Chance events interrupt the probabilities of reproduction, sometimes leading to extinction, sometimes to novel variations; this is exemplified in both biology and art. Reproduction takes place in the ambit of certainty or accident or chance.

**BIOLOGY**

In biology, reproduction is a process that brings forth new, similar life and so continuity of population, but that continuity is subject to the discontinuities of gene mutation, genetic drift and organism extinction in the course of evolution. Natural selection represents differential success in reproduction across and within species and genera. Changes in ecology affect the health of populations and may lead to extinction or expansion.

S.J. Gould in *Wonderful Life* [1] argues that the paradigm of vertical progression toward ever more “advanced” life forms does not fit the evidence he finds in his consideration of the reanalysis of the form and distribution of the fossils of the Burgess Shale. Instead, he finds that species and genera were most varied in the earliest layers of the Burgess Shale. Contrary to the conventionally accepted belief that the strongest survive and so form the species and genera that evolve, Gould suggests that sometimes a “weak”-looking, inconspicuous creature may be the one that survives in the long term, while more “robust” creatures may become extinct in the short term.

Gould argues that evolution, rather than following the paradigm of vertical progression, instead follows the paradigm of contingency, by analogy with historical contingency. In contingency, a number of chance events coincide to produce one or more unanticipated outcomes—that is, outcomes that are unanticipated within what is known of the regularities of a system, the pattern of life forms. In the short term, the coincidence of chance events has been called a critical incident. Over the longer term, Gould uses historical contingency as an analogy to refer to critical incidents that occur across the millions of years of geological formation.

Chance events may allow survival and the probability of reproduction. Chance events happen but they are not indeterminate (that is, there does not exist an equal probability that any one entity will manifest). Gould warns us to be wary of those who have confidence in their probability statements about evolution. In statistics, probability and chance are on a continuum, they are not polarities, and only valid information pertaining to the case in question can provide guidance—for instance, for the reanalysis that Gould presents in *Wonderful Life*. “Chances are not those probabilities that arise when there is some genuine indeterminacy in the world. Chances are those probabilities that play a certain explanatory role” [2].

Prior to the publication of Darwin’s *Origin of the Species*, there were two widely accepted explanations of the variety of life: first, an interpretation based on the book of Genesis, that God created the variety of life, and second, that life was destroyed and created rapidly by catastrophic natural events. Scientific explanations of variety are based on processes leading to change: Lamarck believed that characteristics acquired during an organism’s lifetime could be passed on to the next generation; and D’Arcy Thompson believed that new species formed from spatial changes in body form—morphogenesis—based on mathematical formulae, more recently claimed to be part of fractal geometry.

What was hidden from Darwin, although he knew that change was not solely caused by changing environments, was genetic transmission and mutation, which are part of the processes that bring about change in the varieties of life. Gould accepts natural selection but not the tautology of the fight for existence leading to the survival of the fittest. Gould argues that the Burgess Shale fossil record displays the survival of species and genera that seem less robust in form and function. Gould calls the process “contingency” to distance his understanding from the genetic determinism of many evolutionists. Contingency includes the proposition that the variety of systems of life cannot be predicted as some probability package a posteriori from current forms. Statements of probability are based on human preference for a particular story or explanation. Gould argues that we are too attached to four controlling biases of Western thought—progressivism, determinism, gradualism, and adaptationism . . . [which] have combined to construct a view of human evolution congenial to our hopes and expectations. . . . These four biases have long stood as the greatest impediments to a general understanding and appreciation of the Darwinian vision, with its explicit denial of inherent progress and optimality in the products of evolution. . . . Yet our new ideas about the importance of randomness in evolutionary change—particularly at the highest level of mass extinction—seriously upset this comforting and traditional notion [of determinism] and strongly suggest that we must view the evolution of human consciousness as a lucky accident that occurred only by the fortunate (for us) concatenation of numerous improbabilities [3].
These “improbabilities” are those linked to the mass extinction of life, especially of the dinosaurs, in the Cretaceous period, and the survival of small mammals and their subsequent evolution into human beings.

