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ARTICLE

Fragments of Thought: Considering Sophie Germain's Process Epistemology

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Abstract

In this paper I look at the philosophical work of Sophie Germain, a woman mathematician and philosopher in nineteenth-century France. Although forgotten after her death, Germain's contribution to mathematical sciences has been revisited and reappraised in recent years, but with very few notable exceptions, her philosophical work is still in the margins. In addressing this gap in the literature, I revisit Germain's contribution to the history of ideas, particularly focusing on her contribution to process epistemologies. I argue that Germain was a truly transdisciplinary thinker *avant la lettre* and that her philosophical work should be mapped in the wider field of process philosophies. In doing so I make connections between Sophie Germain and Alfred Whitehead's philosophy of the organism, particularly focusing on their take on feelings, prehensions, happy ideas, and events.

1. Introduction

"Time preserves only the works which defend themselves against it,"[1] Sophie Germain wrote in her philosophical notes, and the editors of her posthumously published work, chose this fragment to be first in the section of what they called "Diverse thoughts" (*Pensées diverses*). Sophie Germain (1776–1831) is mostly known as a mathematician, with significant contributions to number theory, as well as to the mathematical laws underpinning the physics of acoustics.[2] While forgotten after her death, Germain's contribution to the mathematical sciences has been revisited in recent years with a small but growing body of literature revolving around her life and mathematical work.[3] Even in this literature, however, and with very few notable exceptions, her philosophical writings remain broadly undiscussed, and they have not been translated in English yet.[4]

In addressing this gap in the literature, in this paper I revisit Germain's contribution to the history of ideas, with a particular focus on her take on epistemology. In doing so, I have studied and analysed the second edition of her collected philosophical work, *Œuvres philosophiques*, which was published in 1896 (Germain 1896). All the references to Germain's philosophical work in this paper have been translated by me, but I have also included the original French text in the notes for the sake of transparency and clarity.

The paper unfolds in four parts: after this introduction, I look at Germain's unfinished philosophical thesis, *Considérations generales sur l'etat des sciences et des lettres aux differentes époques de leur culture* (General considerations on the state of the sciences and the letters at different times of their culture), which I read in relation to her *Pensées diverses* (Diverse thoughts), but also in the light of her knowledge and research in mathematics. In the third part I make connections between Germain's work and processual approaches to epistemology, particularly highlighting connections with Alfred North Whitehead's philosophy of the organism. What I suggest by way of conclusion is that Germain's transdisciplinarity is an original and innovative stance in process epistemologies.

2. Philosophy and mathematical reasoning

> We would imperfectly appreciate the high range of Mademoiselle Sophie Germain, if we limited ourselves to consider her as a mathematician [*géomètre*], whatever the eminent merit she demonstrated in mathematics. Her excellent posthumous discourse, published in 1833, on the state of science and the letters in the different periods of their culture, indicates in her a very lofty philosophy, both wise and energetic, of which very few superior minds have such a clear and profound feeling today. I will always attach the highest value to the general conformity that I saw in this writing with my own way of conceiving the whole intellectual development of humanity. (Comte 1835, 604, n. 1)

Auguste Comte included this lengthy reference to Sophie Germain's philosophical work in the second volume of his major corpus *Cours de philosophie positive,* first published in 1835, only four years after Germain's untimely death in 1831. What made the founder of positive philosophy praise so highly a woman who was mostly known as a mathematician in the Parisian academic circles in the first half of the nineteenth century? This is what I want to discuss in this section by mapping Germain's philosophical writings in the field of process epistemologies. In doing so I consider the cultural and philosophical contexts within which she wrote and worked, but I also make connections with Alfred North Whitehead's philosophy of the organism.

"These pages, found in Mademoiselle Germain's papers, were not intended for printing. She wrote them in the moments when the severe pains to which she succumbed did not allow her to devote herself in the study of mathematical sciences that had made her famous," Jacques-Amant Lherbette, the editor of the first publication of her philosophical work wrote in introducing his aunt's "Considérations générales", in 1833. For Lherbette then, Germain's essay was an unfinished substitute for her "real" scientific work, which she was unable to pursue in the last months of her life, when suffering from breast cancer, and it was because of her "lack of time" (5) that the work remained unfinished.

