The role of the imagination in the development of artificial hearts: towards an understanding of embodied and shared imagination

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This article explores the role of imagination in the development of circulatory assistant devices, technologies known as artificial hearts in contemporary biomedicine. Ethnographic data suggests an imagination that is characterised by material and bodily engagement. Feminist theorists who propose new materialisms and the anthropology of science and technology provide a basis from which we can be attentive to practices in the enactment of new devices/bodies. These are theoretical approaches that foreground the participation of different entities and beings in the process of creating and developing medical technologies. A focus on practices enables us to observe how things can impact and contribute to the shape of their own forms, which implies that in addition to being embodied, the imaginative process is also shared. The article (re)situates the imagination, which is commonly rejected or sidelined in purified modern scientific output, highlighting material engagement as an essential element in the process of technological development. The task of describing and claiming an embodied imagination, one that is shared and not reduced to human intentionality, will establish a conversation with different approaches to and understandings of the creative process.

**Keywords**: Imagination, Creative process, Responsible innovation, Body and embodiment.
The challenge of approaching a multifaceted theme and the claim for an understanding of the imagination based on ethnographic data

The painter Edgar Degas is once supposed to have remarked to Stéphane Mallarmé: “I have a wonderful idea for a poem but I can’t seem to work it out,” whereupon Mallarmé replied: “My dear Edgar, poems are not made with ideas, they are made with words” (Sennett 2009:119).

The theme of imagination and innovation has already yielded many verses, analyses, books and motivational lectures in fields as diverse as art, science and technology. There are also multiple approaches and attempts to create methods to ‘unveil’ or abstract possible logics, universal models capable of summarising what is considered the inventive process responsible for bringing things into existence, some attributing sociological reasons, referring to the conditions of production, others valuing individual geniuses, psychological profiles, metaphysical explanations, etc. Such models seem to be interested in the nature of the creative process, which means that they almost always ask questions about where ideas come from. The task before us here is less about interrogating where they come from, and more how they gain existence and materiality.

Based on research conducted with a network of circulatory assistance devices and researchers engaged in the production of these cardiac technologies – whose purpose is to mitigate the high rate of deaths due to heart failure – the effort is to retrieve ethnographic scenes that enable us to develop an understanding of shared, embodied imagination.

While developing my ethnographic research, I navigated amidst some distinct enclosures: bioengineering laboratories linked to public universities, a laboratory for experimental surgeries on animals, and surgical centres intended for interventions in human patients, located in a recognised public hospital in the city of São Paulo. In all of them I witnessed scenes that referred to the action of the imagination, to the inventive dimension present in the processes of the development and improvement of artefacts. They were almost always occurrences and aspects that vanished from the records of scientific and technological production. I refer above all to unforeseen events, intercurrences, accidental actions that were present in the development process – from the bench tests, the so-called in vitro tests, which the initial prototypes went through, that is, the first forms of these devices took shape;
followed by the inventive action that took place in the trajectories of the artefacts, the deviations in *in vivo* tests accountable for transforming the material forms of the artefacts in the surgeries performed in pigs; and even in their implantation in humans, a moment in which a certain stability was foreseen, which did not always materialise.

The imagination referred to, for example, the effectiveness of a specific wing format\(^1\), the assessment of which showed its evident superiority in relation to other designs; the inadequacy of a device fitting, revealed while being handled by a surgeon in an attempt to implant it with native organs, a fact that demanded its reshaping; the running time that revealed the non-conformity of the materials, which wore out prematurely (considering the resistance required by cardiac function and conditions). Each of these situations, respectively witnessed in *in vitro* tests, *in vivo* tests, and in human evaluation – the three stages required for developing artificial heart validation – reveal the inventive relationships emerging in the material engagement that shape technologies. These are actions that elucidate the shared character of the creative process, fundamental to imaginative efforts in the search for new solutions, for alternative strategies in the face of the limitations posed by current technologies.

The most common, trivial situations, even tedious procedures\(^2\), participate in the production of medical technologies and are as fundamental as the far-fetched ideas – maybe more so if we consider that the extravagant concepts operate mainly as a marketing strategy, to justify and strengthen the targeting of resources for the research from which these devices derive. Creating, innovating and the birth of daring, original, alternative solutions demand a projective imaginative effort, together with a lot of material engagement and negotiation between the most diverse actors and entities. It is in the unfolding hours of a device ‘running’ persistently on a bench, put into effect in a body (human or non-human) that things happen.

\(^1\) The wing is a type of blade attached to the pump rotor that pushes and drives the blood forward when it rotates, similar to the blades of fans, helicopters, and blenders, for example.

\(^2\) Here, I am referring to the first stages of bench-top procedures to which I was sometimes not even invited, because, according to one of the bioengineering researchers, nothing interesting happened during them. Unlike *in vivo* tests, for example, which mobilised a team of surgeons and nurses, in addition to the presence of pigs, which made them expensive and exciting procedures. Despite the ‘sacrifice’ of the animal, which necessarily ended the procedure dead – since euthanasia is an ethical requirement – the character was one of manipulating life, recognising that a life was at stake. These were procedures that required enormous preparation, advance scheduling and that fulfilled the role of forming alliances between bioengineers and medical teams. Bench tests operated more along the lines of creating intimacy between bioengineers and the devices themselves. Following these initial, more reserved assessments, the engineers and devices seemed safer, more prepared for *in vivo* tests and for more public performances.
These are the relationships that give life to the devices, that (trans)form them until they have encountered their best (provisory) forms. And it is these transformations that provide clues to the shared, embodied creative process that is developed here.

It is not only experimental scientific and technological production, engaged in finding new answers or ways of improving mechanisms that still present a certain instability or precariousness, which is interested in the imagination and the projection of possible, alternative futures.

The anthropological approach to imagination has gained interest and relevance, whether concerning discussions on the challenges posed by socio-environmental crises – like the debate around the Anthropocene, which places an urgency on imagining and constructing new modes of existence (Krenak 2020; Kopenawa & Albert 2013; Haraway 2016; Danowski & Viveiros de Castro 2017;) – or in theoretical efforts interested in reflecting on change and the dynamic, creative processes of cultures (Wagner 1981). The theme has burgeoned and presented yields in different fields and problematics, proving to be pertinent and challenging.

The proposed reflection is limited to the challenges related to biotechnological development and navigates among: 1. the proposition of a fundamental embodied imagination for the improvement of artificial hearts, which leads us to reflections surrounding the body, corporeality and materiality; 2. diverse understandings of the creative process, including a dialogue with the field of arts and techno-scientific production; 3. a brief archaeology of the trajectory of the imagination of ‘heartless’ bodies, present in different strategies for replacing cardiac function in the history of biomedicine; and 4. a broadening of the reach of imagination, including a cosmopolitical dimension, aimed at understanding the worldviews and conditions of technological production that inform the Brazilian context.

