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5 LADDERS, TREES, COMPLEXITY, AND OTHER METAPHORS IN EVOLUTIONARY THINKING

Andreas Hejnol

METAPHORS ARE ALWAYS A DOUBLE BIND: they at once allow us to see and stop up our abilities to notice.

For centuries, biology has relied on a particular set of metaphors—including ladders and trees—to classify and order living beings. Such metaphors have depicted life as a slow but inexorable march upward—up a stairway of creatures with humans at the top, positioned as the most advanced beings. This hierarchical understanding of life, which defines "progress" as a linear movement from the so-called simple to the complex, has long haunted biological inquiry. At the same time that such metaphors have been essential to the development of evolutionary thinking, they have also limited biologists' queries about lateral relations, movements toward simplicity, and the lives of seemingly lesser organisms. In this chapter, I first trace the history of hierarchical notions of life and evolution and the suites of metaphors about ladders and trees that they have produced. Then, I turn to describing how new biologies are forcing us to tell very different stories with dramatically different metaphors—ones that challenge long-standing notions of hierarchy and complexity and that ultimately reconfigure our own place in the world of living creatures, past and present.

Tree Thinking and Complexity

Evolutionary theory itself proved insufficient to destabilize the hegemony of systems of classification that categorized animals (or plants) as “higher” and “lower” (or “primitive”). On the contrary, evolutionary theory became increasingly wedded to metaphors of ladders, which imagined life as proceeding from the simple to the complex. Evolutionary theory, however, also allowed for a novel kind of metaphor, the tree of life. The tree turns the ladder’s stagelike image of life into a genealogical one. One of the first trees of relationships is the iconic depiction in Charles Darwin’s notebook where he scribbled “I think” next to the depiction of a branched tree (Figure G5.1b). We can see this picture as the origin of a new thought—tree thinking. As old-fashioned as the metaphor of the tree appears today, it still marked a revolution in the biological understanding of life. Borrowing the kinship metaphor of the family tree, biological trees posited that organisms were both historical and related to each other. But in their shape, biological trees retained the sense of movement through time from a simple world to a more complex one—from a single trunk toward countless branches.

The image of the branches of a tree became the basis for another considerable contribution, namely, the so-called cladistics or phylogenetic systematics developed in the twentieth century by German entomologist Willi Hennig, who made it the foundation for a theoretico-historical systematization of organisms.⁹ Although cladistics is also used in fields such as linguistics, to determine the origin of languages, they have been particularly important in biological classification.¹⁰ Hennig proposed to order animals in a system according to their genealogy—and provided the theoretical framework for how morphological characteristics can be used as arguments for proposing particular “clades” that group together species that all share a common ancestor. Comparative anatomical methods allow researchers not only to detect shared morphological characters for a clade but also to infer evolutionary relationships. This theory of cladistics developed by Hennig provided the foundation of modern studies of the relatedness of organisms.

In the latter part of the twentieth century, however, new technologies allowed for observations not only of organisms’ morphologies but also of their genes. With the development of polymerase chain reaction (PCR) and related technologies, biologists were able to see

DNA and RNA sequences, the building parts of proteins and nucleic acids in organismal genomes. Such technologies introduced a new kind of information from which scientists can reconstruct the relationships among organisms. No longer restricted to morphological traits, cladistics is now enacted through the comparison of the molecular data that become available through analysis of the nucleotide sequences of proteins that are shared between organisms.

Rethinking Trees

Although “similarity” is still the unit that is used to group and classify organisms, the theoretical frameworks for thinking about these relationships are much more elaborate than they were five decades ago. Notions of relationality are becoming more nuanced. For example, biologists no longer think in terms of “transitional” and hierarchical relationships among living species (i.e., “humans evolved from apes”) but instead think through genealogical cladistics that stress the ongoing changes of all organisms (i.e., “humans and apes evolved from a common ancestor”).

Perhaps most importantly, the application of cladistic methods to the vast number of molecular sequence data has led to profound changes in our understanding of animal relationships.¹¹ Put simply, molecular data uproot the phylogenetic tree. Not only do they strengthen the deconstruction of the teleological elements in the understanding of the processes in evolution, including hierarchical orderings of beings, they also demonstrate that evolution itself is non-directional and unpredictable.

