

Behind the Fear

by Víctor Manuel Cruz Atienza · Panel discussion on Alexandre Estrela's Réplica (larva) · MUAC

The Work as a Point of Departure

I would like to begin by thanking you for the invitation, and by confessing something: when I was asked to speak in front of this piece, I struggled to imagine what a seismologist could possibly say in a museum of contemporary art. But as I looked calmly at Alexandre Estrela's *Réplica*, I realized that this luminous larva and I do, in the end, the very same work: we listen to the Earth and respond to what it tells us.

The text that accompanies the work uses three words that carry a particular weight for a seismologist. The first is *sentinel*. We, too, have sentinels: across the Valley of Mexico there are hundreds of sensors buried in parks, in schools, at the bottom of the ancient lake, which for decades have recorded every movement of the ground, day and night, like watchful animals that never sleep. The second word is *réplica*. In Spanish, and in our trade, a *réplica* is the earthquake that follows the main shock, an aftershock. But I am more drawn to its other meaning, that of a replica, a copy, because Mexico City is in a certain sense a replica —a distorted and amplified copy— of what happens three hundred kilometers from here, on the Pacific coast, where the Cocos plate plunges beneath the North American plate. And the third word is *synchrony*. The text tells us that when the Earth trembles, everything falls into synchrony. As we shall see, this may well be the most accurate description one can give of what happens to our city during an earthquake.

I would like, then, to use these minutes to answer a single question: what lies between the rupture of a fault far away, beneath the ocean, and the fear we feel here, in our bodies, when the city begins to move?

Perception and Fear

Let us begin with fear, which is what we all know. When the earthquake arrives, Estrela's larva neither fights nor flees: it freezes. Many of us have felt exactly that, the stillness of a body that does not know which way to go. What is striking is that fear is lived as a single, indivisible experience —the ground shakes, and that is all— and yet what provokes it is not one thing. What we feel beneath our feet is not the earthquake; it is the ground of the city responding to the earthquake, and that response is the superposition of many different waves, which have traveled along different paths, arrived at different moments, and vibrate with different rhythms.

I often think of what happens when we listen to an orchestra with our eyes closed. What reaches us is a single emotion, a single mass of sound that moves or unsettles us, yet behind it there are dozens of instruments, each with its own timbre, its own register, its own moment of entry. An earthquake is something similar: a single sensation of vertigo and disorientation that is, in reality, the sum of an extraordinarily complex physical concert. What seismology has been learning, above all in recent years, is to separate those instruments, to listen to each one on its own, in order to understand why the whole symphony sounds the way it does.

There is, moreover, something deeply human in the way we perceive that concert. In this city, large earthquakes are not felt as a sharp blow but as a slow swaying, lasting one or several seconds, that rocks us as if we were on a ship and defies our sense of balance. It is no coincidence that those of us who live here describe earthquakes as a kind of seasickness, a rocking that never seems to end.

That rocking has a precise physical explanation, and it is the one I want to share with you.

The Apparatus: A Symphonic Resonator

To understand that apparatus, we must look beneath the city. Only a few centuries ago, much of what is now Mexico City was a mosaic of lakes. As they dried up —and as we drained them— they left behind a deposit of extraordinarily soft lacustrine clays, so saturated that in some places they contain more water than solid matter. These clays, a few tens of meters thick, rest upon far more rigid volcanic deposits. And a soft layer over a hard floor is, in physical terms, the same thing as the sound box of a guitar or the skin of a drum: an instrument.

Like every instrument, the valley has notes of its own. Each point in the city vibrates preferentially at a characteristic period, which depends on how thick and how soft the clay is beneath our feet: near the edges of the ancient lake the note is high, around one second; toward the center, where the clay is thickest, it becomes low, three, four, even five seconds. When the waves arriving from the coast carry energy at those notes, the ground amplifies them tens of times relative to what we record on firm rock, at Ciudad Universitaria for instance, some fifteen kilometers from the clay-bound downtown. Buildings, which also have a note of their own according to their height, suffer when that note coincides with the ground's. This is the synchrony Estrela speaks of, and it is a tragic synchrony: in 1985 it was mostly buildings of eight to fifteen stories that collapsed in the city center; in 2017, lower buildings, closer to the edge of the ancient lake. Each earthquake struck different notes of the same instrument.