In the narrative that unfolds the proposition of a specific way of understanding imagination, the task of describing and claiming an embodied imagination, one that is shared

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3 The problematic of imagination proved to be increasingly relevant in the process of writing my thesis, in which, however, it was presented without due depth. Interest in the topic found reverberation in the work of research colleagues, including André Bailão and Joana Cabral de Oliveira. In addition to our debates and dialogues within the scope of the Laboratório de Estudos Pós-disciplinares (LAPOD) [Laboratory of Post-Disciplinary Studies], our common interest resulted in the working group on the Imagination and Knowledge production, held at the 18th IUAES (2018), in partnership with Cristián Simonetti. I am very grateful for the partnerships and the instigating provocations, in particular, Joana Cabral de Oliveira’s attentive reading of a version of the article and for her contributions.
and not reduced to human intentionality, leads to a dialogue with consolidated and validated understandings of the creative process in other fields.

Dialogue with other discussions on the creation process allow us to problematise the limits of an approach based on the image, on the understanding of imagination as projection or visualisation, or imagination as outlined for the future, for something that does not exist within a linear understanding of time. The centrality of the image, a certain ‘intuitive’ character of the imagination, the boundaries between cognitive and material aspects are investigated using formulations of the creative process in the arts, as well as inventor Nikola Tesla’s discussions on his own invention processes.

In addition to exploring the division between the manual and the cognitive, I recall the history of speculation on the possibilities of maintaining a living body without its native heart, which, as I argue here, enabled the emergence of the imagination of new bodies.

Finally, the scientific imagination gains a new qualification when investigated as key to the conditions of experimental projects and innovation, given the local specificities when facing a production considered both central and exemplary, which designates a ‘marginal’ position for Brazil. Addressing the conditions of production, which involves recognising the mercantile logic in which scientific and technological production is inserted, calls into question the imagination itself as property.4

The potential of imagination in the fields of science, technology and biomedicine contains intrinsic dangers that are subject to apprehension. The development of atomic bombs is emblematic of this fear. Resuming Hannah Arendt’s argument in The Human Condition, Richard Sennett (2009) argues that the fear of inventing destructive materials in Western culture goes back to the Greek myth of Pandora. Fears associated with the Pandoran crises that place us at risk of inflicting extensive and irreparable damage on ourselves, on other

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4 As Magda dos Santos Ribeiro indicated when reading this text, considering that there is a fundamental relationship between image and form, idea and image, that I attempt to argue later, we should consider that the idea of a thing, imagination itself, can be treated in terms of ownership, and not of imagination, evincing a primary capture, that is, the place of imagination in science can be captured by the logic of authorship, of property rights, which initially limits imagination. From this comes the recognition or a certain intensification of the perception that capitalist and neoliberal mechanisms place techno-scientific creativity in crisis, compromising the innovative capacity itself. I had the opportunity to present and debate this text within the scope of the Laboratório de Antropologia das Controvérsias Sociotécnicas (LACS) [Laboratory of Anthropology of Socio-Technical Controversies], at the Federal University of Minas Gerais (UFMG), in February 2021. I am grateful for the professor’s careful reading and record this thought-provoking note here, since it enables the opening of paths that I can explore in the future.
species, to the planet, refers to the belief that, in some senses, there are no limits to scientific and technological production – an insatiable, risky curiosity, added to the seduction of the discourse of technical progress and its infinite possibilities. An example of this belief is explicitly made in diary entries by Robert Oppenheimer, director of the Los Alamos project, responsible for the first weapon of mass destruction: ‘When you see something that is technically sweet, you go ahead and do it, and you argue about what to do about it only after you have had your technical success’ (Sennett 2009:2). Should the scientific imagination be unrestricted, unlimited, unregulated? In the final part of the argument, looking at the Brazilian scenario, the task is to raise questions about what it means to claim imaginative freedom in techno-science.

In general terms, the intention is to approach imagination as a practice, as a shared, embodied process, emphasising the procedural character of the development and improvement of biomedical artefacts. These elaborations dialogue with feminist theories interested in resituating materiality, known as new materialisms (Pitts-Taylor 2016), object-oriented (Pollock 2015) and practice-oriented feminism (praxiography, Mol 1999). These are all propositions interested in highlighting the inseparability of matter and meanings. In this sense, it is about exploring how a new materialist approach can displace dualist structures, enabling the conceptualisation of the passage of flows of nature and culture, matter and mind (Barad 2003).

This effort looks at the way things are done, at the processes that lead to unexpected situations, to new arrangements, highlighting the participation of different actors⁵, denaturalising the centrality of the human (rationality) and recognising a multiplicity of actions that impose themselves on the creative process (sometimes silently).

Illuminating imaginative processes for the emergence of new bodies/artefacts, highlighting their procedural character, does not imply thinking about matter as an illusion, or that entanglements are pure flux and becoming. Looking at the processes enables us to pay attention to the efforts to stabilise matter. Looking at materiality becomes central, prompting an examination of the procedures for maintaining the arrangements, the support of the

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⁵For an in-depth understanding and characterisation of the actors in the field of circulatory assistance devices production, see Marini (2019b).
intertwining of matter and meaning. Artefacts are important for sustaining societies; non-humans are a condition of the possibility for the formation of human societies (Latour 1991).

The purpose is to raise suspicion of the understanding that there is a given idea, which is born ready, something that emerges as an image that later gains materiality. Being attentive to the process, problematising linear causalities, invites us to consider development as a producer/creator, and not merely a transformer or translator. Concrete engagement with the world and with things, from which new artefacts arise, is not merely a process of improving an idea pre-formulated mentally. We need to consider that the mental and material processes are intertwined, there is no precedence of one in relation to the other. Thus, if the stages and developments are not isolated from the process, anteriority disappears.

This concerns viewing ‘doing’ as a modality of weaving, considering it a formative (skilled) practice that attenuates and calls into question the division between artefacts and organisms, things built and alive, made and growing (Ingold 2000). Shattering the centrality of ideas, of images, and the notion of something that operates as a mental projection that is born as determined, allows us to highlight the commitment necessary for creation, which, far from occurring through inspiration, is marked by ethereal, magical or transcendental processes, demanding intense and prolonged effort, a tireless doing and redoing.

**Embodied imagination**

The proposition of an embodied imagination stems from a twofold interest in the body: as related to embodiment and phenomenological understandings of bodily experience; and pertinent to the theoretical developments associated with new materialisms, the centrality of the material and practices in techno-scientific development. These are discussions from which new investigative possibilities arise in light of the crisis of the dualistic conception of human beings, in addition to a certain exhaustion of its self-contained limits (Haraway 1991). These reflections are bridges for the fabulation (Haraway 2016) of new forms of existence and political possibilities that include diversity and problematise the hierarchy of knowledge.

