain of aesthetics (1.191, 1.612*ff*., 2.199). Ultimately, Murphey explains (1977, 617–18), Peirce arrived at the conclusion that the *summum bonum* is a form of beauty. Consequently, the goal of inquiry and of evolution is a state of maximum beauty; more specifically, it is a state of perfectly harmonious symmetry. From the perspective of inquiry, this is a state of perfect regularity, order, and rationality. It is the lure of this final state, only ever present as a vague idea at any given time, that urges mind on in its struggle and development.

Peirce also gave an alternative description of this *summum bonum* in terms of "logical goodness." The evolutionary aspect of this conception is clearly displayed in the following passage from his 1903 Harvard lectures on pragmatism:

> We may now profitably ask ourselves what logical goodness is. We have seen that any kind of goodness consists in the adaptation of its subject to its *end*. . . . But the saving truth is that there is a Thirdness in experience, an element of Reasonableness to which we can train our own reason to conform more and more. If this were not the case there could be no such thing as logical goodness or badness; and therefore we need

> not wait until it is proved that there is a reason operative in experience to which our own can approximate. We should at once hope that it is so, since in that hope lies the only possibility of any knowledge. (EP II, 211–12; Peirce, 1997, 224–25)

Here we see again the Hegelian roots of Peirce's philosophical disposition showing clearly through. The cosmology is in essence an expression of a world-historical trend, a trend that is working toward, as Peirce himself so often put it, the "Growth of Reasonableness." As the universal mind (which Peirce at times explicitly called the Absolute[3]) continues to develop agapastically and in accordance with the law of mind/habit, it will eventually weld together all of its diverse systems of coordinated ideas into one continuous and general system.

Socially, what this refers to is the growing sympathy among individual beings to work toward the establishment of a more reasonable and morally coherent community. This constitutes the religious aspect of Peirce's system and provides the important context for understanding his opposition to the philosophy of Social Darwinism, or as he called it, "the gospel of greed." But it also captures his allegiance to the ideals of a community of professional scientists or inquirers, each willing to devote his or her own energies and lives toward the pursuit of truths that may never be fully appreciated in each one's individual lifetime. When Peirce wrote that "Logic is rooted in the social principle" (2.654), he did so in part to emphasize the extent to which knowledge and science is reliant on the mutual efforts and support of a vast network of material resources, communication, and shared ideals. He was also attempting to assure his readers (and himself) that his pragmatic elucidation of truth as the opinion fated to be agreed on in the ideal end of inquiry shares the same kind of long-run guarantee afforded to statements about probabilities by the law of large numbers.[4] "It is mathematically certain that the general character of a limited experience will, as that experience is prolonged, approximate to the character of what will be true in the long run, if anything is true in the long run" (6.200). It is because no one of us can expect our own lives and experiences to extend to the final limit of inquiry at which truth will be the object of unshakable consensus that we each must meld our own interests and ambitions with that of a broader community supposed to extend indefinitely into the future.

From a less social but equally metaphysical perspective, in the final limit the universe will become a completely connected, continuous, coordinated, and self-aware system; nothing shall escape its notice, and all relationships among its ideas shall be perfectly established. This will truly be the "crystallization" of mind—crystallized because it will exhibit a perfect symmetry and order. To get a better picture of what is being alluded to here, one need only imagine the ideal state of one's own ideas and thoughts. Perhaps a helpful image can be found in that of a lattice structure or a Boolean algebra. As he was both a chemist (with interests in crystallography) and a mathematician (who made original contributions to the field of abstract algebra), it would not be surprising that Peirce would have found such a vision inherently worthy of a mind's lifelong devotion.[5]

This chapter has two chief objectives: One is to look more closely yet at the relationship between the law of large numbers and Peirce's theory of agapasm, especially as it involves his idea of *synechism*, the thesis that emphasizes the importance of continuity; the other is to contrast this synechistic vision of the universe's ultimate end with some other popular ideas of his time.

Order Out of Chaos

"What is it," Peirce asked, "that philosophy ultimately hopes to accomplish?"

> It is, if we mistake not, to find that there is some intelligible truth, some absolutely valid reasonableness, to ascertain how far this reasonableness governs the universe, and to learn how we may best do its service. . . . There must be nothing hopelessly and finally unreasonable, or in so far philosophy is to no purpose and its hope is vain. (1899; N2, 208)

So committed was he to the ideal of thirdness that he wrote, "Generalization, the spilling out of continuous systems, in thought, in sentiment, in deed, is the true end of life" (RLT, 163; NEM IV, 346). Generalization, reasonableness, lawfulness, continuity: these are all expressions of Peirce's category of thirdness. And the distinctive feature of thirdness is continuity, the bringing together of formerly disconnected elements into an orderly and continuous relationship with one another. It is this evolutionary merging of atoms, of ideas, and of minds so as to form a whole greater than any of the individual parts that is enshrined in the idea of synechism.

An 1894 pamphlet announcing a planned twelve-volume work titled *The Principles of Philosophy or, Logic, Physics and Psychics, Considered as a Unity, in the Light of the Nineteenth Century* provides interesting glimpses of the overall scope of Peirce's metaphysical system. There we read that "the idea of continuity [is to be] traced through the history of the Human Mind, and shown to be the great idea which has been working itself out" (RLT, 13). We also read there that

> The author's theory of universal evolution, which supposes matter and its laws to be the result of evolution, is now set forth more systematically and argumentatively. Still, it is to be regarded for the present as no more than a working hypothesis. Explanation of the method of reasoning by which a multitude of unmistakable consequences can be rigidly deduced from the hypothesis. A considerable number of these are shown to be true, while none are known to be false. One prediction of a fact hitherto unknown is shown to be supported by observation. Others remain to be tested by future experience, and the theory will have to stand or fall by the result. (ibid., 14)

And finally, just to confirm the Hegelian parallels, we are told that "the philosophy of continuity leads to an objective logic, similar to that of Hegel, and to triadic categories." However, "the movement seems not to accord with Hegel's dialectic, and consequently the form of the scheme of categories is essentially different" (ibid., 15).

But if one is going to devote oneself to the cause of thirdness, to reasonableness, it is important to know first that the cause is not a hopeless one. For that reason, Peirce was concerned to ask, "Is there . . . any general tendency in the course of events, any progress in one direction on the whole?" (6.6). In the next passage, Peirce phrases the question more specifically:

> One of the questions philosophy has to consider is whether the development of the universe is like the increase of an angle, so that it pro-

> ceeds forever without tending toward anything unattained, which I take to be the Epicurean view, or whether the universe sprang from a chaos in the infinitely distant past to tend toward something different in the infinitely distant future, or whether the universe sprang from nothing to go on indefinitely toward a point in the infinitely distant future, which, were it attained, would be the mere nothing from which it set out. (6.27)

Peirce classified these three possibilities in analogy with the types of curves that would best describe them. The first he calls an elliptic philosophy: "Starting-point and stopping-point are not even ideal. Movement of nature recedes from no point, advances towards no point, has no definite tendency, but only flits from position to position" (6.582). The last scenario of the three is referred to as a parabolic philosophy. In this case, universal history is cyclical. But it is the second or middle possibility that Peirce prefers. This he calls the hyperbolic philosophy, in which "reason marches from premises to conclusion, [and] nature has an ideal end different from its origin" (ibid.).[6]

The geometric analogy drawn by Peirce is, in fact, even richer than this. The English mathematician Arthur Cayley had introduced the concept of the geometric "absolute" as an element of geometry that would determine the metric of space. The absolute was meant to correspond to that pair of points which would lie at opposite ends of an infinitely long, rigid bar. It remained an open question whether, for real physical space, these points would be either distinct, coincident, or imaginary. According to Peirce, who even referred to cosmology in his 1898 Cambridge lectures as "mathematical metaphysics" (RLT, 267), there is more than mere coincidence behind this mathematical entity being so named: "The Absolute in metaphysics fulfills the same function as the absolute in geometry. According as we suppose the indefinitely distant beginning and end of the universe are *distinct*, *identical*, or *nonexistent*, we have three kinds of philosophy" (NEM, IV, 377). The three possibilities of a distinct, coincident, or imaginary pair of points correspond to the hyperbolic, parabolic, and elliptic philosophies, respectively.[7] Only according to the hyperbolic formula is there any real progress in the history of the universe. "If your creed is that the whole universe is approaching in the infinitely distant future a state having a general character different from that toward which we look back in the infinitely distant past, you make the absolute to consist in two distinct real points and are an evolutionist" (1.362). It is to the details of this formula that we now turn.

To ensure that nothing is accepted as a brute fact (recall the first rule of inquiry), Peirce's cosmogonic philosophy supposes that

> In the beginning—infinitely remote—there was a chaos of unpersonalized feeling, which being without connection or regularity would properly be without existence. (6.33)[8]

Two points of clarification are needed here. First, because secondness, the feature of action and reaction, is the category of existence and actuality, the primordial chaos cannot properly be said to exist. In accordance with his pragmatic principle, to say of something that it exists or is actual is to say that there is a set of regular experiences that one can expect to undergo when in the presence of the thing. If the thing in question does not exhibit any regularities, then we have no choice but to treat it as an illusion or unreal. Second, because regularity is the thing par excellence that requires an explanation, Peirce maintained that it was legitimate for him to suppose in the beginning a chaos. And if we accept the first point, that something without regularity does not really exist, then Peirce can say that he is not even assuming the "existence" of a chaos. What does seem to go unaccounted for, though, is the assumption that the chaos is a chaos of *feeling*. We saw that Peirce felt compelled to adopt idealism because he saw no way of reducing the vital properties of living organisms and mind to dead mechanical matter. It might be objected that rather than face the challenge of providing an explanation of mind in all its amazing peculiarity, Peirce simply sidesteps the issue by making mind an absolutely ubiquitous and therefore unexceptionable phenomenon. His response to this, as we noted in Chapter Three, was to identify feeling with chance, and because irregular chance is the one thing that does not require an explanation, neither does this primordial state of unorganized and nonpersonalized feeling. Perhaps some of the natural incredulity toward this ascription of feeling to the original chaos can be alleviated if it is supposed that all Peirce means by it is a natural tendency to react to an external stimulus. Now, to ascribe any tendency or propensity at all is to ascribe a type of generality or lawfulness. But Peirce can insist that it is only a very inexact tendency, the mere germ of a habit, no more than the least possible grade of lawfulness along a continuous spectrum ranging from absolute absence of regularity (whatever that might be) to absolutely rigid and exact "mechanical" law.

Let us return now to his account of the primal chaos of feeling:

> This feeling, sporting here and there in pure arbitrariness, would have started the germ of a generalizing tendency. Its other sportings would be evanescent, but this would have a growing virtue. (ibid.)

Because there is no regularity yet, neither can there be any sense of time, for time, Peirce says, "consists in a regularity in the relations of interacting feelings" (8.318). At some point, there would have occurred spontaneous chance occurrences, similar to the chance flashes of ideas in our own minds. And "eventually," by chance, an element of habit-taking tendency would have arisen so that some regularity among the spontaneous outbursts of feeling or reactiveness was established. Now, to talk of such things occurring "eventually" and in some sequence appears to presuppose a temporal relation. "But," Peirce cautions, "this 'time' is only our way of saying that something had been going on. There was no real time so far as there was no regularity, but there is no more falsity in using the language of time than in saying that a quantity is zero" (8.318). Regardless of the analogy with zero quantity, something about the argument seems suspicious. It reminds one of the ambiguity that arose in Chapter Three concerning Peirce's propensity to treat time both as an objective relation between sequences of external events and as a subjective mental experience.

However, granting for the moment the legitimacy of this application of temporal language, Peirce completes the outline of his cosmogony in this way:

> Thus, the tendency to habit would be started; and from this, with the other principles of evolution, all the regularities of the universe would be evolved. At any time, however, an element of pure chance survives and will remain until the world becomes an absolutely perfect, rational, and symmetrical system, in which mind is at last crystallized in the infinitely distant future. (6.33)

The law of habit is destined to be reinforced by acting on itself in an autocatalytic fashion. "The tendency to form habits or tendency to generalize, is something which grows by its own action, by the habit of taking habits itself growing" (8.317). One might raise the objection that it is not at all clear how a tendency can affect itself. It appears, on the surface, to allow a first-order function to stand as a second-order function of itself. In mathematical logic, such moves have proven to be the source of much confusion. And, in fact, in his work in set theory, Peirce did not distinguish between the relations of membership and inclusion. While there is some bite to this line of criticism, it is not clear how relevant it is to Peirce's ideas concerning the law of habit, for what Peirce has in mind is a basic characteristic of psychology, not pure logic. In his own words, "We have to remember that no mental tendency is so easily strengthened by the action of habit as is the tendency to take habits" (6.266). Moreover, he confessed that he believes "the law of habit to be purely psychical" (8.318). So while it may be unclear just how the tendency to take on habits can affect that very tendency itself, we seem forced simply either to accept or reject the plausibility of Peirce's neurophysiological metaphor of the original universal chaos.

Here, then, is the blueprint according to which Peirce envisages the cosmos to be progressing. So far, the emphasis has been on the gradual emergence of law and regularity. But another equally important aspect of the proposal at hand is the trend toward *diversification*. It is with respect to this trend that the role of chance becomes so important, and, as a direct result, that the law of large numbers steps to the forefront.

Variation and the Law of Large Numbers

In the last chapter, we saw that for Peirce evolution is about growth "in the widest sense of that word." In one sense, this means growth of regularity and lawfulness under the tendency to take on habits. But in another sense, evolution is also about the increase of novelty and complexity. In the broadest of terms, Peirce expresses this sentiment thusly: "All the evolution we know of proceeds from the vague to the definite. The indeterminate future becomes the irrevocable past. In Spencer's phrase the undifferentiated differentiates itself. The homogenous puts on heterogeneity" (6.191).

Why, that is, is the world not just one great homogenous lump? According to Spencer, the appearance of variety is the direct result of the principle of energy conservation. Energy (or force, in Spencer's language) can be neither created nor destroyed. Force must affect anything with which it comes into contact. When forces act on matter that is even slightly less than perfectly homogenous in its spatial distribution, the result is a modification of that matter, and this results in a form of variety. But for Spencer, the existence of force is something that must be assumed as a brute inexplicable fact, its origin and true nature being unknowable.

Peirce, not surprisingly, rejects this "explanation" and proposes to account for the emergence of variety by appeal to the notions of chance and agapastic adaptation:

> In so far as evolution follows a law, the law of habit, instead of being a movement from homogeneity to heterogeneity, is growth from difformity to uniformity. But the chance divergences from law are perpetually acting to increase the variety of the world, and are checked by a sort of natural selection and otherwise (for the writer does not think the selective principle sufficient), so that the general result may be described as "organized heterogeneity," or, better, rationalized variety. (6.101)

Like Darwin's explanation of species diversity, Peirce relies on two agencies: a random activity ungoverned by law, and a lawlike adaptation of these chance results to the specifications of a systematic whole.

As construed by Peirce, the mutual presence of chance and law does not constitute any tension or inconsistency, for it is not a purely wild and irregular chance influence that he has in mind here. Laws are never absolute or perfect, he claims. Therefore, there will always be a slight amount of unprecedented "experimentation" going on, and this chance-borne activity results in novelty and variety.

> The party . . . of which I am myself a member, holds that uniformities are never absolutely exact, so that the variety of the universe is forever increasing. At the same time we hold that even these departures from law are subject to a certain law of probability, and that in the present state of the universe they are far too small to be detected by our observations. (6.91)

To what exactly is he referring when he mentions this "certain law of probability"? There can be little doubt that it is the error law of probability, the normal curve of fortuitous variations, which we have seen him speak so much of in connection with the theory of Darwin and the kinetic theory of gases. Closely associated with the normal curve is the central limit theorem, which states that, for instance, as the number of independent samples of some character from a population increases, the dispersion of the sample means will approach a normal distribution.[9] Both Bernoulli's theorem and the central limit theorem are commonly referred to as laws of large numbers. While the former describes a convergence in central tendency, the latter describes a convergence in dispersion. I think the best way to interpret what Peirce is saying in the quote above is that even after there has been a convergence to some mean value, perhaps of a natural constant, deviations from this average value will continue to occur in accordance with the standard error curve. So although a natural law may have settled down to within very narrow limits (i.e., the normal curve representing the law or constant in question has a range of dispersion very closely huddled about the mean value), small deviations will occur fairly frequently, larger ones much less frequently.

When it is taken into consideration that Peirce supposed that laws emerge gradually, growing in regularity with time and with the number of elements involved (here, the image of the central limit theorem is a natural), it becomes pretty clear that what we are dealing with in the quote above is what Peirce called the law of "high" numbers. In the very same set of lectures of 1903, Peirce made the following comments:

> Now there are three characters which mark the universe of our experience in a way of their own. They are Variety, Uniformity, and the passage of Variety into Uniformity [1st, 2nd, 3rd]. By the passage of Variety into Uniformity, I mean that variety upon being multiplied almost in every department of experience shows a tendency to form *habits*. These habits produce statistical uniformities. When the number of instances entering into the statistics are small compared with the degree of variation, the law will be very rough, but when the number runs up into trillions, that is to say cubes of millions, or much higher, as in the case of molecules, there are no departures from the law that our senses can take cognizance of. (6.97; NEM, III, i, 392)

What we have here is a description fitting of both Bernoulli's law and the central limit theorem. When Peirce thought about the evolution of natural laws, he had before him the picture of the law of high numbers, but as I have suggested, this phrase covered, for him, as it did for many others, both Bernoulli's law and the central limit theorem. These stood, for Peirce, as examples of how uniformity and regularity could evolve simply from the effects of chance.[10]

Further support for the centrality of the large numbers principle can be obtained from this next passage:

> Spencer makes the evolution of the world depend exclusively upon the principles of mechanics; while according to other evolutionists there are two factors, force and the effect of accidental variations, *probability acting upon high numbers of elements*,— to these two elements the whole development of the world is attributed. (W5, 260; italics mine)

It takes little imagination to see that Peirce's mention of "accidental variations" here is meant to parallel Darwin's own hypothesis of chance "sports" (random mutations) in biological forms.

Agapasm and the Law of Large Numbers

It may be noted that this last explanation of universal evolution by the law of large numbers sounds suspiciously tychastic (i.e., due predominantly to chance). The reason for this is that it predates by eight years the 1893 "Evolutionary Love" article in which the doctrine of agapasm was first introduced. Another earlier account (ca. 1878) of the presence of teleology in nature is similarly tychastic

> Considering things from the point of view of historical causation, how came they to have tendencies toward ends?
>
> The solution which I shall offer is that the tendency is the sure effect of chance; that is to say, given a vast number of events, each singly undirected to any end, the collective result will inevitably be a tendency to an end. (MS 875)

In a transitional phase, Peirce appeared no longer content to leave the stochastic account of teleology autonomous:

> I think that the existence of God, as well as we can conceive of it, consists of this, that a tendency toward ends is so necessary a constituent of the universe that the mere action of chance upon innumerable atoms

> has an inevitable teleological result. One of the ends so brought about is the development of intelligence and of knowledge . . . (W5, 229; 1885)

But ultimately the agapastic account would win out over both the autonomously stochastic and the theological proposals. In the "Evolutionary Love" essay, Peirce would write that "the movement of love is circular, at one and the same impulse projecting creations into independency and drawing them into harmony" (6.288). In this description, the dual elements of random variation and adaptation are retained, but no longer is the direction of the tendency left up to either chance, divinity, or the environment. Leaning heavily on the analogy with the growth of mental conceptions, Peirce was already writing in 1892 that

> I cannot see how anyone can deny that the infinite diversity of the universe, which we call chance, may bring ideas into proximity which are not associated in one general idea. . . . But then the law of continuous spreading will produce a mental association; and this I suppose is an abridged statement of the way the universe has been evolved. (6.143)

It is of the essence of the thesis of evolutionary love (agapasm) that the developing mind feels some sympathy with the idea acting as final cause. "In genuine agapasm . . . advance takes place by virtue of a positive sympathy among the created springing from continuity of mind" (6.304). "The agapastic development of thought," for instance, "is the adoption of certain mental tendencies . . . by an immediate attraction for the idea itself, whose nature is divined before the mind possesses it, by the power of sympathy, that is, by the virtue of the continuity of mind . . ." (6.307).

What we see here is Peirce struggling with a psychological variant of the problem of physical action at a distance. To account for the ability of bodies separated in space to influence one another's motions, physicists (Boscovich, Faraday, Kelvin, Maxwell, and Lorentz, among others) developed the field theory of the propagation of mechanical influences. By positing the existence of a continuous medium connecting all physical bodies, they were able to ease their discomfort with the idea (introduced by Newton) that bodies could affect one another across vast expanses of empty space.

Peirce's fondness for continuity among ideas and minds reflects this line of research.

I suspect it is because he based his theory of agapastic evolution on introspection of his own mental development that it is easier to understand how agapasm is supposed to apply to the universe by looking at what he had to say about the development of his own ideas. He tells us, for instance, that "the agapastic development of thought should, if it exists, be distinguished by its purposive character, this purpose being the development of an idea" (6.315). We know that Peirce devoted his life to the development of a few key ideas, such as the logic of relatives, continuity, and pragmatism (this last one being itself a method for the clarification and development of ideas). One of the objectives of the "Evolutionary Love" essay was to draw forth the moral implications of Peirce's agapastic philosophy of continuity (synechism), showing that it was consistent with the principles of Christianity, and to deliver a scathing criticism of the social Darwinist philosophy which preached the "gospel of greed."[11] In a rhetorical tour de force that would make the heads of his later positivistic admirers spin, Peirce discussed the connection between universal and individual mental development:

> Everybody can see that the statement of St. John [that God is love] is the formula of an evolutionary philosophy, which teaches that growth comes only from love, from I will not say self-*sacrifice*, but from the ardent impulse to fulfill another's highest impulse. Suppose, for example, that I have an idea that interests me. It is my creation. It is my creature . . . I love it; and I will sink myself in perfecting it. It is not by dealing out cold justice to the circle of my ideas that I can make them grow, but by cherishing and tending them as I would the flowers in my garden. The philosophy we draw from John's gospel is that this is the way mind develops; and as for the cosmos, only so far as it yet is mind, and so has life, is it capable of further evolution. Love, recognizing germs of loveliness in the hateful, gradually warms it into life, and makes it lovely. That is the sort of evolution which every careful student of my essay "The Law of Mind" must see that *synechism* calls for. (6.289)

Synechism, then, is more than a speculative cosmology; it is also a moral philosophy. But this, as we mentioned at the start of the chapter, should come as no surprise, for the difficulty Peirce faced in justifying his optimism about the progressiveness of cosmic evolution was the result of his theory of logic and inquiry lacking any normative bite. And if the goal of inquiry and cosmic evolution is the development of "concrete reasonableness," the "crystallization of mind", then the duty of each individual is clear. "Under this conception, the ideal of conduct will be to execute our little function in the operation of the creation by giving a hand toward rendering the world more reasonable whenever, as the slang is, it is 'up to us' to do so" (1.615).

