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4

CHAOS AND COMPLEXITY THEORY

Ira Livingston

I would not give a fig for the simplicity this side of complexity, but I would give my life for the simplicity on the other side of complexity.

Oliver Wendell Holmes

I accept chaos. I am not sure whether it accepts me.

Bob Dylan

Learning to see chaos

Like many non-scientists, I first learned about chaos theory – as it was widely called at the time – from James Gleick’s popularization, *Chaos: The Making of a New Science* (1987), which led me to Benoit Mandelbrot’s classic *Fractal Geometry of Nature* (1977). I remember, shortly thereafter, standing on a beach in the flux of the waves. At my feet, the sinuous fingers of the sea sent smaller fingers of froth reaching up onto the sand, waves of waves, all webbed with networks of foam made up, in turn, of smaller networks of bubbles, webs of webs. Above me, cirro-cumulus clouds sprawled across a blue sky, popcorn clusters of clusters and wisps of feathery wisps. Everything had become *fractal* – that is, patterned at multiple scales – and *self-similar*, with patterns recurring at every scale, like a feather, each arm of which is shaped like a miniature feather in turn.

Learning to see chaos represented, for me, a kind of re-enchantment of the world. No doubt some version of this experience is widely shared by those in the throes of any old paradigm shift: the sense of being “present at the creation,” the zeal of the convert. And in retrospect, gradual paradigm shifts can tend to seem more and more like acute conversion experiences (see Livingston 2006: 21–22, 85–89). Even so, this episode of world-making bears some very specific historical resonances, even in my highly condensed and aestheticized version. What I saw happening to my world was stark modernist formalism (think of something

elegant and minimalist, like a Mondrian painting) being deconstructed into baroque postmodern plenitude and excess. On a beach in Massachusetts.

Part of the conversion to chaos involves learning to see structures not as structures, but as systems, events in process. This recognition is part of what makes chaos and complexity theory full partners with poststructuralist theory generally. Sociologist Niklas Luhmann describes society as a complex system whose basic elements are events of communication; that is, “not stable units (like cells or atoms or individuals) but events that vanish as soon as they appear” (Luhmann 1990: 83). Likewise (for example), when you deconstruct the image of a human body as a structure with a simple boundary between inside (self) and outside (nonself), you get something much more dynamic and fractal. Negotiations between self and nonself (and the continuous transformations of one into the other) happen not just at the skin but fractally and at multiple scales down to the cellular level: every cell in the body is engaged in this negotiation; in fact, every cell *is* this negotiation. If the body is a structure, it is a fractal one, with all edges and no interior – a whirlpool, a burning bush.

(And by the way, as you were reading those words, did you feel your body subtly opening up, exquisitely flayed and aflame, and in the process, a new sense of being-in-the-moment? If so, you can skip the rest of this section. Otherwise keep reading.)

These examples (of Luhmannian society and deconstructed bodies) are intimately related to poststructuralist accounts of texts not as hermetic interiors but as intertextual negotiations, and more generally to the concurrent paradigm shift in cybernetics from closed to open systems. Fully coming to terms with complexity means understanding it as a feature of open systems (see Chapters 19 and 20, this volume). On the scientific side, Prigogine and Stengers’s *Order Out of Chaos* (1984), and Stuart Kauffman’s *The Origins of Order* (1993) were influential in developing accounts of how chaos and complexity play out *in time* as well as in space. Under their influence, I remember walking in the Nevada desert and noticing some of the ways that the scarcity of water shapes the plants and their interactions. I saw it in the spacing of their branches and blossoms, the shapes of their leaves and stems, their own spacing in the terrain, all selected to optimize water absorption and retention. Looking at a sagebrush bush, I saw a living algorithm – an unfolding reiterated equation – in multidimensional possibility space (that is, the set of all possible parameters), its form-in-process an ongoing exploration of this space.

(A bit more metacommentary: so far these little autobiographical vignettes borrow from the romanticized image of the scientist in the “Eureka!” moment, as in Gleick’s description of physicist Mitchell Feigenbaum at the threshold of a chaos revelation: “his hair was a ragged mane, ... his eyes were sudden and passionate,” etc. [Gleick 1987: 2]. But let me make it even a little more uncomfortable.)