Faced with new phenomena, new political, epistemological and methodological sensitivities emerge that lead us to reconsider matter, the material, reconciling spheres that were forcibly and insistently separated in modernity.
The imagination of artificial hearts enables the emergence of new bodies, compositions sustained by the participation of diverse subjects and entities, which, in light of the exhaustion of purification mechanisms, make ontological separations between things, people, humans, and non-humans unsustainable (Latour 1991, 1993), that is, the new bodies, the new entities that emerge in the relationship with artificial hearts correspond to an assembly, whose ontological definitions become unstable as they become indistinguishable from output (Latour 1987, 1994).

Artificial hearts force us to recognise the implosion of dualistic boundaries and rigidly determined ontological definitions, not only the dualism between body and mind, but also the prolific dichotomies between organism and machine, public and private, nature and culture, animal and human, men and women, primitive and civilised, which are all being ‘cannibalised’ or ‘techno-digested’, as highlighted by Donna Haraway (1991). The imagination and the institution of new bodies call into question rationalism and anthropocentrism as exclusive pillars of the production of knowledge and technologies.

The rupture operated by Descartes enabled the emergence of the ‘biotechnological body’, the machine body capable of being manipulated, by making matter ontologically different from the soul. The biotechnological body turned against the body/spirit duality, making it a problematic on the emergence of post-human and cyborg bodies, thus, what instituted modern science and medicine is also what causes its remaking.

It is precisely in dealing with the limits of Cartesian separation in the face of the emergence of apparatuses that allow new access to materiality that Donna Haraway (1991) proposes the figure of the cyborg. This intellectual strategy enables us to explore the crossing of frontiers, approaching the intimate connection between technology and the body, which occurs in the creation of chimeras – composite entities beyond purist understandings, romanticised visions of the self/human considered pure, natural, inviolable.

The centrality of the body and materiality among feminist theorists corresponds to the reconciliation of matter, following the rupture resulting from the process of moving away from biological determinisms and reductionist explanations – since the entire modern

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6 Transformations in science and biomedicine are related to two central aspects: the failure of dualisms, which includes the dualism between science/biomedicine and society, implying the overthrow of the idea of scientific neutrality; and the crisis of representation, which leads to the confrontation of materiality and socio-material practices from which new bodies emerge.
medical-scientific enterprise located difference in the material body. We cannot speak of a biological body without science, nor of science without a biological body – and the circulation of power is deeply implicated in both. Replacing materiality, however, implies recognising that there is no universal biological matter or body, that is, there can be no generic, decontextualised body or matter (Roy & Subramaniam 2016). This is an invitation to new materialisms, arising from the observation that we experience unprecedented manipulations of matter and life – at least in the realm of biomedicine and techno-science.

Looking at practice and materiality enables us to see the mixture of subjects and their co-production. If, on the one hand, practices reinforce and highlight the pragmatism of certain divisions that enable biomedicine and science to produce things, on the other, it also allows us to highlight the limits of such divisions, the moments in which the ‘purification machine’ of modernity is obstructed, to dialogue with actor-network theory and Latourian understanding of the failure of the modern division between nature and culture. The epistemological and political reaction to these limits turns to the way objects are performed, demonstrating that there is no reality prior to their ordering through practices (Mol 1999).

Ethnographic data on the production of artificial hearts, resulting from the doctoral research I developed, question an assumed division between the projection of something and its development – which in certain approaches is characteristic of the very separation between engineering and technology. This questions the understanding that in the contemporary technological process, the rationalisation of processes has the effect of separating the creative process from the context of physical engagement between the worker and the materials (Ingold 2000)7.

In order to evoke materiality in the understanding of a shared, embodied imagination, what follows is a more detail situation that I experienced during ethnographic research, when the prototype device was implanted in pigs in the context of in vivo tests, after having passed the in vitro tests.

7 ‘[… ] The image of the artisan, immersed with the whole of his being in a sensuous engagement with the material, was gradually supplanted by that of the operative whose job it is to set in motion an exterior system of productive forces, according to principles of mechanical functioning that are entirely indifferent to particular human aptitudes and sensibilities. […] The effect of this rationalisation, however, is to remove the creative part of making from the context of physical engagement between workman and material, and to place it antecedent to this engagement in the form of an intellectual process of design. A thoroughgoing distinction is thus introduced between the design of things and their construction. The thing, we say, is virtually ‘conceived’ in advance of its realisation in practice.’ (Ingold 2000:295).
When trying to connect the device’s cannula to the animal’s organ, the surgeon had difficulty closing the fitting piece that ensured the entities were intimately connected. The device contained two tubes, one inlet and one outlet, which were meant to be implanted in the aorta and in the lower part of the organ (the ventricle apex). Once achieved, the blood was diverted and the device performed the function of distributing it throughout the body. To establish fixation, one of the tubes was sewn together and the other was fitted to the aorta, both using a metal ring, as described by one of the bioengineering researchers, Apollo⁸:

Both connections, inlet and outlet, are cylinders that are attached to the pump body, and they differ in diameter and positioning. The pump inlet has a larger diameter with specific details (grooves and bumps) to connect to the suture ring, which in turn is attached to the heart muscle. This connection is achieved by means of a lock, a type of elastic ring. This lock can also be described as a rigid ring-shaped steel wire. An opening in this ring allows us to manipulate its diameter so that it can be properly positioned in the grooves and bumps to effectively lock the pump inlet in the suture ring. The suture ring is a metal ring that has cloth made of biocompatible material on the outside diameter to fix it to the heart muscle.

Fixing the parts on the ring required pressing two pins at the same time. Faced with the impossibility of performing this action quickly – a necessity for the best course of a surgical procedure, which must combine precision, ease and agility to prevent loss of time and complications that require undoing and redoing actions – the surgeon complained about the structure of the socket, without hiding his irritation from the bioengineers who were present. Attempts to hold the ring and press the pins proved to be complicated, and there seemed to be no appropriate surgical pliers, which possibly stemmed from the fact that engineers and surgeons used different instruments in their tasks. The surgical instrument was developed and adapted to the conditions and needs of surgical interventions. Given the difficulty, it was not feasible to fix a device with that fitting, because it slipped, and there were no tools to grasp it safely and manipulate it with precision – making it difficult to handle an artefact composed of rigid materials, distinct from flesh and the physiological structures that implied new forms of relationality. In addition to difficulties in the coupling, the piece did not seem to offer security, since it could come loose from the cannula attached to the aorta due to the

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⁸The pseudonyms adopted here follow the logic proposed in my doctoral thesis, in which the names of Greek heroes and gods were used. It is a witty strategy that suggests a certain archetypal homology between the characters, providing indications of the relationship constructed with the bioengineering and cardiology interlocutors.
continuous movement of the organ, which could lead to a serious accident after implantation, with the chest already closed and no direct access to the device. After evaluating the episode, the engineer responsible for its development, Orestes, commented:

It turns out that this ‘quick fit’ system had a problem with blood leakage and it was also very difficult for the surgeon to secure it. This was an idea by the cardiologist who created the project and it had worked well in the tests, but at the time, you know how it is… So, we changed this fitting system to a threaded one, something simple, like that used in domestic plumbing. This system worked well, it was easier for the surgeon and there was no leakage problem\(^9\).

