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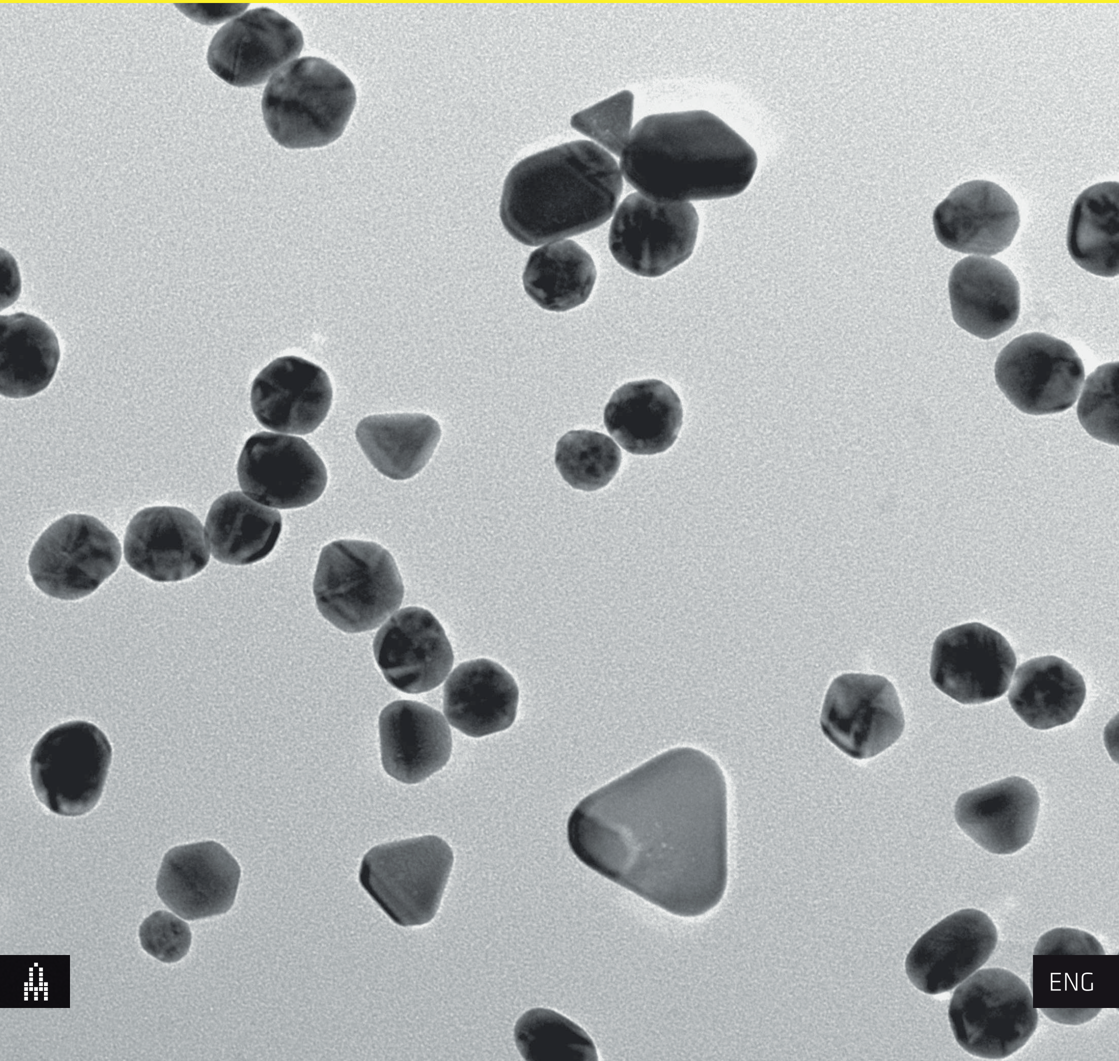
COLLOIDAL ONTOLOGIES: THE GENDERED BODY AT THE INTERFACE OF MATTER



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Ruby Gold

By 1856, chemist Michael Faraday had been interrogating himself for years on the elusive relationship between matter and light. In his time, interactions of optics, electricity and magnetism were typically explained through the presence of the ether – an invisible, weightless substance capable of mediating physical effects between bodies, allowing matter to interact at a distance. Faraday was never fully convinced that the introduction of the ether would likely be a solution to the problem of interaction at a distance; he was also sceptical about the notion of Daltonian atoms as individual, spherical, solid particles. The question on which Faraday had been working was as physical as it was philosophical: How does dense, brute matter become capable of producing immaterial effects? How can disembodied forces act through and between material bodies? How does shifting from the microscopic scale of atoms to the macroscopic scale of materials and forces affect the properties of matter?

