

Published in

Arts of Living on a Damaged Planet

edited by Anna Tsing, Heather Swanson,
Elaina Gan, and Nils Bubandt,

Univ. of Minn. Press, 2017.

6

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

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 theophilosophy 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 Time stopped. The internal mechanisms melted. Time was frozen with a heat as intense as the sun. Time died in a flash. Its demise captured

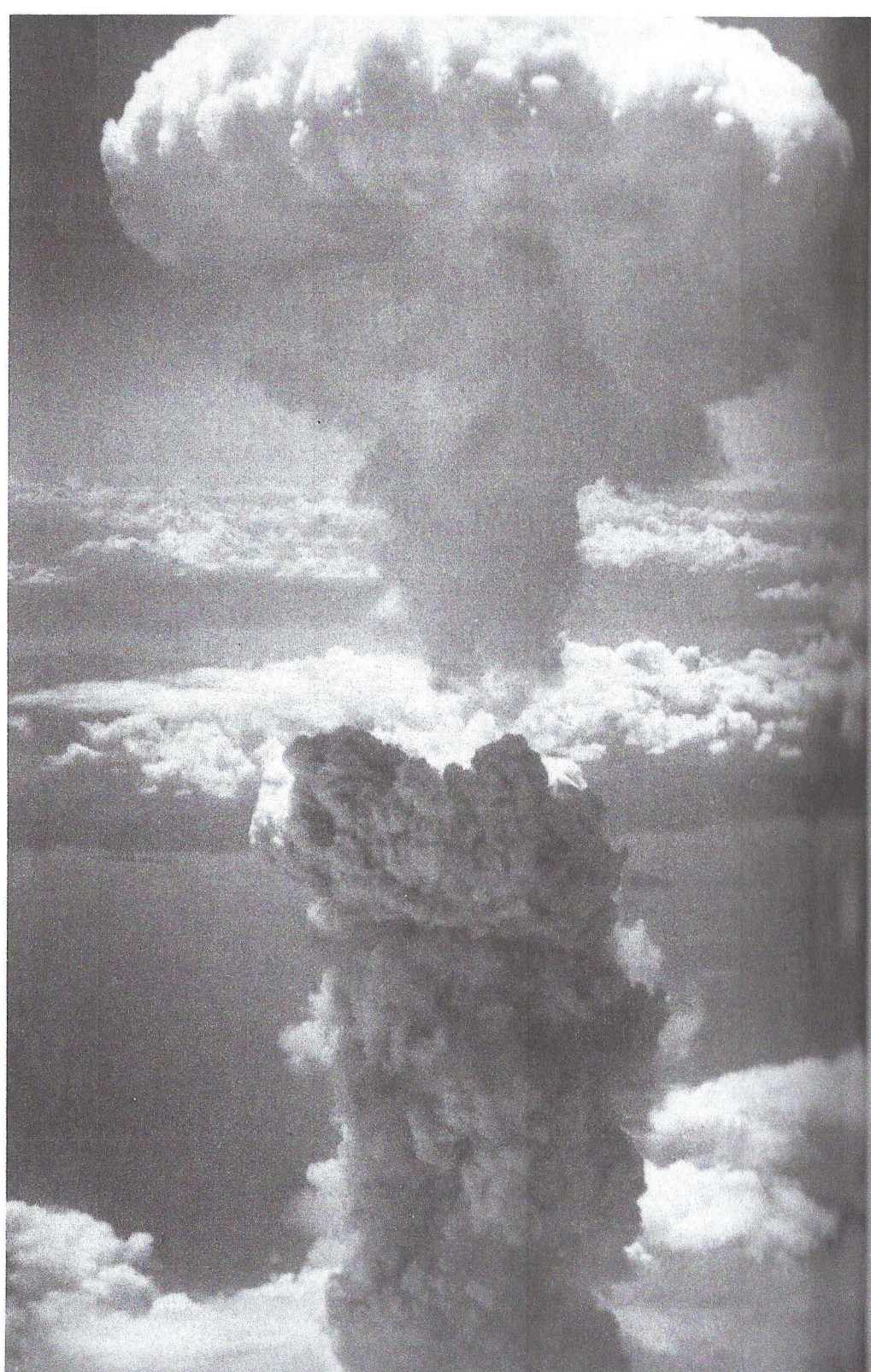


Figure G6.1. Mushroom cloud, Nagasaki, August 9, 1945. U.S. Army Air Force, http://www.getty.edu/education/teachers/classroom_resources/curricula/headlines/ib_nagasaki.html.

in shadows: silhouettes of people, animals, plants, and objects, its last moment of existence emblazoned on walls. Never before was it possible to kill time, not like this. Atomic clocks. Doomsday clocks. The hands of time indeterminately positioned as creeping toward the midnight of human and more-than-human existence, moving and no longer moving.³

Frozen clock faces have become emblematic of nuclear destruction. In the Hiroshima Peace Memorial Museum, there are watches in showcases and larger-than-life pictures of clocks, all forever fixed at 8:15. And in front of the Hiroshima National Peace Memorial Hall is a sculpture of a clock: the face of time forever set at 8:15. Hiroshima-8:15 makes up one space-time point. But there is also Trinity Test site-5:30, Nagasaki-11:02, and Fukushima-2:46 . . . reverberations of time being stopped, coming in waves.

