Dynamics

Dynamics (also known as dynamical systems theory) is the branch of mathematics dealing with patterns in space and time. It has coevolved with our concepts of time, providing abstract models and cognitive strategies for calendars, clocks, theories of history, and so on. For example, linear progress is modeled on a geometrical line, and historical cycles on geometrical circles. Since Isaac Newton's *Principia Mathematica* of 1687, the mathematical structures known as differential equations have dominated dynamics. Our current understanding of these models for dynamical processes in nature is based on the revolutionary work of Henri Poincaré a century ago. The chief features of this new understanding are attractors and their bifurcations. There are three types of attractors, namely static, periodic, and chaotic, and we will give examples of these below. The recent developments in this theory, including chaotic and fractal models, are just beginning to have an impact on philosophy and criticism. This article will suggest some applications of dynamics to the theory of time.

Hierarchies and Fractals

As a first step, consider the model of time as a hierarchical structure. Time has different strata, or time scales, rather than a single cosmic time or universal clock. Such a model, with eight levels, was proposed by J. T. Fraser in 1975 in Chapter 12 of his *Of Time, Passion, and Knowledge*. In an extreme version of this hierarchical model of time, there might be an infinity of strata, with self-similarity across scales. Such a model was proposed in 1975 by the McKenna brothers in *The Invisible Landscape*. Thus, zooming into the microstructure of time one gets lost, as each new view is much like the last. This is the structure of the mathematical objects called fractals, which abound in the mathematical theory of dynamics. (For examples see *The Beauty of Fractals* under *Further Readings*.) The specific fit of a fractal curve to the graph of cultural novelty as a function of time was discussed by Terence McKenna in 1987. For nonlinearity, that is a temporal model which takes the prize. Following this trend, we may find among the new ideas of dynamics some models for time with a richer structure than those considered previously: fractal time.

Lines, Cycles, and Chaos

As described above, lines and cycles have long been employed as models for time, on various strata: psychological, social, historical, and so on. For the sake of discussion, let us consider the historical stratum. The linear-progress paradigm for history may be modeled by a geometrical line or curve. We may construct a dynamical model from the concept of a static attractor in dynamical systems theory. Thus, consider the history of a region as represented by a moving point in space, to which each position has a prescribed motion. As history evolves, it must follow these rules of motion, changing from point to point as it moves. This is a dynamical model. Eventually, the path of this history approaches closer and closer to a fixed point, and moves more and more slowly. It essentially stops at the destination, like a train at a station. This model is an example of a static attractor, and it models the idea of linear progress with an apocalypse, an end of history. Of course, this represents a distant view of history: from up close, history is always chaotic.

Next, consider the cyclic paradigm for history. This may be modeled by a geometric circle. We now construct a dynamical model for cyclic history using the periodic attractor of dynamical systems theory. Consider again the history of a region represented as a point moving in a space with a dynamical rule prescribed at each point. Eventually, the moving point gets closer and closer to a loop, then goes around and around this loop, completing each cycle in exactly the same period of time. This model is an example of a periodic attractor, and it models the idea of history repeating itself exactly in periods of a fixed length. These two examples are classic, and have dominated historiography from antiquity. In other strata of time, the static and periodic behavior are also familiar.

But now we have a new model, this time using the chaotic attractor concept of dynamical systems theory. Again, consider the historical stratum for our example, with the history of a region represented by a point moving in a geometrical space of three or more dimensions. The track left by this moving point, a curve which wanders about the space without crossing itself, moves closer and closer to a thick loop which resembles a coil of rope. It then moves around and around the loop, completing each cycle in a different period of time, and never visiting the same point twice. This model is an example of a chaotic attractor, and models a roughly cyclic history, which almost repeats itself, but at unpredictable intervals. As a time series, this behavior appears to be a cyclical model with noise.