But there is something more, and it is what has occupied us most in recent times. Seismic waves are not all alike. There are waves that shake the ground from side to side, as when we flick a rope horizontally —seismologists call them Love waves—, and there are waves that make it roll, tracing small ellipses, like a cork bobbing up and down on the surface of the sea —the Rayleigh waves—. Each of

these families has, in turn, different modes of vibration, and each mode travels at a different speed depending on its frequency. The slow, long-period waves feel the deep subsurface and cross the entire valley almost without noticing it; the fast, short-period ones become trapped in the shallow clay, where they slow down, grow in amplitude, and fade quickly.

Today we can see all of this. With dense networks of sensors deployed inside the basin, and with techniques that allow us to combine the signals of dozens of stations as if they were a single gigantic ear, we are able to reconstruct how the waves propagate across the city, second by second, as in the animations we have built for an earthquake that occurred earlier this year near Acapulco. What those animations reveal is a landscape far richer than we had imagined: waves entering from the south, from the coast; waves born at the edges of the valley, where the mountains meet the ancient lake, which are reflected and re-emitted inward, like ripples bouncing off the walls of a bathtub; waves that cross one another, that interfere, that reinforce each other in some neighborhoods and cancel out in others.

And here a paradox appears, one that has intrigued us for years. The clays of the valley are a highly dissipative material: they absorb the energy of the waves, turn it into heat, and damp it out, much as a pillow muffles a sound. One would therefore expect the shaking to die away quickly. Yet exactly the opposite occurs. The rupture on the coast lasts only a few seconds, but the city keeps moving for minutes, far longer than any site on rock. How can a material that damps motion sustain it for so long?

The answer we have been building is that the valley is not a single instrument but several instruments superimposed: a resonator of many modes. The shallow clay is merely the skin. Beneath it lie kilometers of volcanic deposits that also guide and trap waves, above all the long-period ones, and keep delivering them to the surface long after the rupture has ended. At the same time, the edges of the

valley generate waves of their own, which arrive late and from unexpected directions. The result is that different waves, at different frequencies, keep the motion alive along different routes, relieving one another, so that when one fades another is still arriving. That endless swaying, which distresses us so deeply, is the signature of this multimodal apparatus.

The Larva's Fifteen Seconds

Let me return to the larva. The artist's work tells us that the Réplicas sense the approach of an earthquake up to fifteen seconds before it physically arrives, and that their internal rhythms grow agitated. This has a very concrete counterpart in our city: the seismic early warning. When an earthquake occurs on the coast, nearby sensors detect it within a few seconds, and the alert signal travels by radio at the speed of light, while the seismic waves advance at only a few kilometers per second. From that difference are born the seconds of anticipation—up to a little more than a minute, depending on where the earthquake occurs—that today allow millions of people to leave their homes. The agitation of the larva before the tremor is, in a sense, the same agitation we all feel when the alarm sounds: the body knows that something is coming before it feels it.

For centuries, the behavior of animals was the only warning we had of earthquakes. I find it beautiful that Estrela has started from there to build a kind of artificial sense, one that grants us a capacity for anticipation that we, as humans, do not possess. Science does something similar, though on another timescale. We cannot predict when the next great earthquake will strike. What we can do, with ever greater precision, is anticipate how each neighborhood of the city will respond when it does, because we already know the instrument: we know which notes it plays, which waves excite it, where they concentrate, and for how long. That knowledge is a much slower form of warning, but an equally vital one, because it is what allows us to build structures that do not share the ground's note, and that endure.

Return to Calm

I will end with the image in this piece that moves me most. When the ground stops shaking, the larva slowly resumes its quiet routines, after having taken refuge in the grooves of its aluminum shell. We do the same. After every earthquake the city returns to its rhythm, its traffic, its markets, its noise. But our shell is neither aluminum nor inert: it is a fossil lake, a soft body full of water, which holds within its structure the memory of every earthquake and which keeps vibrating, imperceptibly, all the time, even now, as we speak.

Understanding that apparatus does not take away our fear, nor do I believe it should, because fear also protects us. But it does transform it. It ceases to be the fear of something invisible and incomprehensible and becomes the awareness of inhabiting a body with laws, rhythms, and notes of its own. Perhaps that is what this work and seismology share at their core: the intuition that hidden connections exist between life, technology, and the geology of the Earth, and that when the Earth trembles, everything falls into synchrony.