What is more, to devote oneself to the cause of thirdness, to reasonableness, generality and continuity, turns out to converge nicely with the teachings of the founder of Christianity. "The gospel of Christ says that progress comes from every individual merging his individuality in sympathy with his neighbours" (6.294). Just so, the ideal end of the universal generalizing tendency is the establishment of one completely continuous system, which, as a continuum of many individual systems of coordinated feelings merged together into one, marks the creation of a supersystem—the universal mind or Absolute becomes finally self-aware.

To summarize, the general nature of the law of large numbers is retained in agapasm—namely, there is a gradual "taming of chance" variation (to use Hacking's phrase) that results, in the long run, in the emergence of a new uniformity. But the difference that is introduced by the thesis of agapasm is that the taming of the random variations is not itself left up to chance. The end result that is converged on is chosen by the developing system (e.g., the developmental teleology of the universal mind) on the basis of its inherent attractiveness.

Rival Cosmologies

Peirce certainly did not hold a monopoly on cosmological speculation. The results of the physical and biological sciences provided ample material for any one inclined to draw broad and general conclusions about the universe's past and future. Three of the biggest scientific developments in the nineteenth century were (1) the conservation of energy principle, (2) the dissipation of energy principle, and (3) the theory of evolution. Not surprisingly, these results were the basis for some of the most popular speculations about the cosmos. Following the guidelines of Peirce's classification of the three general types of cosmological philosophies, we will now look at representatives of each.

Elliptic Philosophy

The earliest such philosophy identified by Peirce was that of Epicurus. According to Peirce's construal of this formula, the development of the world is aimless and without any specific final goal. Epicurus appealed to the random swerving of atoms in the void to account for the presence of large-scale structure. Aside from this, the rest of nature's development obeys the laws of necessity but not of design. In light of this, Epicureanism might be said to be a good example of a tychastic cosmology.

Insofar as the elliptic formula describes a nonprogressive cosmology, we might also include here the scenario put forward by Thomson (later Lord Kelvin) in his essay "On a Universal Tendency in Nature to the Dissipation of Mechanical Energy" (1852), dubbed by Helmholtz the "Heat Death" in 1854 and independently stated by Clausius in 1865. Musing on the implications of the recently discovered principle of energy dissipation, Thomson concluded that the planet Earth would eventually become uninhabitable once all of its energy had been dissipated in the form of random thermal motion.[12] Helmholtz and Clausius each drew the wider conclusion that the universe in its entirety, supposing it to be a finite and closed system, would ultimately suffer a similar heat death in which all temperature gradients would be used up, all portions of the universe coming to share the same average temperature and no further change taking place. Clausius summed up this possibility with the statement that the entropy of the universe tends toward a maximum.

The philosopher Herbert Spencer was another to propose that whatever progress cosmical evolution had managed to achieve was bound to be undone by an opposing period of de-evolution. Spencer's ideas—though not those of Thomson, Helmholtz, or Clausius—drew considerable flak from Peirce:

> Biologists . . . urge that all observed facts point to Evolution in one direction and that nothing whatever in experience goes to support Mr.

> Spencer's theory that the universe during half the time is undergoing a reverse operation of Devolution. I will add that all mathematicians are in accord in holding that Spencer's attempts to connect either Evolution or Devolution with the conservation of energy by mathematical reasonings is simply beneath all criticism as puerile nonsense. (ca. 1898; NEM, IV, xviii)

While such conclusions were in stark contrast with the more optimistic progressivism that emerged from the popular evolutionary *Zeitgeist*, nevertheless, they did supply an important piece of support for those more hopeful interpretations of the universe's ultimate fate. It was owing to the principle of energy dissipation, later to become known as the second law of thermodynamics, that the direction of the arrow of time was to be identified. A universal tendency toward increase in entropy allowed scientists and philosophers to maintain that time marches on in one direction only. The only problem was that the point at which this irreversible progression was aiming seemed to give little cause for hope of an improved future state. Some physicists—for example, P. G. Tait (1831–1901) and Balfour Stewart (1828–87)—were pressed to speculate that there was another "hidden" universe, awaiting the souls of honest folk, beyond the limits of the observable universe.[13] The dissipation of energy from our universe, they conjectured, might be reconcentrated in this other world, thereby allowing for the conditions requisite for intelligent life. The alternative, as Stephen Brush has shown, was considered too horrible for the sensitivities of Victorian England, even if the dreaded heat death was thousands or millions of years off in the distant future.[14] The idea that anything as grand as the cosmos might end with a fizzle was just as much beyond Peirce's own comprehension.

Parabolic Philosophy

If the idea was to be rejected that the universe might in the end accomplish nothing more than a cold and lifeless void, then so, too, was the idea that it would eventually return to the very state from which it had set out. Such a transformation is to be kept distinct from the heat death picture. For the heat death scenario to apply, the universe must have, at some time or other, though perhaps not in the very beginning, been in a state of low entropy. That means that at some point or other, the universe must have been heterogeneous with respect to temperature. There must have been temperature gradients to be depleted in order for the "arrow of time" to trace out a particular path.

Just as Boltzmann's work on the second law of thermodynamics led to the identification of time's arrow with the maximization of entropy, it also spawned an argument for the claim that the history of the universe may be cyclical. Boltzmann had based his chief argument for the irreversibility of time (his H-theorem) on the assumptions of Newtonian mechanics. Heat, which Clausius had shown could be construed as "random" molecular motion, was essentially treated as a standard Newtonian phenomenon of point masses. In 1889, Henri Poincaré, while working on the celebrated three-body problem, proved that for a system of particles of finite energy and volume obeying Newton's laws of motion, for all but a vanishingly small number of initial states, the system will return infinitely many times to as close as one pleases to its initial starting point. This result is known as Poincaré's Recurrence Theorem.[15] It was used first by Poincaré himself in 1893, and three years later by Ernst Zermelo, as an objection to Boltzmann's attempted deduction of his H-theorem from the principles of mechanics.[16] The *H* of this theorem represents a function of mechanical properties of molecules, equivalent to the inverse of the entropy function. Whereas we now say the entropy function tends to a maximum, Boltzmann's original formulation stated that H (very roughly, the amount of "order" in a system) tends to a minimum. The conclusion that universal history is cyclical should not, however, be attributed to either Poincaré or Zermelo. This thesis was considered, though, by Nietzsche.[17]

As he was such a great supporter of Boltzmann's work on irreversible processes, the question might be asked whether Peirce's cosmology is not also open to the Poincaré–Zermelo objection. There are at least two reasons for answering in the negative. First, both Boltzmann's H-theorem and Poincaré's recurrence theorem assume, in essence, the truth of mechanism. Peirce, on the other hand, as we have seen full well, rejected the mechanical philosophy. In his opinion, the laws of mechanics are subject to infinitesimal violations. Consequently, because he does not accept the premises of the argument in total, he need not accept its conclusion, either. In fact, Peirce was much more willing than was Boltzmann to admit the necessity of an extra chance ingredient to make the statistical mechanical account work. And where Boltzmann only slowly came around to admitting the need for a statistical postulate of randomness or chance (the *Stosszahlansatz* or assumption of molecular chaos), Peirce went much further in embracing the postulate of *absolute* objective chance. The second reason why Peirce would have no reason to worry about the recurrence objection (*die Wiederkehreinwand*) was that his law of habit was enough, granted the assumption that it could work on itself, to establish a monotonic approach to a final condition of perfect regularity, distinct from the inchoate state from which it was supposed to have begun.

In addition to the recurrence objection, Boltzmann's H-theorem was also challenged by what is known as the reversibility objection. Josef Loschmidt (1821–95), Boltzmann's colleague, pointed out that because the laws of motion are time-reversal invariant, for every function of a system of gas molecules that is entropy-increasing, there should be another that is entropy-decreasing. What these two objections showed was that Boltzmann could not possibly have succeeded in logically deriving his irreversible H-theorem from the laws of motion alone. Boltzmann was eventually forced to concede that for the H-theorem to be valid, two crucial assumptions must be made: (1) that the initial state chosen (of the system) must be a peculiar one, corresponding to one of low entropy, and (2) that the motions of the molecules are as if random, or more specifically that the properties of motion of the individual molecules are independent of one another prior to interactions but not so afterward. Once these assumptions were made clear, the issue became whether they were factually accurate. But because Peirce's law of habit is not a mechanical law, it is immune from both the reversibility and recurrence objections.

There is, however, a striking similarity in some of what Peirce had to say in his earliest exposition of his cosmology (i.e., the "Design and Chance" lecture of 1884) to the Poincaré-Zermelo thesis. Consider the following passage:

> You have all heard of the dissipation of energy. It is found that in all transformations of energy a part is converted to heat and heat is always tending to equalize its temperature. The consequence is that the

> energy of the universe is tending by virtue of its necessary laws toward a death of the universe in which there shall be no force but heat and the temperature everywhere the same. . . . We may say that we know enough of the forces at work in the universe to know that there is none that can counteract this tendency away from every definite end but death.
>
> But although no force can counteract this tendency, chance may and will have the opposite influence. Force is in the long run dissipative; chance is in the long run concentrative. The dissipation of energy by the regular laws of nature is by those very laws accompanied by circumstances more and more favorable to its reconcentration by chance. (W4, 551)

What he appears to be getting at here is that even once the molecular energies throughout the universe have attained a state of thermal equilibrium, there will still occur chance fluctuations from this state from time to time. Although there is no evidence that Peirce had any kind of a proof of this claim (and more doubtful that if he did, it resembled anything like Poincaré's), it is worth noting that Peirce was aware of the possibility of stochastic fluctuations from equilibrium nine years prior to Poincaré's raising of the recurrence objection.

William Thomson (later Lord Kelvin) had in 1851 expressed a similar opinion about what it would take to counteract the dissipation of energy. "Everything in the material world is progressive. The material world could not come back to any previous state without a violation of the laws which have been manifested to man; that is without a creative act or an act possessing similar power."[18] It is possible that Peirce was influenced in this regard by Thomson. Or perhaps he was thinking of Maxwell's 1867 thought experiment in which a "very observant and neat-fingered" intelligence (dubbed by Thomson a "demon") showed how the tendency toward dissipation could be counteracted. The "violation" envisaged in Maxwell's example was not taken by him to constitute a true violation of the relevant laws at all, but rather what it showed was the intrinsically statistical nature of the second law of thermodynamics. The heat death was not, on this account, a strict necessity but only the most probable outcome.

In any case, Peirce was in agreement that some form of "chance violation" was the way out of both the heat death and eternal recurrence snares. But as a passage from 1892 shows, Peirce did not hold out much hope for our ever actually witnessing any significant fluctuations from the law of entropy:

> Physicists hold that the particles of gases are moving about irregularly, substantially as if by chance, and that by the principles of probabilities there must occasionally happen to be concentrations of heat in gases contrary to the second law of thermodynamics, and these concentrations, occurring in explosive mixtures, must sometimes have tremendous effects . . . yet no phenomena ever have resulted which we are forced to attribute to such chance concentration of heat, or which anybody, wise or foolish, has ever dreamed of accounting for in that manner. (6.47)

Now, one would think that Peirce would want to make a case for just the opposite conclusion; especially since this passage is excerpted from his celebrated critique of determinism, "The Doctrine of Necessity Examined" (6.35–65). The conclusion here would seem to be in direct conflict with his earlier statement that "chance is in the long run concentrative." The only plausible explanation that comes to mind is that he had come to realize just how improbable such chance fluctuations would be, given the extremely large numbers of molecules involved. Keeping in mind that fluctuations from the mean value of *N* independent variables will be proportional to the inverse of the square root of *N*, and given the huge number of molecules in the universe, one would have to expect to wait many lifetimes of the universe before any noticeable fluctuations from equilibrium would arise. It was for this very reason that Boltzmann felt himself justified in ignoring the implications of the recurrence theorem.[19]

Hyperbolic Philosophy

While it may be true that some of the reason why Peirce was so sanguine about the future of the universe was due to the Victorian spirit of progress, he also drew on empirical sources.

> Question any science which deals with the course of time. . . . Everywhere the main fact is growth and increasing complexity. Death and corruption are mere accidents or secondary phenomena. (6.58)

> Some of us are evolutionists; that is, we are so impressed with the pervasiveness of growth, whose course seems only here and there to be interrupted, that it seems to us that the universe as a whole, so far as anything can possibly be conceived or logically opined of the whole, should be conceived as growing. (6.613)

There is little wonder, then, that he took his law of habit as the fundamental force energizing the world. Peirce spoke of the need for philosophy to embrace a "thorough-going evolutionism or none" (6.14). It was on this account that he disagreed with Spencer's system; Spencer he said was only "half-evolutionist" (ibid.; N2, 227–8). While Peirce was prepared to make the tentative assumption that growth was the general trend throughout the world, he noted that "others say, though parts of the universe simulate growth at intervals, yet there really is no growth on the whole—no passage from a simpler to a more complex state of things, no increasing diversity" (6.613). This comment could just as easily have been directed at Boltzmann as at Spencer, for, under pressure from the objections of Loschmidt, Poincaré, Zermelo, and others, Boltzmann was eventually forced to concede that on the whole and throughout the entirety of the universe, the irreversible approach to equilibrium described by his own statistical interpretation of the entropy law was not quite universally valid. Instead, Boltzmann suggested that under the assumption that equilibrium was by far the most common state of the universe at large, there may occur comparatively small pockets where entropy was actually on the decrease. In such places, time would be running "backward," as it were, relative to our own local understanding of its reliance on the dissipation of energy and increase of entropy. Time would not be uniformly irreversible after all on a cosmic scale. However, in such entropy-decreasing systems, one would also find the birth and growth of new worlds. Still, these would be only extremely rare and improbable fluctuations from a much more common state of death and decay. So in the end, Peirce could no longer look to Boltzmann for support of the thesis that time flows in one direction only, nor could he quite consider him an ally on the question of cumulative universal progress.

It is interesting to note just how complex Peirce's own position on matters of cosmology becomes at this stage. He is really fighting a battle on two fronts. On the one hand, he clearly wished to side with the irreversibility crowd (e.g., Thomson, Helmholtz, Clausius, Maxwell, early Boltzmann) in opposition to those arguing for reversibility or recurrence (e.g., Poincaré, Zermelo, Spencer, later Boltzmann). On the other hand, he also had to reject the final state projected by those in favor of irreversibility (i.e. the heat death of the universe). According to Peirce's theory, the universe should continue to get more and more complex under the influence of the law of habit until it becomes "an absolutely perfect, rational, and symmetrical system, in which mind is at last crystallized in the infinitely distant future" (6.33).

Now, either he was willing to identify the ultimate "crystallization of mind" with the heat death of the universe or else he felt that the law of habit could somehow overcome that fate. Surprisingly, perhaps, there is no immediate difficulty with this first alternative even if we take the crystallization metaphor quite literally. As Nobel laureate Percy Bridgman explains, the formation of a crystal is consistent with an overall increase in entropy:

> Consider, for example, a quantity of sub-cooled liquid, which presently solidifies irreversibly, with increase of entropy and temperature, into a crystal with perhaps a regular external crystal form and certainly a regular internal arrangement as disclosed by X-rays. Statistically, of course, the extra "disorder" associated with the higher temperature of the crystal more than compensates for the effect of the regularity of the crystal lattice. But I think, nevertheless, we do not feel altogether comfortable at being forced to say that the crystal is the seat of greater disorder than the parent liquid. . . . There is a fuzziness about the common-sense notion of "disorder" which makes it not always altogether suited as an intuitive tool in discussing the second law.[20]

Despite this, the implication that the universe will continue to develop in terms of complexity does not appear to fit well with a state of equilibrium. (Even if we grant the vagueness surrounding the notion of complexity). Peirce, remember, alternatively conceived of the final state as one exhibiting great variety and complexity. The solution sought after is therefore not unlike that architectonic problem that Leibniz supposed faced God before the creation of the world: For Leibniz, it is the simultaneous maximization of being and simplicity; for Peirce, it is the simultaneous maximization of diversity and symmetry. And like Leibniz, who sought a solution in making an architectonic principle of a principle of mathematics (a maxi-min principle of calculus), Peirce sought his in the law of large numbers. Peirce believed that the law of habit, acting in accordance with the agapastic formula of "evolutionary love"—throwing off chance variations and reintegrating them into a stronger stochastic habit or propensity—was capable of escaping the less than optimistic conclusions of the thermodynamicists. After all, even those thinkers who had helped establish an understanding of the asymmetry of time were still, by and large, and in Peirce's own opinion, too much under the sway of the mechanistic philosophy.[21]

But this raises the question of whether Peirce really conceived of the evolutionary trend as resulting ultimately in a truly "perfect" system. A letter of 1908 suggests a more tempered opinion:

> When we see the enormous importance of evolution, both in the moral and in the physical universes, how the whole world seems to have been designed, not to be perfect, but to rise, and grow, and ameliorate, I declare that it is urgent that the idea of evolution should be extended far beyond Spencer's conceptions, both as to the Physical as to the psychical universes. (NEM, III ii, 891)

It should be kept in mind that the ultimate end of universal evolution, which Peirce describes in terms of "perfection," "symmetry," and "harmony," and so on, is only an unattainable limit off in the infinitely distant future.

Closely tied to the notion of perfection is the notion of progress. Throughout the nineteenth century, the idea that unlimited progress was a realizable possibility stemmed largely from two sources: (1) from the great strides made in science and technology, resulting directly in improved living conditions (for the middle and upper classes, at least), and (2) from what were taken to be sound implications of the theory of evolution—namely, the suggestion of an unlimited potential for human perfectibility, via the competition among peoples and the eventual dominance of the "fittest" race ("fitness" being understood to cover traits as widely divergent as economic and military success and virtuousness). Peirce clearly shared this optimism with regard to the prospects of science. But as we have seen above, he expressed severe disapproval of Social Darwinism, dubbing it the "gospel of greed." The kind of progress pertinent to his cosmology is of an *intellectual* variety. What the evolutionary trend is trying to accomplish is the "crystallization of mind," the development of "concrete reasonableness," or a more rational—that is, more lawful and regular—world.

Involved in this process is the introduction of new possibilities, a subprocess that Peirce alternately called diversification or variescence. In his explication of this process to Lady Welby, it becomes a bit clearer that when he talks of *progress*, its primary intention is not necessarily normative:

> I may however spend a few minutes in explaining what I *mean* by saying that if the universe were governed by immutable law there could be no progress. In place of the word progress I will put a word invented to express what I mean, to wit, *variescence*, I mean such a change as to produce an uncompensated increment in the number of independent elements of a situation. (SS, 143)

Variescence, then, is just that fortuitous variation involved in the law of large numbers. From a dynamical perspective, it is nothing more than a growth in the number of degrees of freedom in the universal system. On its own, this can be considered neither good nor bad. It is for this reason, so I have argued, that Peirce required the thesis of agapasm, of evolutionary love. It is only by selecting and adapting the raw material that is supplied by the process of random variescence that any progress in the *normative* sense can be made.

The fortuitous creation of novel forms and the adaptive force of evolutionary love are each necessary but insufficient on their own to bring about the crystallization of mind. In the very end, the law of habit must become fixed so as to produce perfect regularity, thereby completely diminishing the presence of spontaneous chance. The sense in which cosmic evolution leads to perfection (in regular behavior) in this case is quite clear. It is the eventual triumph of law over randomness. Whereas Helmholtz and Clausius would have the universe suffer in the end a heat death, Peirce would have it meet with a "habit death." In an odd way, then, the final outcome of this growth of reasonableness and crystallization of mind is the death of all life, all spontaneity, and all consciousness.

But until such time as the influence of law has become perfectly exact and rigid, chance has yet a crucial role to play, for in addition to its role in supplying the force of agape with raw material, without it the law of habit could not be of the evolutionary type Peirce required—that is, one capable of developing under its own influence and in so doing requiring no arbitrary and permanent law. To invoke a law already exact and precise would be to violate the first rule of inquiry forbidding the assumption of brute facts: "Do not block the path of inquiry."

Peirce's was not the only example of a hyperbolic cosmology espousing some form of real progress. Nor was his the only one in which the ultimate goal was the development of mind or reason. Hegel had, of course, preceded Peirce in this direction. And Peirce was not beyond admitting the similarities between his own and Hegel's philosophy:

> The truth is that pragmaticism is closely allied to the Hegelian absolute idealism, from which, however, it is sundered by its vigorous denial that the third category (which Hegel degrades to a mere stage of thinking) suffices to make the world, or is even so much as self-sufficient. (5.436)

This repeats what has just been said above concerning the ultimate accomplishment of the evolutionary goal relying on both the fortuitous variation (i.e., the first category) and the adaptive influence of agape (i.e., the third category). The failing of the majority of philosophical systems thus far had been their emphasis on one of the categories to the exclusion of the remaining two. Mechanism, being closely allied with nominalism, attempted to get by on secondness alone (i.e., the category of force, of action and reaction, and of present, actual existence). Hegel, on the other hand, focused all of his attention on thirdness, the category of law, of generality and of all that is mental or ideal. But in Peirce's estimation, all three of the fundamental categories are necessary to make sense of the world.

As I have noted from time to time, a helpful way of understanding the cosmological writings is to think of them as a personal history of the operation of Peirce's own mind in his attempts to clarify ideas in mathematics and logic.[22] In light of this, it is ironic to see Peirce quip that "the Absolute Knowledge of Hegel is nothing but G.W.F. Hegel's idea of himself" (8.118). On his behalf, it should be mentioned, though, that Peirce offered his cosmological speculations not as absolute truth but as a hypothesis to be accepted or rejected on the basis of observed facts. There have been complaints by some of his later commentators that his metaphysics does not lend itself to refutation. But Peirce believed that it did, and even supplied a brief—if ambiguous—clue as to how this might be done. "I ought to add the confession that were *Fechner's law* shown not to be the true one, the refutation of it would at the same time refute my synechistic hypothesis of the evolution of the universe" (NEM, IV, 98). Gustav Fechner (1801–87) was a German professor of physics and pioneer in experimental psychology; he was also, according to Michael Heidelberger, the first modern thinker to espouse a well-worked out indeterminism.[23] It was Fechner's research (*Elemente der Psychophysik*, 1860) on the existence of a limit of least-perceptible difference in sensations (an *Unterschiedsschwelle*) that provoked Peirce to undertake his own experiments, published as "On Small Differences of Sensation" (W5, 122–35). In addition to having claimed the existence of a threshold of minimum sensation, Fechner also introduced the law that quantifies the relationship between sensation and stimulus. This law, expressed as $S = C \log R$, states that as the intensity of a sensation, S, increases, it requires increasingly greater levels of excitation, R, to create a perceptible difference. Peirce claimed to have refuted the existence of the *Unterschiedsschwelle* (or least-perceptible difference) by having shown that test subjects were able to make judgments in differences in pressure sensations, even beneath the level at which they claimed to be able to detect any difference, with a success ratio greater than was to be expected by chance, and with a dispersion exhibiting the familiar error curve. According to the hypothesis that there did exist a least-perceptible difference, the ratio of correct to incorrect responses at this threshold or beyond was predicted to be an equal 50:50. As Nathan Houser's editorial notes to volume five of the *Chronological Edition* (W5, 436) explain, in disproving the existence of a "differential threshold" Peirce's experimental results supported his claim that "cognition is continuous, *not* beginning with *first impressions of sensation.*" In other words, Peirce's experiment supported the opinion that there is no discrete quantum of sensation. This is of quite obvious importance for Peirce's thesis of synechism, for it supports his claim that minds are in a continuous contact with one another and the rest of the universe. It had likewise been Fechner's ambition to establish that mind and matter were merely two different modes of a single substance. The importance of his psychophysical law for Peirce's cosmological theory becomes clearer in light of this, for what it shows is the continuous relationship between psychical sensation and physical matter. Because all substance is essentially mind, there could be no development in the way Peirce supposes without the possibility of continuous interaction and influence among islands of feeling and sensation.[24]

Peirce's Acquaintance with Modern Physics

Within Peirce's cosmological scheme, cosmic evolution is progressive and irreversible, culminating in a final state of absolute rigidity of laws and perfection of thought in terms of symmetry and harmony. Once everything is guided by exact laws, there will be no more arbitrariness and spontaneity, and everything will be perfectly "reasonable." It is difficult to gauge whether the end state envisaged by Peirce is supposed to be as static and frozen as his crystallization metaphor suggests or whether a dynamical element remains, with events continuing to take place, but in a perfectly regular and lawlike fashion.