Here I want to focus on two animal groups—tunicates and comb jellyfish—both of which have recently been repositioned in biological orderings of life in ways that have important consequences for how we understand life more broadly. The tunicates and comb jellies have the power to teach us about evolution in a different key. They illustrate that evolution does not necessarily proceed from simple to complex; they rupture the foundational ideas that underpin the Great Chain of Being. They also force us to question the forms of anthropocentrism that still haunt evolutionary theory, even within the scientific community. Tunicates and comb jellyfish demonstrate that nature does not have an apical structure; humans have to find new ways of representing their place in nature.

Such insights are important in many ways, because hierarchical metaphors for ordering beings have shaped not only human perceptions of nature but also human strategies for managing natural worlds. Rethinking relations among organisms and the metaphors we use to describe them can shift how we value other beings—and thus change how we aim to protect our natural environment. For example, many current conservation projects focus on the protection of charismatic megafauna, an approach that, at least to some degree, has its foundation in assumptions about “higher” versus “lower” animals and, thus, their relative importance. Moving away from hierarchical metaphors for ordering organisms might therefore open up more holistic ways of protecting our environment that do not necessarily begin with animals assumed to be at the top of the ladder.

Tunicates

The so-called urochordates, or tunicates, are marine animals that are mostly sessile filter feeders (Figure G5.2). Some species also drift in the water column as colonies (salps). Urochordates are sack shaped with two large openings: water flows inward through one opening, passes a structure that filters food particles, and then eventually exits the body through the other opening. In addition to this feeding system, the animal has male and female gonads that are responsible for reproduction. For more than a century, this relatively simple morphology has meant that the tunicates were seen as evolutionary precursors to more complex groups of animals, including the so-called cephalochordates (*Branchiostoma*) and vertebrates (including humans). This is because the tunicates share, with these two groups of animals, a stabilizing structure, called chorda, but lack the other major characteristics of those groups, such as segmented packages of musculature and a closed blood vascular system. As a result, the metaphorical ladder of evolution that has organized life from simple to complex has consistently placed the urochordates as our most distant and primitive relatives.

About a decade ago, however, the first large-scale molecular analyses of animal relationships began to hint at a different arrangement, an arrangement that has been confirmed by follow-up studies.¹² These studies revealed that the relatively simple urochordates are indeed the closest relatives of the vertebrates. The more complex

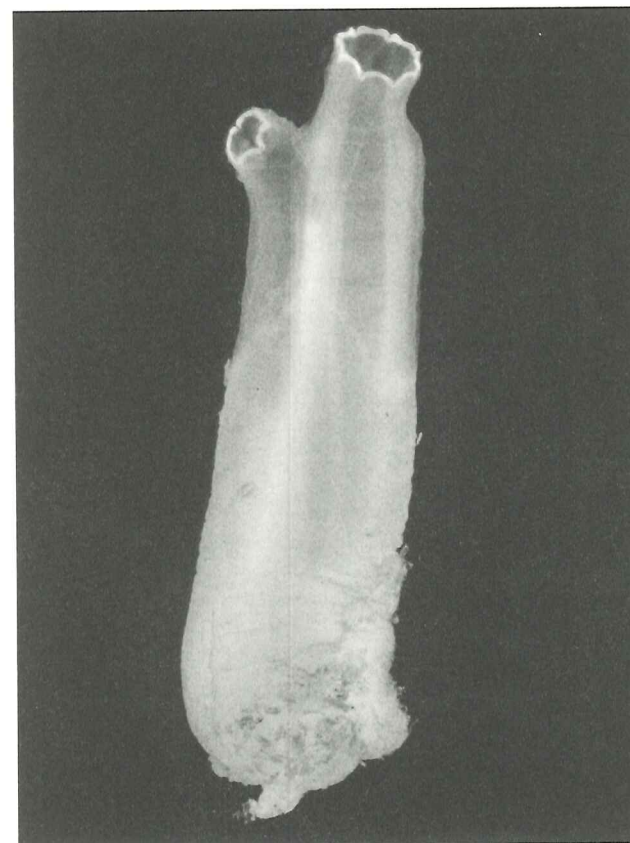


Figure G5.2. Representatives of urochordates: the urochordate sea squirt *Ciona intestinalis* and, below, its relationships to other animals. Photograph by Andreas Hejnol, Sars Centre.

cephalochordates, which share many more morphological characteristics with vertebrates than the tunicates, are actually far more distantly related to vertebrates.¹³ The most parsimonious explanation for this apparently illogical arrangement is that the urochordates have lost the shared characteristics of the vertebrate group, such as the closed blood vascular system, without leaving any visible remnants.