Guglielmo Libri, a fellow mathematician and friend, seems to follow Lherbette's evaluation of this work and he only devotes one paragraph to it in his obituary, which eventually became Germain's first biographical note, as well as an important source of all biographical writings around her: "We have also found in her papers, immense works on history, on geography, in particular that of the ancients, and on the natural sciences, and also very fine philosophical reflections because she had been much occupied with

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metaphysics" he wrote (1832, 2). What we understand from this short reference is that there was a selection of "the pages" that were initially published in 1833 and perhaps the "Pensées diverses", which were added in the first full edition of her *Œuvres philosophiques* in 1879, were amongst these "immense works" that Libri's obituary refers to. Libri was a passionate collector of scientific manuscripts, having created one of the largest private libraries in Europe, often under dubious circumstances, and he must have been collecting Germain's papers as well, through his acquaintance with her nephew.[5] Seen as a mathematical set of thought fragments, Germain's *Pensées* can be configured as a philosophical annex to her "Considérations," a poetic rendition of the ideas that her philosophical work either develops or leaves out at least in its extant unfinished form, but it can also serve as an exemplar of the interwoven intellectual processes between science, literature, and the arts.

Unlike Libri, who only makes a passing reference to Germain's philosophical work, Hippolyte Stupuy, the editor of the second publication of her philosophical work as well as her second biographer, discusses Germain's posthumous discourse at length, criticizing Libri for not mentioning her "Considérations" in his obituary (1896, 45). In disagreement with Lherbette, Stupuy argues that this work must have started much earlier: "it is without temerity to suppose that, imperfect as it still was, as to the execution, when death tore the quill from the hands of the writer, a work of such great significance had been conceived long before, at length thought through, often revised and retouched" (44). There is no evidence for this assertion, only clues that Stupuy takes by studying in depth not only the text of the posthumous essay, but also Germain's "Pensées," particularly drawing on the following fragment:

> If the men who have advanced the sciences through their work, those to whom it has been given to enlighten the world want to retrace the path they have taken, they will see that the most beautiful, the greatest ideas are the ideas of their youth, matured by time and experience. They are enclosed in their first attempts like the fruits in the buds of spring.[6] (Germain 1896, 208–9)

We cannot be sure that a fragment of Germain's "Pensées" can sustain Stupuy's argument about the period that she wrote her philosophical work. Perhaps this essay was "the outgrowth of her early habit of writing down pensées," as Louis Bucciarelli and Nancy Dworsky have suggested (1980, 112). Dora Musielak has further considered the idea that Germain perhaps followed the lead of the *Pensées* of seventeenth-century mathematician and philosopher Blaise Pascal in writing down her own (2020, 144). Both her philosophical treatise and her "Pensées" include her reflections on the complexities of the human condition, the possibilities, but also limitations of human reason, as well as the existential dimensions of human experience, as I will further discuss. Jil Muller (2023) has further explored similarities between Germain's and Pascal's take on space and time, notions that are treated both mathematically and philosophically in their work, as she has noted (2023, 85).

Since Germain was first and foremost a mathematician, she drew of course on the field of mathematical sciences and thus the concept of "symmetry" is at the heart of her philosophical thesis and thought fragments. As mathematician Edward Frenkel has argued, symmetry is a key concept in mathematics, a property that allows any object "to keep its shape and position unchanged, even when we apply changes to it" (2013, 15). In this context symmetry is a unifying and organizing principle that allows mathematicians, scientists, and in our case philosophers to discern patterns, simplify problems,

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and reveal the underlying structure of reality, including mathematical objects. Moreover, symmetry contributes to the elegance and beauty of mathematical reasoning, which Germain extends to philosophy and the reality of the cosmos.

Musielak has added analogy as a mathematical concept in Germain's philosophical toolbox: "the key concept that unifies her text is the 'analogy' that she believed allows one to sort and discover the laws of the universe," she has noted (2020, 141). Analogy involves drawing parallels or making comparisons between different mathematical structures and concepts, when solving problems or proving theorems. While symmetry and analogy are distinct mathematical concepts, they are often interconnected in mathematical thinking in general and Germain's mathematical logic in particular, as I will further discuss in the paper.