Much of the difficulty surrounding Peirce's cosmological theory arises from the all-embracing scope demanded of it by his stringent methodological principles, specifically the first rule of inquiry (i.e., no fact is to be accepted as brute or inexplicable). It was his ambition to leave nothing unaccounted for, at least nothing that he felt deserved a suitable explanation. Chance and spontaneity were the only things he could find that did not appear to him to require explanations themselves. It should be noted, however, that despite its radically metaphysical tinge, Peirce's strategy is not without its adherents in modern cosmology. As D. R. Finkelstein (1996, 278) writes of respected Princeton mathematical physicist John Wheeler, "Today some speculate on an autonomous cosmology rather as Peirce did in the 19th century. For example, Wheeler (1973) proposes that 'The only law is the Law of Large Numbers. . . .'" Furthermore, the presently popular quantum cosmological theories, which have the universe popping into being as a chance fluctuation from the quantum vacuum, have a distinctly familiar ring to them.[25]

Nor did the idea that the laws of nature themselves might be subject to an evolutionary development get buried with Peirce.[26]

But perhaps the two most conspicuous reasons why his cosmology appears odd from a modern perspective are the absence of relativity and quantum theory. Peirce can hardly be blamed for not being familiar with modern quantum mechanics, as it was not properly developed until well after his death. But in fact he is often credited for the degree to which he foresaw the plausibility of a radically indeterministic physical theory. And there can be no denying that he was well acquainted with some of the experimental evidence turning up at the end of the nineteenth century that would eventually result in the quantum revolution. In several places, Peirce questions the assumption that the laws of dynamics hold for atomic bodies. For instance, at 2.732 he writes, "Although all the bodies we have had the opportunity of examining appear to obey the law of inertia, this does not prove that atoms and atomicules are subject to the same law." Similarly we find him writing at 6.11 that "there is room for serious doubt whether the fundamental laws of mechanics hold good for single atoms, and it seems quite likely that they are capable of motion in more than three dimensions." In a 1906 discussion of phenomena concerning radium and the spontaneous nature of radioactivity, he wrote quite presciently that such evidence

> Promises to mark the deepest revolution of scientific conceptions, by reducing matter from the rank of primordial substance to that of a special state of electricity. After that, we shall be prepared for anything, even for experimental demonstration of the tychist's doctrine that electricity is a psychical phenomenon. (N3, 255)

It should be noted too that despite his tendency toward speculative thought, Peirce's motivations were firmly rooted in an appreciation for the fallibility of experimental results, and for the essential need for flexibility in the scientific mind-set. As he wrote, perhaps overly pessimistically,

> The non-scientific mind has the most ridiculous ideas of the precision of laboratory-work, and would be much surprised to learn that, excepting electrical measurements, the bulk of it does not exceed the precision of an upholsterer who comes to measure a window for a pair of curtains. (NEM, III, ii, 897)

This imperfect degree of precision necessitates an attitude of caution with regard to scientific results:

> But nowadays how many fools there are who think that laboratory experience measures what goes on in the world, who are cocksure of the doctrine of energy, etc., etc. That great Canadian Rutherford with J. J. Thompson [sic] on the other side are in a fair way to show that the three laws of motion are not true. If they succeed, the effect on men's minds ought to be salutary though no doubt the race of fools will not become quite extinct. So much then for science. (In Ketner, 1998, 159)[27]

One must be careful not to overextend one's confidence in specific propositions beyond the strength of evidence available to support them.

> Students of molecular physics presume, for reasons that seem good to them, that certain things are absolutely true of the universe in every part, such as the tridimensionality of space, its infinity, the law of action and reaction, the principle of energy, and the like. These universal truths, as they are held to be, have a basis in experience, but are extended so far beyond the domain of observation as to be fairly termed metaphysical. In many branches of physics it is easy to show that they are near enough true for practical purposes; but in molecular discussions the question of the truth of such things has to be sifted to the bottom, on pain of leaving a grave doubt over the whole subject. (N1, 152–53)

There can be no doubt, then, that Peirce was aware of the early developments in molecular and atomic research that would eventually become quantum physics. Granted, though, as Charles Hartshorne (1973) has objected, Peirce's insistence on the importance of continuity in scientific theory made him ill-prepared to foresee the full nature of the quantum revolution to come.

It is rather curious that there is no apparent mention of Einstein's 1905 paper on Brownian motion in Peirce's papers. This paper, one would have thought, having provided such convincing support for the reality of atoms and their "random" motions, would have also been, in Peirce's eyes, a natural piece of evidence in favor of the thesis of tychism. With respect to relativity, no mention of Einstein appears to be present in Peirce's vast manuscripts and correspondence, although he clearly was familiar with the work of Hendrik Lorentz (1853–1928). In a 1905 review of Sir Arthur Schuster's *An Introduction to the Theory of Optics* (London: Edward Arnold, 1904), Peirce says of the law of inertial motion that

> At this moment a growing moiety of the world of physics assumes this law to be only approximately true, and that only for velocities not too great. The physicists of the nineteenth century took for their sole aim of their hypotheses the explanation of phenomena as special cases under the general laws of dynamics. The new school, however, proposes to explain dynamics as a special case under the general laws of electricity. (N3, 204–5)

And five years later, in 1910, he wrote:

> Since it now appears necessary to the representation of the motions of Mercury and Venus to introduce a rotation of the line of apsides that signifies that gravitation is not precisely proportional to the inverse square of the radius vector, since Lorentz's extraordinary conclusions concerning time and space, and since Newton's laws of motion are recognized as not exact when the moving body has nearly the velocity of light, scientific men must be ready to examine the evidence that the laws of nature are subject to irregular violations. (NEM, III, i, 213)

And again in 1911, we find him writing that

> All scientific reasoning, outside of mathematics and the Arabian Nights, *is* provisional. Every scientific man knows it. It was only the other day that the second law of motion was exploded. The same force that would accelerate a slowly moving body very much, will have hardly any effect if the body affected is moving nearly as fast as light. (NEM, III, i, 197)

In 1911, just three years before his death, an ailing and elderly Peirce complained to his friend, Englishwoman and student of semiotics Victoria Lady Welby, of the poverty that had kept him from the books and journals necessary to stay abreast of modern science: "For the last three years I have not had sight of a new book" (SS, 142). Peirce died penniless and cancer ridden on April 19, 1914, at his home, Arisbe, in Milford, Pennsylvania. Brent (1993, 321) writes that after his widow, Juliette, died in 1934 and the articles of any value were auctioned off, the new owner of the home burned the remnants of Peirce's life in the front yard, a truly sad end to the individual who nurtured a vision of the evolution of a universal community of minds energized by the twin ideals of Reason and Christian-Socialism.[28]

6

Chance and Law

> Chance *alone* is at the source of every innovation, of all creation in the biosphere. Pure chance, absolutely free but blind, at the very root of the stupendous edifice of evolution . . .
>
> Jacques Monod (1972, 4a)

In Peirce's system, the fates of chance and law are inversely related. What starts off as a chaotic sequence of events gradually becomes more and more regular and lawlike, until all semblance of spontaneity and life are forever diminished. Until then, both chance and law coexist in an intimate relationship, entwined in the law of habit. From the usual perspective, we would start with the presumption of already established laws and then add that these are occasionally violated by chance events. But as envisaged by Peirce, what we have first is a rather unruly sequence of events, which only approximately follows the guidelines of law; then, with an increase of repetitions and of time, these events come to be more and more lawful and regular. In this way, the laws themselves become more stable in the process, just as a statistical law such as is described by the normal distribution curve becomes more exact as the number of trials increases. It is important to keep in mind Peirce's own words that "Chance is First, Law is Second, and Habit-taking is Third." Habit taking is the intermediary step that takes us from chance and randomness to regularity and law. Essential to the habit-taking principle is a stochastic element that allows for growth and development. Chance is, in a manner of speaking, the lubricant that keeps the engine of law from seizing up and the evolution of the universe from coming to a screeching halt. One of the results of Peirce's analysis was to situate all natural laws on a statistical continuum. The two extreme end points of the continuum stand out as exceptions: At one end, there is no law—complete randomness (whatever that might be), and at the other, perfect 100 percent correlation.[1]

The chief objective of this chapter is to submit to critical analysis Peirce's notions of chance and the growth of statistical law. After first discussing the ambiguity surrounding Peirce's multiple interpretations of the notion of chance, I will offer an objection to the viability of combining the law of habit taking with the law of large numbers. I will make the criticism, first, that the account of the growth of law by the principle of habit taking makes the statistical mechanical account of irreversibility redundant (which is a serious problem because it is to this that he constantly appeals for evidential support of both the irreversibility of physical and mental processes and the role of chance in natural events), and second, that the statistical mechanical account and the law of habit taking are simply incompatible with one another.

What Is Chance?

To the question "What is chance?" Peirce gives several distinct answers. To begin with, probability, for which the idea of chance is so essential, is not a merely subjective measure of our own ignorance or beliefs (6.612). Were that so, the success of the entire business of insurance companies and of gambling casinos would constitute something of a miracle. The stable frequencies on which these enterprises are dependent, and that are so closely associated with the notion of chance, are objective facts about real aspects of the world. To say that slightly more than 50 percent of newborns are male is not the expression of a guess on our part. It is a figure compiled from real events occurring in the world. Moreover, to say that the probability of tossing a head with a fair coin is 50 percent is just as much a statement of fact about the world; in this case, the subject of our statement is a tendency, a potentiality, a disposition, or a habit that would make itself manifest in the long-run series of repeated trials.[2] Although chance is of the nature of a first, it displays itself in a fashion that distinctly portrays an element of thirdness and law. "But in the long run, there is a real fact which corresponds to the idea of probability, and it is that a given mode of inference sometimes proves successful and sometimes not, and that in a ratio ultimately fixed."[3]

This notion of chance that is so important for the theory of probability and the practice of statistics has a distinct mathematical structure. In what follows, I will employ the term *mathematical chance* to refer to this conception. Peirce called this conception of chance "relative," "ordinary," or "quasi" chance (W4, 548–49). As a mathematician, experimental scientist, and logician, Peirce was intimately familiar with the mathematical notion of chance.

But as a philosopher, he was also interested in a deeper, more metaphysical notion. For this second notion of chance, so fundamental to the thesis of tychism, I will use Peirce's own term of *absolute chance*. We are compelled to invoke the notion of absolute chance, he argued, to explain a number of very general facts about the universe, facts that otherwise would have to go unaccounted for because no explanation of them in terms of mechanical causation is forthcoming. We met these phenomena once already in the first chapter. They are

1. The general prevalence of growth, which seems to be opposed to the conservation of energy
2. The variety of the universe, which is chance, and is manifestly inexplicable
3. Law, which requires to be explained and, like everything that is to be explained, must be explained by something else—that is, by nonlaw or real chance
4. Feeling, for which room cannot be found if the conservation of energy is maintained (6.613)

Peirce's strategy amounts ultimately to invoking some very different forms of chance to explain each of these four explananda. By investigating the way in which each of these is dealt with, I will introduce Peirce's different conceptions of chance.

1. The general prevalence of growth, which seems to be opposed to the conservation of energy: This first phenomenon could be more simply expressed as irreversible phenomena in general. We have seen Peirce remark, numerous times now, that the law of the conservation of energy is equivalent to the statement that conservative forces are time-reversible (6.14, 6.274, 8.187). Because growth is a paradigm of an irreversible process, Peirce often wrote that growth is an apparent violation of the law of energy. It is only an apparent violation because physicists such as Maxwell and Boltzmann attributed irreversible phenomena to the result of chance interactions among large numbers of molecules (1.157). They did this while preserving the assumption that such systems are perfectly conservative. The important feature of the notion of chance appealed to here is just that of independence among events.[4] Because independence also happens to be the chief feature of the mathematical theory of probability and statistics, we may say that the first problem involves the notion of mathematical chance.

In one of the most extensive discussions of the notion of chance (RLT, Chapter 6, 6.78*ff*.), Peirce concentrated on the different ways in which a number of things can be distributed. There are three basic ways in which a series of things or events, such as outcomes of coin tosses, can be distributed, he claims. In a *uniform* distribution, *heads* and *tails* will follow one another in a regular fashion (e.g., *H, T, H, T, H, T* . . .). In a *sifted* distribution, the two types will be separated out from one another (e.g., *H, H, H,* . . . *T, T, T* . . .). Finally, if the types exhibit no regularity or discernible pattern in their distribution, then they are said to be distributed *randomly* (e.g., *T, H, T, T, H, T, H, H, H* . . .). This leads Peirce to write that "chance, then, as an objective phenomenon, is a property of a *distribution*" (RLT, p. 204), and that "chance, then, in the sense in which the doctrine of chances studies it consists in a statistical law and no other law governing the succession of a species of events in the endless future" (NEM, III, i, 398). For Peirce, much of what is regular and lawful about chance is expressed in the normal frequency distribution curve: "Everybody is familiar with the fact that chance has laws, and that statistical results follow therefrom" (6.606).

2. The variety of the universe, which is chance, and is manifestly inexplicable: Notice that Peirce says here, "the variety of the universe, which *is* chance . . ." [italics mine], thereby equating chance and variety. This was an identification that Peirce originally held for some time.[5] He would later revise this position, however:

> For a long time, I myself strove to make chance that diversity in the universe which laws leave room for, instead of a violation of law, or lawlessness. That was truly believing in chance that was not absolute chance. It was recognizing that chance does play a part in the world,

> apart from what we may know or be ignorant of. But it was a transitional belief which I passed through . . . (6.602)

The idea behind this earlier view that chance is "that diversity in the universe which the laws leave room for" is simply this: If the queen of England has a coughing fit at the very same time I take a drink of beer, there is no law that determined this confluence of events to occur (6.90). Coincidences of this sort are happening all the time, and it would be fallacious to read anything more into them than a spurious correlation. Not every fact (or relation between facts) about the world has been determined by law.

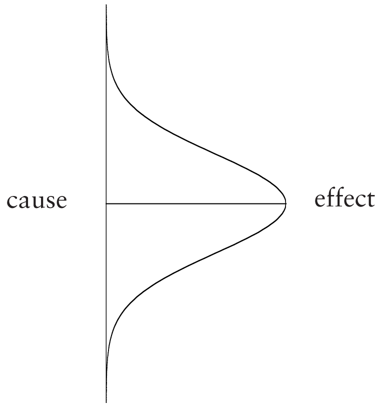
Alternative expressions of this notion of chance used by Peirce are *unlawfulness*, *fortuity*, *freedom*, and *arbitrariness* (6.322, 6.612). Even if one were to hold that the laws of motion determine every physical outcome one cared to study (something no one familiar with modern quantum physics would do), few would wish to assert that the initial conditions of an arbitrary physical system were determined by exact law to be just as they are and no other way. Arranging the different opinions one might have about the degree of arbitrariness in the world from *A* through *E*, Peirce set his own beliefs in an informative contrast with others (6.90–92). According to the class of *A*'s, who admit the least amount of contingency, for every fact and relation among facts there is a corresponding reason or law responsible for its being just so. The *A*'s believe that the synchronicity of the queen of England's cough and my sip of beer are significant of some deep cosmic plan or providence. *B*'s will admit that every *individual* fact is determined by law but that some *relations* between facts are accidental, whereas *C*'s believe that "uniformity within its jurisdiction is perfect" but will confine "its application to certain elements of phenomena" (6.90). The *D*'s, with which Peirce aligned himself, hold that "uniformities are never absolutely exact, so that the variety of the world is forever increasing" (6.91). The *E*'s, the last class, believe in miracles and that nature is "subject to freaks." An example of an *E*, he explains, is the astronomer Simon Newcomb, who supposed the human will capable of deflecting the motions of molecules, "in plain violation of the third law of motion," as Peirce objects.[6]

Peirce's object, then, is just to point out that contingencies and spurious correlations do exist. Not every fact is governed by law and reason. "Chance may mean that which, while necessary causally, is not necessary teleologically; the unplanned, the fatalistic" (6.366). But as the quote being discussed here suggests, the view that equates chance with variety is weaker than the idea that chance is a violation of law. It is this stronger notion of chance as a violation of law that Peirce later calls *absolute* chance. The argument for positing chance in this sense is that we could not account for the variety and diversity in the world (both organic and inorganic) were it the case that laws were always exact and completely deterministic of their outcomes. The idea of necessary mechanical law prescribes that like causes will always produce like effects (1.174). We must then suppose, Peirce argues, that laws do not exactly determine their outcomes in every instance. There must be a spontaneous source of novelty that will allow for the observable variety of the world (1.161).[7] This spontaneous source of novelty and variety is "absolute chance." To fulfill this function, absolute chance must be a real suspension or interruption of natural law. "That there is an arbitrary element in the universe we see—namely, its variety. This variety must be attributed to spontaneity in some form" (6.30). It is very likely that Peirce had been influenced by Darwin's explanation of phenotypic variation between parent and offspring by appeal to random "sports" in genotypic material.

It is unfortunate, though, that Peirce chose to speak of absolute chance as a "violation" of law, for there are two different ways of understanding the violation of law, one of which is very misleading for anyone trying to understand what Peirce is really saying. This misleading interpretation might be called the *active* form of violation. With this reading, we take an exact law as given and posit the occasional suspension or interruption of its influence upon events.[8] The alternative is a *passive* construal whereby laws are not assumed to be exact but are imperfect in their ability to "shape" events. A violation, with this reading, occurs when the law does not completely determine the event in question. Rather than the same causes always producing the same effects, the same cause would produce a normally distributed variety of effects about a mean or average tendency (see Figure 6.1). The passive interpretation is more compatible with Peirce's picture of the evolution of laws as being modeled on the law of large numbers or central limit theorem.

Laws, recall, become more exact as the number of elements or

Figure 6.1. Tychistic causation: The same cause results in a range of effects normally distributed about a mean or average effect.



events increases to infinity. Chance is first, law is second, and habit taking is the intermediary third by which we get from the first to the second. By insisting on talking of laws as being "violated," rather than of their being inexact and imperfect, Peirce is constantly inviting misinterpretation of his intentions. Laws are inexact because they have not yet finished developing. To talk about their being violated suggests that they are already exact and are somehow subject to a mysterious interruption. Peirce is often more lax in his language than one would expect from the inventor of a method for the clarification of ideas. Because of this, it is difficult not to repeat his unfortunate choice of expressions. The best we can do is to try to keep the important distinction in mind throughout the remainder of this chapter.

In sum, we see that the second class of phenomena results in two distinct notions of chance: (1) the identification of chance with variety and diversity and (2) an appeal to spontaneous chance violation (imprecision!) of law as the *source* or *cause* of this variety.

In his *Century Dictionary* article on chance, Peirce included a paragraph on absolute chance:

> Absolute chance, the (supposed) spontaneous occurrence of events undetermined by any general law or by any free volition. According to Aristotle, events may come about in three ways: first, by necessity or an external compulsion; second, by nature, or the development of an

> inward germinal tendency; and third, by chance, without any determining cause or principle whatever, by lawless, sporadic originality. (C, 918)

This characterization of Aristotle's conception of chance is slightly peculiar. It would be more accurate to say that for Aristotle chance is just an intersection of two or more independent causal chains undetermined by any general law.[9]

3. Law which requires to be explained and, like everything which is to be explained, must be explained by something else—that is, by nonlaw or real chance: In contrast to the idea of mechanical law whereby causes determine their effects with necessity, Peirce's law of habit taking is stochastic. Its influence on events is neither exact nor necessary. The law of habit only makes a particular type of outcome more likely to recur than not as a result of its having occurred in the past. And as the law of habit is itself just another type of inexact regularity among events, it, too, is prone to be strengthened by the natural tendency of things to become more regular. The law of habit acts on itself in a fashion similar to the way in which autocatalytic systems of chemical reactions create a self-sustaining feedback loop.

But what kind of chance is supposed to be operating within this process of habit taking? Clearly it must fall under the guise of absolute chance, for mathematical chance cannot have anything to say about anything like this that is supposedly going on in the real world. Mathematical chance is really only a feature of the models we create to make predictions about certain systems or processes in the world that satisfy appropriate conditions of randomness. So what kind of absolute chance is at work in the law of habit? That it is a violation of law seems at first on the right track, because the increase of regularity or habitualness called for implies some kind of "updating" function. At any point in its development, the law of habit, we may suppose, is "set" to impose a correlation of p percent between event types (e.g., A is followed by B, with a probability of p percent), and with each repetition of a cause-and-effect or stimulus-and-response pair (B/A, read "B given A"), the probability of their recurrence together in the future must get updated by some unspecified amount. But how does this updating in the transition probabilities get done? With each repetition of *A–B* event-type pairs, the probability of their recurring together in the future somehow (rather mysteriously) increases. It must be remembered that Peirce's model for the entire habit-taking phenomenon is mental in origin. "I believe the law of habit to be purely psychical" (8.318). And "we have to remember that no mental tendency is so easily strengthened by the action of habit as is the tendency to take habits" (6.266). How or why does this tendency to repeat past actions appear? In the "Design and Chance" lecture delivered in 1883–84, in which Peirce first went public with his cosmological speculations, he suggests that such a tendency is just one of many that may have arisen from the original chaos by sheer chance. A tendency to do otherwise than to become more regular and systematic would be self-defeating, and so by a kind of natural selection, the habit-taking tendency, once arisen by chance, is destined to become ever stronger and to result in the kind of systematic and coherent world in which we find ourselves (cf. EP, I, 223–24).

