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Brain in a chip: biocomputing infrastructure and the limits of urban governance

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ABSTRACT

Biocomputing data centers are facilities that use human neurons cultured from stem cells as their computing substrate. These pose a challenge to urban governance that it is not equipped to meet. Because biocomputing is assembled through data centers, biomedical precincts, energy regimes, and experimental planning environments, it is both a bioethical issue and an urban problem of siting, infrastructural regulation, and public oversight. Focusing on the emergence of facilities in Melbourne and Singapore, this paper argues that urban infrastructure studies implicitly assume the material substrate to be inert. Pipes, cables, fiber, and code do not raise questions of sentience, consent, or biological sourcing. Yet biocomputing disturbs that assumption. The paper identifies a qualitative break with people-as-infrastructure, ghost work and clinical labor, each of which retains the whole person as its unit of analysis. Biocomputing incorporates fragments of the human body that are stripped to their biological minimum. This life is present in the data center to compute, yet remains absent from urban governance. Singapore's convergence of Smart Nation ambition, Biopolis strategy, and serious energy constraints makes it a theoretically productive first case for exploring the conceptual landscape of urban infrastructure studies post-inert turn.

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The inversion

In March 2025, Australian biotech startup Cortical Labs announced what it describes as the first commercially available biological computer, the CL1.[1] This is a device housing 800,000 lab-grown human neurons on a silicon chip, kept alive by an internal life support system of pumps, nutrient delivery, gas mixing, and temperature control (Kagan, 2025). In early 2026, the company reports early deployment of 120 units at its Melbourne-based facility, forming part of what it describes as a "wetware-as-a-service" platform, with anticipated subscription-based access to neuronal processing via API – pricing details vary across early reports.[2] A second facility is taking shape in Singapore, initially deploying 20 units at the National University of Singapore's Yong Loo Lin School of Medicine,

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scaling toward 1,000 units, subject to technical validation and regulatory approvals, in partnership with data center operator DayOne.[3]

While Melbourne-based Cortical Labs developed the underlying wetware computing platform, Singapore-based DayOne is seeking to provide the data-center infrastructure through which biological computing can be scaled and commercialized. Their collaboration to establish Singapore's first biological data center demonstrates how organoid intelligence is becoming embedded within wider urban infrastructures of computation, energy provision and digital development. The primary justification for using a human substrate is energy efficiency. Advocates argue that organoid-based systems may eventually offer substantial energy advantages over contemporary AI hardware. Early prototypes and commercial models have reportedly operated at approximately 30 watts of power, compared with the substantially higher energy demands of training and operating large-scale AI models. The pitch is sustainability. The substrate is human.

A recent paper in this journal, "Borg Urbanism" examined what happens when the "chip enters the brain". It focused on how neurotechnology colonizes human brains, transforming neural states into a bidirectional urban infrastructure and raising the prospect of people becoming manipulated neural nodes in a sociotechnical collective (Marvin & McCay, 2026). In contrast, this current paper examines the precise inversion by focusing on the "brain in the chip" problem. A fragment of human biology is incorporated as the technical system's substrate. Cortical Labs' Brett Kagan described the relationship directly at a Neurotech Summit in Sydney, Australia, in December 2025, as "not a chip in a brain but a brain on a chip'.[4] Critical urban geography has begun to theorize the first move (Marvin & Zhang, 2026). Yet it has not yet asked what the second one means, and this paper argues it urgently needs to. This matters for urban geography because biocomputing is not emerging in an abstract laboratory context.

Rather than emerging evenly across national territories, biocomputing is concentrated within a small number of highly specialized urban regions that combine advanced neuroscience, biotechnology, computation, venture capital, and regulatory capacity. As this paper shows, the geography of organoid intelligence is therefore highly specific, emerging through experimental urban districts such as Melbourne's biomedical innovation precincts, Singapore's Biopolis ecosystem, and Zurich's neurotechnology cluster. Understanding why these cities become sites for biological computation is a wider question for critical urban geography. It is being assembled through urban data-center infrastructures, biomedical districts, energy-intensive computing systems, and city-regional regimes of experimentation. The issue in this paper is therefore how cities host, regulate, and normalize biological infrastructures for computation.