What happens to time when nuclear forces are harnessed and unleashed? Is (space)time(mattering) not shattered, torn, broken into dis/connected pieces? Vaporized, dispersed, made particulate,

whisked away on the breeze? Condensed into raindrops that fall to the ground making puddles on streets and quenching the soil's thirst? Sent up in smoke as the water

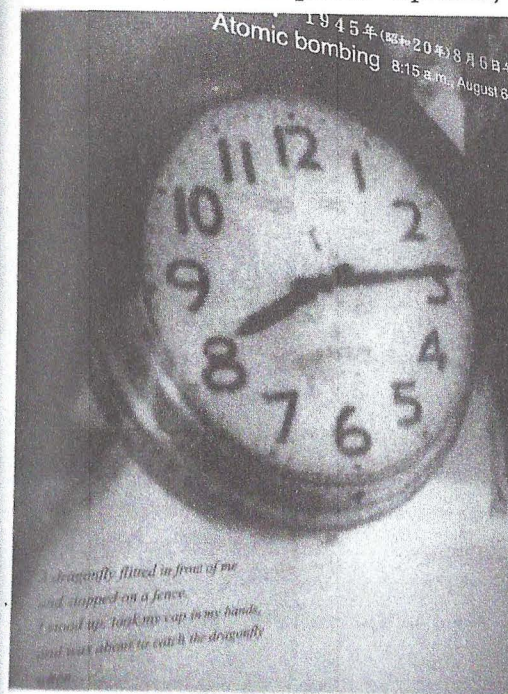


Figure G6.2. Photograph of a clock frozen at 8:15 A.M., the time the atom bomb was dropped, as displayed at the Hiroshima Peace Memorial Museum. Photograph by Amanda Patterson.

invades the electrical systems of the nuclear plant? Leaked into the groundwater as the nuclear core melts?

Time is/had been crossed out. Time drawn out like taffy, twisted like hot metal, cooled, hardened, and splintered. In the twentieth century, time is given a finite lifetime, a decay time. Moments live and die. Time, like space, is subject to diffraction, splitting, dispersal, entanglement.⁴ Each moment is a multiplicity within a given singularity. Time will never be the same—at least for the time-being.⁵

The body clocks of *hibakusha* have been synchronized to the bomb; their cells tick with the rhythms of radioactivity.⁶ *Hibakusha* have been robbed of their pasts, their homes, their city, their health, and their future. Used by the postwar Atomic Bomb Casualty Commission to set standards for radiation exposure, *hibakusha* bodies have been reduced by U.S. officials to a yardstick for measuring bodily tolerance limits, although they have proven inadequate; in actuality, these figures are more a measure of entangled capitalist-imperialist-racist forms of violence and exploitation.⁷ Radioactivity worldwide is now synchronized to the bombings in Japan. The entire world is entangled with the explosion, a global dispersal of the bombing. The bomb continues to go off everywhere (but not everywhere equally). The whole world is downwind.

When it comes to nuclear landscapes, loss may not be visibly discernible, but it is not intangible. There are losses emblazoned on walls: shadows of what once was become eternal . . . the flash so bright, the heat so hot, nearly every surface becomes a photographic plate. Loss is not absence but a marked presence, or rather a marking that troubles the divide between absence and presence.

A speaking silence permeates the spacetime-mattering-scape, like the forgotten movements of the wind that trouble any static notion of landscape.⁸ “In Hiroshima and Nagasaki, it is . . . ‘deathly silence’ or ‘ghastly stillness’ that many survivors speak of as one of the most chilling parts of the atrocity. . . . The silence atomic bomb writers refer to might also represent the massive, instant or rapid deaths that overwhelmed the survivors and descended over the time and space of the burned Hiroshima and Nagasaki. These deaths are in every *hibakusha*’s body and mind and the awareness of this negative space is a part of their living.”⁹ Histories, geopolitics, nothingness, written inside each cell.