4. Feeling, for which room cannot be found if the conservation of energy is maintained: Peirce writes that there is no room for feeling in our picture of the world if the conservation of energy principle is maintained. What did he mean? We have already become very familiar with the statement that the conservation principle is (without special assumptions about the atomic nature of matter and the random motions of those particles) incompatible with processes of an irreversible nature. To make the two compatible, Peirce believed, we must admit into our theory of the world an objective reading of chance. The kinetic theory of gases does this by positing that the motions of molecules and atoms are virtually, *for all intents and purposes*, independent of one another, except for the collisions the particles have with one another. Aside from these brief interactions, all other features of their motions are supposed to be essentially distributed at random.

But when Peirce brings up the issue of feeling, he is thinking of more than just the fact that the action of mind is "nonconservational"—that is, irreversible or goal-directed. During the time he was writing, some scientists and philosophers were attempting to deal with the problem of mind–matter interaction by supposing that mind could somehow influence the motions of molecules and atoms.[10] In response to these proposals, Peirce pointed out that they were tantamount to a rejection of Newton's third law of action and reaction (itself equivalent to the conservation of momentum principle). In his own opinion, it was both simpler and more methodologically sound to suppose that either the energy conservation principle did not apply to minds and living organisms (and so, in effect, was not a universal principle) or was not a perfectly exact principle operating within nature.

To meet this challenge, Peirce identified chance, or rather spontaneity, with life and feeling. "Chance is but the outward aspect of that which within itself is feeling" (6.265). This is really no more than the thesis of objective idealism with Peirce's own peculiar twist of tychism. Matter is not completely dead; it just does not have enough spontaneity or feeling left in it to be of notice to us. But insofar as matter does exhibit spontaneous random activity (think of measurement error and Brownian motion), it still has an element of life left in it.[11] This should not be confused, however, with the claim that matter is animated with consciousness. That, he admits, requires a chemical arrangement of great molecular complexity; though just how a complex molecular system is supposed to result in all the phenomena familiarly associated with the human mind is never adequately discussed by him.

In making this move of admitting chance and feeling into his system, Peirce was aware that he was following a path blazed many years before him: "Epicurus, in revising the atomic doctrine and repairing its defences, found himself obliged to suppose that atoms swerve from their courses by spontaneous chance; and thereby he conferred upon the theory *life* and *entelechy*" (6.36; italics mine). This gives us a third conception of absolute chance—namely, chance as spontaneity and vitality.

The extent to which Peirce was willing to identify chance with feeling and life is really quite striking.

> But it is a question whether absolute chance—pure tychism—ought not to be regarded as a product of freedom, and therefore of life, not necessarily physiological. . . . Pure chance may itself be a vital phenomenon. (6.322)

> That it [absolute chance] is a being, living and conscious, is what all the dullness that belongs to ratiocination's self can scarce muster the hardihood to deny. (6.612)

When contrasted with the others, this notion of chance stands out as the least intuitive.

Let us take stock now of the range of interpretations available. Chance, as employed by Peirce, means

1. Independence of events
2. Random distribution
3. Diversity or variety
4. Contingency or freedom from law
5. Violation of law (imprecision)
6. Feeling, spontaneity, vitality

Items 1 and 2 fall squarely within the range of what I have called "mathematical" chance. Items 3 through 6 involve, to some degree, what Peirce called "absolute" chance. In light of the great diversity and even incongruity of these different interpretations, it comes as a bit of a shock to hear Peirce say that when he speaks "of chance, I only employ a mathematical term to express with accuracy the characteristics of freedom or spontaneity" (6.201). What he means, I believe, is that the spontaneity that he has identified as chance exhibits a range of variation that is precisely described by the normal probability curve. This is the same law that describes the distribution of errors of observations and, as we saw him claim in Chapter Four, errors in reasoning. The normal probability curve, in other words, describes the range of intensity of spontaneous vital activity. Infinitesimal chance fluctuations from well-established laws occur continually, but great ones only with infinite infrequency (6.59).

It would appear that in tolerating such a wide understanding of chance, Peirce did not see himself as being out of line with sound mathematical and logical practice. For as he explained,

> I do no more, then, than follow the usual method of the physicists, in calling in chance to explain the apparent violation of the law of energy which is presented by the phenomena of growth; only instead of chance, as they understand it, I call in absolute chance. For many months I en-

> deavoured to satisfy the data of the case with ordinary *quasi* chance; but it would not do. (6.613)

There is a question, though, whether the "usual" method of the physicists would remain valid if instead of supposing that certain mechanical properties of individual molecules were merely independent of the values taken by other molecules, we understood the mechanical laws describing their motions actually to be violated. Would gases, for instance, continue to behave in the usual way if the molecules did not precisely follow Newton's laws of motion?

Certainly Peirce represents a unique position on the question of chance among his mathematical and scientific colleagues. Even though James Clerk Maxwell was equally concerned to find room for the idea of free will, he could not bring himself to endorse as radical an interpretation of chance as did Peirce. To save the freedom of will from the dictatorship of mechanical causation, Maxwell was willing to suppose that the mind was able to influence the outcome of material events. It could do so, he speculated, by exerting its influence at "singularity" points, points of instability at which an infinitely small variation in the initial conditions of a system may bring about a finite difference in the future state.[12]

> The rock loosed by frost and balanced on a singular point of the mountain-side, the little spark which kindles the great forest, the little word which sets the world a fighting, the little scruple which prevents a man from doing his will, the little spore which blights all the potatoes, the little gemmule which makes us philosophers or idiots. Every existence above a certain rank has its singular points: the higher the rank the more of them. At these points, influences whose physical magnitude is too small to be taken account of by a finite being, may produce results of the greatest importance.[13]

That Peirce was familiar with these possibilities is evident from the following passage:

> Some suppose that while law is absolute, yet there are constantly arising cases analogous to unstable equilibrium in which, owing to a passage of velocity through infinity or otherwise, the law does not determine what the motion shall be. . . . Such "singularities," as the mathematicians say, are theoretically possible; and may be supposed to occur very often. (6.101)

Henri Poincaré also believed that chance arises in physical situations at points of instability.[14] Poincaré agreed with Maxwell that chance exhibits itself in the tendency of small variations in causes to result in large differences of effect. Today this tendency is familiar as the extreme sensitivity to initial conditions that lies at the heart of chaos theory. When differential equations have the property of being nonlinear,[15] an influence as minute as the randomization of thermal motion may be enough to give the appearance that events are the result of pure random chance. An inverted cone, for instance, before toppling over because of the force of gravity, displays a symmetry with respect to the different possible directions in which it may fall. The breaking of this symmetry is a result of the instability of the system. Altering the initial conditions ever so slightly can produce very different outcomes—for instance, in the direction of the cone's fall.

Gustav Fechner was closer to Peirce on the topic of objective chance in many respects. In fact, Peirce drew from Fechner a good deal of inspiration for his theses of idealism and tychism. Fechner identified four sources of objective indeterminism that are worth comparing with Peirce's own list of phenomena calling for objective chance. These may be expressed, with some liberty of interpretation, as

1. Fuzziness or imprecision of objects (cp. Brownian motion)
2. Suspension of causal law
3. Contingency of initial conditions
4. Nonpredictability of processes (cp. nonlinearity).[16]

Peirce's earlier view of chance as variety fits sufficiently well with the third entry on Fechner's list. Absolute chance conforms in an obvious way to the second entry, as well as to the first and fourth entries. Peirce's list of interpretations of chance is broader than Fechner's (for better or for worse), as it includes the additional possibilities of random distribution and spontaneous vitality.

So far, my discussion of Peirce's proposal that there is an objective element of chance at work in the world is compatible with the idea that while the *behavior* of a particle, for instance, fluctuates in a random but vanishingly small fashion over time, the values of the physical properties of each particle *at any given instant* are mathematically precise. (Imagine an extremely fine indicator needle on some measuring device pointing to mathematically precise values but fluctuating randomly about a mean value.) But Peirce's notion of absolute chance also suggests a reading closer to the first item on Fechner's list, for one way of interpreting his thesis of tychism is that at any given instant, the actual microproperties of any particle are in fact imprecise, inexact, indeterminate.[17] If we could observe nature at its deepest and most fundamental level, in other words, we would find that it has no truly sharp points and edges but rather is objectively "smudgy" and indeterminate. If we contrast this tychistic picture of the world with that which William James called the "block universe" of the determinist, we might say that according to the tychistic blueprint the universe is found, on close inspection, to be "drawn" with a blunt and soft-leaded pencil, whereas according to the blueprint required by the block universe, in which the world is a system of perfectly determined clockwork, the plans are found to have been drawn with the ideally exact and precise instruments of a divine geometer-artisan.

This reading of what Peirce intended by his thesis of tychism provides a distinct alternative to the deterministic picture of the world as a piece of perfect clockwork. It is perhaps this reading that inspired Karl Popper's (1972, 213) remark that "so far as I know Peirce was the first post-Newtonian physicist and philosopher who thus dared to adopt the view that to some degree *all clocks are clouds*; or in other words, that *only clouds exist*, though clouds of very different degrees of cloudiness."

There is a striking resemblance between this reading of tychism as involving a cloudy indeterminism and the quantum fuzziness or indeterminacy of the later quantum theory of atomic physics. This should not be entirely surprising, because Peirce was led to develop his metaphysical theories from an interest in the developments in atomic and molecular research of the last decade of the nineteenth century. He was well aware of the peculiar phenomena of radioactivity and saw perhaps sooner than most that it would ultimately prove incompatible with the mechanical philosophy so popular among the majority of his scientific peers. Peirce, as we have seen, also drew inspiration for the thesis of tychism from the random molecular (thermal) motion posited by the kinetic theory of gases.

An additional type of chance phenomenon not mentioned by either Peirce or Fechner is that of genetic drift within population genetics. This is described as a form of "sampling error." The best explication of this phenomenon is in terms of a short (finite) run of coin tosses with a fair coin. The long-run expected frequency for heads is, of course, 50 percent. But for small numbers of repetitions, it is not unusual to get frequencies differing significantly from the most probable value (e.g., getting seven heads in ten tosses). This is sometimes referred to as a "breakdown" of the law of large numbers. The same thing can happen in small breeding populations for which the large numbers required to get the expected gene frequencies do not obtain. When it does, the result is a fixation of genotype quite different from that predicted, and the characteristics of the population are said to experience a "random genetic drift." There is every reason though to believe that Peirce was aware of the possibility of such breakdowns in the law of large numbers: "For chance," he once wrote, "is merely the possible discrepancy between the character of the limited experience to which it belongs and the whole course of experience" (6.100).[18]

If one were concerned to find which of the previous notions of chance entertained by Peirce this one resembles the most, the answer would have to be, I think, that of contingency or variety. Simply put, the fact that we might on occasion get seven or eight heads in ten tosses is not the result of any law but is an arbitrary and contingent event for which no reason or element of thirdness can be found. This is in agreement with Peirce's claim that chance events require no explanation but laws and regularities do. It makes sense that someone who spent as much time in a laboratory as did Peirce would think in this way. In the search for general laws of chemistry and physics, occasional chance deviations from the expected run of events are best explained as the result of errors in experimental design or statistical anomalies, at least until the unusual phenomenon can be replicated under controlled conditions.

In summary, then, we see that Peirce's understanding of chance is rather rich—perhaps overly so, one might complain. The reason for this, I would suggest, is that he was continually attempting to fit all aspects of experience into the framework of his three categories.[19] Any phenomenon weak in the characteristics of lawfulness and regularity (thirdness) or of brute resistance and force (secondness) naturally found its way into the first category.

The Laws of Chance

Now although chance is of the first category and is associated with such properties as spontaneity, arbitrariness, contingency, fortuity, and randomness, we have seen already that it is not entirely without an element of regularity (thirdness) of its own. Individual chance events may be unpredictable and free from law, but when they amass in large numbers, features of lawfulness and regularity become clear. (Should we say become crystallized?) As I have tried to show throughout this book, the laws of large numbers (Bernoulli's and the central limit theorem) exhibit the emergence of thirdness from firstness, of law from chance, and of order from chaos. Given his interest in cosmology and his preoccupation with generalization, Peirce could not have been anything but impressed by these results, and especially the use already made of them by people like Siméon-Denis Poisson (1796-1877).

In his 1837 textbook on probability (*Recherches sur la probabilité des jugements en matière criminelle et en matière civile*), Poisson wrote:

> In many different fields, empirical phenomena appear to obey a certain general law, which can be called the Law of Large Numbers. This law states that the ratios of numbers derived from the observation of a very large number of similar events remain practically constant, provided that these events are governed partly by constant factors and partly by variable factors whose variations are irregular and do not cause a systematic change in a definite direction. Certain values of these relations are characteristic of each given kind of event. With the increase in length of the series of observations the ratios derived from such observations come nearer and nearer to these characteristic constants. They could be expected to reproduce them exactly if it were possible to make series of observations of an infinite length.[20]

The blurring of the distinction between laws of mathematical probability and empirical laws is apparent in this passage. While Peirce himself is guilty of perpetuating this conflation of empirical and mathematical law, he was clearly aware of the distinction. At one point he draws a line between what he calls "formal" and "material" laws (7.137). Formal laws, he explains, are those which would hold good no matter what the constitution of the world in fact happened to be. They are those regularities true in all possible worlds. One of the most interesting examples is that of the relation between samples and the population from which they are drawn. If a parent population has any definite character at all, Peirce writes, repeated sampling must eventually exhibit this character and make it known in the long run.

> The truth is that induction is reasoning from a sample taken at random to the whole lot sampled . . . judging of the statistical composition of a whole lot from a sample is judging by a method which will be right on the average in the long run, and, by the reasoning of the doctrine of chances, will be nearly right oftener than it will be far from right. (1.93)

That this does justify induction is a mathematical proposition beyond dispute (1.94). In this way, Peirce offers a justification of induction that he insists does not rely on an assumption of the uniformity of nature:[21]

> . . . studies in the theory of probabilities made subsequently to Mill's writing have shown that, in any case, no peculiarity of this universe can be the sole support of the validity of induction, since in any universe whatever in which inductions could be made, induction would in the long run lead toward the truth. (N2, 177)

Cheng (1969, 25*ff.*) calls the mathematical proposition in question the "logical law of large numbers" because it serves for Peirce as a leading principle of logical (statistical) inference. The principle in question is formulated by Cheng as follows: *Given any large population, a majority of samples of a fairly large size in the population have the same or nearly the same (such as allowing for a small range of approximation) value for its composition ratio as the value for the composition ratio of the population* (ibid., 25–26).[22] Both this principle and the typical expression of the law of large numbers are formal principles and hence will be true no matter what the actual constitution of the universe might be.

That they are formal means they are not to be confused with empirical laws such as the law of gravity or the laws of thermodynamics. It is clear that Peirce recognized this, as we find him writing about "the so-called 'law of high numbers' or of averages, which is in reality no law at all, but is only the mathematically necessary effect of the throw of each individual die being unaffected by any others . . ." (NEM III, i, 153–54). Yet the probability calculus has widespread applicability to physical situations and had, in Peirce's opinion, almost single-handedly raised the level of science to a new level of success.[23] His statement of the nature of the theory in general is strongly reminiscent of Poisson's own explication of his law of large numbers:

> All but the whole of the science of probabilities consists in the tracing out by mathematical deduction of the phenomena that must necessarily result when a vast multitude of precisely similar objects of any description that under the same general influences are subjected to a great number of small causes of diversification. (NEM III, i, 152)

It should be clear by now just how central the convergence theorems of the mathematical theory of probability were to Peirce's thinking on questions concerning his evolutionary cosmology. In the next section, I want to draw out some of the difficulties that attend his attempts to press these theorems into a service of a distinctly more metaphysical nature.

The Law of Habit

It is significant that Peirce identifies those principles which justify induction as formal:

> But as the laws which we have mentioned, that as is sample so is the whole and that sameness of a number of characters manifests identity, are laws which would hold so long as there were *any* laws, though only formal ones, it is plain that no alteration in the constitution of the world would abrogate them, so that they are themselves formal laws, and therefore not laws of *nature* but of *the conditions of knowledge in general*. (7.137; italics in the last clause mine)

In his *Century Dictionary* article on probability, Peirce gave an account of an important convergence result that goes there unnamed but should by now be easily recognizable. It is worth looking at this article at length, as it highlights several important themes of this book:

> All the essential features of probability are exhibited in the case of putting into a bag some black beans and some white ones, then shaking them well, and finally drawing out one or several at random. The beans must first be shaken up, so as to assimilate or generalize [!] the contents of the bag; and a similar result must be attained in any case in which probability is to have any real significance. Next, a sample of the beans must be drawn out at random—that is, so as not to be voluntarily subjected to any general conditions additional to those of the course of experience of which they form a part. Thus, out-of-the-way ones or uppermost ones must not be particularly chosen. This random choice may be effected by machinery, if desired. If, now, a great number of single beans are so taken out and replaced successively, the following phenomenon will be found approximately true, or, if not, a prolongation of the series of drawings will render it so: namely, that if the whole series be separated into series of 100 and of 10,000 alternately, then the average proportion of white beans among the sets of 100 will be nearly the same as the average proportion among the sets of 10,000. *This is the fundamental proposition of the theory of probabilities—we might say of logic—since the security of all real inference rests upon it.* (C, 4741; italics and contents of square brackets mine)

We see from these two passages that the leading principle of induction (the law of large numbers) is a condition of knowledge in general. Equally evident, especially in the second to last quotation, is Peirce's Kantian approach to the subject of epistemology. That he endorsed Kant's architectonic approach to metaphysics has already been noted in the first chapter. As Peirce understood the architectonic method, the results of logic are to be generalized into principles of metaphysics.[24] The law of large numbers therefore becomes an architectonic principle underlying Peirce's cosmological theory. To repeat Hacking's eloquent expression of Peirce's philosophy of pragmaticism, "the universe reaches its successive states by processes formally and materially analogous to those by which sound method reaches its conclusions" (Hacking, 1990, 213).[25]

Now, as Peirce pointed out, "we all think of nature as syllogizing" (RLT, 161). Even the mechanical philosopher, the most nominalistic of thinkers, regards the immutable laws of mechanics in conjunction with the laws of attraction and repulsion as the major premises, the initial conditions of the positions and velocities as the minor premise, and the resultant accelerations as the conclusion.

Despite this widespread attitude, Peirce lamented, “I have not succeeded in persuading my contemporaries to believe that Nature also makes inductions and retroductions” (ibid.). In Hegel, the development of the Absolute Mind proceeds by the necessary and mechanical guidelines of dialectical (deductive) logic alone. In Peirce, all three modes of inference are at work. That principle which serves as fundamental guarantee of the correctness of this evolutionary development is, as we have seen, the law of large numbers. In other words, Peirce made of the law of large numbers convergence theorem a fundamental principle of his objective logic of events, guaranteeing the coherent evolution of natural law over the long-run series of events.

The significance of this is the following: One of the most central strands running throughout the cosmology has been the law of large numbers; it represents for Peirce a justification of both the inductive method of inquiry and the evolutionary logic of the universe’s development, as well as the possibility of explaining large-scale stable regularities as the result of the accumulative (chance) effect of multitudinous independent elements. But the law of large numbers is not the only principle of importance in Peirce’s system; there is also the law of habit to consider. When both of these are given fundamental status within the architectonic of the cosmology, two problems arise: The first I will call the redundancy problem; the second, the incompatibility problem.

The Redundancy Problem

The content of the redundancy problem, simply put, is that the law of habit makes the statistical mechanical account of irreversibility redundant. Why? Because the law of habit, that principle which describes the evolution of *all* natural laws, is itself an irreversible process. And because the law of habit is obviously more fundamental than the principles of statistical mechanics, in both a logical and chronological sense, it ought itself to be sufficient to provide us with an explanation of irreversibility long before the principles of statistical mechanics are suitably developed. Peirce tells us himself quite frequently that the irreversibility of time is the result of the law of mind or law of habit. That should be enough to make us suspicious that some sort of duplication is going on when he also cites the kinetic theory of gases as accounting for the nonreversibility of physical processes.

Peirce could still claim that the statistical mechanical theory accounts for the irreversibility only of processes *in* time, not of *pure* time itself. This response is open to a number of objections but appears nonetheless to be an option. The redundancy problem runs deeper than this, though, for even if we grant the response just proffered, the difficulty still remains that the law of habit–law of mind is an irreversible trend underlying the very structure of the world and, as such, should provide an explanation for the irreversibility of both "pure" time and the events within its flow.

Redundancy in itself might be only an embarrassment of riches. But the real problem is that Peirce's law of habit actually undercuts the statistical mechanical account, which is one of the most significant sources to which Peirce appeals to gain scientific legitimacy for his cosmological speculations. The real pinch of the redundancy problem, therefore, is that the law of habit actually robs the cosmology of the evidential support it so badly needs. Without the support of statistical mechanics, there is no scientific account of irreversibility, and the scientific legitimacy of the thesis of tychism is greatly reduced. The reason Peirce finds himself in this predicament is that his first rule of reason will not permit him to take the principles of statistical mechanics as brute inexplicable facts. And to give them an explanation that satisfies his convictions, he must introduce the law of habit. And without constraining the evolutionary development of laws to proceed in a nonreversible fashion in some way, he can have no guarantee of getting back those laws he set out to explain in the first place.

The Incompatibility Problem

The content of this second problem can be best understood by concentrating on the general effect that follows from the law of habit. As Peirce describes it, "all things have a tendency to take habits. For atoms and their parts, molecules and groups of molecules, and in short every conceivable real object, there is a greater probability of acting as on a former like occasion than otherwise" (1.409). As I described above, the law of habit involves an updating of the transition probabilities among types of events consequent on their occurring together in sequence.[26] What the law of habit does, essentially, is to establish and strengthen correlations between events of certain general descriptions. Now, the problem is that Bernoulli's law of large numbers—to which Peirce ascribes so much importance in the entire process of evolution of law, stable complex arrangements of molecules such as protoplasm, and irreversible-teleological phenomena in general—requires the dual conditions of *independence* and *identical distribution* of trials or events. An event, B, is said to be independent of another event, A, just in case the $Pr(B/A) = Pr(B)$—that is, the occurrence of A does not affect in any way the probability of B. A sequence of events, $e_1, e_2, e_3, \ldots, e_i$, is said to be identically distributed just in case there is a constant probability, $Pr = p$, of occurring for each of the e_i.[27] It is clear that the law of habit violates both of these conditions. By establishing correlations between events, the condition of independence is broken; were this not the case, then there could be no laws of nature such that all *A*s are *B*s, nor could there be any regular causal relationships. On observing the occurrence of an A, we would have no better than an even chance of guessing correctly whether or not a B is to follow. The law of habit is precisely meant to establish regular causal connections between certain types of events.