As a pure experimentalist, Faraday approached theoretical questions synthetically: he created artefacts and materials that could help him answer his questions about the nature of matter. To interrogate the problem of the interaction of light and matter, he began working with increasingly thin films of gold, etching the metal with chemicals until he obtained layers of only a handful of atoms in thickness. While working on these films, he soon realised that the chemical preparations he had used for the dissolution of the metal were not colourless, as he had expected, but tinted with an incredibly bright red colour, which he named "ruby gold". He also began to observe that if he changed the concentration of the chemicals and the conditions of the etching process, the colour of the solution changed into a spectrum of other colours, from purple to deep blue to emerald green.

The samples that Faraday prepared were "gold colloids": materials composed of incredibly small particles of gold, only billionths of a metre in diameter, uniformly suspended in a liquid. But how can gold – the material we all know as a solid, reflective, yellow metal – transform itself into a whole rainbow of different colours? The particles were too small to be visible through all instruments of observation available at the time, but Faraday was still convinced that the colours he saw were not simply the result of a chemical byproduct dissolved in the water. He rightfully believed that it was the gold itself, interacting mysteriously with the invisible electromagnetic forces, that produced the mesmerising effect he observed.

Faraday's gold colloids – some of which are still preserved to this day – are materials that, prior to the emergence of quantum physics, demonstrated the capacity of bodies to transcend their own boundaries: they showed that the reality of what we know as "matter" was much more elusive and complex than a collection of intrinsic properties. Today, we know that their surprising colours are the result of a quantum phenomenon known as "surface plasmon resonance". When metal particles are small enough, the electrons on their surface resonate with specific frequencies of light, absorbing some and reflecting others back into our eyes. The colour of these colloids is only observable if an immense number of nanometric particles resonate together, creating a fully delocalised optical effect.

Why the physical properties of colloids are relevant beyond the realm of science and how we can use them as a starting point to construct an alternative ontology of the body are the guiding questions of this essay. As did Faraday in the nineteenth century, I will adopt the approach of the experimental scientist: I will allow materials to guide us through the complexity of their own being, challenging the established boundaries between subjects and objects of knowledge. Rather than understanding the objects of scientific inquiry as simple small-scale "models" for larger-scale phenomena, we can begin to address them as autonomous and self-sustaining systems capable of generating meaning across different scalar dimensions. Faraday's colloids were, as historian of science Ryan Tweney called them, "epistemic artefacts"[1] – that is, not simply objects of study but active non-human participants in the process of knowledge. What can materials tell us about their ontologies? How do bodies answer the question of the production of their own reality?

What Is a Body?

By the expression "ontology of the body", I refer to our attempt to answer a seemingly elementary, albeit surprisingly elusive question: what is a body? This question can sound rather unusual. While we can ask the same question about souls, ghosts and other immaterial beings, bodies – by virtue of their materiality – "are" simply themselves: they are, as we understand it, the matter contained within their own surfaces. But although we usually think of bodies as inherently endowed with a self-evident reality, there are contexts in which attributing a stable reality to bodies becomes more challenging.

Many of the objects of contemporary science seem to escape any one-directional definition, emerging not as universally identifiable "things" but as networks of materials, practices, technologies and theories. From molecules to black holes, from viruses to DNA, many of the beings that science summons

1 Tweney, R. D. (2002). Epistemic Artifacts: Michael Faraday's Search for the Optical Effects of Gold. *Model-Based Reasoning. Science, Technology, Values* (L. Magnani & N. J. Nersessian Eds.). Springer, p. 287.

are culturally treated as self-evident realities, but they are not simply things we can see and touch. In the case of atoms, for instance, it's not so easy to tell the difference between an atom in itself and the models we use to understand it, or the technologies we need to represent it. Here, ontology (the question of what something "is") and epistemology (the question of how we can access the knowledge of that something) become somewhat inseparable: the identities of bodies and the processes we use to conceptualise them often become one and the same.