Although agility is a necessary quality in surgical procedures, it is important to demystify the rush routinely represented in films, typical of popular media repertoires that characterise surgical situations as distressing moments of extreme agitation\(^10\). More than haste, precision is the most valued attitude in in vivo tests that simulate surgical situations. The texture and viscosity of the blood interfered with handling agility, producing a distinct temporality. In the in vitro tests, the materials did not seem to require such agility, or rather, they seemed to tolerate certain lapses or adjustments throughout the procedures, which were almost always longer, not characterised by celerity, but by functional relations in view of the extended duration of the tests.

Thus, temporality and material conditions produced different relationships in in vitro and in vivo tests. In the former, there is no inconstancy, variability caused by the movement of organic structures and slippery textures. The bench is configured as a simplified model and, therefore, a facilitator. The task of handling the ‘same’ fitting structure can differ in each situation.

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\(^9\) Leakage was not only related to the type of fitting, but also in the relation between the cannula and the blood. Cannula permeability is directly related to blood viscosity, that is, cannulas only become impermeable when the patient’s blood is not anticoagulated. This is not the case in surgical interventions due to the risks of clot formation. The problem of reduced blood viscosity which interfered with leakage through the cannula was solved by applying a layer of material on the outside of the cannula, making it waterproof but less flexible.

\(^10\) During the dozen or so procedures that I followed – surgeries performed on pigs and on human patients – there were rare situations that appeared to get out of control, causing nervous or agitated reactions. Overall, the surgeries were performed according to a script, even though moments of greater tension formed part of the script.
With the performative character of practices (Mol 1999), what is evident in this scene is that a device can act in different ways in different ecologies. The designed fitting established different relations in each of the situations. There is an ecology of practices specific to each of the tests. It is in this sense that Ingold (2000) suggests wagering on an ecological approach to understand the generation and dynamics of skills development, considering them to be techniques that are cultivated, incorporated into the organism through practice, which are not characterised as human attributes, but form part of the intertwining between bodies and environments – a necessary encounter for the realisation of skills.

The relationship that later evolved into a new device shape involved the more or less engaged participation of the surgeon’s body11, the artificial heart, the engineers who had developed it and who were asked to deal with the difficulty of handling the assemblage, as well as the pig itself, characterised by the structures of its heart. The (complicated12) involvement established between the actors present in the scene elicited the need to seek new shapes, another fitting mechanism. What happened was a set of material relationships that differed in the bench and animal tests, such that the pump fitting acted in different ways in the different ecologies of practices. It was only in the midst of experimental surgeries performed13 on pigs that the need to (re)create the device was revealed. The need for a new fitting structure between them was invented in the context of the material intertwining of the pig’s native organ and the mechanical heart. Based on the inadequacy of that encounter, a new form was instituted. Although the fitting ring was not the focus of the test assessment,

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11 For an in-depth understanding of the role of the surgeon’s hands/body and their techno-ritualistic effectiveness, see Marini (2019b).

12 Or *co-implicada* [lit. co-implicated and/or com-implicated], as suggested by the brilliant pun formulated by Joana Cabral de Oliveira (2020). In the context of her ethnography, the term refers to the relationships established with a group of academic researchers (which included herself) who worked in an Indigenous land, where she conducted her research. The complication lies not only in her position as a researcher in the field, but also in the sophisticated methodological strategy she uses, which embroils the classic anthropological divisions between us and them, sustaining them in a differentiation typical of the Wajápi language, between an inclusive we and an exclusive we.

13 The suggestion that surgeries can be understood as performances in the sense of theatrical performances was developed and described in Marini (2019b). In surgical scenes, the actions are a performance in the sense of being scripted; however, the performative character also refers to the work of Annemarie Mol (1999) and her proposal that the theatrical metaphor better serves what occurs in a hospital than the construction metaphor, that is, considering that things and relationships are performed concerns not only the dramatic performance of actions guided by a script of acts and relationships, but also articulates the central proposition of Mol’s work concerning the way in which diseases are ‘made’. In the same manner that Mol seeks to distance herself from a connotation of performance as representation, a falsification of reality or masking through acting, here the purpose is to treat performance as an act that produces reality.
which was intended to certify the haemodynamic efficacy of the pump in ensuring body perfusion, its performance posed challenges and instigated changes to the very shape of the device.

During a previous implantation procedure of the device, the same surgeon faced difficulties in fitting it. On that occasion he complained about the pig’s aorta, which he described as smaller than the average human aorta. It was as if the pig and its physiological structures were not acting well as a human substitute or animal model\textsuperscript{14} in that situation. Its invisible, unproblematic actuation was apparently not achieved. By imposing difficulties, the pig’s aorta acted unpredictably, driving the progression of the surgery. In the following procedure, performed on a larger pig, whose aorta consequently had larger dimensions, the same difficulty in fitting was experienced again.

The relational challenges that presented themselves with the device’s coupling mechanism had previously been imagined in terms of an active anatomy, one that is distinct and poses challenges. Subsequently, the inability of an agile fitting was attributed to the device, whose open, more unstable form was apt for (re)invention. There are limits to the possibilities of reconfiguring pig anatomy as an ideal substitute for human anatomy.

The ‘embodied imagination’ seeks to illuminate bodily attributes, the material dimension put into practices, characteristic of the involvement between different actors, extrapolating the understanding of imagination as a cognitive ability, in the sense of a mental disposition, that is, an ability to envision solutions for improving technologies under development.

The sphere of artificial heart production is composed of several imaginations, which operate as a motor in the invention of these devices, that is, as a constitutive force, in the sense that it is this that composes the search for new solutions, through practices of improvement, through which the devices and innovations emerge.

In general terms, I consider that imagination in this field refers to the search for new answers regarding challenges emerging from technological development, that is, the attempt to find solutions in the face of limitations or undesirable interactions that devices present when implanted. The engagement between materials, devices, human and non-human bodies

\textsuperscript{14} Marini (2019b).
in the validation practices of medical technologies throughout the phases of their development – *in vitro, in vivo* and human evaluation – leads to unexpected interactions, unforeseen reactions, relationships that demand adjustments, that transform the devices, that alter their shapes. Everything happens as if the embodied imagination were an imposition of the devices themselves, of the human and non-human actors in their interaction, in situations in which these bodies are perceived, transforming the original projects and projections.

Imagination is fundamental for idealisation, for the formulation of problems, for the search for solutions, for projecting futures. However, it is necessary to consider an understanding of the creative process that is inscribed in manual work, in dealing with materials, with animals, etc., thus characterising it as an embodied imagination that is shared among different actors. It is not a purely cognitive or mental activity, unless we consider the mind as ‘a “leaky organ” that refuses to be confined within the skull but shamelessly mingles with the body and the world in the conduct of its operations’ (Clark 1997, cited in Ingold 2001:143).