Examples of such “regressive” evolution that includes the loss of whole organ systems, such as brains and hearts, had been previously noted in parasitic animals, for example, tapeworms or flukes, but it was also assumed to be limited to them. Tapeworms and flukes lost their digestive systems, including their mouth openings, as they evolved to take up nutrients from their hosts via their skin. By similarly evolving to have less so-called complexity, tunicates force biologists to reconsider long-standing assumptions about directionality in evolution.

Comb Jellyfish and Sponges

Comb jellyfish, or *Ctenophora*, is another animal group whose placement has recently provoked taxonomic discussions. Comb jellies are pelagic predators that show a fair variety of cell types, such as nerve cells, individual muscle cells, and elaborate sensory organs. One species—*Mnemiopsis leidyi*—has become particularly famous as an invasive species, originally from the U.S. East Coast, that moves around the world (Figure G5.3). Traveling in the ballast water tanks of trading ships, this highly reproductive species and devastating predator is likely introduced annually into the Baltic Sea. In the 1980s, it was introduced into the Black Sea, where it destroyed the region’s anchovy industry.

Thirty years later, these gelatinous ctenophores became famous for another reason: with the advent of the first large-scale molecular reconstructions, this group of marine animals dramatically changed their phylogenetic position.¹⁴ Although gelatinous and mostly composed of water, their physical cell composition—which was seen as relatively “complex”—led scientists to conventionally place them as close relatives of other animals that also show nerve and muscle cells. Indeed, they were assumed to represent a sister group to all remaining animals. Yet, massive comparisons of gene sequences revealed that, despite their morphologic features, these animals were actually among the most distant relatives of so-called complex animals, such as vertebrates.

Sessile sponges, in comparison, had been seen as much less “complex.” Sponges lack nerve cells and musculature and thus have been treated as more ancient animals than comb jellies. As a result, zoologists had labeled the sponges as the animal group most distantly related to vertebrates.

Recently, however, the positions of comb jellies and sponges have

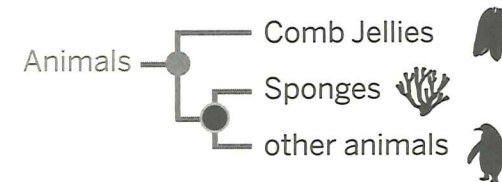
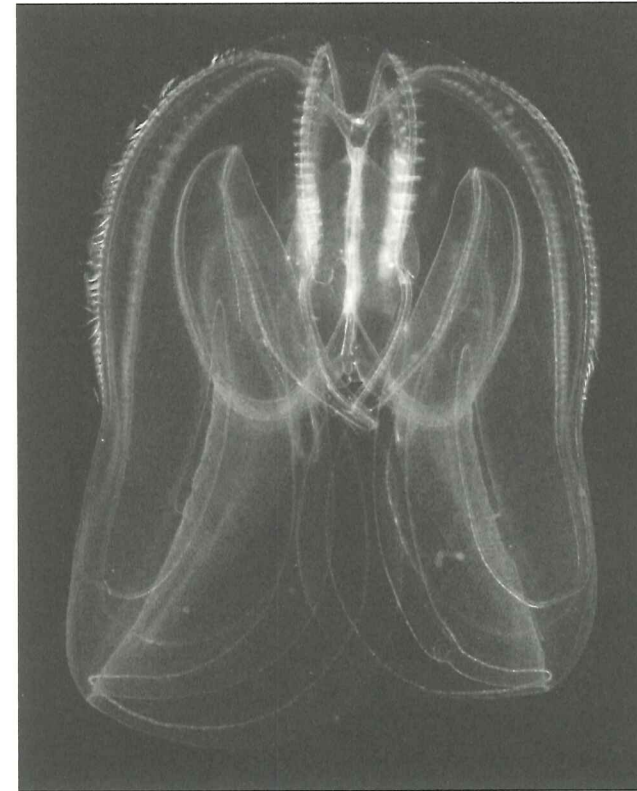


Figure G5.3. The comb jelly *M. leidyi* as representative of the ctenophores and its relationship to the other groups. Photograph by Andreas Hejnol, Sars Centre.

been reversed. The comb jellyfish may have a variety of cell types similar to those of other animals, but it is genetically quite distant. Sponges, meanwhile, may look primitive and strange, but they are genetically closer to the remaining animals, excluding ctenophores. The way that sponges have evolved implies that something unexpected happened in evolutionary processes. One hypothesis for understanding the genetic similarity of sponges with more complex animals is that sponges once

possessed, but have since lost, a diversity of neuronal and muscular cell types. In this case, nerve cells and musculature may be much older than previously thought, with cellular diversity preceding the early split of sponges and creatures like comb jellies. The second possibility, even more heretical, is that these rather complex cell types may have an independent origin: cellular tissue diversity evolved, independently, twice in evolutionary history.¹⁵ Despite evidence, this latter possibility is still met with considerable resistance from the scientific community.