The condition of identical distribution also goes out the window with the introduction of the law of habit, because it acts constantly to update the transition probabilities—for example, $Pr_t(B/A) \neq Pr_{t+1}(B/A)$, where $t+1$ is later than t and an event of the B type has already followed an event of the A type in the past. The more often a B follows an A, the more likely it becomes that *B*'s will follow *A*'s in the future. That is the essence of the law of habit.

Curiously enough, Peirce was well aware of the importance of the independence condition for the large numbers result:

> But it is the law of high numbers that extreme complication with a great multitude of *independent* similars results in a new simplicity. (1.351; italics mine)

> Now introduce the non-conservative action. Depends on the *independence* [of] events of different times. (MS, 446; italics mine)

In fact, when he was lecturing on the probability calculus, he was *emphatic* about this point. Witness the remark from the *Century Dictionary* article on probability:

> The beans must first be shaken up, so as to assimilate or generalize [i.e., randomize] the contents of the bag; and a similar result must be attained in any case in which probability is to have any real significance. (C, 4741)

> Now if these events are independent, which is the only case in which the calculus [of probability] can be applied at all . . . (NEM, III, i, 400)

No doubt this last remark is an overstatement (because we can still apply the probability calculus when events are either positively or negatively correlated with one another), but other passages reveal his own stipulation that for the doctrine of chances to apply in a situation, there must not be any correlation or influence ruling the succession of the events in question.

> The books on the subject [probability] are full of the word "independent." The instances must be independent. We must make sure that they are so. This "independence" that is so much insisted upon is nothing but *the absence of any law of recurrence*. (ibid., 395; italics mine)

> It would be an excellent practice to restrict the expression "*happening by chance*" to meaning happening so in a series of experiences . . . that the fact is not governed by any order of succession that holds in the *long run*, no matter whether it be intended, or otherwise necessitated, or not. (ibid., 396)

Is it possible to reconcile the law of habit with these expressions? It is open to Peirce to respond that when he uses the term *chance* in a metaphysical context, he means something different than in strict mathematical contexts. But given that his metaphysics is so clearly shaped by his mathematics and logic—it is the essence of the architectonic method, remember, to generalize the results of logic into metaphysical principles—this is hardly a compelling rebuttal. Recall, too, his declaration that "when I speak of chance, I only employ a mathematical term to express with accuracy the characteristics of freedom or spontaneity" (6.201). It is rather puzzling, then, that Peirce nowhere appears to consider the possibility of calculating probabilities for events exhibiting an increasing amount of correlation in any fashion consistent with the law of habit taking.

The reason I have called this an incompatibility problem is that the law of habit and the law of large numbers—more specifically, Bernoulli's law—each require conditions that are exact contradictories of one another and so are mutually unsatisfiable. One of the chief assumptions of the Maxwell–Boltzmann program, and it is an assumption that runs right through to the ergodic theory of modern physics, is that at some level of description a condition of independence must be met for the theory to properly explain why the correct values of state parameters of gas systems can be obtained from taking the average values of mechanical properties of the individual particles of the system. There are various ways of phrasing this assumption and as many names for it: the assumption of equal initial probabilities, the *Stosszahlansatz* (assumption that there are no correlations in the collisions of molecules of different velocities), the hypothesis of molecular chaos, and the ergodic hypothesis.[28] Each of these introduces a condition of randomness or independence at subtly different locations in either the gas model employed or in the method of calculation of the state properties of the gas (e.g., temperature, pressure, entropy). Some of the methods involve the phase space diagram of a single system, others a multitude of similar systems, all satisfying the same energy constraints (ensemble theory).[29] Now it is true that, as it turns out, the actual physical systems dealt with need not satisfy this independence condition precisely. As Russian mathematician Andrei Kolmogorov writes:

> If the condition of independence of terms in most applications of the law of large numbers is fulfilled, it is only with one or another approximation. Thus . . . the motions of individual molecules of gas, strictly speaking, cannot be considered independent. Therefore, it is important to investigate the conditions of applicability of the law of large numbers to the case of dependent terms. The basic mathematical work in this area has been done by A. A. Markov, S. N. Bernshtein, and A. Ia. Khinchin. Qualitatively, their studies have shown that the law of large numbers is applicable if the dependence between addends with numbers far removed is sufficiently weak.[30]

The question then becomes: Will the law of habit keep the level of dependence within acceptable limits for the statistical mechanical account of temporal irreversibility to be applicable at all stages of cosmic evolution? This is a difficult question to answer. Peirce talks as if the final limit of the evolutionary development is the establishment of perfect order and regularity (i.e., that the scenario of lawfulness in the universe will eventually justify that position held by the group of *A*'s discussed earlier). In that case, it would seem that the law of large numbers would eventually cease to apply to the natural world and that consequently, the statistical mechanical account of irreversibility would no longer work. (But as the discussion of the redundancy problem made apparent, this would not really be a problem because the law of habit itself is enough to guarantee an irreversibility of events right up until the ideal point at which all laws become perfectly exact and all chance is vanquished!)

But is it really the case that Peirce is committed, on account of the law of habit, to the conclusion that everything will eventually wind up in a dense tangle of correlations? To suppose this to be the case would be to suppose that Peirce was committed to being a member of the party of *A*'s concerning the degree of arbitrariness in the world.[31] Peirce certainly didn't see himself as an *A*, at least not for the current state of the universe. As a member of the *D* party, he held that no regularities were exact. But his stance on the evolution of laws does appear to commit him to something approaching an *A* policy for the distant future. Perhaps Peirce would respond that he is committed only to the eventual development of the laws of mechanics as we now know them, only in a more exact form from which chance fluctuations will be even more minute and infrequent than he supposes them to be at present. In this case, one would want some explanation of why the law of habit was determined to produce just these laws and not any others of a radically different nature. What is it about these specific mechanical laws that makes them the most suited for the fulfillment of the developing universal mind's purposes? That is, why do they fulfill the needs of agapasm better than any other laws? I doubt Peirce has anything better to offer than that he simply wants to save the most important laws of physics to date. As reasonable as this is, it makes the law of habit appear highly ad hoc.

A related question concerns the ultimate fates of chance and law. In the introduction to this chapter, it was said that the fate of the two were inversely related: Chance diminishes as law increases.

What does this mean for those laws in which chance seemed to play such a vital role? What, for instance, is to become of the second law of thermodynamics? As Maxwell and Boltzmann explained it, the universal trend toward equilibrium relied quite crucially on the "chance" motions of molecules. When chance is no longer active, things will, in a sense, have frozen up. In this respect, Peirce's "habit death" and the "heat death" are equivalent. The increase of entropy has traditionally been identified as the "arrow" of time. But Peirce appears to replace this with his own "arrow"—namely, the law of habit, whose consequences, as we saw in the last chapter, seem to be the direct converse of an increase in "disorder." As the law of habit works to make the universe more orderly, should the second law of thermodynamics become less exact, then, undergoing a reverse evolution? Unfortunately, Peirce never addresses this question. It is possible, though, to speculate about what his response might have been.

In one of the few places where he talks about the second law of thermodynamics, Peirce wrote of it that "this law, as Maxwell first showed and as is now universally acknowledged, merely stipulates that nothing shall interfere with certain chance distributions" (N3, 200). Accordingly, we can guess that he might say that as the ideal end of the evolutionary development of the world approaches, the second law of thermodynamics still holds in the sense that it continues to describe the move toward the normally distributed range of molecular energies (i.e., the equilibrium temperature of the universe at the point of heat death). Of course, once the universe has reached thermal equilibrium and there are no longer any significant temperature gradients to be leveled, the irreversible behavior described by the second law will no longer be present; the universe will lie in slumber, at least until there occurs some significant chance fluctuation or reconcentration of energy in some region. This response presupposes that Peirce never intended that the law of habit would ultimately render every atom or every fact correlated (generalized).

In just the same way, we can see that the law of large numbers will continue to be applicable at the point where chance ultimately dies off (at the habit death). (Of course, as a "formal" principle, this is to be expected.) But insofar as the normal error curve was assumed by Peirce to represent the spontaneity of "fortuitous" chance activity in the world, the law of large numbers will continue to describe the degree of chance left in the world. Only as chance becomes more and more restrained by the law of habit, the variance from the mean regularity (which is chance) will shrink indefinitely, until the normal curve becomes in the absolute limit a perfectly narrow line centered on the mean with zero variance.

Granted, this way of speaking may seem an abuse of the technical language involved. But it is helpful in picturing the way Peirce was thinking about chance and law. The metaphor becomes a little more plausible, perhaps, if we apply it to the case of physical constants. Peirce speculated that along with the laws of physics, the natural constants involved should also undergo a kind of development. If we think of the value of some constant, *c*, as a mean value that fluctuates with some degree of inexactness, being sometimes lesser, sometimes greater ($c \pm e$), then its evolution would consist in the gradual shrinking of its variance about the mean value. The result of such an evolution would be to make nature's constants more precise and ultimately exact (see Figure 6.2).

Given the legitimacy of Maxwell and Boltzmann's interpretation of laws of nature as statistical regularities of varying degrees of precision, Peirce's suggestion that we consider that laws of nature undergo a kind of evolution based on the model of the law of large numbers and the central limit theorem is not entirely absurd. It is probably the most initially plausible way of construing the vague proposal that laws evolve, especially if all that we mean by a law is a "uniformity" or "regularity" in the sense of a stable statistical frequency. But Peirce understood a law to be much more than an acci-

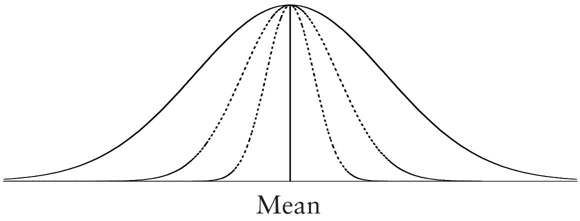


Figure 6.2. Four curves showing the evolution of the value of a natural constant over time. As the law of habit involving the constant becomes more perfect, the amount of chance variation shrinks until reaching the final limiting case, represented by the line centered exactly on the mean.

dental generalization. This points to a very important ambiguity in his thought. As a realist about laws, he believed that laws were the *reason* (or cause, perhaps) that things happen in a regular fashion.[32] But many of his discussions of the law of large numbers involve the emergence of a law in the much weaker sense of a statistical uniformity.

Now, it is fine for a nominalist to say that the law of large numbers explains how laws come about, because all the nominalist means by a "law" is a regularity or uniformity of some kind. But a realist like Peirce cannot, or at least should not, accept such a weak account. While early statistical mechanics appealed to the law of large numbers, it also relied on the laws of Newtonian mechanics and the more specific laws of chemical kinetics. The statistical law of large numbers tells us only the most likely result of the interaction of a large number of (mostly independent) elements that are already characterized by a very high degree of regularity and law-like behavior. For instance, for the law of large numbers to be of any help to us in predicting the likely outcome of tossing a hundred coins, it must first be assumed that the properties of the coins, and of the physical laws affecting their motions, are of a suitably constant nature. If the coins have one mass at one moment and a different mass at another time, are sometimes soft and sometimes hard, or disappear into thin air, then the law of large numbers cannot be expected to tell us much about the outcome of our tossing them into the air. It is just as important that molecules and atoms obey fairly strict mechanical laws, individually and in isolation from one another. It is a "law" that closed thermodynamic systems increase in entropy. Physicists tell us that this is merely a statistical regularity, a physical analogue of the law of large numbers. But it is also a "law" (Newton's second) that every object is affected by an externally impressed force in direct proportion to the quantity of the force and in inverse proportion to its own mass. Now, how is the law of large numbers supposed to account for that kind of regularity? It would appear that to give an explanation of these kinds of regularities, Peirce must fall back on the law of habit. That is, to explain how it was that atoms and molecules came to obey Newton's laws, Peirce must be proposing that initially proto-atoms and proto-molecules (for surely he cannot assume the eternal existence of atoms and molecules) exhibited behavior only very roughly (on average and with great variability) approximating the current laws of motion. As time went on, their average behavior came to display less and less variability, and consequently, the laws of motion emerged as rather exact regularities.

As we have seen several times already, many important themes in Peirce's cosmology are more subtle and complex than they first appear. So it is with the proposal that laws evolve over time. To get the numerous regular-behaving, independent elements required for the emergence of statistically regular laws at the "population" level, Peirce must first invoke the law of habit to explain how these regular individual units emerged in the first place. Here, too, he often mentions the law of large numbers, but when speaking about the gradual emergence of regular behavior at the level of *individuals*, he must have something different in mind. When he does talk about the evolution of lawlike behavior of individuals—molecules and atoms, say—I suggest that he was guided by the model of the central limit theorem and its associated normal probability curve, where we see a diachronic emergence of a more exact regularity through the shrinking of random variation about a mean tendency. On some occasions, Peirce appears to be invoking the law of habit to explain the emergence of individual regularity, while on others he seems to be drawing on the law of large numbers. That there is some ambiguity in his strategy has not, so far as I know, been commented on before.

There is another deficiency, it would seem, in the strategy to explain the presence of laws *simpliciter* with the law of large numbers. The law of large numbers deals with events or entities that are independent of one another. So despite the appearance of interesting regularities in the long run, we can learn nothing about the present or near future from the observation of the individual terms of a (Bernoulli) series (recall van Fraassen's fundamental problem of chance). But for Peirce, this gets at the crucial feature of a real law:

> There is . . . one character which all truths called laws of nature possess in common and it is a character that ought never to be lost sight of, it is the best guide to right inductions! It is that every proposition called a law of nature can serve and does serve, as basis for predictions. (MS, 870, 3)

What Peirce needs is some account of how events become correlated in such a way that one thing can exert some degree of regular causal influence on another and thereby allow the observation of the one to serve as the basis of a prediction of the other.

This is the problem Peirce attempted to draw people's attention to with his famous "stone experiment" of the 1903 Harvard Lectures on Pragmatism (cf. EP, II, 181*ff*). Peirce, the Scotistic realist, attempted to convince his audience of Ockhamite nominalists that the possibility of successful predictions required the assumption that "general principles are really operative in nature" (EP, II, 183*ff*.). To assume, as the nominalist does, that laws are just convenient fictions introduced by the mind to tie up our experiences into manageable bundles is to suppose

> that the facts are, in themselves, entirely disconnected . . . one stone dropping to the earth has no real connection with another stone dropping to the earth. It is, surely, not difficult to see that this theory of uniformities, far from helping to establish the validity of induction, would be, if consistently admitted, an insuperable objection to such validity. For if two facts, *A* and *B*, are entirely independent in their real nature, then the truth of *B* cannot follow, either necessarily or probably, from the truth of *A*. (6.99)

If we are able, in other words, to make successful predictions—not just on the average and in the long run but here and now—it must be that we are able to draw on the knowledge of laws differing substantially from mere statistical uniformities. That there are such laws is the very import of Peirce's insistence on the "reality of Thirdness."

We see, then, that just as in the evolution of the universe as a whole (where Peirce could not simply accept a blind, random walk), so, too, for the development of law he must have something stronger than a sequence of random events, something that will result not in mere "uniformities" but in real laws of causal influence. Yet oddly enough, he never gave up the attempt to explain the evolution of laws by appeal to the law of large numbers, while at the same time, but in different contexts, perhaps, also appealing to the law of habit. In a sense, Peirce's ambiguous understanding of "laws" might be said to stem from a failure to mark the distinction drawn by Maxwell between "statistical" and "dynamical" laws and explanations.[33] The law of large numbers provides a plausible model for the explanation of statistical laws. But to account for dynamical laws, the model of the law of habit is a better option. It may be that Peirce saw this himself. This would provide a way out of the incompatibility problem, for there would be no incompatibility in explaining one type of law (e.g., dynamical laws) with the law of habit, and a different type (e.g., statistical laws) with the law of large numbers. But if this was Peirce's intention, he never made it explicit in any of his writing.

Another way of stating the confusion in Peirce's thought is to say that he failed to distinguish between the processes of development and evolution. As we noted in an earlier chapter, evolution is something that occurs at the population level. Development, on the other hand, occurs at the level of individuals. (The thesis of recapitulation helps to blur this distinction.) Peirce's law of habit seems a better fit for explaining the development of regular behavior in individual atoms and molecules from relative spontaneity to rigid mechanical law (though it fails to explain why all molecules of a particular chemical element should behave alike); the law of large numbers is better suited to explain how groups of molecules and other identical units can come to assume a regular or stable behavior on average and in the long run. But again, Peirce never makes this distinction so far as I am aware.

There is another possible resolution of the incompatibility objection. It is possible, as the Russian mathematician Markov showed in 1908, to prove a law of large numbers for dependent events. If a series of events does show a tendency toward increasingly strong correlation, the ultimate trend may be toward a fixation of perfect 100 percent correlation. Such a series of events is called a nonstationary Markov chain. It is possible, then, that Peirce had some inkling, before this, of the possibility of a limit theorem for dependent variables. But there is nothing in his extant papers that would back this up in any way. There is, however, a very provocative statement in his 1892 essay "The Doctrine of Necessity Examined," in which he lists his own motivations for considering the thesis of tychism. He writes:

> But I must leave undeveloped the chief of my reasons, and can only adumbrate it. The hypothesis of chance-spontaneity is one whose inevitable consequences are capable of being traced out with mathematical precision into considerable detail. Much of this I have done and find the consequences to agree with observed facts to an extent which seems to me remarkable. But the matter and methods of reasoning are novel, and I have no right to promise that other mathematicians shall find my deductions as satisfactory as I myself do, so that the strongest reason for my belief must for the present remain a private reason of my own, and cannot influence others. I mention it to explain my own position; and partly to indicate to future mathematical speculators a veritable gold mine, should time and circumstances and the abridger of all joys prevent my opening it to the world. (6.62)

Unfortunately, it seems that whether due to the censure of whomever it is that is in charge of joy or to more practical circumstances, Peirce left us with only this (rather Fermatian) promissory note. And this leaves us with the following question: If in fact all laws (both dynamical and statistical) have evolved in accordance with something like the law of habit taking, then why is it that it has resulted in just that degree of correlation and law that we do in fact observe, neither more nor less?

Peirce and Prigogine

Before leaving this topic, I want to consider the issue of the relationship between Peirce's law of habit and the "dissipative structures" of Ilya Prigogine's theory of nonequilibrium thermodynamics. Prigogine (1984) has himself cited Peirce approvingly in this regard. After quoting his statements about the "concentrative" effects of chance and its ability to counteract the dissipative effects of force,[34] Prigogine writes, "Peirce's metaphysics was considered as one more example of a philosophy alienated from reality. But, in fact, today Peirce's work appears to be a pioneering step toward the understanding of the pluralism involved in physical laws" (op. cit., 303). This passage has been the basis for a trend within Peirce scholarship of crediting him with having anticipated Prigogine's notion of dissipative structures. *Dissipative structure* is the term given by Prigogine to those novel forms of fluid and material formations that arise when there is a flow of high-grade (low-entropy) energy through a system far from equilibrium. As Prigogine explains (180), under these conditions there is a "breakdown" of the law of large numbers in the sense that molecules cease to behave independently of one another and, through their correlated motions, lead to the establishment of striking patterns and spatiotemporal order.[35] Chance continues to play an important role here, according to Prigogine, in that the breaking of certain symmetries just prior to the emergence of these patterns is not determined by any foreseeable law. Chance allows the system to "wander about" the state space, exploring a wider range of possibilities than would be permitted by strict law alone.

This similarity with the effects of the law of habit has been emphasized by students of Peirce's philosophy. But it should be noted, for the sake of accuracy, that Peirce's few remarks, as vague as they are, hardly support any claim stronger than that he realized that somehow physical systems must be able to counteract the dissipating trend of the second law of thermodynamics, and that chance might be somehow involved in this. To attribute more to him than this is to claim that Peirce introduced the law of habit to fulfill the function of a Markov chain. In that case, the law of habit serves as the intermediary third that takes us from "random" Bernoulli series to correlated Markov processes.[36]

But in actuality, those remarks of Peirce's that are in question here are, I would argue, more compatible with the suggestion that he was thinking of something closer to Poincaré recurrence, a phenomenon that would take place at equilibrium rather than far from it. An additional question is whether Peirce conceived of the law of habit as working in relatively small and local "pockets" throughout the universe or whether he supposed it to be working uniformly all at once, throughout the world as a whole.[37] If the latter is true, then the law of habit, *insofar as it also describes an irreversible increase in complexity*, is very much in tension with the universal trend toward entropy increase described by the second law of thermodynamics. There would appear to be no plausible and intuitive way of understanding the notion of complexity that would allow both Peirce's law of habit to increase indefinitely the complexity of the world and the second law to increase entropy and dissipate energy. I cannot see how it could be the case that both of these trends are working universally and contemporaneously. If, however, the law of habit is only meant to make laws more regular and the values of physical constants more exact and has no consequences for the increase of complexity and order, there does not appear to be any incompatibility with the universal increase in entropy. Yet that Peirce understood his evolutionary law to be increasing the amount of order and complexity in the universe seems incontrovertible.

It is not my chief concern, however, to evaluate Peirce on the grounds of what he may or may not have anticipated or to engage in speculation over his possible responses to questions we would like to be able to ask him. Rather, a more productive strategy would be to restrict our criticisms to those beliefs and positions for which there is clear evidence that he openly endorsed. On this count, I would urge that the problems of redundancy and incompatibility are two of the greatest difficulties afflicting Peirce's cosmology, alongside of the ambiguities laid out above in his understanding of the notion of chance and in the proposal that laws of nature evolve. These represent problems worth being taken seriously by Peirce, were he alive to do so, and by students of his philosophy, precisely because they are of a chiefly logical nature and have to do with the consistency of his cosmologicometaphysical system.

7

Conclusion

> The Universe as an argument is necessarily a great work of art, a great poem—for every fine argument is a poem and a symphony—just as every true poem is a sound argument. (5.119)

There is an ongoing dispute within Peirce scholarship between those, on the one hand, who make the charge that his philosophy as a whole is inconsistent and at odds with itself in its ambitions (e.g., Goudge, 1950; Gallie, 1952; Apel, 1987; Murphy, 1993) and those, on the other, who argue that it is highly systematic and coherent (e.g., Corrington, 1993; Hausman, 1993; Rosenthal, 1994; Anderson, 1995; Parker, 1998). Like Hookway (1985), I am sympathetic to both parties, to varying degrees. There can be no doubt, after having witnessed the recurrence of key philosophical themes throughout and their eventual convergence within the cosmology, that Peirce's thought is highly systematic. Yet neither can it be denied that there are deep tensions in his philosophy when considered as a whole.

Goudge (1950) first launched the thesis that there are two distinct and incompatible strains in Peirce's philosophy. He identified these as distinct personalities, referring to them as the "Naturalistic" Peirce and the "Transcendentalist" Peirce. The naturalistic tendency in Peirce's thought is positivistic, and its best-known symptom is the pragmatic theory of meaning. It is concerned with the clarification of ideas so that they might be put to positive empirical test. It expresses what might be called the "British" tendency in Peirce's thought. The transcendentalist tendency is metaphysical and is best known for producing the evolutionary cosmology. It is highly speculative and difficult to see how it might ever be put to an experimental test. This we might call the "German" aspect of Peirce's thought.