Evolution and Bifurcations

Periods of disintegration in the world of ideas, which result in numerous small disciplines scorning each other, are followed by opposing movements of integration, which result in numerous small disciplines in a tightly coupled network. Closely related examples of integrative movements are the study of time, and general evolution theory. The latter, part of the systems theory approach growing since World War II, studies the universal patterns presented by all evolving systems. The recognition of these patterns in human prehistory and history, following the pioneering ideas of Ibn Khaldun and Vico from centuries past, is one of the main projects of general evolution theory. Dynamical systems theory provides models for the space-time patterns observed by general evolution theorists on all levels of the evolutionary hierarchy, and again, we will illustrate these model patterns on the historical level. Consider a dynamical system, characterized by a set of attractors dispersed within a geometrical space of virtual states, which we will call the state "space." This system is generated by a fixed rule of motion attached to each point in the space. After starting at one initial point and following these rules, a model history ends up at one of these attractors, whether a point, a cycle, or a chaotic motion. This fixed system is too rigid to model evolution in the natural world, or in the history of a social system, in which the rules are slowly changing in time. What happens to the dynamical system when the rules of motion shift? Well, the configuration of attractors shifts. And eventually, while wandering about in the state "space," they may be radically altered. Such transformations are called bifurcations, and dynamical systems theory is gradually developing an atlas of them.

The emerging atlas of bifurcations is organized in three categories: subtle, explosive, and catastrophic. These model transformations may be applied to evolutionary studies in any empirical domain to enhance our understanding. For example, imagine a dynamical model with a single attractor, a point. A model history in this context is a curve of linear progress, coming to rest at an apocalyptic state, as described above. But then the rules begin to drift, as environmental factors evolve, for example, and at some time the point attractor becomes a very small cycle, which then grows. In mathematics, this is called a Hopf bifurcation. It is a subtle bifurcation, in that at first it is qualitatively invisible. Eventually, one sees that the course of time has changed from a static state to a cyclic oscillation.

Similarly, a periodic attractor may subtly change to a chaotic attractor, and one observes that the periods of history gradually become irregular. For the next example, imagine a model with a point attractor as above, where once again the rules gradually begin to drift. And again, the point attractor drifts, and turns into a periodic attractor. But in this case, it suddenly jumps from a point to a cycle of a large girth. This is an explosive bifurcation, and might be applied to a social transformation such as the emergence of civilization, the Renaissance, or the Reformation. Explosive bifurcations of chaotic attractors are characterized by a sudden increase in the magnitude of their chaotic behavior. After one of these, another explosion (in reverse) might suddenly decrease the amount of chaos. This is typical of the transient phase of a social transformation or revolution.

For another example, imagine a model with two point attractors. They represent static conditions for two different apocalyptic states, such as Communism and Capitalism, or let us say, A and B. All initial states might be tested, in principle, to see if they evolve to rest at A or B. Those that end up at A fill up a certain area of the state space, called the basin of attractor A. Those that evolve to rest at B fill out the basin of B. Between these two basins there is a thin region of indecision, called the separatrix, which divides the entire state space into the two basins. Now we imagine, in this model, that a history starting up in the A basin has come to rest at A. Then the rules begin to change, and the two point attractors begin to drift about in their basins. The history we are observing tracks A, following its motion closely. The separatrix also moves. Attractor A approaches closer and closer to the separatrix. At the climactic moment, they collide, and vanish! Such an event is called a catastrophic bifurcation. After the event, the rules continue to drift and there is only one attractor, the point B. Our history finds itself near the point where A was when it ceased to be an attractor. This point is now in the basin of B, the only remaining attractor. Our history then rushes off, attracted to B. Here we have a model for a catastrophic social transformation, such as the end of an era. While eras end and are reborn in historical bifurcations, history can only end once.

Conclusion

In these examples we have seen just a few of the ways in which dynamical systems theory can extend our view of time. Fractal geometry gives us models for a richer geometry of time, while dynamics provides chaotic models for the behavior of time and an atlas of bifurcations for modeling sudden transformations in evolution. We may combine these into very complex temporal models, in which static periods give way to chaotic motions, and evolution proceeds in epochs alternatively static, periodic, or chaotic, and punctuated by transformations of subtle, explosive, or catastrophic character. Chaotic attractors are themselves fractal objects, and chaos theory empowers us to make more realistic temporal models than those of the past. We may call them models of Kairotic time.

See also **Hierarchical Theory of Time; Kairos; Time Series.**

[R.H.A.]

Further Readings

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