Evolution, as Gould argues, is not represented by the familiar diagram in which the many species and genera at the base are reduced to a few at the top—that is, the survival of the few, the fittest. Evolution takes many paths, and these paths branch off at various times without obvious benefit to the “advance” of “higher” forms. I interpret Gould to be saying that the conventional scientific representation of Darwinian evolution became imbued with hierarchic improvement by elimination of the weak and thus the inference that eugenics is part of the “natural” biological order. Instead of a clear path to improvement of the genus and the determinism and probability that entails, contingency has many layers and planes (these include the environment, population density, competition, speciation, mutation rate, duration and spatial distribution) in which life forms interact, protecting the weak and making the new, adding up to what humans call “unexpected” species. At any given time in the biological record, reproduction is a complex, multilayered, interactive process.

**ART**

In art, reproduction of two-dimensional images became possible with woodcuts and especially with the printing press. Visual analogies to mutation and extinction were introduced into reproduction by Marcel Duchamp in the second and third dimensions and—some suggest—in the fourth dimension, space-time [4].

Marcel Duchamp based much of his work on geometric and algebraic and physical systems and sometimes introduced, or retained, the chance events that arose during the process of creation. *Nude Descending a Staircase, No. 2* (1916) [5] is a system without chance or novelty, whereas his *The Bride Stripped Bare by Her Bachelors, Even* (1923) [6] introduces chance but only as potential conceptual interaction of extant forms. Duchamp tried to represent chance with what for him were intentional actions with outcomes ranging from predictable to accidental (Fig. 1). On reading Richard Hamilton’s explanation next to *The Large Glass* at Tate Britain, I began to see the multiple interactions of space, object, plane and dimension, making up the system, a system that is interrupted by conceptual accidental and chance events contributed to by the Malic Moulds, the Three Standard Stops and the Chocolate Grinder [7]. Hamilton states that the two sandwiched plates of glass with their inscriptions should be viewed from the underside upward to appreciate these three- and four-dimensional relationships.

Although the words “reproduction” and “evolution” are not used by Duchamp in his conception and plans for *The Large Glass*, Duchamp describes the means used and attempts made to inseminate the Bride [8]. The Malic Moulds represent nine suitors of differing potency. The Bride is potentially receptive to some advances, but these advances are blocked or obscured by objects such as the Scissors and the Chocolate Grinder. So there is an interruption of cause and effect. The means to reproduction are also circumscribed by the desire and orientation of the Bride. Duchamp expresses these ideas by what appear to be working mechanical parts inside *The Large Glass* [9].

But the most important aspect of such objects as the “Chocolate Grinder” remains to be mentioned: the interruption of the conventional collaboration between cause and effect, whether physical, psychical or artistic [10].

Richard Hamilton [11] states that D’Arcy Thompson’s [12] morphogenesis was one of Duchamp’s inspirations, along with Eadweard Muybridge’s chronological stop-frame photos of human and animal movement. For instance, Thompson drew a species of fish onto a sheet of rubber and stretched it laterally. The new appearance was that of another living species. The implication is that new species may arise by differential growth. The system stays the same while the surface appearance is changed, as in fractal geometry.

Reproduction, mutation and extinction are formative in the art of Robert Rauschenberg [13], Richard Hamilton and others, and also in the music of Steve Reich and John Adams and in some of the music of John Cage. Cage and Hamilton raise many questions about the extent to which reproduction, mutation and extinction in art are predictable, accidental or chance events. The pertinent literature often suggests that indeterminacy is the same as chance. I think it useful to propose that the occurrence of a manifest event may be predictable (so, determined), that it may allow an estimation of its predictability (that is, probability), and of all the events that could occur, each of those events has the same probability of occurring as any other of the events.

On first seeing the “drip” paintings of Jackson Pollock, many have the impression that the paint is applied by a method of chance. Pollock stated that they were “no accident” [14].

In 1999 physicist-artist Richard Taylor used computer analysis to show similarities between Pollock’s painted patterns and fractals (patterns that recur on multiple size scales), reflecting Pollock’s own words, “I am Nature” [15].