In an effort to reconcile these two seemingly irreconcilable forces, I make the following observation: Both tendencies in Peirce's thought, the "good" and the "bad" (as people have been wont to view them), are direct products of sound methodological principles, each of which we are indebted to Peirce for their development and emphasis. The principle of pragmatism implores us to make our ideas precise and unambiguous so that we do not waste time arguing in circles over mere verbal ambiguity or vagueness.[1] The influence of this doctrine on such movements as verificationism and operationalism is testimony to its philosophical sobriety. But at the root of Peirce's much less popular metaphysics is a methodological principle of equal soundness—namely, the first rule of inquiry. It implores us not to accept any positive matter of fact as inexplicable or self-evident. He insisted that it is no explanation at all to pronounce a thing to be absolutely inexplicable. To do so is to commit oneself to an opinion "which no reasoning can ever justify or excuse" (RLT, 180), for it is the express aim of reasoning about natural phenomena to render it intelligible. It is this latter methodological principle that impelled Peirce to seek an explanation for the degree of natural law and orderliness we find in the universe, and for the relationship between psychical and physical properties. This was a pursuit that, as we have seen, required speculations of rather heroic proportions. That it required such bold conjecture does raise the question whether it is in fact sound advice to seek an explanation for every proposition purporting to make a statement of fact.

It may be that much of the difficulty people experience (myself included) in facing Peirce's cosmological writings arises from his strict realism about laws coupled with the first rule of reason. For once laws themselves are admitted as phenomena to be explained, the very things that we typically turn to for explanations become useless to us, and we exhaust ourselves in the attempt to perform an impossible explanatory regress, much like the snake that begins to consume its own tail.

But perhaps even more difficult for modern readers to swallow is his anthropomorphic thesis that nature ought to display rational features characteristic of human intelligence. A central tenet of the modern scientific attitude (closely akin to the positivism and agnosticism of Peirce's day) is that we ought not to project our own peculiarly human qualities onto the natural world. To do just that, however, is very much a central mode of operation, according to at least one interpretation of what it is to "understand" the world. This is the attempt to make sense of all things in intuitively appealing or familiar terms. It is, perhaps, symptomatic of a deeper desire to make ourselves feel "at home in the universe."[2] In this connection, we saw how Peirce attempted to evade the problem of psychic–physical interaction by invoking a construal of mind so liberal as to include both animate and inanimate properties. As Peirce describes mental properties, we are to see a seamless continuum between the spontaneous capriciousness of thought and the mechanically regular (i.e., "rational," "reasonable") behavior of inorganic matter.

The founder of positivism, Auguste Comte, declared through his law of three stages of intellectual development that in the final scientific ("positive") stage, we no longer seek to "understand" natural phenomena but only to be able to predict and control it. The philosopher of science Bas van Fraassen provides us with an example of the modern positivist spirit (although he refers to his position as "constructive empiricism" and eschews the positivist label). According to van Fraassen, the proper aim of science is not the pursuit of truth but of *empirical adequacy* (van Fraassen 1980, 12; 1991, 193). A theory is empirically adequate insofar as it states the verifiable truth about observable entities and phenomena. An empirically adequate theory may also purport to make statements about unobservable things, but with these, we do best not to commit ourselves to any degree of belief as to their truth. They may have utility, but that is all we should say of them. This antimetaphysical program implies that we give up the search for deep understanding of the universe, especially if that understanding is meant to rely on an acquaintance with unobservable entities and principles. This in turn establishes certain restrictions on our desire for explanations. Understanding is a rather mysterious thing. There can be no denying its psychological nature, since what constitutes a satisfactory explanation for one person may not be such for another (or even for the same person at different stages of education, for that matter). At present, one of the most popular ideas among philosophers of science is that scientific theories are best understood as abstract and formal models that exhibit some degree of "fit" or "correspondence" with particular restricted aspects of the natural world. But this degree of fit or correspondence—which is always imperfect—is understood to consist in a purely observable demonstration of predictive success, the very virtue that van Fraassen refers to as empirical adequacy.[3]

Peirce's realist commitment to the idea that it is the aim of science and philosophy to find satisfactory and complete explanations (i.e., to assist in the growth of "reasonableness" and understanding) for every matter of fact runs against this way of thinking. Moreover, in van Fraassen's constructive empiricist image of science, we are to resist appealing to such occult principles as "laws of nature," principles assumed to have some objective existence, as explanations for why observable events appear to exhibit the degree of regularity and order that they do. The natural laws of which we do have knowledge, he argues, are best understood as arising from certain formal symmetries implicit in the models and theories we create in our quest for improved control over nature. On this count, I think Peirce might even tend to agree, for as we have seen, he was quite cautious in his attitude toward specific scientific laws, such as the conservation of energy principle. Where he does differ from van Fraassen is on the question of whether it is helpful to explain the presence of a general orderliness and regularity in nature by inferring the existence of an underlying general continuity, of principles or laws ("thirdness," in Peirce's parlance). Peirce, like other nomic realists before him and since, believed that we must appeal to the existence of some such general principle of connection underlying and influencing the outcome of individual events; otherwise, we are forced to accept the appearance of a general pattern in events as a brute inexplicable fact. Such an abductive move is, according to van Fraassen (1980, 19*ff.*; 1989, 18*ff.*), not really helpful, though, because it only pushes the need for explanation back one step further and deeper, into unobservable waters. Science should stick with describing and predicting observable phenomena, as far as is possible. And by restricting science to the pursuit of empirically adequate theories, we will not be tempted by the kind of anthropomorphic excess that has come to stand as one of the identifying features of bad or pseudoscientific research.

How did Peirce manage to reconcile his bent for metaphysics with his self-image as an exact logician and experimental scientist? The answer is that he failed to see any incompatibility between his methodological philosophy of pragmaticism and his attempt to sketch out a speculative metaphysical cosmology. "Pragmaticism," he wrote, "is a species of prope-positivism," but "instead of merely jeering at metaphysics, like other prope-positivists. . . , the pragmaticist extracts from it a precious essence, which will serve to give life and light to cosmology and physics" (EP II, 339). Though he was trained as a scientist and attempted to bring to philosophy the habits of the exact sciences, Peirce's understanding of what it means to be "scientific" deserves special attention. The following passage lays out quite nicely his thoughts on this subject.

> Scientific workers do not insist on anything as absolutely certain. There is not a more marked characteristic of the true scientific investigator than his perfect readiness to entertain any question which there is any possibility of settling by experiment. Indeed, "science" is an unfortunate designation for the department of civilized life that it denotes. It implies a body of knowledge. But it is not half so much knowledge that makes the scientific man as inquiry—the effectual wanting to know that involves the acknowledgment one does not know already. In the days of our childhood, before the present jargon came in, people talked of natural *philosophy*; and philosophy, or wanting to know, much better than science, describes the most precious endowment of the physicist or naturalist. (1893; N 1, 176)

This is the spirit with which Peirce set out to challenge the fashions of agnosticism, nominalism, and scientism prevalent in his time. According to his description, to be "scientific" means to accept or to recognize what one does not know, to be fallibilistic about what one does presume to know, and to be willing to look into any question that lends itself to the tools and methods of experimental practice, no matter how unfashionable that particular topic may perhaps be. In this way, Peirce hoped to be able to revise attempts to answer the age-old questions of natural philosophy in the light of modern scientific methods (including his pragmatic method for clarifying the meaning of ideas and propositions). This application of modern scientific methods to the unsolved "riddles of the universe," if successful, would open up a whole new field of experimental metaphysics.

Now, if Peirce's attempts to answer the big questions strike us as excessively speculative, he should at least be commended for his attempts to formulate what he believed to be testable hypotheses. On this score, he has the definite advantage over the Spencers, the

DuBois-Reymonds, and other agnostics who merely announced certain questions forever intractable on the basis of dubious a priori reasoning, and he might be equally praised for the fallibilistic attitude he took toward his own hypotheses, in contrast to the "cocksuredness" of the "scientific" philosophers like Spencer, Büchner, and Haeckel, who insisted that their ideas were founded on a bedrock of scientific fact.[4] It might also be mentioned in his defense that it is all too easy to retain an air of sobriety and good sense when it comes to such difficult questions by simply refusing to hazard any guesses at all.

It does, however, remain an open question to what extent, if any, Peirce's metaphysical hypotheses are either verifiable or falsifiable and so open to experimental investigation. We have seen hints he dropped as to how they might be refuted and claims that they had led to successful predictions, yet unfortunately, he was never forthcoming about these successful confirmations of the theory.

But let us return to the issue of the truly scientific attitude and the willingness to seriously pursue any question for which there is positive hope of reaching a resolution. The negative reaction that had traditionally been so common a response to Peirce's metaphysical philosophy throughout the twentieth century is unjust for at least two reasons. One, it typically fails to consider it within its proper historical context. Peirce was by no means alone in his interests and topics of theorizing; the decades around the turn of the nineteenth and twentieth centuries were witness to the popular writings of Haeckel, James, F. H. Bradley (1846–1924), and Henri Bergson (1859–1941), just as much as they were to the anti-metaphysical writings of Karl Pearson and Ernst Mach. In addition, with respect to the question of evolution, Bowler (1983) has shown that while Darwin and Wallace may have convinced the majority of people of the reality of evolution, neo-Lamarckian explanations of its occurrence had become much more popular in the decades surrounding the end of the nineteenth century than the materialist and mechanistic principle of natural selection. I suspect that some people feel let down by Peirce on account of his metaphysical musings because he strikes them in his more popular logical researches not as a figure of another age but as a solid contemporary who ought to have known better.

The second reason why it is unfair that Peirce is so often written off as an eccentric "crank" is that our modern adulation of science is based on a professed respect for the very attitude of open-mindedness and freedom from prejudicial judgment that, as the quotation above well attests, led Peirce to hazard hypotheses about the nature of the universe in the first place. It is on this attitude of challenging dogma and unreason that democratic and open societies are supposed to be built. If our professions of respect for this attitude are to be anything more than empty rhetoric, then we had better not roll our eyes at those figures whose lives it has animated. It is not my suggestion here that we need to show patience with every proponent of flat-earth theories or "scientific" creationism. Where evidence and logical analysis are sufficient to show that certain claims are unfounded or nonsensical, we should move on to more plausible candidates. But when the issue is one of evaluating figures from the past, it is all too easy to allow our superior hindsight to decide for us who among those historical figures are the keen-sighted heroes and who the poor misguided souls.

As Kuhn (1970, Chapter XIII) pointed out, the history of science is selectively written by the victors so as to exhibit a trend of seemingly inevitable progress. And toward this end, it would appear that historians of science and philosophy do not always single out for praise those individuals who display the values to which they who are writing the history themselves profess to be committed but rather in hindsight choose those who happen to bet, as it were, on the right horses. This tendency has been evident in the relative insignificance assigned to Peirce in contrast to his more narrowly focused colleague Frege, by the leaders of twentieth-century analytical philosophy.[5]

The antimetaphysical tenor of twentieth-century "scientific" philosophy was quite properly motivated (in part) by a desire to critique the excessively emotional rhetoric of fascist ideologues. This, in turn, led to the search for some principled means of demarcating true science from pseudoscience, the assumption being that anything smacking of unreserved speculation—poetic and visionary language, for example—was potentially dangerous nonsense. For this reason, "scientific" philosophy, as practiced by those trained in the analytical school, has been less in sympathy with Peirce's vision of science than with the positivists, nominalists, and agnostics with whom he disagreed.

William James (champion of the rights of faith over reason and longtime friend and benefactor of destitute C. S. Peirce) wrote that our visions are usually our most interesting contributions to the world in which we play our part (James, 1996, 10). Peirce's metaphysical cosmology surely has the appeal of a great poetic vision. It is reminiscent of the pre-Socratic philosophers of the ancient Ionian coast. But can it be justly considered an example of *real* science? We have seen that it has the share of inconsistency and ambiguity to be expected of a partially developed pet project. Nor can there be any denial that it makes quite dubious assumptions of its own about the kinds of propositions that can stand without need of explanation (e.g., that the original chaos was composed of some kind of pure "feeling," that there can be "events" of any meaningful kind in an original state of purely "random" chaos, that the law of habit can be expected to act on itself). On these counts, Peirce's attempt to construct an experimental metaphysics complete with testable hypotheses must, I think, be judged to have fallen short of the mark. But if it is not quite good science, it remains at least very interesting metaphysics, which in its effects can act something like good poetry, providing a guiding vision for future research of the kind such as the cosmological theories of the early Ionian philosophers, which proved to be the seeds of an extremely fruitful scientific research tradition. It is interesting to see the biologist Richard Dawkins—as staunch a scientific rationalist as ever there was—writing recently in praise of what he calls "poetic science," even going so far as to speak favorably of Herbert Spencer's philosophy of universal evolutionism (Dawkins 1998, 192 passim). At the risk of sounding disrespectful of the positivist image of science (with which I happen to share much sympathy), I would like to finish by offering my own poetic observation that the gap between science and poetry is not so great as it may at first seem. In fact, one might argue that every great work of science is also a veiled work of great poetry, for what, after all, are the key ingredients of great poetry but the expression of some deep but previously unspoken truth and an appreciation for the order and symmetry that is shared by both human reason and the external world in which it is nurtured? Without minds like Peirce's (and Spencer's), our scientific image of the world might be more utilitarian and more solidly rooted in established fact, but it would also be less vibrant and provocative.

Notes

Introduction

1. An exception must be made here for Murphey (1993).
2. Hookway (1985), 291, note 2.
3. Here Esposito (1980) must be noted as an exception for his emphasis of the influence of Schelling and *Naturphilosophie* on Peirce's thought.

Chapter One

1. In the 1898 Cambridge lectures that concentrated on cosmology, he wrote:

> Logic is the science of thought, not merely of thought as a psychical phenomenon but of thought in general, its laws and kinds. Metaphysics is the science of being, not merely as given in physical experience, but of being in general, its laws and types. Of the two . . . logic is somewhat more affiliated to psychics, metaphysics to physics." (RLT, 116)

It should be added, however, that Peirce later, in the same set of lectures, qualified this statement, noting that he did not intend to say that logic was merely psychologistic: "Logic, in the strict sense of the term, has nothing to do with how you think" (ibid., 143).

2. These are actually mentioned by Peirce as reasons supporting the thesis of *tychism* (i.e., the claim that chance has a real role in the workings of the universe). But insofar as Peirce's evolutionary cosmology brings to the fore the effects of chance they constitute the important features of the world in his estimation.
3. See Ayim (1982) for a discussion of this topic.
4. The classic explication of the covering-law model is found in Hempel (1965).

5. See his “A Theory of Probable Inference” (2.694–751), originally published as a separate essay in Peirce (1883).

6. Hacking (1980) and (1990, 210); Levi (1980).

7. For discussion of inference to the best explanation and abduction, see Boyd, Gasper, and Trout (1992). It is important to note, however, that the employment made of abductive arguments, especially by Boyd, differs from what Peirce would have found acceptable. For instance, notice that in 6.273 he states that an abductive explanation should be subject to experiential verification of further predictions. Boyd’s “abductive” arguments for scientific realism do not appear to fulfill this condition.

8. See also 1.156, 1.405, 1.170, 5.291, 6.171, 6.612, 7.480, 8.168.

9. Compare the following from Bertrand Russell (1963):

> There is, as we all know, a law that if you throw dice you will get double sixes only about once in thirty-six times, and we do not regard that as evidence that the fall of the dice is regulated by design; on the contrary, if the double sixes came every time we should think that there was design.

10. Boler (1963) gives the classic description of Duns Scotus’s influence on Peirce.

11. In a word, Peirce rejected the identification of the continuum with any discrete set of elements. A true continuum, he argued, must be capable of accommodating *any* multitude of points. And this means a multitude even beyond Cantor’s nondenumerable set of real numbers.

12. In 1898, Peirce wrote: “I came to the study of philosophy not for its teaching about God and Immortality, but intensely curious about Cosmology and Psychology. In the early sixties I was a passionate devotee of Kant, at least as regards the Transcendental Analytic in the *Critic of Pure Reason*” (4.2).

13. Peirce’s 1891 *Monist* paper “The Architecture of Theories” is an explicit endorsement of Kant’s architectonic method. Cf. especially 6.9.

14. See Hookway (1992), Chapter III passim for details.

15. “When in 1866 . . . I had clearly ascertained that the three types of reasoning were Induction, Deduction, and Retroduction . . . I thought that the system I had already obtained ought to enable me to take the Kantian step of transferring the conceptions of logic to metaphysics” (RLT, 146).

16. See Hookway (1992), Chapter III, for a detailed account.

17. Goudge, p. 274. It is also interesting to note that the key ingredient in mathematics, according to Peirce, is the process of generalization. It is by generalizing methods and solutions that mathematics attains its great strength and applicability. The parallels between this essentially mental process of mathematical generalization and the generalizing tendencies of the law of habit will become obvious. This perhaps goes some way to ex-

plaining why in the final lecture of the 1898 Cambridge series (*Reasoning and the Logic of Things*, p. 267) he refers to cosmology as "mathematical metaphysics." Furthermore, his characterization of reasoning assumes the familiar triadic form as he says that it involves the mental operations of (1) observation, (2) experimentation, and (3) habituation (MS 444) or, alternatively, (1) imagination, (2) concentration, and (3) generalization (MS 94). Cf. Eisele NEM 2, 236. Ideas from the cosmology also seep into his discussions of the logical graphs; cf. 4.431.

18. Esposito (1977, 122–41) is a useful discussion of the influence on Peirce of Schelling and the *Naturphilosophen*.

19. Some—for instance, Rosenthal (2001), Hausman (1993), and Pape (1997)—debate whether Peirce's position is adequately described by the "objective idealism" label. I merely use the term here because Peirce used it to describe his position. However, I think it is very helpful to note, as Rosenthal (1994, 109) does, that when Peirce talks of "mind" as being more fundamental than matter, he is not really talking about a kind of substance but about a mode of behavior.

20. MS (928), published in NEM IV, p. 377.

21. Ibid., p. 378. Other expressions of this attitude are given in the following:

> This is all the categories pretend to do. They suggest a way of thinking; and the possibility of science depends upon the fact that human thought necessarily partakes of whatever character is diffused through the whole universe, and that its natural modes have some tendency to be the modes of action of the universe. (1.351)

> Metaphysics consists in the results of the absolute acceptance of logical principles not merely as regulatively valid, but as truths of being. Accordingly, it is to be assumed that the universe has an explanation, the function of which, like that of every logical explanation, is to unify its observed variety. (1.487)

It might easily be argued that Peirce inherited his affinity for German idealism and *Naturphilosophie* from his father. Consider the following from Benjamin Peirce's *A System of Analytic Mechanics* (1855, 477): "Every portion of the material universe is pervaded by the same laws of mechanical action, which are incorporated into the very constitution of the human mind." It is interesting to note, too, that Peirce studied for a time with the Harvard biologist Louis Agassiz (1807–73), who was himself a student of the German developmental biologist Lorenz Oken (1779–1851) and of Schelling.

22. It is in response to the apparent incompatibility between Peirce's positivistic/pragmatistic leanings and his speculative transcendental-

ist metaphysics that Thomas Goudge proposed his thesis of the "two Peirces"—that is, that Peirce was pulled in opposite directions by two incompatible impulses. Cf. Goudge (1950).

23. See Gould (1977) for an extensive historical study of the idea.

Chapter Two

1. For accounts of his scientific credentials, see any of the following: Eisele (1970–80, 1979); Lenzen (1964, 1972, 1975).

2. It is because of this extra complication, I would suggest, that Peirce sometimes simply explained the reversibility to be the result of the negative time value being squared. In an attempt to explain this point to correspondents and people attending his lectures who may not have been familiar with the requisite mathematics, the example of squaring a negative value would have been a useful heuristic.

3. Yet it is unclear why he would say in part b of the definition of energy that it is the greatest possible value of the vis viva of a system but for friction and other velocity-dependent forces, because friction is itself a form of kinetic energy. It would seem that Peirce must be thinking about the loss of *molar* kinetic energy in the form of *molecular* kinetic energy (i.e., in the form of heat, friction, and so on). It was precisely by accounting for this "missing" kinetic energy that the kinetic theory of matter and heat allowed for the development of the conservation of energy principle.

4. Here it is correct to say that reversibility follows as the result of the sign for time being squared, because in the expression for kinetic energy, $^1/_2 mv^2$, velocity, $v = ds/dt$, is squared. Hence $(ds/dt)^2 = [ds/d(-t)]^2$.

5. Peirce footnotes, Tait (1876, 17).

6. The second arbitrary constant Peirce mentions is required to set the zero value of the potential energy function, which is a function of position. Consider a book resting on a table. Relative to the tabletop, it has zero potential energy, but relative to the floor, it has a positive potential energy.

7. See Margeneau (1950, 182) and Feynman (1963, 13-1) for similar arguments showing that under the restriction to positional forces, the conservation of mechanical energy follows from the second law of motion.

8. Compare the following remarks from Symon (1971, 172):

> The conservation laws are in a sense not laws at all, but postulates which we insist must hold in any physical theory. . . . We prefer always to look for quantities which are conserved, and agree to apply the names "total energy," "total momentum," "total angular momentum" only to such quantities. The conservation of these quantities is then not a physical fact, but a consequence of our determination to define them in this way. It is of course, a statement of physi-

> cal fact, which may or may not be true, to assert that such definitions of energy, momentum, angular momentum can always be found.

With regard to Peirce's claim that the quantity represented by the constant *C* is independent of the time and position, and so conserved regardless of the nature of the forces involved, compare this further remark by Symon:

> We have seen that the familiar conservation laws of energy, momentum, and angular momentum can be regarded as consequences of symmetries exhibited by the mechanical systems to which they apply; that is, *they are consequences of the fact that the Lagrangian function L, which determines the equations of motion, is independent of time and of the position and orientation of the entire system in space*. . . . We might, in fact, define energy as that quantity which is constant because the laws of physics do not change with time (if indeed they do not!). (ibid., 380; italics mine)

I am grateful to Francisco Flores and Dave Irwin for their assistance in helping me to understand the technical details of the energy conservation laws, and to Dave Irwin for drawing my attention to the remarks of Symon (1970) quoted above.

9. The "scientists" in question are those whom Peirce would consider more motivated by a spirit of scholasticism than by a genuine love of wisdom or truth (e.g., Spencer, Ludwig Büchner, Haeckel). As the following passage from Poincaré (1952, 129) shows, Peirce was not alone in adopting a cautious attitude toward the extension of the conservation principle into a universal law:

> There is no one who does not know that it [the conservation of energy principle] is an experimental fact. But then who gives us the right of attributing to the principle itself more generality and more precision than to the experiments which have served to demonstrate it?

10. It is difficult to assess the accuracy of Gallie's claim that Peirce was "one of the first, if not *the* first, of philosophers of physics to suggest that the fundamental division in that subject is between laws of reversible and laws of irreversible processes" (Gallie, 1952, 231).