These devastated landtimescapes are surely haunted, but not

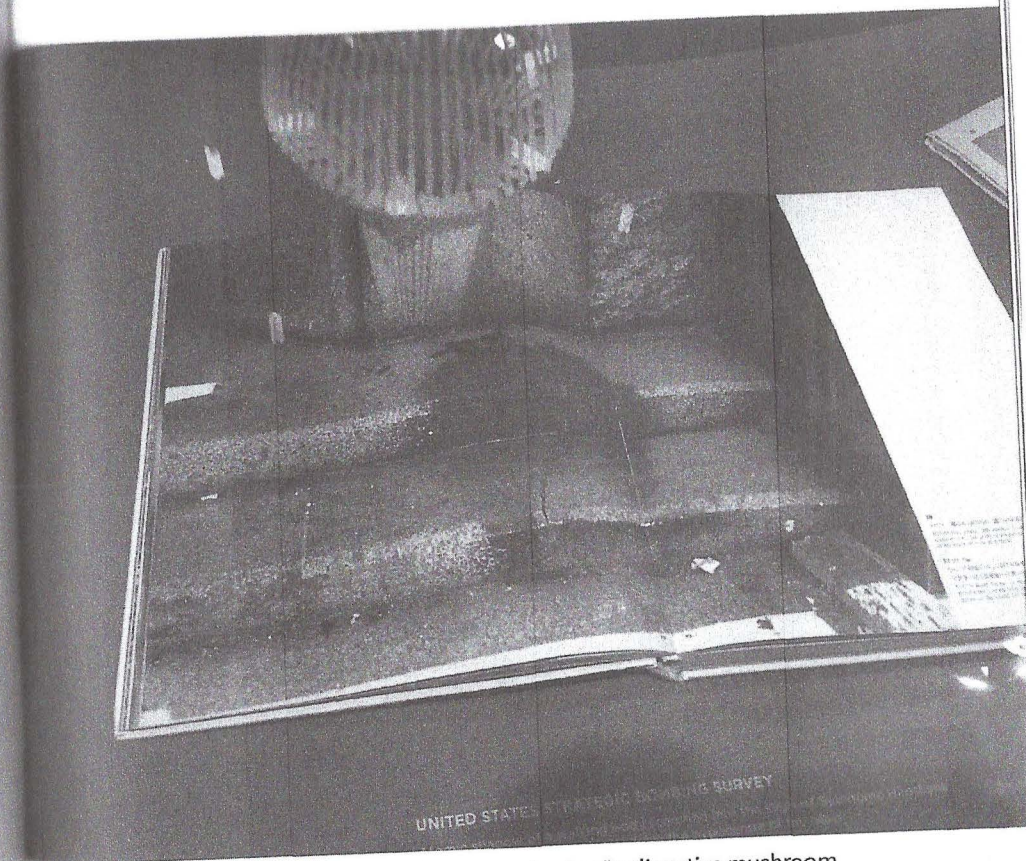


Figure G6.3. Superposition of a green-glowing “radioactive mushroom cloud” and a photograph of a photograph of a photograph; the latter is an “atomic shadow” imprinted on a staircase, the trace of a victim photographed by the atomic bomb. The green mushroom cloud is the inverted reflection of an antique chandelier frame refitted with uranium glass beads and UV bulbs, created by Japanese–Australian artists Ken and Julia Yonetani in the wake of the Fukushima disaster. *Camera Atomica*, Toronto, 2015, curated by John O’Brien, in association with Sophie Hackett. Photograph by Karen Barad.

merely in the sense that memories of the dead, of past events, particularly violent ones, linger there. Hauntings are not immaterial. They are an ineliminable feature of existing material conditions. In the aftermath of Fukushima, for example, nuclear time, decay time, dead time, atomic clock time, doomsday clock time—a superposition of dispersed times cut together-apart—are swirling around with the radioactivity in the Pacific Ocean. Time itself is nationalized, racialized, out

of joint. The entanglements of nuclear energy and nuclear weapons, nationalism, racism, global exchange and lack of exchange of information and energy resources, water systems, earthquakes, plate tectonics, geopolitics, criticality (in atomic and political senses), and more are part of this ongoing material history, which is embedded in the question of Japan's future reliance on nuclear energy, where time itself is left open to decay.

No Small Matter

The trace elements of Los Alamos weapons science now saturate the biosphere creating an atomic signature found in people, plants, animals, soils, and waterways. The Manhattan Project not only unlocked the power of the atom, creating new industries and military machines, it also inaugurated a subtle but total transformation of the biosphere . . . we need to examine the effects of the bomb not only at the level of the nation-state but also at the level of the local ecosystem, the organism, and ultimately, the cell. . . . America's nuclear project has witnessed the transformation of human "nature" at the level of both biology and culture . . . turning the earth into a vast laboratory of nuclear effects that maintain an unpredictable claim on a deep future.

—Joseph Masco

What is the scale of nuclear forces? When the splitting of an atom, or more precisely, its tiny nucleus (a mere 10^{-15} meters in size, or one hundred thousand times smaller than the atom), destroys cities and remakes the geopolitical field on a global scale, how can anything like an ontological commitment to a line in the sand between "micro" and "macro" continue to hold sway on our political imaginaries? When incalculable devastation entailing uncountable deaths is unleashed in the harnessing of a force that is so fantastically limited in extension its job is merely to hold together the nucleus of an atom—a tiny fraction of a speck, a mere wisp of existence, a near-nothingness—then surely anything like some preordained geometrical notion of scale must have long ago been blown to smithereens, and the tracing of entanglements might well be a better analytical choice than a nested notion of scale (neighborhood $\subset$ city $\subset$ state $\subset$ nation) with each larger region presuming to encompass the other, like Russian dolls. That is, when a force extending a mere millionth of a billionth of a meter in length reaches global proportions, destroys cities in a flash, and reconfigures geopolitical alliances, energy resources, security regimes, and other

large-scale features of the planet, this should explode the geometrical notion of nested scales that remains operative when the question arises as to what quantum physics has to do with the "macro-world."¹⁰