When Metaphors Fall Apart

How could the relative simplicity of sponges and urochordates possibly be the result of a long evolutionary process by which complexity was lost? How could it conceivably be possible for relatively similar, and fairly complex, cell types, such as muscles and neurons, to evolve twice independently? Genetic technologies have raised a suite of new questions about the ordering of organisms, and they have shifted the ways through which we understand evolutionary relations. They force us to rethink the anthropocentric notions of complexity, with their origins in ancient Greece, that continue to haunt biological thinking today. The figure of Aristotle's Great Chain of Being persists in the ongoing resistance to illustrating the actual evolution of sponges and urochordates.

According to ladder thinking, comparatively complex animals should not come prior to simpler animals. But what, after all, is complexity? If there is such a thing as "complexity," it is an adaptation to specific ecological conditions, not the outcome of a teleological process. Furthermore, in any use of the term, complexity should not be defined as morphological or behavioral similarity to humans.

It is important to emphasize that all animals alive today have had similar time to evolve from the last common ancestor. Evolution is an ongoing process; no group of animals got stuck in their ancestral state, even those, such as the horseshoe crab (see Funch, in *Monsters*), that appear to be morphologically similar over a long period of time. The notion that some animal got stuck is intrinsic to the idea of a stepped evolutionary process leading inexorably in one direction, namely, complexity. From an evolutionary perspective, today's comb jellies are as distant from the last common ancestor of all animals as are today's

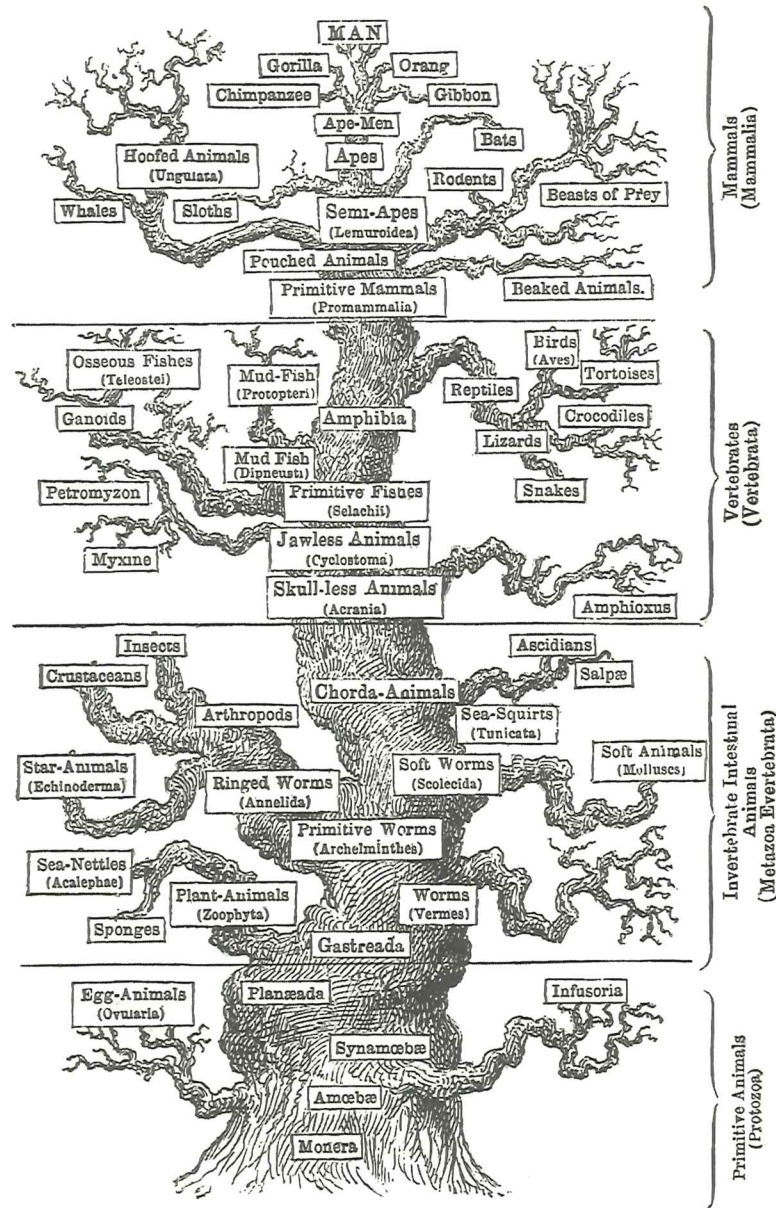
humans. In other words, comb jellies and other contemporary animals have spent the same amount of time developing their individual and specific traits and relative complexity. Evolution is an ongoing process and has not placed a hold on the adaptation of any lineage.