The desert ecology felt deeply strange and deeply familiar to me. What I recognized in the sagebrush was a fellow creature engaged, like me, in the

question of how to find what nourishes you in the middle of a desert. “Danger makes human beings intelligent,” as Anna Freud (1937) put it. If this strikes you as hopeless anthropomorphism or New Age twaddle, consider the following interchange:

Chuang Tzu said, “See how the minnows come out and dart around where they please! That’s what fish really enjoy!”

Hui Tzu said, “You’re not a fish – how do you know what fish enjoy?”

Chuang Tzu said, “You’re not I, so how do you know I don’t know what fish enjoy?”

(Chuang Tzu 1964: 110)

This, in any case, is also the kind of questioning, of both kinships and differences, that chaos and complexity make possible.

Complexity

Complexity and chaos both have a range of technical definitions, but both remain nonetheless profoundly ambiguous and paradoxical. The paradox of complexity can be indicated quickly: “if what we are interested in is complexity itself, then an image that we can easily identify as complex is thereby *less* complex than one whose complexity we find it difficult or impossible to ascertain” (Livingston 2009: 253). In the example of a social system as described by Luhmann, complexity derives from “an observer’s inability to define completely all [the] elements’ connections and interactions. ... [T]here is no totalizing perspective or omniscient selector. Each act of observation is embedded in what it observes” (Rasch 2000: 47). Such a definition should also be historicized: only *against* the fantasy of a disinterested, totalizing and transcendently objective perspective – a fantasy most specific to imperialist modernity – can complexity come to be defined as embeddedness, or rather, as the contradiction between transcendence and embeddedness (see Livingston 1996: 84–104).

Physicist Stephen Wolfram’s quick definition of complexity also coordinates an observed and an observer: “In everyday language, when we say that something seems complex what we typically mean is that we have not managed to find any simple description of it – or at least of those features in which we happen to be interested” (Wolfram 2001: 557). This notion of the impossibility of simple description gestures toward a range of possible philosophical commitments, from antireductionism (the rejection of the principle that the whole can be known simply by knowing its component parts) to nominalism (the doctrine that all entities are radically unique, even if the same word can be applied to each of them). Wolfram (no philosopher) seems to remain committed to an extreme reductionism in which complex behavior always derives from the iteration of

simple rules. Even so, his Principle of Computational Equivalence suggests some of the more world-changing implications of complexity. Wolfram posits, first, “that all processes, whether they are produced by human effort or occur spontaneously in nature, can be viewed as computations” (715), and second, that “almost all processes that are not obviously simple can be viewed as computations of equivalent sophistication” (716–17). Recognizing a single common level of complexity (or *virtual kinship* as I have called it) radically undercuts the master narrative of growth and development as increasing complexity. Instead of deploying increased complexity as a way of characterizing more “advanced” societies against more “primitive” ones (or sonnets from pop lyrics, or Guinness from Miller Lite), can we imagine more *empathetic* complexities?

Chaos

Nailing down chaos as a concept is also difficult, first of all, since even scientists use the word in several ways. Sometimes the word is used in its popular sense as a synonym for simple disorder. In this case, the more complex and fruitful kind of disorder – the kind of disorder out of which order can emerge – tends to be identified as “the *edge* of chaos.” More often, though, *chaos* is used to mean the complex disorder itself; but to make things more confusing, it can also refer to the kind of order that emerges from such disorder. And here’s the punch line: this ambiguity is not so much an obstacle to be cleared away, as it is *what chaos really is*.

The word comes from ancient Greek, where it signified the primal emptiness of space, the nothing from which something emerges. As it turns out, post-modern physics has elaborated this notion nicely: time and space are “crystallized from nothingness,” and empty space, it turns out, “is not so empty – it is actually seething with activity” – the generative chaos of a “blooming, buzzing confusion” (as Victorian psychology pioneer, William James, famously described the perceptual world of the infant out of which, as the child learns to focus, discrete figures emerge). Physicist Frank Wilczek

calls this non-empty emptiness the Grid. The Grid is reality’s substrate, built from a host of ingredients: quantum commotion; the metric field that delineates space, time and gravity; exotic materials like the quark–antiquark condensate and the Higgs field that together transform empty space into a multilayered, multicolored semiconductor.