What is time's measure?¹¹ In a flash of an eye (a blinding flash, a flash that has been known to melt eyes), the explosion is over but forever lives on. Bodies near ground zero "become molecular"—nay, particulate, vaporized—while *hibakusha*, in the immediate vicinity and downwind, ingest radioactive isotopes that indefinitely rework body molecules all the while manufacturing future cancers, little time bombs waiting to go off.¹² The bomb that went off, the cascading energy of the nuclei that were split, lives on and continues its explosion in the interior and exterior of bodies. The temporality of radiation exposure is not one of immediacy; rather, it reworks this notion, which must then include generations before and to come. Radioactivity inhabits time-beings and resynchronizes and reconfigures temporalities/spacetime-matterings. Radioactive decay elongates, disperses, and exponentially frays time's coherence. Time is unstable, continually leaking away from itself.

What is the scale of matter, of spacetime-matter? We are stardust—made of atoms cooked inside of stars through a process of nuclear fusion—all the while, a brilliance "brighter than a thousand suns" resides inside the nucleus of an atom.¹³ The largest of space-time-matter measures, the smallest of space-time-matter measures: *each contained inside the other, each threaded through the other. A strange topology.*

If, as anthropologist Joseph Masco urges, "we need to examine the effects of the bomb, not only at the level of the nation-state, but also at the level of the local ecosystem, the organism, and ultimately, the cell"—indeed, at every scale, from the grandest cosmological and astrophysical scales to the scale of subatomic particles—what analytical tools might we use to understand not merely the entanglements of phenomena across scales but *the very iterative (re)constituting and sedimenting of specific configurations of space, time, and matter, or rather, spacetime-matter(ing), and the (iterative re)making of scale itself?*¹⁴

In contrast to the universality and homogeneity of space, time, and matter in Newtonian physics, quantum physics—in particular, quantum field theory—holds that every bit of matter, every moment in time, every location (if we for a moment forget that we cannot speak of these conceptions separately), is diffractively/differentially

constituted; or more precisely, *every "morsel" of spacetime-mattering is diffractively/differentially constituted, each "bit" specifically entangled inside all others. Spacetime-mattering is not a set of static points, coordinates of a void, but a dynamism of différencing.*

If quantum physics provides useful conceptual tools for understanding the politics of matter and the matter of politics in the "nuclear age," it is not because quantum physics gets right what Newtonian physics got wrong (apropos some modernist notion of progress), nor is it a question of providing a politically neutral frame, nor even one with inherently better, necessarily more radical politics (as if this could be determined in advance); rather, it is because it is fully implicated in, and arguably marked by, the making of the atomic bomb. Quantum physics and the atom bomb are directly and deeply entangled.¹⁵ Indeed, the point is that *the theory and the bomb materially inhabit and help constitute each other.* Indeed, just like the ontology (hauntology) it suggests, quantum physics, too, and any measure or analytical tool it might provide, is shot through with the political (i.e., by virtue of the very nature of its ontology). This is *why* it might be helpful.

Quantum Physics and Inseparability

The Newtonian nature of space, time, matter, and the void are undone by quantum physics. In particular, it undoes the Newtonian assumptions of separability and metaphysical individualism. There are no self-contained individual entities running in the void. Matter is not some givenness that preexists its interactions. Matter is always already caught up with nothingness. Bodies, space, time, and the void are not ontologically separate matters.

Contra Newton's conception that there are external forces acting on inert matter, according to quantum physics, matter is understood to be agential, and forces, in their multiplicity, are "immanent in the sphere in which they operate."¹⁶ Interpretations of quantum physics differ vastly, but at least on my *agential realist* reading—the result of a diffractive reading of quantum physics through contemporary theories of social justice—ontology is not a matter of givenness. On the contrary, agential realism understands the very nature of matter and the very matter of nature as (iteratively re-)constituted through a(n iteratively reconfigured) multiplicity of force relations. This by no

means invalidates notions such as entity, force, time, scale, boundary, resistance, or resilience. Rather, the point is to get underneath as it were, to have an analytical frame for asking a set of *prior questions* about how to understand such notions in their materiality and to ask how such things come into existence, rather than starting the analysis after they've arrived on the scene. Entities, space, and time exist only within and through their specific *intra-actions*; this is not to say that they are mere transient and fleeting effects but rather that they are specifically materially constituted.¹⁷ On this account, *quantum entanglements* are not mere contrivances, nor simply the outcome of highly technical laboratory practices, but rather the core of this relational agential ontology.¹⁸ Entanglements are not the mere intertwining of, or linkages between, separate events or entities or simply forms of interdependence that point to the interconnectedness of all being as one. *Entanglements are the ontological inseparability of intra-acting agencies. Natural/cultural phenomena are entanglements, the sedimented effects of a dynamics of iterative intra-activity*, where *intra-actions* (contra interactions do not assume separability, but rather) *cut together-apart, differentiate-entangle. Phenomena are specific material relations of the ongoing differentiating of the world, where "material" needs to be understood as iteratively constituted through force relations. Phenomena are not located in space and time; rather, phenomena are material entanglements enfolded and threaded through the spacetime-mattering of the universe. Entanglements are the iterative intra-active (re)configurings and enfoldings of spacetime-mattering.*