The question of ontology, however, is not strictly limited to the objects of science; instead, it becomes especially significant when the bodies we are speaking of encompass not only atoms and black holes but also political subjects. The ontological question "What is a body?" has been at the heart of feminist theory since its earliest days, starting with Simone de Beauvoir's proclamation that "one isn't born a woman".[2] However, understanding the essence of "being" a woman, without fully subscribing to the biological essentialisation of sex or accepting gender as a disembodied cultural construct, requires the elaboration of new ontologies and epistemologies of the body.

It should not be surprising, then, that science and feminism have often grappled with similar questions and employed similar tools to address them. Feminist philosophers of science have emphasised the importance of deconstructing nature as a passive object of knowledge, while also highlighting the materiality of the processes that contribute to the construction of scientific objects. Similarly, in contemporary feminisms, sex and gender are not understood as ontological givens but rather as the condensation of both material and cultural processes.

In her book *Bodies That Matter*, Judith Butler suggested that matter should be understood "not as a site or surface, but as a process of materialisation that stabilises over time to produce the effect of boundary, fixity, and

2 Beauvoir, S. de. (2015). *The Second Sex*. Vintage Classics.

surface".[3] This implies that matter does not exist independently of our cultural understanding; instead, it is constructed through a series of discursive practices. In the realm of science, for instance, Butler's statement could imply that atoms are not ahistorical, natural entities existing prior to the knowledge processes that made them observable; rather, they were "materialised" through the experiments and theories that led us to acknowledge their existence. Of course, it is important to recognise that this ontology of the body is inherently political, as it suggests that our knowledge of bodies can never be neutral or innocent.[4]

Philosopher and physicist Karen Barad famously built upon Butler's framework of materialisation to develop an ontology of the body grounded in the physical concept of entanglement. Drawing from Niels Bohr's quantum theory, they adopted the idea of "complementarity": the notion that quantum bodies assume the characteristics of either particles or waves not due to their predetermined nature but as a result of interacting with a specific measuring apparatus. Consequently, the quantum body becomes epistemologically and ontologically inseparable from the instruments and practices that materialise it within the scientist's observation. Here, Barad works at the boundary of the subatomic scale of quantum particles to produce a more general ontology that is translated into the political and social scales. "I don't want the reader to misunderstand and think that indeterminacy, or rather, the play of in/determinacies, is limited to the domain of the small," they write in the essay *What Is the Measure of Nothingness? Infinity, Virtuality, Justice*. "On the contrary, the play of indeterminacies is ontologically prior to notions of scale and, more generally, space and time."[5] Barad's concept of entanglement integrates Butler's theory of materialisation by emphasising the agency of matter. Rather than asserting that matter is solely the consolidation of

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3 Butler, J. (1993). *Bodies That Matter: On the Discursive Limits of "Sex"*. Routledge, p. 9.
4 The entanglement of knowledge and power was first conceptualised by Michel Foucault in *La Volonté de savoir: Histoire de la sexualité I* (Gallimard, 1976).
5 Barad, K. (2012). *What Is the Measure of Nothingness? Infinity, Virtuality, Justice*. Retrieved June 23, 2023, from https://infrasonica.org/en/wave-1/what-is-the-measure-of-nothingness

discursive practices, and thus passively determined by external forces, it allows for the possibility that matter possesses the autonomous capacity to generate meaning. Barad writes: "Matter is not a fixed essence; rather, matter is a substance in its intra-active becoming – not a thing but a doing; a congealing of agency."[6]

The issue with our old ontological paradigms of the body, especially in the context of feminist thinking, may be summarised in the tension between depth and surface: while essentialism leads us to believe that bodies are endowed with deep realities, constructivism suggests that this reality is the result of a purely immaterial, superficial effect. In mediating between essentialism and constructivism, Barad's framework of entanglement and complementarity points to the urgency for a *relational* ontology of the body: the idea that matter emerges as a result of processes of "intra-action". But *where* does this "intra-action" actually take place? Inside of material bodies, or in the invisible, immaterial ether that separates them? Is there any room left for a material space *between* surface and depth? What if this speculative space was the location where all materialisation processes actually take place?

Colloids, Interfaces and Scalar Phenomena

Colloids are suspensions of particles with sizes ranging from 1 nm to 1 μm dissolved in a fluid medium, and they are ubiquitous in our daily lives: from the milk in our fridge to the clouds in the sky, from liquid soap to our own blood. Our entire biological bodies could be understood as remarkably intricate colloidal systems, consisting of trillions of tiny biochemical particles dispersed in water. Colloids belong to the realm of "soft matter": they are neither solids nor liquids, and their behaviour cannot be easily reduced to the properties of the individual materials that comprise them.