Yet, too often, assumptions about hierarchy and complexity continue to limit biological thinking. For example, in Haeckel's depiction of the evolutionary tree in Figure G5.4a, animal groups that have evolved more recently are assigned to the stem of the tree (e.g., "Vermes," "Chorda-Animals," "Amphibia"), which suggests that these represent intermediate forms from which other recent animals have evolved.

This would correspond to the narrative that humans evolved from apes—which is indeed how the relationship is depicted in Haeckel's treetop. In Haeckel's illustration, recent animal groups have a one-to-one correspondence to human ancestors and would thus be resistant to evolutionary change. A similar motif can be found in the newest edition of a leading textbook about animal evolution.¹⁶ Figure G5.4b is an illustration from this textbook that is evocative of a ladder, with the names of animal groups forming its rungs. The diagram put "Bilateria," that is, animals with bipolar bodies such as humans, on top. From this placement, students are easily led to believe that humans are the most evolved or most complex beings. Animals listed on the left appear as if they wandered off the path of Progress, forming evolutionary dead ends.

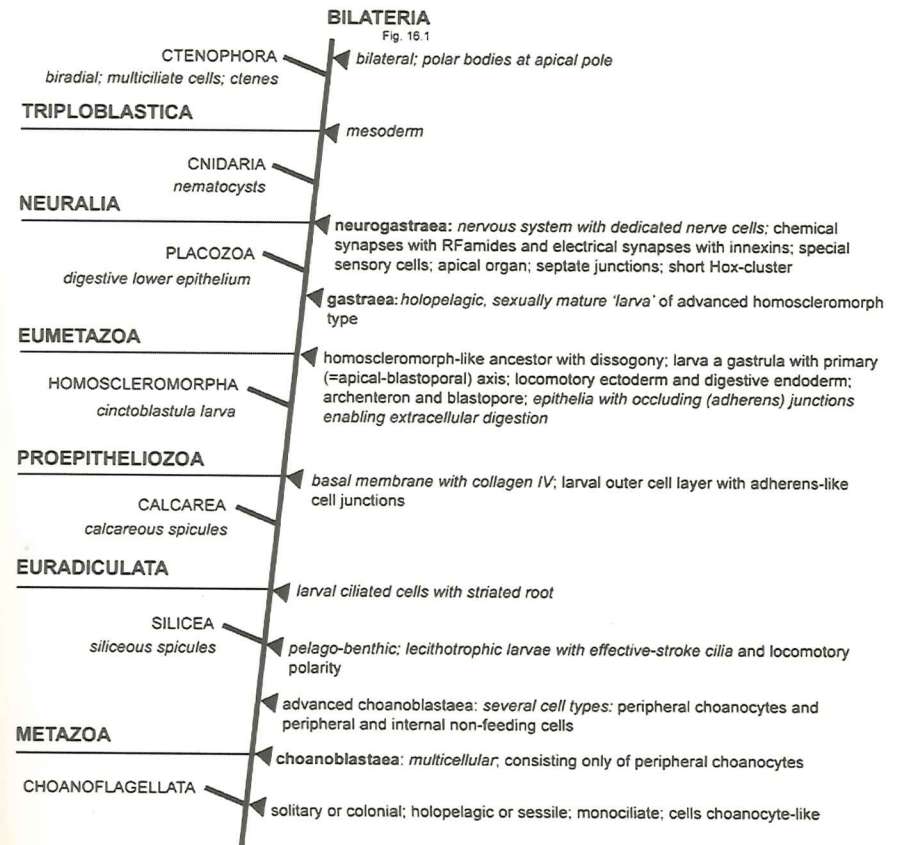
Such misconceptions about animal evolution, rooted in the ideas that evolution proceeds from simple to complex and that less complex animal groups are eventually superseded, remain not only in textbooks but also among zoologists. They deserve our attention because they matter: they shape our thinking about the biology of life and have consequences for what we find important to investigate in animals, plants, fungi, and bacteria. In a recent review of the impacts of new insights into the evolution of sponges, Casey Dunn and collaborators highlight how the assumption that sponges are less complex animals prevents us from investigating the unique complexity and diversity of these animals.¹⁷ Evolution has likely produced—in lineages distant from humans—complex adaptations that remain undiscovered, because we view these animals from an anthropocentric perspective as being at the lowest and most primitive rungs of an imagined evolutionary ladder and thus not as a place to look for evolutionary insights.