Not only does *spacetime-mattering* mark the inseparability of space, time, and matter in a radical troubling of Newtonian metaphysics and epistemology; also, the verb form is intended to signal the dynamic (re)making of spacetime-mattering through the iterative sedimentation of intra-actions in their specificity. *Spacetime-mattering* is a dynamic ongoing reconfiguring of a field of relationalities among "moments," "places," and "things" (in their inseparability), where *scale is iteratively (re)made in intra-action.*

Quantum field theory, the attempt to make a coherent theory that combines the insights of quantum mechanics with those of the theory of relativity and field theory, takes this Newtonian undoing even further, producing a radical rethinking of the nature of being (time-being) and nothingness.

Quantum Field Theory: How Big Is an Infinitesimal?

In the mid-twentieth century, the nature of change changed. The design of new physics, a *quantum field theory* (QFT), from 1927 to 1947 and beyond, indeed, to the present day, had a profound impact on the nature of temporality and change, to say nothing of the technoscientific dimensions of World War II, and vice versa. In fact, there was a striking overlap between the physicists who worked on the Manhattan Project and those who worked on the development of QFT. During this time, being and time were together remade. No longer an independent parameter relentlessly marching forward in the future, time is no longer continuous or one. *Time is diffracted, imploded/exploded in on itself: each moment made up of a superposition, a combination, of all moments* (differently weighted and combined in their specific material entanglements).¹⁹ And directly linked to this indeterminacy of time is a shift in the nature of being and nothingness.

According to QFT, matter is not eternal. Birth and death are not merely the inevitable fate of the animate world; so-called inanimate beings are also mortal. Particles have finite lifetimes, decay times. "Particles can be born and particles can die," explains one physicist. In fact, "it is a matter of birth, life, and death that requires the development of a new subject in physics, that of quantum field theory. . . . Quantum field theory (QFT) is a response to the ephemeral nature of life."²⁰

Particles are born out of the void, go through transformations, die, return to the void, and are reborn, all the while being inseparable from the wild material imaginings of the void. At the core is the *indeterminacy of time-being* (i.e., the reciprocally related indeterminacy of time and energy/matter/being), and this gives rise to the fact that nothingness is not empty but flush with *virtuality*—the *indeterminate play of the non/presence of non/existence*. As a result of a primary ontological indeterminacy, the void is not nothing but a desiring orientation toward being/becoming, flush with yearning and innumerable imaginings of what could be/might yet have been. Nothingness is a material presence, belying any insinuation of emptiness—an indeterminate movement, an intra-active self-touching of no-thingness. It is a matter of time-being itself that is at stake in the play of indeterminacy, where an event is not one and living and dying are inseparable (though not the same): the dying is within the living within the dying.²¹

The fact that the void is not empty, mere lack or absence, matters. The question of absence is as political as that of presence. When has absence ever been an absolute givenness? Is it not always a question of what is seen, acknowledged, and counted as present, and for whom? The void—a much-valued colonialist apparatus, a crafty and insidious imaginary, a way of offering justification for claims of ownership in the "discovery" of "virgin" territory—the notion that "untended," "uncultivated," "uncivilized" spaces are *empty* rather than plentiful, has been a well-worn tool used in the service of colonialism, racism, capitalism, militarism, imperialism, nationalism, and scientism.

The void is not the background against which something appears but an active, constitutive part of every "thing." As such, *even the smallest bits of matter—for example, electrons, infinitesimal point particles with no dimensions, no structure—are haunted by, indeed, constituted by, the indeterminate wanderings of an infinity of possible configurings of spacetimemattering in their specificity. Entire worlds inside each point, each specifically configured. Infinitesimals are infinite. Matter is spectral, haunted by all im/possible wanderings, an infinite multiplicity of histories present/absent in the indeterminacy of time-being.*

Much has been made lately of hauntings. Some understand hauntings as one or another form of subjective human experience—the epistemological revivification of the past, a recollection through which the past makes itself subjectively present. But according to QFT, *hauntings are lively indeterminacies of time-being, materially constitutive of matter itself*—indeed, of everything and nothing. Hauntings, then, are not mere remembering of a past (assumed to be) left behind (in actuality) but rather the dynamism of ontological indeterminacy of time-being/being-time in its materiality. *And injustices need not await some future remedy, because "now" is always already thick with possibilities disruptive of mere presence. Each moment is thickly threaded through with all other moments, each a holographic condensation of specific diffraction patterns created by a plethora of virtual wanderings, alternative histories of what is/might yet be/have been. Re-membering, then, is not merely subjective, a fleeting flash of a past event in the inner workings of an individual human brain; rather, it is a constitutive part of the field of spacetimemattering.*²²