(Gefter 2008: 44)

Ancient Greek cosmology, postmodern physics, Victorian psychology – why engage in a transhistorical treasure hunt for exemplars of chaos, like an old Jungian sniffing out archetypes? Well, first, because I want to offer examples

that best give the feel of chaos, but also to gesture again at the questioning of kinships and differences that chaos makes possible, this time by suggesting that it offers at least the possibility of tracing different constellations of present with past knowledges, and thus, of rearranged genealogies and relationships between science and literature.

Cooking up complexity

Let me try to show you complexity stripped down to its most basic, or, if you like paradoxes, most simple form. First step: start with several things and processes. It may seem obvious, but it's important to recognize that, whenever you have several things, it means that they are not identical, even if they are (for example) three hydrogen atoms. Multiplicity involves difference. Thus, physics begins with certain particles and forces; biology, with assorted cellular components and their various interactions; language, with letters and words and grammar. Notice that, while sciences may desire a countable set of basic elements ("simples" that cannot be divided any further), things start getting stickier when you try to nail them down. For example, the more physics tries to identify a basic set of particles, the more they seem to multiply and evaporate into probabilistic clouds. Again, it seems that this difficulty is in grain: the discretely countable seems to emerge out of a more primal multiplicity. I call it *someness* (see Halberstam and Livingston 1995: 8–9); or, for a sustained account of multiplicity according to French philosopher Gilles Deleuze, see Manuel de Landa's *Intensive Science and Virtual Philosophy* (Landa 2002).

As in other recipes, after assembling the ingredients (nouns), you need to do something with them (verbs): *start combining them*. Now, in order to generate chaos and complexity, the process of combination has to involve non-linearity or *recursion* – the product of a process being fed back into the process again. But note that even simple mixing is describable as recursion. Recursion in mathematics, where the result of a function is fed back as a starting value for the next iteration of the function, is most famously illustrated by the Mandelbrot set, an infinitely complex fractal object generated by a very simple, repeatedly iterated equation. *Autocatalysis* is an example of recursion in chemistry. In the simplest version, some particular chemical catalyzes a reaction, one of the products of which is *more of the catalyst itself*, which thus continues to catalyze more of the reaction as long as more raw materials are present. In a modestly rich chemical environment, such reactions can develop complex self-amplifying and also self-inhibiting loops: behold the emergence of something like *metabolism*!

There is recursion in linguistics, starting with the way grammar enables the embedding of clauses within other clauses. This has been proposed as the way that grammar, given a finite series of elements, "can produce an infinite number of sentences of unbounded length"; even if there might be languages that lack

recursion at the grammatical level (a controversial point, at this writing), recursion is nonetheless “part of how all humans think – even when it is not part of the structure of their languages” (Everett 2008: 240). Consciousness and language are recursive loops in an already very loopy universe.

There are also multiple forms of sociological recursion. Ian Hacking describes the process of social construction of identities as a non-linear process of “Making Up People” in which, for example, a category like “autism” or “multiple personality disorder” co-evolves in tandem with a target group of people and with sets of social practices, institutions, specialists, etc. The various components are bound together by a series of recursive loops and the whole configuration emerges, changes, grows, breaks apart, dissolves, and so on. Likewise, modern *discursive* formations like science, literature, and sexuality are also *recursive* configurations.

Discursive recursion is the subject of Andrew Abbott’s *Chaos of Disciplines*. Taking sociology as his main example, Abbott shows how any particular division of the field, for example, into quantitative and qualitative methodologies, only generates further fractal divisions: the qualitative side itself will turn out to have a quantitative and a qualitative side, and so on. When such divisions are engaged not just as structures but as processes (versions of what is known in mathematics as *binary decomposition*), one is likely to find complex cycles of disciplinary polarizations, hybridizations, supplementations, and so on.