If the intention is to expand the notion of brain beyond the understanding of a human organ – since the purpose is to account for a collaborative, material creative process that escapes rationality, action and purely anthropocentric logic – it is convenient to resort to the propositions of the philosopher Emanuele Coccia, in the interest of recalling and giving due value to the mind and rationality of plants. In this sense, if we expand the understanding of knowledge and thought in a direction contrary to Aristotelianism, as suggested by Coccia, the possibility of achieving a more than human, non-anatomical definition opens up. In his elaboration, the brain is not a human organ, it is not even an organ, but a segment of matter that holds knowledge and learning. Thus, he proposes ‘we do not want to make the intellect a separate organ, but to make it coincide with matter’ (Coccia 2018:107).

According to Coccia, plants express an absolute intimacy between subject, matter, and imagination. In his discussions, the images are related to the forms in the world. Although plants do not have eyes or ears that allow them to distinguish the forms of the world, they make the world: ‘The plant is nothing if not a transducer, one that transforms the biological fact of the living being into an aesthetic problem and makes of these problems a question of life and death.’ (Coccia 2018:13).
Plants don’t have hands with which to shape the world, and yet it would be hard to find more capable agents when it comes to the construction of forms. Plants are not only the most subtle artisans of our cosmos, they are also the species that have given life to the world of forms—they are the form of life that has made the world itself a site of infinite figuration. It is in and through plants that the Earth has asserted itself as a cosmic laboratory, a space for the invention of forms and the making of matter. (Coccia 2018:12)

My interest is not circumscribed by his expanded proposition of the brain, but rather includes his understanding of image associated with form, given that I suggest the understanding of imagination as an activity that is not (purely) cerebral. Beyond this, in the production of artificial hearts, the improvement of such devices involves, among other aspects, the search for different forms that can efficiently perform the function of the native heart, in other words, effectively replacing the organ’s functions does not necessarily involve reproducing its shape. Faced with this task, the search for the ideal form can find inspiration in forms in the natural world. Such a challenge seems to show that imagination is also concerned with the construction of forms.

The seed’s task of imagination, however, does not consist in updating an inert, immaterial image, to then materialise it. This is not an accident, a virtual existence of a form that solely defines an appearance. To imagine is to

[...] contemplate the force that allows one to transform the world and a portion of its matter into a singular life. [...] The seed is only the site in which form is not a content of the world but the being of the world, its form of life. Reason is a seed because, contrary to what modernity has insisted on believing, it is not the space of sterile contemplation, not the space of the intentional existence of forms, but the force that makes it possible for an image to exist as the specific destiny of a given individual. Reason is what allows an image to become destiny, a space of total life, a spatiotemporal horizon. It is cosmic necessity, not individual whim. (Coccia 2018:14-15; emphasis in the original)

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15 The relation between geometric shapes, conceptions of beauty, symmetry and perfection have been elaborated in Marini (2019a). The argument explores the metaphysical approximation of beauty and perfection to the mathematical rules arising from the Fibonacci sequence and the golden ratio – numerical relations often found in the natural world, like in the forms of flower petals, seeds, fruits, shells, etc.
Although the etymology of imagination refers to the formation of mental images, to representation, it is tempting to think of it in terms of the association between image and action. The dimension of action is thus embraced. Images cannot be dissociated from the processes and actions that give existence to new things, to the creation of worlds through material engagement between different actors.

I suggest not only that imagination cannot be disconnected from the socio-material practices through which medical technologies emerge, but that it must also be thought of as embodied, in the sense that it passes through bodies, through sensory and sensitive knowledge, through an engagement with the material world through laboratory practices.

**The division between manual and intellectual, and causal relationships in the creative process**

The desire for something more sustainable than decomposing materials is one of the sources in Western civilization for the supposed superiority of the head over the hand, the theorist better than the craftsman because ideas last. This conviction makes philosophers happy, but shouldn’t. *Theoria* shares a root in Greek with *theatron*, a theater, which literally means a “place for seeing.” The philosopher can pay a certain price in the theater of ideas for durable ideas that the craftsman does not. (Sennett 2009:124)

Nikola Tesla is known for his numerous inventions and patents in the field of electromagnetism, alternating current, power distribution systems, and contributions to wireless transmission. In his autobiography, the inventive character of his work is explored in close connection with his experiences of childhood and adolescence. His inventive skill is associated with his curiosity, as well as the peculiar way he perceived and inhabited the world.

An intense and controversial figure, stricken by numerous ‘sick states’ throughout his life, with frequent episodes of ‘nervous breakdown’, Tesla devoted himself to describing his supersensitive sensory abilities, and his very particular abilities. These were characteristics perceived as fundamental mechanisms for his imagination, which allowed him to design, simulate and improve his inventions.
Such a tool or skill manifested itself as a certain mental affliction[^16^], associated with visions that he sought to develop, turning them into a method of materialising inventive concepts and ideas, which was radically different from the experimental method. He argued that his procedure was faster and more efficient, since it eliminated the costs involved in the execution of prototypes and tests for their improvement. The visions of images, which were not hallucinations, in his understanding, became a method associated with the ability to visualise ‘phantom images’:

> My method is different. […] When I get an idea, I start at once building it up in my imagination. I change the construction, make improvements, and operate the device in my mind. It is absolutely immaterial to me whether I run my turbine in thought or test it in my shop. I even note if it is out of balance. There is no difference whatever; the results are the same. In this way I am able to rapidly develop and perfect a conception without touching anything. (Tesla 2016:6)

Although his method operated ‘as if’ the representations were real – which in a way appears to make it less real, while establishing differentiation between his ‘imaginative’ method and the experimental method (is this not an effect of the obstinate effort throughout the history of science to constitute the experimental method as scientific *par excellence*?) – he argued that in twenty years, invariably, without exception, the experiments would work as he had imagined. After making all the improvements, Tesla would then build his brain’s final product in concrete form.

Throughout the history of science, there are several examples of the contribution of imagination as image projection in the development of hypotheses or solutions: scientists Faraday and Maxwell mentally visualised electromagnetic fields as tiny tubes filled with fluid; Kekulé conceived the benzene ring using the image of the serpent that bites its own tail as a reference; Watson and Crick mentally rotated models of what would become the DNA double helix; Einstein claimed that his ability did not reside in mathematical calculation, but

[^16^] ‘In my boyhood I suffered from a peculiar affliction due to the appearance of images, often accompanied by strong flashes of light, which marred the sight of real objects and interfered with my thought and action. […] This caused me great discomfort and anxiety. None of the students of psychology or physiology whom I have consulted could ever explain satisfactorily these phenomena.’ (Tesla 2016:4)
in visualising effects, possibilities, and consequences – highlighting the relevance of mental images to the cognitive process (Zuanon 2017).

Imagination as a visualisation skill, related to the image, is widely explored in approaches interested in understanding the creative process. Here I inquire about two of these approaches, whose image sources are quite different: one is guided by Jungian analytical psychology, while the other uses brain mappings that enable speculation concerning the process of the emergence of brain images, that is, the first seeks to understand the origin of the images, while the second investigates their effects on a chain of brain events.