6 Barad, K. (2007). *Meeting the Universe Halfway. Quantum Physics and the Entanglement of Matter and Meaning*. Duke University Press, p. 210.

The particles that constitute colloids are too large to be considered molecules but too small to behave like ordinary solid materials; often, this intermediate dimension – referred to as the "nanoscale" – gives rise to the emergence of unique physical properties. The key to understanding the behaviour of colloids is the concept of "complexity": each individual particle in a colloid interacts with its nearest neighbours, and, in turn, all particles in a colloidal system are interconnected, forming a vast, distributed network. Consequently, colloidal systems are highly sensitive and responsive to their surrounding environment. To provide an everyday example of this sensitivity, squeezing a few drops of lemon juice into a glass of milk leads to immediate coagulation. This is the outcome of a change in the surface charge of the colloidal protein particles in the milk: when the environment becomes acidic, the surface charge of the particles is neutralised, causing them to instantly clump together.

Colloidal systems are ontologically interesting because their properties often differ significantly from those of the same materials on the macroscopic scale. Faraday's gold colloids serve as a striking example, demonstrating that a particular material, such as gold, can undergo a complete transformation in behaviour when its particles reach a sufficiently small size. Similar to the coagulation of milk, this transformation of material properties is tied to what occurs on the *surface* of the particles comprising the colloid. The resonance of electrons on the *surface* of the minute gold particles generates their characteristic red colour, while the *surface* charge of protein particles dispersed in milk triggers a change in its consistency.

The term "surface", in its conventional sense, proves inadequate for fully encompassing the complexity of these material phenomena. When we delve into the behaviour of colloids, the "surface" we refer to extends far beyond a mere abstract and geometric boundary separating one entity from another. This "surface" is intrinsically material, perhaps even more so than the body it encloses. It constitutes a site of immense physicochemical complexity, hosting resonating quantum particles and electrostatically charged molecules. It can be touched, inhabited and transformed.

Throughout my work, I have frequently employed the term "interface" to address the irreducible materiality of surfaces.[7] The word "interface" encompasses various meanings. In contemporary usage, it mostly denotes the multitude of devices, both tangible and intangible, that grant us access to technology.[8] However, in the realm of chemistry and materials science, the term "interface" assumes a peculiar connotation. It refers to the region where two distinct phases of matter meet, giving rise to a third, different material state. What renders interfaces particularly significant in scientific inquiry is their capacity to profoundly influence the behaviour of materials, and not simply in the context of colloidal systems. Consider, for example, how water droplets change their shape depending on the nature of the surface they encounter. When deposited on plastic, they assume an almost perfectly spherical form, whereas they spread out entirely when deposited on glass. This behaviour is not driven by a change in the water's composition, but rather by a transformation of its deeply material *interface* with the outside world.

Differently from other, more conventional materials, colloidal systems bring interfaces to the forefront due to the specific, and often overlooked, relationship between *scale* and *surface*. While we typically perceive scale as neutral, shifting the scale of a material system has profound implications for its behaviour. Following a geometrical principle known as the "square–cube law", in a system with constant total volume, the surface exponentially increases as the size of objects decreases. Consequently, the same quantity of matter will possess a significantly larger surface area when divided into smaller parts, just like a large rock holds much less surface area than a bunch of sand. This principle elucidates why colloidal systems, composed of trillions of particles on the scale of only billionths of a metre, possess an exponentially greater amount of "interfacial matter" compared to any macroscopic system. In colloids such as Faraday's bright red gold solutions, it could be argued that the properties of the interface become *more real* than any inherent property of matter.

7 Tripaldi, L. (2022). *Parallel Minds: Discovering the Intelligence of Materials*. Urbanomic.
8 For a more in-depth philosophical discussion of the concept of "interface", see: Hookway, B. (2014). *Interface*. MIT Press, Cambridge.

This specific relationship to the interface renders colloids truly "queer" material systems. Their "queerness" lies in the challenge they present to our conventional understanding of reality as an inherent property of bodies, revealing that it can be generated through a vast, delocalised network of interfacial relationships.[9] Beyond the metaphor, interfaces possess significant epistemological, ontological and political implications as the very sites where the reality of bodies is constructed. The history of the pregnancy test, a widespread and complex material technology based on colloidal materials, demonstrates the materialising power of interfaces within the context of the gendered body.