PEDIGREE OF MAN.



a

Figure G5.4. Trees containing elements of a chain of being. (a) Haeckel's tree in *Descent of Man*, with humans on top. (b) Evolutionary tree of a leading zoology textbook of Nielsen with growing complexity during evolutionary time. Reprinted from Nielsen, *Animal Evolution*, with permission from John Wiley & Sons and Oxford University Press.



b

From the Evolution of Complexity to the Complexity of Evolution

This chapter has tried to sketch how old metaphors continue to shape views of animal evolution. It is not, however, an attack on metaphors as such. Metaphors are an important tool for conceptualizing our worlds, yet at the same time, they always betray us because they cannot capture the complexity of the world. Metaphors are not static; they change because the world always exceeds them. While our vision and forms of inquiry are undoubtedly shaped by the metaphors of our times, the world remains able to surprise us and disrupt our frames. The empirical is always stranger than we imagined.

Although it is harder to notice relations that do not fit our metaphors, it has never been impossible. New technologies, such as PCR, can sometimes suddenly allow the empirical to flash up in new ways; but curiosity and long-term noticing, like that of Darwin, can also lead to paradigmatic shifts. Metaphors can, indeed, be changed by observations and empirical research.

Though there is no way out of metaphors, there are certainly better and worse ones. Ladders and trees—structured around the idea of human superiority and linked to problematic ideas of complexity and hierarchy—have proved particularly discouraging of curiosity. When we manage to notice them, tunicates and sponges show us the need to look for better metaphors, metaphors that move us away from the history of life as the evolution of complexity toward a better appreciation of the complexity of evolution. Biologists are beginning to respond with new metaphors. Some have suggested that a branched “coral” with its many intersecting and multidirectional branches provides a better visualization of the evolution of animal life, past and present.¹⁸ However, for some forms of life, such as bacteria with their horizontal gene exchanges, even the complexity of corals is insufficient. Here a meshlike or rhizomatic network might be better.¹⁹ So, too, is there likely still a place for tree metaphors, read nonteleologically, as a way to visualize particular aspects of evolutionary thinking. Indeed, any one image may always be insufficient. We need many metaphors—rhizomes and corals as well as bushy, gnarly trees—to capture the complexity of evolution.

ANDREAS HEJNOL explores the evolution of biodiversity through a focus on unloved and often unnoticed creatures, including bryozoans, brachiopods, xenacoelomorphs, priapulids, and ribbon worms. Internationally known for his work in taxonomy, he is the leader of the Comparative Developmental Biology of Animals group at the Sars International Center for Marine Molecular Biology at the University of Bergen, Norway.

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6

NO SMALL MATTER MUSHROOM CLOUDS, ECOLOGIES OF NOTHINGNESS, AND STRANGE TOPOLOGIES OF SPACETIMEMATTERING

Karen Barad

MATTER FELL FROM GRACE DURING THE TWENTIETH CENTURY. What was once labeled "inanimate" became mortal. Very soon after that, it was murdered, exploded at its core, torn to shreds, blown to smithereens. The smallest of smallest bits, the heart of the atom, was broken apart with a violence that made the earth and the heavens quake. In an instant, in a flash of light brighter than a thousand suns, the distance between heaven and earth was obliterated—not merely imaginatively crossed by Newton's natural theosophy but physically crossed out by a mushroom cloud reaching into the stratosphere. "I am become death, the destroyer of worlds."¹

"Space Is Never Empty and Time Is Never Even":
Haunted Landscapes and Spacetime-mattering

The clocks were arrested in Hiroshima on August 6, 1945, at 8:15 A.M.²