11. Cf. Harman (1993, 5, 56*ff*.).

12. The term *gas*, in fact, is a modified Dutch form of the word for "chaos."

13. Boltzmann (1974), 19–20.

14. See lecture seven, "Habit," in RLT, 218–41. Peirce termed this tendency of nonconservative physical processes *finiousity*.

15. Peirce's definition of Bernoulli's theorem for the *Century Dictionary* is as follows:

> The doctrine that the relative frequency of an event in a number of random trials tends as that number is increased toward the probability of it, or its relative frequency in all experience. This fundamental principle, which is not properly a theorem, was given by Jacob Bernoulli (1654–1705). (C, v. 8, 6275)

16. See von Mises (1981, 104*ff.*) and Stigler (1986, 182–86). Poisson proved a generalization of the DeMoivre-Laplace central limit theorem—that the observed means of random samples drawn from a population (even one that is not itself normally distributed) will be normally distributed in the limit as the number of samples approaches infinity. Poisson called this result a "law of large numbers." It is also to Poisson that we owe the convention of referring to Bernoulli's theorem (which states that long-run frequencies will converge to the objective probability of an event occurring in the long run) as a law of large numbers. To make things even more complicated, Poisson also initiated the practice of thinking of empirical statistical stabilities as resulting from some kind of metaphysical law of large numbers. See Hacking (1990).

17. Consider also another entry from the *Century Dictionary*:

> Friction and viscosity are examples of such [nonconservative] forces, and these are explained by physicists as the result of chance encounters, etc., among almost innumerable molecules. Other effects of this sort are the conduction of heat, the dissipation of energy, *the development of living forms, etc.* (C 2319; italics mine)

In a short debate carried out in the pages of the *Nation* between Peirce and Leander Hoskins, professor of mechanics and mathematics at the University of Wisconsin, Peirce declared that the growth and evolution of living organisms violated the law of vis viva. We have already seen in what sense he meant this, but it took some effort to convince Hoskins. At one point Peirce wrote that he was only attempting to explain "the irreversibility of growth, in the same way in which inorganic irreversible processes are explained, by the application of probabilities and high numbers." (N2, 115)

18. In fact, van Plato (1994, 88) writes that Boltzmann himself admitted in his 1877 *"Bermerkungen ueber einige Probleme der mechanischen Warmtheorie"* that the application of gas theory to the universe as a whole was "highly suspicious."

19. Prigogine (1971, 94) writes, "A large number of degrees of freedom is an essential *prerequisite* for irreversibility. All dynamical properties will be quasi-periodic in a small system in accordance with the famous Poincaré theorem."

20. See, for instance, the discussion in the second chapter of Sach

(1987). On the extension of this account of irreversibility beyond gas systems Sach writes:

> The same line of reasoning leads to an understanding of the irreversibility of the physical and biological evolutionary processes of the universe, whether or not the dynamics of the evolutionary processes are invariant under time reversal. The number of parameters that must be controlled precisely to reverse the evolution of even the smallest organism is so large as to make the reverse motion incredible. (op. cit., 30)

Notice that no assumption is made here about the molecules of the relevant bodies being in a state of molecular chaos. Perhaps the best way to express the difference in the approach taken above by Sach from that of Boltzmann is to call the former a static and the latter a dynamic one. Boltzmann's concern was to provide support for his kinetic H-theorem (i.e., to explain why it is we see particular processes "evolve" in just one direction), whereas Sach's purpose is to explain why we do not see specific kinds of processes reverse themselves. This subtle difference in emphasis thus makes for a crucial difference with respect to the types of assumptions that are made. As it turns out, Peirce adopted both viewpoints on different occasions; we have so far witnessed his remarks on the "fortuitous" motions of molecules, which suggest the dynamic assumption of molecular chaos. In 6.613, however, we find him explaining that colored lights falling on a spectrum seldom—except under very controlled laboratory conditions—produce white light. To achieve this, he explains, an extraordinarily improbable series of events must be coordinated.

In any case, whether an application of the assumption of molecular chaos to liquids and solids is legitimate, it certainly is the case that the second law of thermodynamics has been extended to systems involving all phases of matter. It should be noted, however, that what is properly called the second law of thermodynamics is a well-established empirical generalization that is to be kept distinct from the interpretation of that macroscopic law in terms of the statistical mechanical principle involving the probabilistic construal of the entropy function in terms of a measure of molecular "disorder."

21. A more precise statement is that as the number of trials of a series of independent binomial trials goes to infinity, the probability that the relative frequency of some event (typically termed "success" of some event—e.g., flipping heads with a fair coin) will differ by more than some specified small amount from the objective probability of success on each trial goes to zero. In notation:

$$Pr(|S_n/n - p| < \varepsilon) \rightarrow 1 \textit{ as } \mathrm{n} \rightarrow \infty$$

where S_n/n is the average number of successes after n trials, p is the probability of success on each trial, and $\varepsilon > 0$. This is the classical or “weak” law of large numbers. The “strong” version, which was first stated in 1909 by Borel and later given a rigorous proof by Cantelli in 1917, extends the classical result by guaranteeing that not only will the observed relative frequency eventually converge to the probability but it will also remain there.

22. Paul and Tatiana Ehrenfest (1990, 1).

23. van Plato (1994, 81–82) writes:

> Since the beginnings of the kinetic theory, intuitive probabilistic arguments had been taken to justify the use of an average quantity such as average velocity. The probabilistic counterpart on which the argument was based, was the law of large numbers. This is obvious in Boltzmann. His method of a finite number of energy levels makes probabilistic calculations take on the same combinatorial form as in gambling systems. And there the role of the law of large numbers was understood by everyone: It was taken to show that variation and irregularity in the small leads to regular behavior in the large.

24. The Maxwell–Boltzmann equation is expressed as follows:

$$f \cdot \Delta = \alpha_{\varepsilon}^{-\beta\varepsilon} \cdot \Delta\tau$$

where f is the number of molecules with velocities between certain definite limits, $\Delta\tau$ denotes a very small alteration in molecular state, ε the total energy, and α and β constants. The curve expressing this distribution of molecular velocities is the familiar Gaussian or bell-shaped curve.

25. From MS 1167, Peirce’s notes for the *Century Dictionary*, ca. 1895.

26. That Peirce was familiar with Poincaré’s paper on the three-body problem from which the recurrence theorem came is shown by his review article of astronomer-mathematician Hill in N3, 240–41.

27. The remarks in question are N2, 271.

28. There are passages, however, that suggest just the contrary—for instance: “Time, as the universal form of change, cannot exist unless there is something to undergo change . . .” (6.132). Here Peirce is thinking of time as that form under which a thing can take on contradictory qualities.

Chapter Three

1. For modern considerations of this problem, see Reichenbach (1956), Grünbaum (1963), and Davies (1974, 1995). Paul Davies (1974, 22; 1995, 256–58) notes that from the fact that there is an asymmetry in time with respect to the past and future, it does not follow that time in any way undergoes a “flow.” A road on the outskirts of a town may appear asymmetric depending on whether you are looking into town or away from

town, but it surely does not follow from this that the road is in a state of flow. Many modern writers prefer to keep distinct the notions of the asymmetry of time—with its associated notion of an arrow of time—and the idea that time, or more specifically the "now" or present, flows from the past into the future.

2. However, Peirce definitely does not propose that ideas are simply identical with actual states of feeling. This assumption is tantamount to nominalism, and in his later years, Peirce was dead set against that position. Although ideas show up in the organism as feelings, the real content of an idea is inexhaustible by any of its actual occurrences. His understanding of the ontic status of ideas rests on the scholastic distinction between the actual and the real. A law of nature, for instance, may be instantiated by any number of actual events, but its reality can never be exhausted by these actualities. (In fact, Peirce believed that a true continuum was capable of accommodating an arbitrarily large, transfinite number of elements). Consequently, if we think of laws as continuous in this sense, a law is not only something more than any actual number of instantiations or events; it is more than any possible number of instantiations or events. For this reason, Peirce rejected the Humean identification of a law with an actual regularity. For Peirce, to say that a law is real is to suppose that it would also hold for any number of counterfactual and subjunctive conditionals.

3. See Grünbaum (1963) for a discussion of the causal theory of time and its connection with special relativity theory.

4. See the *Critique of Pure Reason*, Second Analogy of Experience A 192, B 237, for Kant's discussion of these general and objective temporal relations.

5. Unless, that is, we have an argument showing that ideas are purely individual entities that exist only in the present. Peirce does assume that ideas once past are capable of being present to the mind only by virtue of the continuity of time, which allows for some ideas to be only infinitesimally past. But it must be admitted that there appears to be nothing special about any given procession of ideas that can account for the irreversibility of time. In fact, even to ascribe time's irreversibility to some procession of ideas seems to involve already the very feature of a preferred direction, which is at issue.

6. Witness his review of James's *Principles of Psychology* at 8.55*ff*.

7. Note the implicit difficulty here: Peirce proposes to explain such regularities as the time-reversible laws of classical mechanics as habits, while his favorite examples of habit in physical systems are nonconservational ones involving viscous and other nonreversible forces.

8. Consider, for example, the shuffling of a deck of cards: Eventually,

although it may take extremely long to do so, repeated shuffling would bring us back to the original configuration of the deck in which all cards are arranged in an "orderly" fashion by suit and cardinality.

9. We should recall that Peirce is always considering the conservation of energy principle as it was expressed by Helmholtz in terms of central forces.

10. Peirce provides, in MS (446) and RLT (203), algebraic illustrations of this result.

11. See RLT, 227–29, 6.273, and 8.187.12. Peirce suggests at 6.273 that it may have been this curious phenomenon that suggested to Leibniz the doctrine of preestablished harmony.

12. See Short (1981).

13. The term originates with Poincaré and Lyapunov.

14. Related assumptions are the principle of equal a priori probabilities (of finding a system's representative point in some region of the energy surface within phase space), the *Stosszahlansatz*, and the assumption of molecular chaos. These notions will be explained in more detail in Chapter Six.

15. He writes:

> The consequence [of Quetelet, Buckle, Darwin, Clausius, Maxwell] was that the idea that fortuitous events may result in a physical law, and further that this is the way in which those laws which appear to conflict with the principle of the conservation of energy are to be explained, had taken a strong hold upon the minds of all who were abreast of the leaders of thought. . . . The idea that chance begets order . . . is one of the cornerstones of modern physics . . . (6.297)

16. Boltzmann, it is worth noting, proposed that the distinction between past and future is based definitionally on the temporal asymmetry of entropy production. It is a curious result, then, that while Boltzmann defined time's "arrow" in terms of the increase of entropy (so often identified with disorder), Peirce, as it turns out, defined the arrow in terms of the increase of regularity and orderliness. More on this in Chapter Five.

17. See Prigogine (1984, 302–03).

18. Witness the opening passage of Chapter Five of the *Origin of Species* (1958, 131):

> I have hitherto sometimes spoken as if the variations — so common and multiform with organic beings under domestication, and in a lesser degree with those under nature — were due to chance. This, of course, is a wholly incorrect expression, but it serves to acknowledge plainly our ignorance of the cause of each particular variation.

19. The obvious response here is, I think, that the materialist need not be embarrassed at the need for formal principles of mathematics. Although mathematics may be ontologically far removed from the materialist's beloved field of physics, it will at least take some extra argument to show that it is any more essentially intimate with the thesis of idealism. Nonetheless, I have no doubt that Plato, Berkeley, and Peirce would be quick to meet the challenge.

20. See also the entry for Neural Network Models in Corsini (1994, 470–73).

21. See Kaufmann (1995a, 1995b).

22. Again, it is worth noting that Peirce's explanation of the reversibility of the conservation of energy law here is a bit misleading. It is not that the sign for the time differential is actually squared but that if we replace the sign for time with its negative, *–t*, and then take the derivative of a function of the time twice to find the resulting acceleration, we get back a positive quantity by canceling out two negatives.

23. Peirce speaks very differently, however, about time when considering matters of topology and geometry (cf. NEM II), and he did not approve of Kant's nominalistic tendency to make time nothing real outside of the subjective consciousness (cf. RLT, 160–61).

24. Published as W3, 114–60, and NEM III, 639–76.

25. Peirce (1878).

26. One might wonder whether this would imply that the law of mind should be nonmonotonic, rather than displaying the irreversible behavior that Peirce claims of it.

27. In his notes for this lecture (MS, 446), he wrote:

> The reason why chance tends toward a definite result is that when anything is changed by chance since the changes are fortuitously distributed the changed thing is no more likely to be changed back again than anything else. Therefore since chance on the whole produced the first change it will change other unchanged things in the same way and therefore it will also change the changed things still further in the same way.

Note the assumption being made here that the system in question is starting off from a "peculiar" position—namely, that there is a homogeneity or uniformity of quality. Otherwise, Peirce would have to add some extra constraint to distinguish changes "backward" to the original quality. For instance, if the system starts off with a diversity of qualities, how are we to notice any change in any specific "direction"? With this in mind, it is worth noting how peculiar it is that Peirce never mentions that stochastic systems, so long as the number of elements involved is finite, must eventually exhibit a recurrence to the original state from which they began their "irreversible" journey. As was mentioned in the last chapter, this is related to a very important objection to Boltzmann's account of the irreversible increase of entropy.

28. Consequently, this should also make clear that for Peirce the ideal limit of inquiry is not constitutive of the truth, as some modern interpreters have claimed he meant. Rather, Peirce is saying that in the long run we will have converged on or have discovered the truth. Were the long run actually constitutive of the truth, there would be no fixed reality (no fixed proportion of a population) to be discovered by taking samples (and observing the proportion within the samples). Cf. Reynolds (2000) for a discussion of this and other misinterpretations of Peirce's idea of truth.

29. Some qualification is required here, though, for Peirce writes that ". . . although the other instants of time are not independent of one another independence does appear at the actual instant" (RLT, 216). Clearly Peirce does not want to say that all the instants of the past are independent of one another, nor especially that the future is entirely independent of the present or past, for this would nullify completely the law of habit. At the same time, however, it is an interesting question how there is to be any correlation among instants if the present is independent in the way Peirce insists.

30. "On Small Differences of Sensation" (W5, 122–135) was a paper presented to the National Academy of Sciences in October 1884 describing the results of experiments conducted by Peirce and Joseph Jastrow, a student of his at Johns Hopkins. In this paper, Peirce and Jastrow claimed to have refuted Gustav Fechner's theory of the *Unterschiedsschwelle* (that there exists a limit of minimum perceptible difference in sensations). The study showed that subjects were able to make fine distinctions among sensations of pressure, even beyond what they believed they could actually sense, with a success rate greater than would be expected by chance. Incidentally, Stigler (1978) identifies this as the first study to employ a precise and mathematically sound method of randomization.

31. See Hacking (1990, 205) and Stigler (1986, 253).

32. On several occasions, Peirce describes the association of ideas as occurring in a random fashion. Consider the following:

> [Suppose] we are studying over phenomena of which we have been unable to acquire any satisfactory account. Various tentative explanations recur to our minds from time to time, and at each occurrence are modified by omission, insertion, or change in the point of view, in an almost fortuitous way. (1.107)

> Suppose I have long been puzzling over some problem, — say how to construct a really good type-writer. Now there are several ideas dimly in my mind from time [to time], none of which taken by itself has any particular analogy

> with my grand problem. But someday these ideas all present in consciousness together but yet all very dim deep in the depths of subconscious thought, chance to get joined together in a particular way such that the combination does present a close analogy to my difficulty. (RLT, 235)

> There are continual changes going on in the *connections* of ideas in consciousness; and the action of associative suggestion does not take place until chance has brought the two ideas into suitable connection for acting upon one another. Thus, I stand before an emblem wondering what it means. . . . Perhaps the meaning is dimly in my consciousness; but it is not until by the movements in consciousness, chance has thrown the idea of the emblem and the idea of its meaning into the right sort of connection, that they suddenly change in vividness . . . (RLT, 236–37)

This perhaps accounts for his comparison of the association of ideas with the stirring up of a bag of beans so as to ensure a random distribution.

33. There is a vast literature on these results. Rescher (1978) provides a good discussion of Peirce's theory of induction in relation to the convergence and self-corrective theses.

34. Flower and Murphey (1977, 617) write:

> The cosmology is not only a theory of universal evolution, but a theory of inquiry as well. Just as the goal of evolution is the organization of feeling and will into organized systems governed by increasingly stable habits, so the goal of inquiry according to the doubt-belief theory is the explanation of experience by a stable system of beliefs.

35. I would propose that this should dissolve Putnam and Ketner's puzzlement concerning Peirce's explanation of the irreversibility of stochastic phenomena by appeal to the laws of probability (cf. RLT, 84). They find this argument strange, they say, because of the obvious objection that "the laws of probability do not distinguish a direction of time any more than the laws of fundamental physics do."

36. Hacking (1990, 213) puts it nicely when he summarizes the message of pragmaticism: "The universe reaches its successive states by processes formally and materially analogous to those by which sound method reaches its conclusions."

37. The 1898 series of lectures published as "Reasoning and the Logic of Things" were originally intended by Peirce to be called by some variation of "The Logic of Events."

38. "The reality of things consists in their persistent forcing themselves upon our recognition" (1.175). "In the idea of reality, secondness is predominant, for the real is that which insists upon forcing its way to recognition as something *other* than the mind's creation" (1.325).

39. In addition to the discussion of this point in RLT, see also 6.600.

40. According to Pape (1993, 592), the crucial link between final causation and logical causation is through the essentially irreversible process of semiotics or sign activity. Because Peirce had explicit intentions of construing logic as semeiotics (1.444, 4.9, 8.343, 8.377), I believe both Pape's and my own interpretation amount to the same thing.

41. The suggestion here is not that we should attempt to discern anything like nature's "intentions" or "purposes" for the long run. Rather, Peirce's evolutionary history of the development of laws is supposed to assist us in guessing—that is, in making abductions—about what kinds of laws are most likely to be operative in those levels of phenomena, e.g., the constitution of matter, for which our instinctive capacities for guessing are ineffective.

Chapter Four

1. *Natural Inheritance*, noted in Porter (1986), 146.

2. Tursman (1995), 372, note 26. Unfortunately, Tursman does not develop this point. I plan to pick up the ball where he left it and carry the argument through to its conclusion.

3. That this presents a fair summary of Peirce's attitude can be confirmed by a passage in RLT, 232 (cf. also 7.503), in which, after describing the main features held in common by protoplasm and mind, Peirce says:

> Now all this may be summarized by saying that its properties [protoplasm] depend upon Bernoulli's law of high numbers, and every action depending upon that law is, so far as it is so dependent, purely causational and not conservative.

4. Compare, for instance, Schrödinger's (1995) remarks on consciousness:

> Any succession of events in which we take part with sensations, perceptions and possibly with actions gradually drops out of the domain of consciousness when the same string of events repeats itself in the same way very often. But it is immediately shot up into the conscious region, if at such a repetition either the occasion or the environmental conditions met with on its pursuit differ from what they were on all previous incidences. (95)

In fewer words, the similarity between Schrödinger and Peirce is made apparent by the former's statement that "consciousness is associated with the *learning* of the living substance; its *knowing how (Können)* is unconscious." (ibid., 99)

5. I wish to bring to the reader's attention at this point, because it will

be important for the last chapter, that Peirce is here invoking the law of large numbers as an explanation not of an irreversible process but of the existence of a statistical stability from a vast population of uncorrelated individuals. Hence, Bernoulli's law was attractive to Peirce for at least two separate reasons.

6. This theory led Peirce to make some remarkable statements such as the following:

> A decapitated frog almost reasons. The habit that is in his cerebellum serves as a major premiss. The excitation of a drop of acid is his minor premiss. And his conclusion is the act of wiping it away. (6.286)

7. It is worth noting that Peirce was not alone in thinking that primitive organisms were capable of intelligent behavior, as this quote from H. S. Jennings attests:

> The organism *[Stentor roeselii]* "tries" one method of action; if this fails, it tries another, till one succeeds. . . . The phenomena are thus similar to those shown in the "learning" of higher organisms, save that the modifications depend upon less complex reactions and last a shorter time. Jennings (1906, 177)

Incidentally, the initials *H. S.* stand for "Herbert Spencer." Jennings graduated from Harvard in 1896 and had an interest in philosophy.

8. As Schrödinger (1995) proposed in his "What Is Life?" lectures (71, 73), living organisms combat the universal trend toward entropy increase by consuming negative entropy from their environment in the form of food. It is the possibility of nutrition's taking place that establishes living organisms as "open" thermodynamic systems. Because open systems are able to exchange matter and energy with their environment, the consequence of reversibility does not arise. It would not be until the middle of the twentieth century, however, that a theory of nonequilibrium thermodynamics capable of properly dealing with such phenomena would be developed.

9. It is clear from what actually gets discussed in the paper, however, that Peirce's specific interest is to explain how the most primitive forms of life are capable of goal-directed behavior.

10. Actually, Peirce raises another objection immediately after this first one. It is one that we have seen before—namely that without the posit of a primordial habit-taking tendency, the laws of nature must go unexplained.

11. Of course, cosmology today does attempt to explain the formation of solar systems, galaxies, and the universe as a whole. I believe that Peirce was thinking of terrestrial and celestial mechanics when he made this remark.

12. See Maxwell (1986, 211).

13. An additional criticism Peirce raised against the mechanical philosophy was that it could not account for the occurrence of certain light-polarizing sugar molecules essential to life into "left-handed" and "right-handed" varieties. "The three laws of motion draw no dynamical distinction between right-handed and left-handed screws, and a mechanical explanation is an explanation founded on the three laws of motion. There, then, is a physical phenomenon absolutely inexplicable by mechanical action. This single instance suffices to overthrow the corpuscular philosophy" (EP2, 159).

14. One really should keep distinct the notions of *evolution* and *development*. Evolution, according to the modern understanding, is a phenomenon of populations (e.g., species), whereas development is a phenomenon characteristic of an individual (e.g., an organism). See Dawkins (1998, 192–193).

15. See Hoppen (1998, 477).

16. This mention of the growth of crystals is a likely sign that Peirce intends to contrast his own thoughts with those of Ernst Haeckel. As Mason (1962, 427) writes, Haeckel "thought that salt crystals and organic cells were strictly comparable in the way that they grew, and in their composition and symmetry of form, for both were the products of the same matter and the same cosmic force." See Haeckel (1905, 40*ff*.).

17. As a clue of how this will figure into the next chapter, I offer this passage from "Evolutionary Love":

> Love, recognising germs of loveliness in the hateful, gradually warms it into life, and makes it into life, and makes it lovely. That is the sort of evolution which every careful student of my essay "The Law of Mind" must see that *synechism* calls for. (6.289)

18. See also 6.17 for a similar statement.

19. All the examples Peirce draws on from statistical mechanics and statistical thermodynamics—Boltzmann's H-theorem, for instance, which describes the statistical increase in entropy—assume that the system in question starts off in an improbable condition (one of low entropy). Another way of putting this is to say that these systems begin their trajectories confined to a very small number of the available degrees of freedom; their "irreversible" motion consists in their "seeping out" from this initial state so as to occupy a maximum of the available degrees of freedom.