The Pregnancy Test: A More-than-Human History

Although they may sound like very unusual and uncommon materials, most of us have encountered gold colloids on multiple occasions in our lives. In fact, they play a crucial role in a significant everyday technology: the home pregnancy test. Gold nanoparticles serve as both sensors and signals in pregnancy test sticks. The faint pink lines that appear on the test are made visible through the same phenomenon of "surface plasmon resonance" that gave Faraday's gold colloids their vibrant red colour. In pregnancy tests, gold colloids undergo a biotechnological process to render them sensitive to a specific protein, hCG, which is present in the urine of pregnant women. During this process, the surface of colloid particles is chemically transformed, enabling them to bind to hCG and subsequently adhere to the porous substrate of the test stick.

While we are accustomed to regarding pregnancy as a self-evident, unquestionable reality, we often overlook how this reality is determined by a complex network of cultural and technological practices. These, of course, possess deep political significance. Instead of being a purely ahistorical,

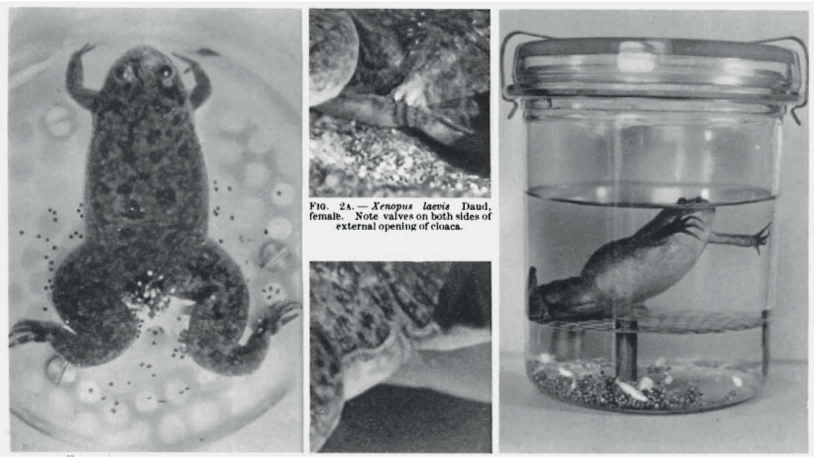
9 Karen Barad has used the term "queer" in this broader philosophical meaning in the 2011 article "Nature's Queer Performativity" (*Qui Parle: Critical Humanities and Social Sciences 19*(2), p. 125).

unchanging truth, the "fact" of being pregnant has carried different meanings for women throughout history. Feminist historian of medicine Barbara Duden has demonstrated that, before the rise of modern medicine, the social and political reality of pregnancy in the western world was almost entirely reliant on women's personal and private self-perception.[10] The subjective experience of "quickening" – the initial movements felt by the mother from the baby in the womb – determined the reality of the pregnant body. However, with the advent of contemporary medical practices, the reality of pregnancy became entirely externalised and transformed into an "objective" truth, determined solely through the eyes of predominantly male physicians.

Precisely because they are interfaces capable of materialising the political reality of the gendered body, pregnancy tests are ambiguous technologies. Throughout their history, their medical objectivity has been used as a tool to deprive women of their reproductive autonomy and self-determination, exerting a new level of biopolitical surveillance. On the other hand, home pregnancy tests have also been a valuable ally for women's self-determination, providing access to early abortions and empowering women to make informed choices regarding their reproductive future.

In this context, pregnancy serves as an illuminating example of how the ontological question "What is a body?" gains political significance. The pregnancy test functions as the interface where the reality of the pregnant body is constructed. This does not imply that pregnancies are fabricated fictions or immaterial abstractions; they are undeniably material. However, akin to the manifestation of the red colour in gold colloids, this materialisation occurs through the interplay of a vast network of bodies operating across diverse scales, ranging from the molecular to the political. The use of colloidal materials in contemporary pregnancy tests is not coincidental. The extensive and sensitive interface of gold colloids acts as a medium capable of translating the invisible molecular signals of the body into a visible reality.

10 Duden, B. (1993). *Disembodying Women: Perspectives on Pregnancy and the Unborn*. Harvard University Press.



Images from a 1938 article in the British Medical Journal by Edward R. Elkan that helped popularise the Xenopus pregnancy test among physicians. Source: Wikipedia. CC BY-SA 4.0.