And there are several important kinds of recursion in literature. Structuralist linguist Roman Jakobson defined *poeticity* as that aspect of a message that refers back to itself. In the most basic sense, rhyme and meter and other devices self-referentially call attention to language as language rather than – referentially – to any content. And there are multiple ways that literature works recursively to thematize its own operations, starting with plays-within-plays, metafiction, and other self-referential narrative maneuvers.

My example here (and see Livingston (1996, 2006) for a great many more) is Alice Walker’s well-known short story “Everyday Use” (Walker 1973). The story is set in the 1960s; the narrator is a tough old African-American woman who lives in the rural South with her younger daughter, Maggie. She is visited by her upwardly mobile older daughter, Dee (also known as Wangero), who is returning from the northern city where she has discovered Black Power and high culture, making her painfully condescending to her family of origin. Dee asks for a family quilt to take back with her to display but, in a sudden and almost religious inspiration, the mother gives the quilt instead to her younger daughter, even though Maggie will only put it to “everyday use.”

Even in this thumbnail account, it’s easy to guess at least one way the story is looped back around self-referentially: the story itself is an artifact rather like the quilt, part of the cultural legacy of mothers to daughters. If you wanted to shut down interpretation, you could try reducing the reinsertion of the story into itself to a slogan: stories, like quilts, are best put to use rather than aesthetically revered as art. This reading will do the trick only if you’re allergic to

interpretation – and to chaos and complexity. Otherwise, finding the recursivity helps you open up a set of generative contradictions at the heart of the story, such as the vexed relationship between art and utility. Even the apparently simple proposition that short stories can be understood as utilitarian objects implies a radical redefinition of utility with big, paradigm-shifting consequences.

Again I want to stress the experiential aspect of engaging recursive chaos and complexity, here via the reading and writing of literature. The way that a piece of literature is about itself is something that one often discovers only belatedly; it does not short-circuit interpretation but begins it anew. Likewise, in listening to poetry, the recursivity of the language need not produce an alienating art-for-art's-sake closure, but rather increase the living-thing-likeness of the language as layers of mediation work to intensify the sense of immediacy of the experience. And the act of writing in the grip of recursion is not a navel-gazing exercise but a much more dynamic process, a surfing on the recursive curl of things. Find that moment and try to sustain your balance in it.

What it all means

So what does it mean that we can find chaos and complexity in what is called nature and in the works of our own hands and brains, literature in particular, especially when we weren't exactly intending to place them there? I suggest three main ways of approaching this question.

First, it is often claimed that chaotic and complex processes are universal, so we should expect to find them everywhere – transculturally, transhistorically, and on both sides of the nature/culture divide. For example, Oliver Sacks proposes that the often conspicuously fractal visual hallucinations many people who suffer from migraines experience derive from the fractal structures of the brain:

These hallucinations reflect the minute anatomical organization, the cytoarchitecture, of the primary visual cortex, including its columnar structure – and the ways in which the activity of millions of nerve cells organizes itself to produce complex and ever-changing patterns. We can actually see, through such hallucinations, something of the dynamics of a large population of living nerve cells and, in particular, the role of what mathematicians term deterministic chaos in allowing complex patterns of activity to emerge throughout the visual cortex. This activity operates at a basic cellular level, far beneath the level of personal experience. They are archetypes, in a way, universals of human experience.

(Sacks 2008)

The paradoxes here are compelling: apparently it takes a hallucination – seeing something that is not really there – to see self-referentially what really is there,

namely, the neurological mechanism *by which* we see. And the dazzling complexity of this vision, this ethereal meta-reflection, seems to derive from how it short-circuits us back to the solid substrate, the hardware. To put it another way, the universality of chaos and complexity loops back around to complicate and paradoxify even the simple assertion of their universality.

Of course, suspicion of universalized truth claims is also a leading operating principle of cultural theory. I'm still a card-carrying poststructuralist, which is why I will only identify this as a "leading operating principle" and not a truth claim itself (although the claim that "there are no universals" is at least interestingly contradictory). But it needs to be pointed out, too, that the *rejection* of universality claims often functions as a rear-guard action to bolster the nature/culture divide and to maintain the monopoly of humanists over the culture side. Although this maneuver may have some strategic value (for example, in trying to fend off scientists with their reductive explanations for everything), it's a rear-guard action insofar as it's driven by an exceptionalism about humans that is, at bottom, theological rather than theoretical.