20. See Gould (1996).

21. Peirce's take on the Darwinian hypothesis is adequately summed up in this passage:

> Natural selection, as conceived by Darwin, is a mode of evolution in which the only positive agent of change in the whole passage from moner to man is fortuitous variation. To secure advance in a definite direction chance has to be seconded by some action that shall hinder the propagation of some varieties or stimulate that of others. (6.296)

22. See Spencer (1900 [first published in 1860]).

23. Spencer also gave an alternative definition of evolution as "an integration of matter and concomitant dissipation of motion; during which the matter passes from a relatively indefinite, incoherent homogeneity to a relatively definite, coherent heterogeneity." (*First Principles*, 367). This was subsequently lampooned by the mathematician Kirkman, who gave the following "translation" into English: "Evolution is a change from a nohowish, untalkaboutable, all-alikeness, to a somehowish and in-general-talkabaoutable not-all-alikeness, by continuous somethingelseifications and sticktogetherations" (originally from a letter published in *Nature* in the 1890s ; cf. Spencer (1900).

24. I am very grateful to Paul Handford for valuable comments and criticisms that much improved the following sections.

25. For instance, Wiener (1965, 82), Arthur Lovejoy in Wiener (1965, 227–30), and Rulon Wells (1964, 304–22). Wiener writes that "it is remarkable that Peirce took his mathematical analogy seriously as an illustration of his metaphysical generalization of Darwin's theory."

26. See, for instance, 1.174, 6.14, 6.553, and 6.554. I reproduce this last passage to give a taste of Peirce's annoyance with Spencer's theory.

> I know that Herbert Spencer endeavours to show that evolution is a consequence of the mechanical principle of the conservation of energy. But his chapter on the subject is mathematically absurd, and convicts him of being a man who will talk pretentiously of what he knows nothing about. The principle of the conservation of energy may, as is well known, be stated in this form: whatever changes can be brought about by forces can equally happen in the reverse order (all the movements taking place with the same velocities, but in the reverse directions), under the government of the same forces. Now, the essential of growth is that it takes place in one determinate direction, which is *not* reversed. Boys grow into men, but not men into boys. It is thus an immediate corollary from the doctrine of the conservation of energy that growth is not the effect of force alone.

27. This kind of talk itself shows the confusion that surrounds the notion of "order" involved in the probabilistic treatment of entropy. The formal expression only pertains to a kind of "orderliness" that is exhibited within phase space diagrams (any realistic examples of which would be beyond our own conceptual abilities to visualize, given our confinement

to three dimensions); there is an equivocation between this notion of order within an abstract mathematical space and the more intuitive notion of spatial orderliness within three dimensions or less. For a discussion of the problems surrounding the identification of entropy with disorder, see Bridgman (1961) and Denbigh (1989, 323–32). A positive attempt to resolve the tension between the "law of entropy" and evolution notes that the Earth (on which the only biological evolution we are familiar with takes place) is neither an isolated nor a closed system, and consequently the law of increasing entropy does not strictly apply to it. In addition, recent developments in nonequilibrium thermodynamics (e.g., Prigogine) have shown that one way for an open system to maximize entropy is to branch off into more complex forms and behaviors in an attempt to dispense with the influx of (low entropy) energy. In light of this, it has been claimed that the law of increasing entropy and the law of increasing complexity (evolution) are two sides of the same coin.

28. Boltzmann was thinking about entropy in terms of disorder by 1877 and the analogy is explicit in his *Lectures on Gas Theory* of 1896. See Brush 1976 for a detailed discussion of the debates surrounding Boltzmann's assumption of "molecular disorder." My thanks to Stephen Brush for helping me track down some references on this topic.

29. For example:

> That law [the second law of thermodynamics] is that heat flows from hot bodies to cold, as water runs down hill; so that when bodies are all cooled down to one level of temperature, the heat in them above the absolute zero is no more available to run an engine than is the height of the sea above the centre of the earth available to turn a water-wheel. (N2, 64, ca. 1894)

30. Here follows Peirce's definition of entropy for the *Century Dictionary*:

> (1). As originally used by Clausius, that part of the energy of a system which cannot be converted into mechanical work without communication of heat to some other body or change of volume.
>
> (2). As used by Tait (who wrote for the purpose of discrediting Clausius) the available energy, that part of the energy which is not included under the entropy, as properly used. (ca. 1884–86; W5, 405)

31. The categories, of course, are discernible in Darwin's theory, where "the idea of arbitrary sporting is First, heredity is Second, the process whereby the accidental characters become fixed is Third" (6.32).

32. Peirce used the term agap*ism* to refer to the general thesis that final causes are operative in the universe ("the law of love"), agap*asm* to refer

to the specific mode of evolution which involves the mechanism of creative "love," and agap*asticism* to refer to the doctrine that the agapastic mode of evolution is of principal importance. Similar distinctions apply to the terms tychism, tychasm, tychasticism, and anancism (from the Greek ananke meaning necessity), anancasm, and anancasticism. See 6.302 or EP1, 362.

33. If Peirce's employment of the term *love* seems odd in this context, recall that in some of the ancient Greek cosmologies—for example, Empedocles—the primary forces at work in the world are "love" and "strife." Fisch (1986) provides an excellent account of the influence of the ancient Greek cosmologists on Peirce's thought at the time he began to formulate his own "guess at the riddle" of the universe.

Chapter Five

1. For an argument that this is an inadequate expression of the relationship between organism and environment from the standpoint of modern biological science, see Lewontin (2000).

2. Alternatively, Murphey asks (Flower and Murphey, 1977, 617; Murphey, 1993, 357), in what sense could it be said that the universe is attempting to escape from doubt?

3. See, for instance, 5.466; 5.358, n. 1; 6.603; 6.606, n. 1; and 6.605. "I carefully recorded my opposition to all philosophies which deny the reality of the Absolute. . . ." What did Peirce understand the Absolute to be? "Accordingly, every proposition, except so far as it relates to an unattainable limit of experience (which I call the Absolute,) is to be taken with an indefinite qualification" (7.566). And "the Absolute is strictly speaking only God, in a Pickwickian sense, that is, in a sense that has no effect" (8.277).

4. See Reynolds (2000) for a discussion of the relevance of the convergence theorems of probability and statistical theory for Peirce's conception of truth.

5. These images of the final goal are ultimately misleading, however, as it turns out, for the simple fact that in the kind of truly continuous system Peirce has in mind, there can be no ultimately discrete atomic elements. Each individual must become welded together with its neighbors. A lattice structure in the sense of a Boolean algebra seems less likely to have been the ideal Peirce sought when one considers that his work in this area was done algebraically in terms of matrices rather than with graphs. His notebooks on logic are, however, filled with different graphical attempts to represent the "logic of relations." It should be noted, too, that his inspira-

tion in this direction was Kempe's modeling of relations in analogy with the valency graphs of chemists (4.561). Cf. Kempe (1886).

6. To understand the motivation behind these labels, consider how, in the case of a parabola, the curve is often represented as approaching the origin from a point at infinity along one axis and reflecting back again toward the same point at infinity along the same axis; in the case of a hyperbola, the curve approaches the origin from a point at infinity along one axis and then heads off toward a different point at infinity along the other axis.

7. For other remarks on Cayley and the absolute, see 4.145, 4.219, 6.27, and 6.82.

8. For a comparison with modern cosmological theory, consider the remarks of French-Canadian astrophysicist Hubert Reeves: "Fifteen billion years ago . . . [a]ll matter was maintained by extremely high temperatures in a state of complete and permanent dissociation. Or more precisely, any bond was immediately destroyed. This was the primordial chaos; there were neither structures nor organizations" (Reeves 1991, 52).

9. Discovery of the central limit theorem is first credited to Abraham De Moivre (1733), with more general instances of the result following later by Laplace (1810) and Poisson (1835). Cf. Stigler (1986, 136–138) and Hacking (1990, 95–104).

10. In Chapter Six, I will discuss how incongruous this picture of the evolution of law is with Peirce's alternative explanation using the law of habit. As I will show, there is a deep ambiguity surrounding Peirce's conceptions of chance and uniformity or law.

11. Peirce's reasons for doing so may have been somewhat calculated, for a good deal of his failure to win the support of his peers in academia—and consequently a permanent university position—appears to have been due to the widespread opinion that he was either agnostic or atheist. That he was unorthodox at least is beyond doubt. The repeated financial failures of his patents, which had a nasty habit of falling into the hands of unscrupulous entrepreneurs, would explain his loathing of "survival of the fittest" capitalism. It is sadly ironic that when so many of his schemes to raise himself and his second wife out of the poverty of his last ailing years came to nothing, he gave away for free in a letter to a friend and former student the first documented sketch of an electronic Boolean logic circuit (Cf. NEM, III, i, 632). Such a design would, of course, eventually become the foundation of today's multibillion-dollar computer industry (cf. Ketner, 1984). For more details of Peirce's inventions, see Brent (1993, especially 248*ff.*).

12. The humourist Stephen Leacock (1956, 2461) wrote of Lord Kelvin

that "being Scotch, he didn't mind damnation and he gave the sun and whole solar system only ninety million years more to live."

13. See Stewart and Tait (1875), published anonymously.

14. See Brush (1977), especially Chapter V, "The Heat Death." Darwin provides a good example of the kind of response typically evoked by the possibility of the heat death:

> Believing as I do that man in the distant future will be a far more perfect creature than he now is, it is an intolerable thought that he and all other sentient beings are doomed to complete annihilation after such long-continued slow progress. (quoted in Fox Keller, 1995, 51)

15. Cf. Sklar (1993) and S. G. Brush (1965, 194–202) for selections from the original Poincaré paper.

16. Poincaré originally raised the objection in the *Revue de Metaphysique et de Morale* 1 :534–37. Zermelo followed with *"Uber einen Satz der Dynamik und die mechanische Warmetheorie," Annalen der Physik*, 57:485–94. See Brush (1965) for translations of each.

17. Cf. Brush (1977, 72*ff.*).

18. From a draft of "Dynamical Theory of Heat," cited by Sharlin and Sharlin (1979, 112).

19. Milic Capek has, in a couple of articles, raised the issue of Peirce's having held at the same time an antimechanistic philosophy and the theory of eternal recurrence. Capek has focused on a couple of passages in which Peirce speculates that time must be a self-returning line, if it is to be conceived of as infinite. This consideration arose as a result of his views about continuity but should not, I would argue, be given more emphasis than it is due. In comparison with the importance of the irreversibility of time for Peirce's philosophy, I think this to be fairly noncontentious. Cf. Capek (1960, 289–96; 1983, 141–53).

20. Bridgman (1961, 175–76).

21. Peirce consistently sided with Boltzmann in the latter's debates with Poincaré, despite the fact that Boltzmann was in many ways much more of a mechanist than Poincaré. Peirce's opposition to Poincaré (evident in NEM, IV, 33, 37; HP, 45) was driven by their differences of opinion on epistemic questions in science and over the status of the atomic hypothesis. Peirce was a realist about atoms and molecules; Poincaré was not. However, as is apparent from his *Revue de Metaphysique* article in which he first raised the recurrence objection, Poincaré was himself critical of the mechanical philosophy precisely because it led to conclusions incompatible with the experience of irreversibility in nature. Cf. Brush (1965, 203–07). Poincaré never, to my knowledge, corresponded with or referred to Peirce in print.

22. Nor is it so easy to dismiss the idea that Peirce's vigilant emphasis on the establishment of lawfulness and order over the spontaneous outbursts of chance are in some way reflective of his own attempts to bring his volatile and sometimes socially maladjusted temperament under leash.

23. Michael Heidelberger (1987, 117–56).

24. A 1908 letter from Peirce to Cassius Keyser, contained in NEM, III, ii, 889–99, describes how he conceived that an infinity of continuous etherlike layers could account for mind–matter interaction. The model for this "introvortical" conception, Peirce explains, was Kelvin's vortex theory of the atom. The details of this model, complete with an equation expressing the rate of propagation of a signal between layers, are described by Murphey (1993, 390–93).

25. This idea began with Tryon (1973) and was later picked up by Vilenkin (1982, 1984). According to Vilenkin's model, and in contrast to Peirce's, "the structure and evolution of the universe(s) are totally determined by the laws of physics." In response to the question why the quantum fluctuation should have occurred, Tryon responds: "I offer the modest proposal that our Universe is simply one of those things which happen from time to time." (op. cit., 397)

26. See, for instance, Balashov (1992), Walter Thirring (1995), and Lee Smolin (1999). It should be added that Peirce was not original in the nineteenth century on this point; Emile Boutroux had been arguing for the contingency of natural laws since 1874; cf. Boutroux (1874). Poincaré (1963, 1–14) offers criticism of Boutroux's proposal that natural laws evolve over time.

27. Ketner cites this quote as among Max Fisch's papers and uses Fisch's reference system F55:87, indicating that the date of the passage was 1855. But this surely can't be right, because Thomson would then have been only one year old and Rutherford yet to be born.

28. The house is now owned and occupied by the Delaware Water Gap Park Authority and displays a small exhibit about Peirce's life and accomplishments. Peirce's widow did manage to sell his papers and much of his library to Harvard University.

Chapter Six

1. It is not very clear what behavior could be described as "completely random." The best candidate is lack of any regular law of succession between events. But this is precisely what is denoted by the case of the normal probability curve in which events are independent of one another. So there is, as I shall discuss presently, some ambiguity in Peirce's supposition

that the universe evolves from a state of random chaos to one marked by exact regularity, in analogy with the law of large numbers.

2. In his early years, Peirce interpreted probability statements as statements about *actual* relative frequencies. This was a nominalist position that he would eventually grow out of, adopting later a theory of probability as the limit of a series of relative frequencies and finally a propensity interpretation similar in respects to that of Karl Popper. For a discussion of the development of his thought on probability, see Burks (1964).

3. The rest of the passage draws on the convergence properties promised by the law of large numbers:

> . . . As we go on drawing inference after inference of the given kind, during the first ten or hundred cases the ratio of successes may be expected to show considerable fluctuations; but when we come into the thousands and millions, these fluctuations become less and less; and if we continue long enough, the ratio will approximate toward a fixed limit. (2.650)

4. Strictly speaking, the assumption, known as the *Stosszahlansatz*, or assumption of molecular chaos, is that there is no correlation among molecules of given velocities *before* they interact. This amounts to the assumption that collisions among molecules occur at random. For details, see Sklar (1993).

5. Compare these other statements:

> Generally, in all its meanings, *chance* refers to variety, in contradiction to uniformity . . . (NEM III, i, 396 [1903])

> [Chance] is that diversity and variety of things and events which law does not prevent. (6.612; [1893])

6. Initially, one cannot help but feel one has just heard the pot calling the kettle black. But Peirce's accusation is not without some basis. The difference between him and Newcomb is that whereas Newcomb is ready to posit an arbitrary and ad hoc hypothesis involving the constant violation of the most central laws of mechanics, Peirce is offering a hypothesis (the evolution of laws) that in addition to explaining the presence of these laws would also explain why any apparent violations take place.

7. Victor Cosculluela (1992) points out that Peirce does not consider the possibility that an increase in variety can arise from the interaction of independent but fully deterministic causal chains. What Cosculluela has overlooked, however, is that Peirce is concerned to explain the very fact of variety in the first place, not just its increase. Cosculluela must presuppose the existence of some variety to begin with to have his intersecting

causal chains, and these, Peirce would object, are simply assumed as brute inexplicable facts.

8. As I have said elsewhere (Reynolds, 1997), the picture of law here is that of a set of steel tracks; an active violation, then, is like a hiccup or jumping from the tracks. According to the passive construal of a violation, the rails themselves have a kind of quantum fuzziness about them that only partially determines the trajectory of future events.

9. It has been noted by Hwang (1993) and Sfendoni-Mentzou (1993) that Peirce's notion of absolute chance seems closer to what Aristotle described as the "spontaneous" (automaton) than that which he called "chance" (tyche). Sfendoni-Mentzou mentions (endnote 8) that James Feibleman (1970) had made the same point earlier.

10. We have already encountered the astronomer Simon Newcomb in this regard, the physicist Oliver Lodge was another. See the latter's "Force and Determinism" (*Nature*, 43:491; 44:198, 272 [1890–91]).Peirce mentions only that Newcomb's speculations appeared in the *Independent* (6.92).

11. If Peirce really believed that phenomena such as these counted as evidence for tychism, one is led to wonder about the implications for the very successful theory that heat is a form of random molecular motion. Is all thermal motion, then, an instance of primitive spontaneous activity?

12. See Porter (1986) for a discussion of Maxwell's opinions about determinism and freedom of the will.

13. In Campbell and Garnett (1884, 365).

14. See Poincaré (1946, 395–412).

15. A differential equation is said to be *linear* if the sum of two possible solutions is also a solution. *Nonlinear* differential equations do not satisfy this condition. Their more interesting feature is their sensitivity to small displacements of initial boundary conditions. Changing the initial conditions slightly can result in radically different and unpredictable behavior.

16. See Heidelberger (1987, 123). According to Heidelberger, Fechner was the first modern figure to espouse a well-developed scientific indeterminism.

17. I am grateful to Richard Keshen for helping me see this.

18. Likewise, Peirce wrote that "to say that it [chance] is not absolute is to say that it—this diversity, this specificalness—can be explained as a consequence of law. But this . . . is logically absurd" (6.612). We can take him to mean that the long-run probability can tell us nothing about what we should expect on any specific, individual event. Relative frequentists, like Peirce, can sensibly apply probability values only to long-run series of events. As a result, frequency theorists cannot make any deductively sound

inferences as to the probability of the single case. Even though the law of large numbers gives us a guarantee (in some sense) that in the long run the relative frequency of heads will be approximately one half of all the outcomes, it is still possible—though very unlikely—that we will get nothing but tails. Van Fraassen refers to this as the "fundamental question about chance"(cf. van Fraassen, 1991, 81*ff*.). Putnam has dubbed a related issue "Peirce's Puzzle" in Putnam (1987, 80–86).

19. This is the point of that enterprise that Peirce called "phenomenology" or "phaneroscopy."

20. Quoted in von Mises (1981, 104–05). What is new in the mathematical result derived by Poisson is that the probabilities of the individual events in question are permitted to vary about a mean value. For example, Bernoulli's theorem may be taken to describe the repeated tossing of a single coin with a fixed probability for heads. Poisson's theorem considers, in a sense, the case of flipping many different coins all at once, each with a different probability of turning up heads.

21. Mayo (1996, 440) backs up Peirce's claim to have justified induction without assuming the uniformity of nature.

22. I am grateful to Ian Hacking for pointing out to me that Cheng's expression must be corrected by adding the requirement that the samples be drawn randomly.

23. Witness the notes for his essay "Why should the Doctrine of Chances raise Science to a higher Plane?" in NEM III, i, 150–58.

24. Forster (1997, 57–80) provides a good explication of the architectonic underpinnings to Peirce's tychism.

25. As a variation on Ernst Haeckel's recapitulationist theme, Peirce's idea might be expressed as "Psychology recapitulates cosmology."

26. I discuss this in Reynolds (1997) in greater detail with respect to a computer model simulation of the law of habit described in Dearmont (1995). Dearmont models the law of habit with what amounts to a nonstationary Markov chain.

27. A typical example in which the condition of identical distribution fails is that of sampling without replacement from an urn containing finitely many balls. Poisson's own law of large numbers (for events with varying probabilities) is another example of a series for which the condition of identical distribution fails.

28. Sklar (1993) provides a good overview of these conditions and their relative logical strengths with respect to one another. Tien and Lienhard (1971) also give a very good account of the different independence and randomization assumptions. For instance, they write (p. 59):

> The fundamental assumption in statistical mechanics is the principle of equal a priori probabilities. In slightly restrictive form it says: *All microstates of mo-*

> *tion occur with equal frequency*. . . . The principle of equal a priori probabilities includes as a special case the principle of molecular chaos. The latter principle says that there is no order in molecular motion, and it generally takes the form of Maxwell's second assumption [i.e., "the distribution of molecular speeds in any one component of velocity is independent of that in any other component" (45).

29. In ensemble theory, one supposes that the time-average of an individual system—that is, the proportion of time it spends in a certain state—equals the ensemble average—that is, the proportion of systems of the entire ensemble that are in that state at any given time. This assumption is known as the ergodic hypothesis. A related assumption formulated with respect to an individual system says that the representative point of a system traces a trajectory that fills (nearly) that region of the phase space consistent with the energy constraints of the system. This is also sometimes referred to as the ergodic hypothesis.

30. Kolmogorov (1973, 703).

31. The *A*'s, you will recall, hold that every fact and relation among facts follow as the necessary conclusion of some law. In other words, to be an *A* means to be committed to the opinion that no two things whatsoever happen without being correlated in the sense that there is some law or reason responsible for their coming out as they did. *A*'s reject the existence of coincidence and arbitrariness in nature. People who believe in astrology or "synchronicities," I suppose, would qualify as examples of the *A* party.

32. Hookway (1997) provides a helpful discussion of how Peirce's change of attitude from nominalism to realism affected his cosmology.

33. See, for instance, Maxwell (1888, 329): "In dealing with masses of matter, while we do not perceive the individual molecules, we are compelled to adopt what I have described as the statistical method of calculation, and to abandon the strict dynamical method, in which we follow every motion by the calculus."

34. Cf. Chapter Five, p. 128–29.

35. See also Prigogine (1980, Chapter 6) for an extended discussion of what he calls the breakdown of the law of large numbers.

36. Prigogine (Prigogine and Stengers, 1984) does discuss certain self-organizing systems and structures that are uncanny in their resemblance to Peirce's ideas. For example, Prigogine explains how the large spatial structures that are termite nests get created. The construction begins with a few termites "randomly" depositing grains of sand within a clear area. Into these granules the termites have injected a special pheromone that attracts other termites and leads them to deposit their own granules

nearby. As the density of pheromone-soaked granules increases, the probability that more pheromone-soaked granules will be added to this pile increases. It is difficult not to see here some analogue of Peirce's law of habit at work.

37. Oliver (1964) also raises this question (cf. p. 298).

Chapter Seven

1. For a classic illustration of how the pragmatic principle can be employed to dissolve a pointless verbal disagreement, see William James's discussion of the squirrel and the tree in "What Pragmatism Means" (James, 1978, 27–28).

2. For a more modern example of this tendency, see Kauffman (1995a).

3. See Giere (1999) for a useful introduction to this "semantic" or "model" theory of theories. Giere also attempts to salvage some semblance of realism in his conception of scientific theories.

4. Ludwig Büchner's (1824–99) *Kraft und Stuff* ("Force and Matter," published in 1855) was a classic and very popular materialist treatise.

5. Happily, this has been corrected somewhat in the last few years. See, for instance, "Peirce the Logician" in Putnam (1990) and Hintikka (1997).

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