The only chance elements may have been a brush splitting or accidental extra drips of paint. If these were to his liking, Pollock retained the painting; otherwise, it was destroyed.
In 1966 Steve Reich issued “Come Out,” a four-second tape loop phase-shifting with a second tape loop, both sounding the spoken phrase “come out to show them.” In one recording there are about 400 phase shifts to reach one beat of difference between the two loops in 12 minutes of presentation. What begins as speech becomes music. The aural manifestation of such microshifts could not have been anticipated by Reich, and although the idea was intentional, the outcome was unknown and outside intentionality. “Come Out” exemplifies chance [16].

One method of chance used by Cage was to select by the faces of tossed coins one of 64 hexagrams of the I Ching, each of which provided guidance for assembling a composition. Another chance composition of Cage entailed filling 12 conch shells of different sizes with some water and then turning them all simultaneously. The water eventually entered the second chamber of the shell, but the timing and duration was unpredictable and, as the water entered the second chamber, each shell made a sound—or, rather, sounds.

In seeking unpredictability, Thelonious Monk implored his saxophone soloist, John Coltrane, to “Make a mistake”: intentional unpredictability!

Artists, for the most part, imitate or make small variations in the extant repertoire. And as in biology, innovation by chance is rare. Those, like Duchamp and Cage, who have consciously tried to represent chance events have done so by metaphor, as with the visual arts, or, as in music, by using biological materials—for instance, the 12 conch shells Cage used.

The present and future challenge to routine repertoires is offered by artificial intelligence (AI) and genetic engineering. One of the aims of these is to reduce, even eliminate, accident—but chance events will continue to occur, even within AI systems, and may perplex human understanding. Innovation would be by planning rather than chance or inspiration. Would novelty arise and be recognized as worth saving? Would mistakes be recognized?

I realize now that the usage in the literature of “chance,” “accident,” “random” and “chaos” often elides; here I offer a graphic representation of this elision (Fig. 1).

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References and Notes
4 “But Duchamp, as a disciple of Henri Poincare, also understood the mathematics of non-Euclidian geometry and higher dimensional-ity in a far more serious and technical way than any other artist of his time.” S.J. Gould and Rhonda Shearer, “Of Two Minds and One Nature,” in McGarr and Rose [3] pp. 59–63, p. 61.
5 A painting by Duchamp dated 1916.
6 The Bride was first exhibited to the public in 1923.
7 For further detail and explanation of the parts of The Large Glass, see Tate Papers 10 and 26 at www.tate.org.uk/research/publications/tate-papers.
9 The glass of the original Large Glass cracked in transit to an exhibition. This was an accident, not chance, but the effect and the repair were liked by Duchamp. The repaired cracks neither add to nor subtract from the many significations of The Large Glass; they only make viewing the interior more difficult, especially when many others are trying to view it at the same time. The original Large Glass remains in the Philadelphia Museum of Art.
10 Hamilton and Hamilton [8].
11 Hamilton and Hamilton [8].
14 Hans Namuth, Jackson Pollock 51. In the voiceover for this film, Pollock states, “I can control the flow of the paint. There is no accident, just as there is no beginning and no end.”

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Leonardo Art Science Evening Rendezvous (LASER) Leonardo Special Section

Guest Editor:
Tami I. Spector, University of San Francisco Professor of Chemistry, Member, Leonardo Governing Board, LASER host

In 2008 cultural historian Piero Scaruffi piloted the first Leonardo Art Science Evening Rendezvous (LASER) in San Francisco, CA with the intention of bringing together artists, scientists and technologists for presentations that foster cross/trans-disciplinary insights and dialogue with their co-presenters and the LASER audience. Since that time the program has grown to include a global network of more than 30 LASER programs, each of which is inflected by the vision of the specific organizers, presenters and environs (www.leonardo.info/laser-talks). With this special section we aim to expand the purview of the individual LASER programs beyond their localities into conversation with each other and the larger Leonardo community. To this end we seek manuscripts from speakers and organizers highlighting work presented at the LASERs worldwide.

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