Pregnancy tests, therefore, unveil the ontological, epistemological and political power of the interface. They also demonstrate that the "reality" of our human bodies often emerges from an assemblage of other bodies, many of which are radically non-human. Prior to contemporary pregnancy tests, up until the 1950s, the most common methods for pregnancy determination involved the utilisation of animals as "living interfaces". Initially, female rabbits were the primary subjects: they were injected with women's urine and subsequently dissected to examine their ovaries. It is from this practice that the English expression "the rabbit died", commonly used to indicate an unexpected pregnancy, originated. However, the South African frog Xenopus laevis soon became the most popular animal for pregnancy testing.[11] When injected with the urine of a pregnant woman, female Xenopus toads promptly began laying eggs. Following World War II, medical laboratories worldwide began exporting thousands of frogs, captured in the African rainforest, to serve as living test subjects. Unfortunately, numerous frogs managed to escape, leading to disastrous and enduring ecological consequences for several local ecosystems.

11 A detailed history of the use of Xenopus laevis in pregnancy testing can be found in Denise Lynn's 2022 article "World's Oddest Toads: Xenopus Pregnancy Tests and Animal Commodities" (*Capitalism Nature Socialism 33*(2), pp. 103–119).

The forgotten non-human history of the pregnancy test further illustrates how the intricate materiality of interfaces is frequently overlooked and disregarded. In answering the question “What is a body?”, we often fail to recognise that the reality of our bodies is shaped by a historical, cultural and material process that encompasses both human and non-human actors. If even the seemingly natural occurrence of pregnancy attains biological, social and political significance solely through the materialising influence of interfaces, then the reappropriation of interfaces is the only possible way to become active participants in the construction of the political realities of our own bodies.

Reclaiming Interfaces

In the 1960s, the methods for pregnancy testing had advanced beyond the need for frogs. Instead, a more technologically sophisticated approach was adopted, employing red blood cells extracted from sheep and antibodies obtained from rabbits’ blood to detect the presence of hCG in women’s urine. In these “in-vitro” tests, urine was introduced into a solution containing the modified sheep’s blood cells. If hCG was present, the blood cells would coagulate, resulting in the formation of a discernible, dark red ring at the base of the test tube.

Despite the procedure becoming relatively straightforward, pregnancy tests were still exclusively conducted in medical laboratories. The notion of enabling women to conduct their own tests at home was deemed absurd and even socially dangerous. The first prototype for a home pregnancy test was proposed in 1967 by designer Margaret Crane while she was working at the pharmaceutical company Organon. She assembled it herself using a plexiglass paperclip box and a small mirror. Initially, her idea was wholly disregarded by her colleagues, who were concerned about the potential political repercussions and harboured scepticism regarding women’s capacity to conduct the test autonomously, without any assistance from a man. Thanks to her persistence, however, the first home pregnancy test was eventually commercialised in

1978 under the name "Answer" and acclaimed as a "private little revolution" for women's rights.[12]

The advent of the home pregnancy test serves as an exemplary narrative for the re-appropriation of the interface as a political, epistemological and ontological space. Previously, the reality of the pregnant body was exclusively determined through a process in which women had no active participation. However, the home pregnancy test restored agency to women, enabling them to assert their self-determination and knowledge of their own reality. Through the historical lens of this seemingly unassuming technology, the question "What is a body?" reveals itself to be complex, as it involves a vast network of materials, cultural representations and scalar effects.

Similar to colloidal particles of gold, the reality of our own bodies also emerges from resonating surfaces, encompassing an unconventional amalgamation of materials, histories, times and spaces. The notion of "micropolitics" is often used to refer to how power struggles in contemporary society are played out at different scales, from the private lives of individuals to the demographic scale of nations and communities. In the context of contemporary technologies of gender, this micropolitical scale becomes even smaller, extending to the non-human scale of atoms, molecules and invisible particles. How do these non-human actants participate in our politics and ontologies? How can their effects cut across so many different scalar dimensions? With their extensive and dynamic material interfaces, colloids can assist in delineating the boundaries of a new feminist ontology of the body capable of shifting across scales. Technological devices such as the pregnancy test serve as the sites where the reality of the gendered body is constructed: as a result, they are simultaneously instruments of control and territories of struggle that, if reclaimed, grant us the opportunity to redefine the frameworks through which our bodies are represented and disciplined.

12 The cultural history and anthropology of the home pregnancy test in contemporary western society is illustrated in Sarah A. Leavitt's 2016 article "'A Private Little Revolution': The Home Pregnancy Test in American Culture" (*Bulletin of the History of Medicine 80*(2), pp. 317–345).

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