Both focus on visual skills and the imagination’s relationship with images. Other senses can be added to vision. In the words of the social philosopher and poet William E. Thompson, imagination is expressed in terms of an ability to feel what is not yet known, to intuit what cannot (yet) be understood: ‘The song you did not hear you may begin to hum. The bacteria you did not see you may begin to envision’ (Thompson 1987:8). In seeking a new proposal for a theory of knowledge, Thompson understands images as a result of other dimensions of sensitivity, that is, as an imaginative, sensitive capacity—without thereby instituting a division between rationality and sensitivity, but at the same time trying to escape the simplifying rationality of the Enlightenment. The sensitive and ‘intuitive’ capacities highlighted by Thompson are not attributes recognised as inherent to techno-scientific rationality. Either way, they need to be qualified.

In Jungian analytical psychology, Filipe Mattos de Salles finds terrain that supports his understanding of the creative process. Interested in formulating a model that can interpret the subjectivity and multidisciplinarity intrinsic to the field of art, this proposition begins with the diagnosis that the existing approaches were incapable of offering a broad and definitive explanation of the creative process. In an effort to propose a general answer, his suggestion is that the fundamental essence of creation is not located in the object itself, but in the (human) psyche. The Jungian approach is thus conveniently presented as a foundation, since for Jung,

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17 These are propositions developed by two professors from the Institute of Arts at Campinas State University (IA-UNICAMP), to which I had access during the course taught by them in the Post-Graduate Programme in Visual Arts. I participated as a listener in the course entitled ‘Tópicos Especiais em Poéticas Visuais e Processos de Criação I’ [Special Topics in Visual Poetics and Creation Processes I], offered in the first half of 2020. I am grateful for the opportunity, the repertoire studied, the classes and for their openness in the dialogue between us.
not only art or aesthetic experience, but reality itself, the way we experience reality is a psychic experience: ‘everything thought, felt, or perceived is a psychic image, and the world itself exists only so far as we are able to produce an image of it’ (Jung 2014:479).

The raw material of creative processes is found in the archetype. What occurs is the processing of images and sensations that result from an energetic attraction, that is, the formalisation, the finished work, consists of an unconscious activation of archetypes (Salles 2019). Archetypes are like a stock of images mobilised by energetic attractions. They are instinctive ways of imagining, as Nise da Silveira inferred from Jung’s work, recalled by Salles. Creative conceptions are psychic products that dialogue and find resonance in the psychic energy contained in the archetypes.

Everything happens as if archetypal images sprout in the psyche through a process that is described as a sensitisation to an archetypal ideal: ‘From a creative point of view, when an archetype sensitises us, there is a natural reaction of cerebral, physical interpretation, which more often than not translates into archetypal images’ (Salles 2019:5). The creative process consists of updating the psychic energy of the archetypal images.

In an effort to understand the mediation and interaction between creative and cognitive processes in the field of art and design, Rachel Zuanon uses neurosciences and the discussions of one of its exponents, António Damásio, to explore the emergence of mental images in the creative process. Such an approach offers scrutiny of the biological processes of the emergence of images, their pattern recognition and understanding. From this perspective, the creation and manipulation of mental images are fundamental for the emergence of ideas and thoughts that result from brain operations. Neural representations can become images, which can be manipulated in a process called thinking: ‘At the mental level, the integration of images from current perception with those from memory occurs. And these integrations are directly responsible for the innumerable manipulations of these images, indispensable for the solution of new problems and creativity’ (Zuanon 2017:604)

The creation process involves image formation, that is, images are fundamental for the formation of thought, or to continue in the words of Zuanon: ‘The construction of images is constituted in a fundamental brain process [...]. The factual knowledge necessary for

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18 Salles explores the idea of energy and the energetic field in dialogue with contemporary understandings of quantum physics.
reasoning and decision making comes to mind in the form of images’ (Zuanon 2017:605). They are of different types and can be articulated: there are images that represent the present, those that represent the past, and those that relate to the projection of futures. The images of the past and present are the result of actions, perceptions, that is, they are related to the senses and ways of being in the world.

Propositions encountered in the speeches of two gurus – the American Steven Johnson and a Scotsman living in Brazil, Charles Watson, whose methods are derived from research with and aimed at artists, scientists, entrepreneurs, etc. – highlight the importance of the process, realisation, and development of ideas. Yet in these approaches, in concrete terms, very little attention is paid to processes and practice. Thus, the procedural character is valued, but the narrative surrounding its realisation does not appear to rupture with the perception of the idea of how something that arises in the head (and somehow ready) will be later developed, improved, tested. Paradoxically, although understood as fundamental, the processes are not explored as producers. Thus, they do not problematise the understanding of creation as resulting from a consolidated image.

The focus given to the nature of the creative process that ends up conditioning it to a causal relationship, in which the idea emerges as an image, first occurs as a cognitive process. Among the distinct approaches to the creative process, even when the dimension of realisation is included, it almost always seems to be reduced in light of the importance of the idea as a concept, as something separate from its realisation. The process, therefore, is barely explored to the detriment of the emergence of the image, which is directly linked to the establishment of something new. But does bringing things into existence mean translating something sensitive and impalpable into something material and intelligible? It is requisite to question to what extent understandings focused on the image can reduce creation to a moment in the creative process, emphasising this as predominant. In some manner, are these approaches not reducing a chain of events and phenomena to a single moment in the process, considering the creation of something new as the projection of an idea/image?

How can the creative process be synthesised as a phenomenon in which something is detached and forcibly isolated from a series of events? What is lost and which actors are silenced when the emergence of an innovative idea is established as the moment of a mental projection? How does this purification mask the participation of different actors? In what
sense is this ‘detachment’ convenient in enabling the institution of something that has the potential to become intellectual property, that is, something for which (individual) authorship can be recognised?

As Flora Rodrigues Gonçalves (2019) clearly demonstrates in her ethnography on the processes of intellectual property recognition, authorship is a tool for constructing the notion of author, and is closely related to the notion of property. Copyright is a legal instrument used to protect the rights of authors. If someone seeks recognition of the creation of something, a legal convention recognises and guarantees authorship as a property right.

We can extrapolate from her hypothesis that the concept of intellectual property is linked to the notion of personhood in Western thought, characterised in terms of singular entities. If the property right is linked to the understanding of the person as an autonomous individual, the conception of the idea as separate from a process and the erasure of the participation of other non-human actors seem to serve the same mechanism, a logic guided by the recognition of (individual) authorship and property rights, a thing that can be patented.

The interweaving between authorship, the individual, and the notion of property rights is inspirational for reflecting on the detachment of the notion of idea from a process of the emergence and (trans)formation of things. I suggest that conception of the anteriority of the idea (in relation to the process of construction and development, as activities that bring things to life) can be convenient for establishing the authorship of things. If something is born in someone’s head, if something springs up as an idea (allegedly ready-made), if someone is the channel for an original and innovative idea – that is, if there is something that can be detached from the most diverse chain of events, actions and interactions –, then such an idea, in the context of copyright held by a legal institution, must be understood as someone’s property.