Mushroom Clouds

Almost immediately after the bombs hit Hiroshima and Nagasaki, images of mushroom clouds spread across the front pages of newspapers and magazines more quickly than any fungal spores were ever carried by the wind. In 1960, *Time* magazine described the cloud as cauliflower-shaped. But perhaps it's not accidental that the toadstool association won out. Mushrooms are the ultimate *pharmakon*—traditionally associated with life and death, food and poison—matter with occult virtues. Historian of physics Spencer Weart traces the association of nuclear energy with cosmic creation back to medieval alchemy's contention that it is in fact possible to unlock the secrets of a cosmic life force.²³ At the crux of the matter is a fascination with and anxiety over the alchemical notion of transmutation, hitched to fantasies of human control over life and death. Harkening back to the birth of modern science in the crucible of these desires, alchemy itself was transformed into a mature, rational, and mechanistic philosophy. Transformation is arguably a particularly charged kind of change, and an entire history of modern sciences, persecution of witches, and more is packed into it.

But when the atom bomb exploded, the mushroom cloud that connected heaven and earth was a condensation of matters that were more than merely symbolic. "When Hiroshima was destroyed by an atomic bomb in 1945, it is said, the first living thing to emerge from the blasted landscape was a matsutake mushroom."²⁴ Whether or not this story is historically accurate, it has been verified that mushrooms were found not only in the immediate area surrounding the Chernobyl nuclear reactor after the accident in 1986 but also growing *inside* the reactor, on its walls.²⁵ What is it about mushrooms and radioactivity?

Radioactivity, like the mushroom, is a *pharmakon*, and they are entangled with each other in specific ways. It turns out that fungi that contain melanin actually *thrive* on radioactive emissions, using beta and gamma rays (ionizing radiation) as a digestive aid of sorts. "Radiotrophic" fungi use melanin ionization rather than photosynthesis for "food." The highly concentrated radioactive materials in mushrooms make their way up the food chain and thereby hitch a ride outside of contaminated areas (for example, via wild boar gobbling up mushrooms around Chernobyl). At the same time, some

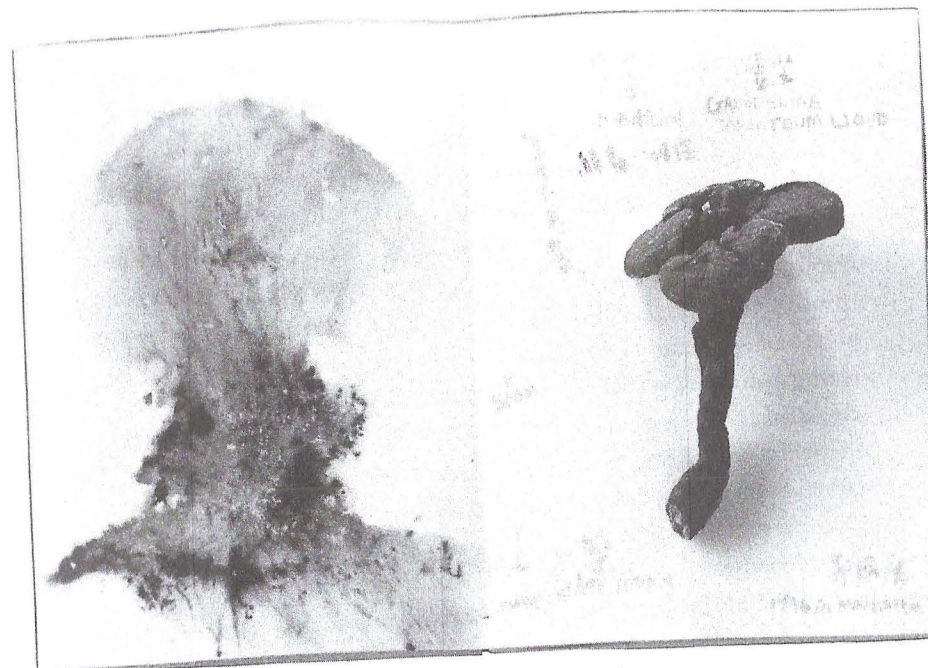


Figure G6.4. Cai Guo-Qiang, *Mushroom Cloud and Mushroom*, 1995–96. Gunpowder, ink, and dried lingzhi mushroom on paper, 20-page folding album. Drawing for "The Century with Mushroom Clouds: Project for the 20th Century." Photograph by Hiro Ihara. Courtesy Cai Studio and Solomon R. Guggenheim Museum, New York. Partial gift of the artist and purchased with funds contributed by the International Director's Council and Executive Committee Members.

scientists see the possibility of using mushrooms for purposes of nuclear remediation (a project being considered to help remediate areas of Fukushima).²⁶

There are also specific material connections between mushrooms and clouds. "Clear-cut the land and you . . . clear-cut the sky!" warn scientists who have been following a hunch that mushrooms may be responsible for the cloud cover over the Amazon.²⁷ A sample of rain forest air was brought to the Lawrence Berkeley National Laboratory in California and placed in the facility's synchrotron, where X-rays of varying energies were fired at the collected specks.²⁸ The analysis supports a linkage between the potassium released from fungi living in the rain forest and cloud formation. The Lawrence Berkeley National