"Universality" as understood in chaos theory (the idea that blew Mitchell Feigenbaum's mind) is the prevalence of certain mathematical processes over a range of otherwise disparate phenomena. As I have already indicated, such prevalence need not be understood as difference-effacing similarity but as a kind of *virtual kinship*, what I have also called *witness* (Livingston 2006: 4): language resembles the world of which it is a part. If you prefer to stress difference rather than resemblance, you can start by considering instead how the plurality of all that is called "language" is riven by differences as radical as those that cleave language from the world.

The charged question of universality aside, we can trace historically particular discursive forces at work whereby literature came to occupy a privileged position to engage chaos and complexity. In an emergent modern ecology of discourses in the West, coming to a head around 1800, recursion and self-reference were banished from science and became the particular province of what came to be called literature. Foucault's account is that literature emerged as

merely a manifestation of a language which has no other law than that of affirming – in opposition to all other forms of discourse – its own precipitous existence; and so there is nothing for it to do but to curve back in a perpetual return on itself; as if its discourse could have no other content but the expression of its own form.

(Foucault 1973: 300)

We can trace this legacy in literature and literary studies over the past two hundred years, from Coleridge's principle of organic form, to Aestheticism's art for art's sake, structuralist accounts of language-as-system, Jakobsonian poeticity, the New Critics' insistence on literary texts (and on literature in general) a

self-contained systems, and into postmodernism's anti-realisms and metafiction. And what does it mean for literature and literary studies that science has now also begun to embrace recursion and self-reference? This remains an open question. The melancholy account would be that literature, the novel, poetry, and so on are well on their way to extinction, their niche in the modern discursive ecology having been invaded and compromised from all directions. It seems to me, however, as though their modern incarnations are turning out to have been only a warm-up act for a process just beginning to unfold!

Finally, the argument can also be made that paradigms of chaos and complexity are in some larger and primary sense historical constructions of postmodernity and late capitalism. This can be understood as an epistemological claim, that our history shapes our understanding of the world and (for whatever reasons) is now causing us to notice and to name and to know chaos and complexity in new ways. A more ontological historicist claim – that is, a truth claim – can also be made: that chaos and complexity are actually being more intensively produced and selected for in the present era. In this account, capitalist modernity is often understood as an epidemic of systematizations – proliferating systems and subsystems – amid dynamic crosscurrents of trade and migrations and exchanges whereby “all that is solid melts into air.”

But we can engage chaos historically without subscribing to linear historicisms, either the kind that traces a one-way trajectory of ever-increasing complexity, or the kind that finds a one-way determinism from economic base to ideological superstructure. In tracing the emergence of chaotics, chaos-and-literature pioneer N. Katherine Hayles rejects another (related) kind of linearity:

In particular, I am not arguing that the science of chaos is the originary site from which chaotics emanates into the culture. Rather, both the literary and scientific manifestations of chaotics are involved in feedback loops with the culture. They help to create the context that energizes the questions they ask; at the same time, they also ask questions energized by the context.

(Hayles 1991: 7)

You may notice that – to put it in the pejorative senses reserved for it by classical logic – there is a rather glaring bit of question-begging or circular reasoning here: the description assumes the operation of feedback loops whose emergence it was meant to explain – or to put it another way, Hayles participates in the development she describes. My function here – and, I hope, dear reader, yours, too – is not to straighten out this circularity but to participate in turn, to weave more loops into the fabric. Enrich the mix beyond the simple dichotomy of science and culture – add capitalism, neurology, reality television – in any case, a bunch of things that are self-reinforcing – and perhaps ultimately self-limiting or even self-annihilating – into a complex loop, toss lightly, and there you have it.

A metabolism. A culture, describable as a more-or-less sustainable self-fulfilling prophecy. An ecology. A chaology.

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