**Imagining ‘heartless’ bodies and life forms that exist without native organs**

Demonstrating the way in which the conception of imagination is detached from the processes that give rise to new artefacts and concepts does not imply that these fictions cannot be productive. The history of the development of cardiac devices, the search for a replacement for a failed native organ demonstrate the fundamental role of imaginative
projections and the way in which ideas are highlighted, individualised, and attributed to certain ‘geniuses’.

By constructing a linearity and providing intelligibility to a series of technological developments and evolutions, we encounter cumulative and imaginative efforts that consolidated and sustained understandings concerning physiology, and the possibilities for intervention and its transformation. Since the beginning of the nineteenth century, questions have been raised regarding the possibility of replacing the heart with an alternative form of blood circulation. In 1812, the French physiologist Le Gallois speculated on ways to replace the native organ by artificially pumping the blood, which would make it possible to keep an organism alive for an indefinite period.

These idealisations were not restricted to the medical imagination, given that a few years later Mary Shelley’s Dr. Frankenstein discovered the secret for generating life and created his own creature. The novel was written between 1816 and 1817, and the first edition was published in 1818 without crediting the author. The definitive version, the third revised version, is from 1831.

Imaginative speculation is a valued dimension in the field of cardiac device development, since they are radical interventions that demanded daring stances, breaking taboos. Imagining solutions ‘outside the box’ continues to be valued, since there are still no definitive or stable solutions for heart failure. Organ transplantation imposes insurmountable limitations, and mechanical devices still do not offer survival or quality of life equivalent to transplants.

Among the progressions in the history of producing circulatory assistance devices, we see that it was first necessary to idealise the possibility of sustaining a living organism by substituting its cardiac function, so that this speculation could open up new imaginative possibilities. In other words, imagining that artificial pumping was conceivable opened up new imaginations, such as performing the transfer of an organ from one body to another.

Although currently the search is focussed on alternatives to transplants, speculation surrounding the possibility of transplanting hearts came later, resulting from speculation on mechanically replacing the organ.

Narratives concerning the ‘race’ to perform the first heart transplant in the 1960s presented yet another imaginative aspect. South African Christian Barnard had learned the techniques in the United States when he worked with Norman Shumway at the University of
Minnesota. He performed the first human heart transplant, despite the favouritism afforded to Shumway.

On the morning of the accident that would later make Denise Darvall a donor, Barnard took a nap and slept fitfully. He later recounted that at that moment his subconscious took over, ‘leaving him with the sudden conviction when he woke that he should not follow Lower and Shumway’s surgical technique to the letter’ (McRae 2007:157). Instead of cutting the entire back wall of the atrial chambers of the donor heart, Barnard decided to make two small holes that provided access to the vena cava and pulmonary veins, which allowed the septum to remain intact in the donor heart.

The procedure was successful and enabled the recipient, Louis Washkansky, to survive 18 days. In one of his controversial statements to nurses, Washkansky said, with a sense of humour, that Barnard was the new Frankenstein. It was as if the literary imagination, (co)produced by the medical-scientific imagination, had made it possible and intelligible to perform the first transplant.

Barnard’s determination stemmed from a nonconscious state and had not been tested before. However, the accumulation of practice with the surgical technique developed by the Americans provided him with a conviction, an intuitive, non-rational disposition (at least in terms of modern, medical, scientific rationality). This imaginative, intuitive ability, sustained and orchestrated by his technical skills, enabled Barnard to perform the procedure in a manner different to that he had tested. In his narrative, dreams and a turbulent nap opened up the possibility of imagination, a projection of that which did not exist.

Imaginative potential is fundamental in fields of knowledge production that are unstable, in which there are no ready-made answers, no definitive solutions. These are experimental investigations characterised as anticipatory science, which carry hopes and promises (Sharp 2014). These are fields in which problems are framed in terms of ‘what ifs’. Scientific experimentation is seen as a creative enterprise, similar to creation in art, since it is the reflections of ‘what if’ types of scientists that open up the possibilities for creating innovative procedures and devices, as Lesley Sharp suggests.

**Cosmopolitical digressions – Where did the courage to create take refuge?**
I grew up in a beautiful era, now sadly in the past. In it there was great readiness for change, and a talent for creating revolutionary visions. Nowadays no one still has the courage to think up anything new. All they ever talk about, round the clock, is how things already are, they just keep rolling out the same old ideas. Reality has grown old and gone senile; after all, it is definitely subject to the same laws as every living organism—it ages. Just like the cells of the body, its tiniest components—the senses, succumb to apoptosis. Apoptosis is natural death, brought about by the tiredness and exhaustion of matter. In Greek this word means 'the dropping of petals'. The world has dropped its petals. (Tokarczuk 2018)

Although invention is the engine that turns the wheel of scientific and technological production, its reduction to a profit-oriented income through the logic and temporality imposed by the market seems to cause a crisis in creativity and its potential contributions.

When addressing the difficulties in producing and patenting medical technologies, the bioengineering researcher who was an interlocutor in my doctoral research, Agamemnon (coordinator of an institution that produces medical devices), highlighted that the main challenge currently is associated with over-regulation. In his opinion, the imperative of adapting to the logic of patents and the procedures recommended by regulatory agencies slows down and hinders development. Hence, researchers and institutions are discouraged by the excessive regulation of the patent process: ‘When you go to file a patent, you need to state what you have. But how do you know what you have before doing experiments, tests? The system is too complex to create these days. Creativity is stifled because of this. Before, creativity was crowned by results.’

The different dimensions of the creative process highlighted above seem to depend on a sense of freedom that does not correspond to the idealisation of creative freedom defended by Agamemnon, though we should also consider that his discourse includes a diagnosis of the seriousness of the neoliberal advance on research practices that are now motivated by the development of patents. Agamemnon highlights that there is a distinct difficulty in patenting, because a secret must be kept, that is, the production needs to be done in secrecy (otherwise the idea may become public domain), which is somewhat contradictory, since the creation

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19 My initial contact with Agamemon occurred in the second half of 2013, when I participated in a postgraduate course and he was one of the professors responsible for it. Over the years, we met a few times in the bioengineering laboratory where I conducted part of my research. However, these quotes are the result of a formal interview with him in January 2017.
must also be submitted to assessments before registering it, which in a way implies sharing it with certain actors and institutions. In addition, a patent is a claim on an idea, which is not synonymous with a product that can be marketed, since, as he points out, registration is required for something that the author barely knows what it will be.

His argument seems contradictory and to some extent confuses two processes, which is the need to ask regulatory agencies for authorisation to perform tests and the patent application processes, both of which, in his opinion, are counterproductive to the development of technologies. The apparent contradiction in his argument, and in the very logic of patent registration, demonstrates the creative character that I want to highlight here, present in all stages of technological production. The recognition that an idea does not correspond to an artefact indicates the need for material engagement, being explicit about all the work involved in creating something.