Lab (LBNL) (owned by the University of California, as is its offshoot, the Lawrence Livermore Laboratory [LLL], which is dedicated to weapons development) was the brainchild of Ernest Lawrence. (Edward Teller of hydrogen bomb and Strategic Defense Initiative/Star Wars fame collaborated with Lawrence in helping to establish LLL.) Lawrence worked in collaboration with Robert Oppenheimer (lead scientist on the Manhattan Project) and other Berkeley theoretical physicists to strengthen the bonds between particle physicists and military research. Lawrence's radiation lab is credited with finding a process for uranium enrichment. After the war, Lawrence sought to strengthen military ties to his lab. Lawrence and his "Rad Lab" are also directly connected to the discovery of the process of photosynthesis.²⁹ The Rad Lab, and other particle physics labs, also made miniature clouds in the lab—so-called Wilson cloud chambers—to detect ionizing radiation (the kind mushrooms feed on). Wilson clouds—so named because of a visual similarity to the detector—are a specific feature of mushroom clouds. Mushroom clouds inside mushrooms inside clouds . . . infinities of infinities inside each infinitesimal.

These are just some small bits of a very entangled story. The earth and the heavens are connected in oh so many ways.

It is not simply that there is a homology between terrestrial and atmospheric mushrooms; rather, there is *an uncanny material topology: each inhabiting the other*. When a nuclear bomb explodes, each radioactive bit of matter is an imploded diffraction pattern of spacetime-mattering, a mushrooming of specific entangled possible histories. Tiny radioactive particles raining down from the sky, radiotrophic mushrooms thriving in nuclear contaminated areas, wildlife thriving around the reactors in Chernobyl, mushrooms living inside reactors, Fukushima multiple reactor meltdowns, remediation by mushrooms, radioactive particles traveling ocean currents to North America, *Bulletin of Atomic Scientists* Doomsday Clock resynchronized to include the climate crisis, cloud formation over the Amazon rain forest sustaining millions of species tagged to microscopic bits of potassium emitted from mushrooms, tested at LBNL, connected to LLL, the University of California, cyclotrons, particle accelerators, uranium enrichment, particle physics, nuclear physics, quantum field theory, the Manhattan Project, bomb testing and uranium mining on native lands, racism, internment camps, war, militarism, imperialism, fascism, capitalism, industry expansion, GI Bill, housing boom, boom in racial disparity in

U.S. housing markets, nuclear annihilation of cities with single bombs, security state, nuclear power plants, power plant failure and uninhabitable areas, mushrooms growing. And much more.

All these material-discursive phenomena are constituted through each other, each in specifically entangled ways. This is not a mere matter of things being connected across scales. Rather, matter itself in its very materiality is differentially constituted as an implosion/explosion: a superposition of all possible histories constituting each bit. The very stuff of the world is a matter of politics. Matter is not only political all the way up and all the way down; it has all matters of matter inside it. Planetary geopolitics inside a morsel—a strange topology, an implosion/explosion of no small matter.

How big is infinitesimal? What is the measure of nothingness?

KAREN BARAD is an expert in theoretical particle physics and quantum field theory who has opened up transdisciplinary theories and practices. She is professor of feminist studies, philosophy, and history of consciousness at the University of California, Santa Cruz, and author of *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*, a groundbreaking book that rethinks central questions in philosophy and social theory through rigorous attention to the physical sciences.

Notes

1. The remarkable discovery that matter is not eternal is an insight that comes from quantum field theory, discussed later. This line from the Bhagavad Gita was famously quoted by physicist J. Robert Oppenheimer (his translation from Sanskrit) in the wake of the first atomic bomb explosion.
2. Section subtitle inspired by the artists Eiko and Koma; *Time Is Not Even: Space Is Not Empty* is a retrospective exhibition, first shown at Wesleyan University's Zilkha Gallery in 2009.
3. The Doomsday Clock of the *Bulletin of Atomic Scientists*, introduced in 1947, represents scientists' estimation of the proximity to global catastrophe.
4. See Karen Barad, "Troubling Time/s, Ecologies of Nothingness: On the Im/Possibilities of Living and Dying in the Void," in *Eco-Deconstruction: Derrida and Environmental Philosophy*, ed. Matthias Fritsch, Phil