Infrastructure's inert substrate assumption

Urban infrastructure studies have built their conceptual architecture on an implicit premise that the substrate is inert. Pipes, cables, fiber, and concrete are the core objects of infrastructure theory from foundational accounts of relational embeddedness to splintering urbanism (Graham & Marvin, 2001; Star & Leigh Ruhleder, 1996). Urban infrastructures do not usually raise questions of sentience, consent, or human biological sourcing. The vast literature on the cultures of infrastructures, urban intelligence, smart and platform urbanism makes the same assumption. The substrate is material but never moral. Recent mappings of the field have, however, identified new materialist thinking and agentic materialities as a key frontier for infrastructure studies (Wiig et al., 2021).

Biocomputing represents the moment that the frontier becomes unavoidable. The neurons in the CL1 are alive. They are derived from human stem cells sourced from adult blood or skin samples. They form synaptic connections, exhibit adaptive responses to stimuli, and demonstrate limited forms of reinforcement-based learning in experimental settings. Cortical Labs' own peer-reviewed research described the system as exhibiting adaptive, goal-directed behavior within experimental environments (Kagan et al., 2022). The substrate is not inert because it is human in origin and alive in operation. It is potentially morally significant in ways that no existing urban governance instrument is equipped to assess. Planning consent, zoning and land-use categories, environmental review, data-center energy regulation, and biomedical ethics oversight each grasp only part of this assemblage, and none is designed for living human-derived computational substrate.

This paper argues that this form of organoid intelligence signals a post-inert turn in urban infrastructure. By a post-inert turn, I do not mean that previous infrastructures were entirely passive or static. Urban infrastructures have long involved dynamic and living processes, from transport systems and communication networks to the mobilization of human labor as infrastructure. Instead, biocomputing introduces a novel category of infrastructure in which biological tissue itself becomes the computational substrate, blurring distinctions between living matter, technical systems, and urban infrastructure. This development raises new questions about how cities govern infrastructures that are simultaneously computational, biological, experimental and invisible to the planning and regulatory apparatus that governs the urban built environment.

The human in the substrate

The incorporation of human biological and cognitive capacity into urban technical systems is not new. The foundational account of "people as infrastructure" in Johannesburg established that people, their movements, networks, and provisional economic arrangements, become the substrate on which urban life depends (Simone, 2004). The ghost work literature extended this into the distributed human cognitive labor invisibly embedded in AI systems through content moderation, image labeling, and training data generation, as the substrate beneath automated urban intelligence (Gray & Suri, 2019; Irani, 2015). The clinical labor framework went further still, tracing the relocation of the labor process to the sub-organismic level, below the threshold of conventional labor recognition (Cooper & Waldby, 2014). Taken together, these literatures show how urban systems rely on human capacities as hidden supports but still assume an embodied human subject who remains socially recognizable, however exploited.

Biocomputing is a qualitative departure from all of these. People-as-infrastructure retains the whole person as social, embedded in relations of survival and mutual dependence and capable of withdrawal. Ghost work retains the worker as underpaid and hidden, yet still a person who can log off. Clinical labor retains the research subject, even if inadequately governed by ethics review and consent frameworks. The neurons in the CL1 retain none of this. It is a fragment extracted from the human body, reprogramed, grown onto silicon, enrolled as a computing component, kept alive for up to six months, and made available to paying subscribers. Donors provide informed consent to biomedical research uses of their biological material. Whether that consent extends to commercial computing infrastructure is a question those consent frameworks were not designed to answer. This demands a new theoretical figure that existing frameworks struggle to supply.

The cyborg is the foundational concept for thinking about human-machine hybridity in urban life. In Haraway's (1991) formulation, the human is the referent while technology extends, enhances, or colonizes the person. The cyborg is disturbing precisely because the human is still there and the subject whose boundaries are being renegotiated. Urban studies have productively drawn on this figure to think about enhanced residents, wearable technologies, and the porosity of the human body in technologically mediated urban environments. Borg Urbanism pushed this further into specifically urban territory. It focused on the human wired into urban infrastructure through neural interfaces, their subjectivity intact but endangered, and their individuality absorbed into a networked sociotechnical collective (Marvin & McCay, 2026). Here too, the human remains the referent, the subject whose absorption into the system is the political problem. The person is still present, still at stake.