According to Agamemnon’s conception, we live in a delicate transition period in relation to creativity. Before, researchers were used to ‘things being easy: they formed an idea, sought to prototype it, made models until they achieved something that was useful for an intervention, for improving health. There was a certain ease in doing these things’. At the time, however, there had been an excess of regulation in Brazil and in a large part of the world over the last twenty, twenty-five years regarding the production of technology and intervention in interactions with the human body. In the past, a doctor created a partnership with a researcher, an engineer, a scientist, and together they conceived an idea, established partnerships with other professionals, made devices, performed tests until ‘they felt comfortable putting it in patients’. However, the current scenario is so ‘stuck that scientists, researchers […], no one has the courage to do anything anymore, they get mired in the system’.

In his position as leader of the laboratory, a relative of the doctor who gave the institution its name, being part of its history and understanding himself as a guardian of its legacy, Agamemnon complained that although it was still possible to produce technology, there were an increasing number of obstacles. Heir to a production mode in crisis, he recalled a time when the three stages were carried out with agility, without what he understood as bureaucratic impediments. He regretted having to ask permission ‘for something that no one even knows how it will work’. In his descriptions, the ideal past in which an idea was conceived and developed practically without impediments contrasts with a present in which,
after conceiving an idea, you need to face the difficulties of conducting tests on animals, a ‘series of prohibitive legislations that impede development’, in addition to the bureaucratic procedures required for implantation in humans. Not to mention the intimidations when faced with unsatisfactory results, such as when one of the devices the group developed was approved by the Brazilian Health Regulatory Agency (ANVISA), but if there were two subsequent deaths, the authorisation to implant in humans would be suspended.

Agamemnon affirms that in the process of regulating creativity – that is, the production and registration of new technologies –, a retraction of imagination has occurred due to the validation procedures of devices. Following the expansion of bureaucracy, which makes the processes slow and costly, it is as if regulation has established what can or cannot be imagined and produced.

Agamemnon’s argument concerning the censorship of creativity produced by a ‘policy of discouragement’ in the current context of the production of medical technologies adds a new aspect to the idea of imagination proposed herein: imagination is also traversed and shaped by regulation, since this control intervenes directly in the production practices of these technologies.

When considering how regulation imposes limitations on creativity, Agamemnon highlights creation as a process that goes through the different stages of technological development, and is not merely the conception of the initial project. According to him, ‘creativity can have no limits’ because ‘limitation takes away the right to think freely’, which is an important aspect, because innovative solutions can emerge from the unexpected. ‘Thinking freely’ – which also includes the dimension of doing, associated with the practical aspects of techno-scientific production, and not just the projection of ideas – is understood as a condition for technological production.

For different reasons and in different ways, Agamemnon and I agree that it takes courage to create, in addition to investments and a planning policy. Besides courage, his discourse reveals an understanding of freedom, the absence or reduction of which is implicated in difficulties in creating. Perhaps, at some level, the freedom he claims corresponds to that defended by movements that gamble on Open Science, on shared endeavours based on cooperation. Rather than a lack of accountability on the part of researchers, such freedom refers to the possibility of being oriented by ideologies different from those homogenised by
the market. In the case of techno-scientific production, the problematic surrounding creation accompanies such questions as: Who can imagine? Who should imagine? Are there limits to achieving that which is (technically) possible to envision? Who benefits from the creations? Who profits from the inventions?

Sennett suggests extending Hannah Arendt’s proposition regarding the need to promote public debate, allowing society to discuss and decide what to do with the technologies produced, or even that these should be debated while they are still under development. Furthermore, he suggests moving forward with Martin Heidegger’s understanding that it is necessary to retreat in the face of the ‘technological frenzy’, opting for a simpler way of life in nature. Recalling the discussion of modern theologian Reinhold Niebuhr, who affirms that ‘it is human nature to believe that anything that seems possible should therefore be tried’ (Sennett 2009:2), Sennett suggests ‘imagining ourselves to be like immigrants thrust by chance or fate onto a territory not our own, foreigners in a place we cannot command as our own’ (Sennett 2009:13).

**How to synthesise this kaleidoscope of themes?**

The social studies of science and technology theories affirm that there is no nature outside the laboratory (Latour & Woolgar 1997), that the bodies emerge through (bio)medical and scientific practices (Mol 2008), which demonstrates the place of imagination, as well as the forms taken by technologies and artefacts that are fundamental for the maintenance of society, of collectives (Latour 1991). Exploring the invention of cultures, Roy Wagner shows not only that the entire world is invented, but that in the so-called modern Western societies, which separate the spheres of nature and culture, the invention of the natural world is taken so seriously ‘so that it is no invention at all, but reality’ (Wagner 1981:56).

The invention of nature stems from technological and cultural means, which are updated with each new invention. In this sense, Wagner’s effort is to highlight the imbrication between nature and culture, so that ‘without the invention of Culture that this creativity originates and embodies, Culture, in turn, could not be used to invent nature’ (Wagner 1981:57). Nature and Culture are closely related, and underlie their own division:
Like so many things, our technological Culture must ‘fail’ if it is to succeed, for its very failures constitute the thing that it is trying to measure, harness, or predict. If the formulae and predictions of science were completely effective and exhaustive, if the operations of technology were completely efficient, then nature would become science or technology itself. [...] Science and technology ‘produce’ our Cultural distinction between the innate and the artificial to the extent that they fail to be completely exact or efficient, precipitating an image of ‘the unknown’ and of uncontrolled natural force. (Wagner 1981:56)

With this, Roy Wagner claims the creative capacities of Culture to invent Nature, identifying techno-science as one of the means of the invention of the ‘physical world’, recognising the natural phenomenal universe as simultaneously the object and product of invention. Establishing conventions implies their dialectical antithesis, as he suggests, posing the requirement of invention. Invention is an engine: ‘We create, and propel ourselves with, our problems as we go’ (Wagner 1981:59). The invention of things is not a human privilege, however, as Wagner argues, recalling the poet Rainer Maria Rilke: there is a morality of things that are not merely utilitarian devices, if we consider that ‘tools “use” human beings’ (Wagner 1981:59). This is the path along which the argument made about the embodiment and sharing of imagination moves, demonstrating that it is not only values and attitudes that materialise, but also the creative process takes place based on socio-material practices that involve different beings.

In the specific arrangement between nature and culture developed herein, a germane interest was claiming imagination as a practice, supported by actions that implode the limits of the image as a substrate of the creative process. It is in the friction between projection and development that the divisions between mind and body, idea and practice, image and form are tensioned. Finally, the understanding of imagination as a ‘doing’ makes it possible to highlight the intense relations and the tireless doing and redoing necessary for the emergence of new artefacts. Giving shape to the world, occupying it with fullness are behaviours that require material, cognitive, political engagement and responsibility.

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