- Lyons, and David C. Wood (Bronx, N.Y.: Fordham University Press, 2017). Variations on this theme were explored for keynotes for the Society for Literature Science and the Arts and the Society for Phenomenology and Existential Philosophy and invited lectures at Columbia, Johns Hopkins, Rice, and Emory universities during 2014–2015.
5. With a wink to Ruth Ozeki regarding her novel *A Tale for the Time Being* (New York: Penguin, 2013).
 6. *Hibakusha* is Japanese for “explosion-affected people.”
 7. See, e.g., Gayle Green, “Science with a Skew: The Nuclear Power Industry after Chernobyl and Fukushima,” *The Asia-Pacific Journal* 10(1), no. 3 (2011), <http://apjif.org/2012/10/1/Gayle-Greene/3672/article.html>.
 8. “The word landscape is a bit strange, it gives the impression of static. But for the Japanese, landscape is not static image. Landscape is *ku-kai*, wind-scape. So, landscape is always moving, trembling by wind.” Vdrome video *The Radiant* (The Otolith Group, 2012).
 9. Eiko Otake, “Artistic Representation of Human Experiences of the Atomic Bombings” (MA thesis, New York University, 2007), 29–30.
 10. There is no scale at which the laws of physics change from quantum physics to Newtonian physics, from “microworld” to “macroworld”; to the best of our knowledge, quantum physics holds at all scales (Newtonian physics is simply a good approximation in some cases). Furthermore, entanglements call into question the geometrical notions of scale and proximity; topology with its focus on issues of connectivity and boundary becomes a more apt analytical tool. It’s not that scale doesn’t matter; the point is that it isn’t simply given and that what appears far apart might actually be as close as the object in question, indeed, it may be an inseparable part of it. Scale—indeed, spacetime(mattering) itself—is iteratively intra-actively materialized and (re)configured. See the concept of *spacetimemattering* in Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meeting* (Durham, N.C.: Duke University Press, 2007).
 11. For a more detailed discussion of how the notion of time is reworked according to agential realism, see especially Barad, “Troubling Time/s.”
 12. “In this flash the body becomes molecules.” Bill Johnston and Eiko Otake, video of class at Wesleyan University, 4:58, <https://vimeo.com/10387574>.
 13. “Brighter than a thousand suns”—this phrase is from a verse from the Bhagavad Gita said to have been quoted by J. Robert Oppenheimer at the Trinity nuclear test.
 14. Joseph Masco, “Mutant Ecologies: Radioactive Life in Post-Cold War New Mexico,” *Cultural Anthropology* 19, no. 4 (2004): 520–22.
 15. Karen Barad, “Infinity, Nothingness, and Justice to Come” (unpublished manuscript).
 16. Michel Foucault, *History of Sexuality, Volume I: An Introduction*, trans. Robert Hurley (New York: Vintage Books, 1980), 92. The force relations I have in mind here are not merely social, and their effects (in a reworking of cause-effect) are not limited to the formation of human subjects. On the contrary, it is only through the workings of apparatuses of bodily production that forces come to be distinguished as social, biological, geological, political, etc., as the case may be. For more details on agential realism, see Barad, *Meeting the Universe Halfway*.
 17. *Intra-action* does not simply refer to a change from presumed separability to nonseparability (a relational ontology) but entails a radically different understanding of causality and an ontoepistemological framework with implications for thinking about questions of justice. See Barad, *Meeting the Universe Halfway*.
 18. The technical notions of “wavefunction collapse” and “decoherence” do not constitute fundamental objections here. See Barad, *Meeting the Universe Halfway*, chapter 7.
 19. For more on time diffraction, see Barad, “Troubling Time/s, Ecologies of Nothingness,” and Barad, “Infinity, Nothingness, and Justice-to-Come.”
 20. Anthony Zee, *Quantum Field Theory in a Nutshell*, 2nd ed. (Princeton, N.J.: Princeton University Press, 2010), 3–4.
 21. See Karen Barad, *What Is the Measure of Nothingness? Infinity, Virtuality, Justice* (DOCUMENTA [13]: 100 Notes—100 Thoughts, book 099, 2012), and Barad, “On Touching—The Inhuman That Therefore I Am,” *differences: A Journal of Feminist Cultural Studies* 23, no. 3 (2012): 206–23, for a detailed presentation of my agential realist understanding of quantum field theory (which also entails a further elaboration of agential realism).
 22. This brings to mind the work of (*hibak*) *denshoshu*—memory keepers in Japan (and also elsewhere). The question of how to keep memories alive as survivors die is poignant and urgent.
 23. Spencer Weart, *The Rise of Nuclear Fear* (Cambridge, Mass.: Harvard University Press, 2012).
 24. Anna Lowenhaupt Tsing, *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins* (Princeton, N.J.: Princeton University Press, 2015), 3.
 25. Albert Einstein College of Medicine, “‘Radiation-Eating’ Fungi Finding Could Trigger Recalculation of Earth’s Energy Balance and Help Feed Astronauts,” *ScienceDaily*, May 27, 2007, <http://www.sciencedaily.com/releases/2007/05/070522210932.htm>; “Radiation-Eating Fungi. They Kill Trees and They Kill People,” *Bobby1’s Blog*, November 14, 2012, <http://optimalprediction.com/wp/radiation-eating-fungi-they-kill-trees-and-they-kill-people/>.

26. Paul Stamets, "Using Fungi to Remediate Radiation at Fukushima," *Permaculture* (blog), November 26, 2015, <http://www.permaculture.co.uk/articles/using-fungi-remediate-radiation-fukushima>.
27. Veronique Greenwood, "How Fungi May Create the Amazon's Clouds," *Discover Magazine*, September 5, 2012, <http://discovermagazine.com/2012/sep/04-mushroom-cloud>.
28. Ibid.
29. The mechanism of photosynthesis was decoded by chemist Melvin Calvin in the Rad Lab using radioactive carbon on the encouragement of Lawrence.