Biocomputing inverts this logic entirely. The machine is now the referent, and the biological fragment is the component. What has changed is the direction and scale of human–machine entanglement. It is not a whole person being drawn into a technical system, but a fragment of the human body enrolled as the technical system's substrate. The Cortical Labs founder named this directly as "not a chip in a brain but a brain on a chip." Following that inversion, we might call this figure the *Vitachine* – a technical system in which living human biological material is enrolled as computational substrate, not as subject but as component.

But the Vitachine is more than an inversion. It marks a threshold crossing. The cyborg retains personhood, which is disturbed, hybridized, and endangered, yet always present. Unlike the cyborg, the Vitachine operates below the threshold of personhood, incorporating fragments of the human body as infrastructural components. The neuron on the chip is not a subject, a worker, or a research participant in any meaningful sense. It is a sub-organismic element enrolled in computation, stripped of agency, consent, and social recognition. This is the deregulated human body, in which human biology is reduced to its biological minimum and incorporated into technical systems through market and experimental logics that bypass the thresholds through which the human would otherwise be recognized and protected.

Urban biocomputing clusters: Singapore, Zurich and experimental biological computing

The question for critical urban geography is what biocomputing reveals about which cities absorb the governance risk of experimental biological infrastructure, who decides, and by what process. Significantly, the urban geography of biocomputing is highly specific. Melbourne is the home base of Cortical Labs, where the technology was built, tested, and proven under the company's direct control. Singapore is something categorically different. The partnership with DayOne brings external capital and commercial data center infrastructure. The NUS Yong Loo Lin School of Medicine provides biomedical legitimacy. The state provides what Ong (2006, 2016) has theorized as its defining offer of graduated sovereignty, regulatory flexibility, and a deliberate capacity to host what other cities cannot or will not. Singapore's urban arrangements, including the Smart Nation, the Biopolis, the Economic Development Board's biomedical strategy, and the Built Environment Living Lab Framework, were all designed to make exactly this kind of investment possible (Ong, 2006, 2016; Woods et al., 2024).

Singapore's Smart Nation program has made data center infrastructure a strategic state priority while simultaneously confronting its acute energy costs. Data centers already account for approximately 7% of Singapore's total electricity consumption in a city–state with no domestic energy resources. This prompted a moratorium on new conventional data center development from 2019. The state will only permit expansion where operators can demonstrate world-class energy efficiency and green energy sourcing (IMDA, 2023, 2024).

Singapore's flagship Biopolis strategy offers what Waldby (2009) describes as "liberal regulation and concessions" to attract global life science institutions and undertake biotechnical governance (Shee et al., 2026). The biomedical research precinct provides the adjacent institutional infrastructure of life-science capital, NUS's research capacity, and ethics-governance expertise that biocomputing equally requires. Biocomputing lands in Singapore because of this context, through a technology that promises dramatic reductions in compute energy consumption, arriving precisely when the state needs exactly that, in a city that has spent two decades building the biomedical infrastructure to support it.

The Smart Nation and Biopolis strategies, usually narrated separately, converge in the CL1. The experimental city (Hamnett & Yuen, 2019) is assembling a governance environment that makes living neural computing infrastructure viable at the urban scale. The absent public is the sharpest urban governance problem this raises. Whatever internal governance processes may have accompanied the Singapore deployment, no public planning consultation, environmental review, or civic participation process has been visible. Even where governance instruments have been engaged, they were designed for clinical research or conventional data center infrastructure, not for a substrate that is simultaneously biological, human in origin, and potentially morally significant. The public lacks the conceptual vocabulary to participate, even if a forum existed. Jasanoff's (2005) civic epistemology, the culturally specific capacity of publics to understand and contest technoscientific decisions, assumes a public that can, at least in principle, access the relevant knowledge. Biocomputing's substrate operates below the threshold of urban civic legibility.

Yet this is not solely a Singapore-and-Melbourne challenge. FinalSpark is a Swiss biocomputing startup based in Vevey that has developed Neuroplatform. This is a remotely accessible wetware computing platform using clusters of human brain organoids as living bioprocessors, already available to university researchers on a subscription basis (Jordan et al., 2024). MetaBOC is a brain-on-chip system developed by researchers at Tianjin University and the Southern University of Science and Technology, announced in June 2024. This integrates human stem-cell-derived brain organoids with a neural interface chip to enable robotic control, which its developers frame as the world's first open-source organoid-robot integration system.[5] The questions this paper raises will soon confront many other cities that are unlikely to have a governance framework any more adequate than Singapore's. The two-city story is the opening chapter of a wider urban condition. Singapore is a theoretically productive first case, with a convergence of digital economy ambition, energy constraints, biomedical infrastructure, and deliberate regulatory flexibility, which will be replicated, adapted, and contested in urban contexts across the globe as biocomputing scales.

Seen in this light, Singapore is a model of how experimental urbanism, biomedical clustering, and digital infrastructure policy are co-articulated to host living computational systems. The urban issue is therefore the production of city-regional environments in which biological computing becomes governable enough to scale, yet insufficiently public to be democratically contested.

What urban geography must now ask

What is at stake is the possibility that core urban systems of data centers, hospitals, robotic infrastructures, and human–machine interfaces, may increasingly rely on fragments of human biology as their operational substrate. The CL1 is the first commercial urban application of organoid intelligence (OI) and is the focus of a research program that prefigures a far more extensive OI-enabled infrastructure (Smirnova et al., 2023). This vision encompasses networked brain organoids connected to sensory organ organoids, trained through biofeedback, capable of disease modeling, biocomputing, brain-computer integration, robotics, and regenerative medicine.

When read through an urban infrastructure lens, this is a program for the biological remaking of the city's core systems, including its digital infrastructure, hospitals, robotic operations, and interfaces with urban residents. This vision anticipates a future in which a growing range of urban operational systems rely on fragments of human biology as part of their computational substrate. Yet the urban is entirely absent from the OI literature, with its governance questions framed exclusively in terms of biomedical ethics and legal regulation (Hartung et al., 2023; Ishida et al., 2026), and never of planning, civic participation, or urban infrastructure. Each of these OI applications lands in a city, is governed by urban instruments, and involves human biological material at scales and in combinations that those instruments were not designed to address.

What biocomputing reveals, in short, is a splintering of bodies through the disaggregation of the human person into biologically useful fragments that can be enrolled in urban infrastructure independently of the whole person from whom they came. Where splintering urbanism described the fracturing of the integrated city along lines of premium connection and bypass, splintering bodies describes the fracturing of the integrated person along lines of biological utility. The fragment that can be computed is enrolled. The rest of the person, their agency, their consent, and their ongoing relationship to what their biology is doing, is irrelevant to the infrastructure and invisible to its governance. Nobody is governing it as urban infrastructure. That gap cannot be closed by the normal lag between technological development and regulatory response. It is structural, produced by the simultaneous failure of three governance logics. Planning and infrastructural regulation assume inert substrates. Biomedical ethics frameworks are designed for research subjects rather than infrastructural components. Urban democratic processes lack a vocabulary through which biological computing can become publicly legible and contestable.

Critical urban geography can name this gap, theorize it, and insist that the right questions are asked before normalization closes them. What does it mean for urban infrastructure theory when the substrate has morally relevant properties? Whose biological material underwrites the computing infrastructure of global cities, under what consent frameworks, and with what ongoing relationship to the infrastructure it makes possible? Which urban political economies are structurally predisposed to absorb the governance risk of experimental biological infrastructure, and which populations bear that risk? What would a civic epistemological capacity on biocomputing look like, and how might urban publics develop it? The post-inert turn is what the city and urban studies now require. Critical urban geography has a narrow window in which to develop the conceptual tools before the infrastructure normalizes, the governance gaps harden, and the deregulated body becomes simply the substrate of the city.

Notes

1. See https://corticallabs.com/cl1 Accessed 10th March 2026.
2. See https://spectrum.ieee.org/biological-computer-for-sale Accessed 10th March 2026.
3. See https://dayonedc.com/sustainability/dayone-and-cortical-labs-to-develop-singapores-first-biological-data-center Accessed 10th March 2026.
4. The author attended this Summit. See https://cybersecurityadvisors.network/event/neurotechnology-summit-2025/ Accessed 10th March 2026.
5. See https://www.scmp.com/news/china/science/article/3268304/chinese-scientists-create-robot-brain-made-human-stem-cells Accessed 10th March 2026.

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