In the light of Germain's distinct mathematical logic then, let us consider the content, context, and form of her philosophical writings in their interrelation. Her unfinished essay comprises two chapters: in the first she formulates the thesis that the human mind is subject to laws and the character of truth is a spontaneous feeling of order and proportion: "a profound feeling of order and proportions becomes for us the trait of truth in all things"[7] (1896, 78). In tackling the question of truth, Germain highlights here two important mathematical concepts: order and proportion. We all know even from our basic mathematics education, how crucial is the order of operations in arithmetic, while in dealing with the equality of ratios, proportion provides a framework for comparing quantities in a meaningful way. What is important in Germain's discourse, however, is that these mathematical concepts are transposed to the epistemological realm in her engagement with the philosophical problem of truth. It is in this light that she argues that both the sciences and the letters are dominated by this feeling which is common to them. What is more, Germain adds simplicity in configuring the universal triangle of "order, proportion and simplicity," which frames her own take on aesthetics and epistemology: "The oracles of taste and the judgments of reason resemble each other; order, proportion and simplicity do not cease to be intellectual necessities. The subjects are different, but judgment is constantly based on this universal type which belongs equally to the beautiful and the true."[8] (79).

Mathematicians and scientists often strive for simplicity as a guiding principle that can lead to greater clarity, elegance, and deeper understanding. In Germain's words, "the mind demands clarity, ... it requires an order easy to understand; it delights in simplicity, the source of elegance,"[9] as she noted in her "Considérations" (79), while her "Pensées" include the fragment that ideas are sublime when they are simple (196). Perhaps the DNA scientist James Watson had this principle in mind when he famously stated that "the truth, once found, would be simple as well as pretty" (2001, xi).

Following the configuration of the tripartite schema of order, proportion, and simplicity, Germain compares the impressions we get from fictional and scientific works and concludes that there are no important differences between them as "the human mind is guided in all its conceptions by the foresight of certain results, towards which all its efforts are directed"[10] (1896, 81), and therefore obeys "the laws of its own existence"[11] (97). In this light in all the strokes of genius, "in eloquence, in the sciences, the fine arts, or literature, what pleases us is the discovery of a multitude of relations which we had not yet perceived"[12] (82).

In making these comparisons, the author draws on the mathematical notions of symmetries and analogies, as already discussed above, and carefully demonstrates the identity of intellectual processes both in poetry and in science by showing that there is a continuous interchange of feelings (*sentiments*), imagination, and rational reasoning in

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the way they unfold. For the poet there is "a tumultuous struggle" of abstract images and opposing projects until a simple idea finally emerges (82). For the mathematician there is also a simple, "fruitful idea" that arises through their struggle with imagining a new problem in areas already researched and established:

> he [sic] sees results he cannot yet achieve; his imagination leaps to seize them, along the paths it has cleared for itself; he fears he has gone astray, he doubts his initial perceptions, he retraces his steps and tries to rethink the clues that had first guided him; a great number of ideas have joined those that were the first; they complicate the subject, divide attention and suspend judgment. But, through this chaos of thoughts, genius discerns a simple idea; his choice is irrevocably fixed, he knows that this idea will be fruitful.[13] (83)

Germain follows these parallel intellectual movements between poetry and science in the realization of the work: "while outlining his plan, the poet will never lose sight of the principal idea. It will give his work the unity of interest and action, the source of all true beauty."[14] (83) By way of analogy, the mathematician "pays close attention to the happy idea that directs his research,"[15] by unfolding a chain of truths, already contained in the first truth of his initial idea (84). In tracing the process of creation, Germain also points to the importance of the choice of style and makes reflections of remarkable accuracy on the perfection of language in literature and of "the language of calculations" in mathematics: "the man of letters will take care of the choice of words, their arrangement, the harmony of the verse or that of the sentence"[16] (86). But the mathematician also needs to attend to the demands of style, since the language of calculations also has its own aesthetics: the choice of words in literature analogically corresponds to the choice of mathematical expressions, which can be "more or less elegant" (87) as "not all authors write with the same degree of perfection"[17] (86).

In concluding the first chapter of the essay, Germain is therefore able to exclaim: "Ah! Let's no longer doubt it, the sciences, the letters and the fine arts were born out of one and the same feeling."[18] (90). The notion of feeling (*sentiment*) is a central concept in Germain's philosophical essay; it is deployed throughout its text in different modalities and contexts and is crucial in her processual thought, as we will further see.

In the second chapter Germain follows a historical investigation of her principles through different periods in science and culture. In this context she recounts how, under the initial reign of imagination, poetry first recounted the most remarkable events and painted the great scenes of nature. Imagining an action would come later for the poet, she notes, but the need was soon felt to discover the rules, which would later become the precepts of art: "unity of action, unity of interest and clarity of exposition"[19] (92). As he found himself "thrown to the earth in the midst of the immensity of things" man marvelled at himself and seeking his own image everywhere, he personified inanimate and intellectual beings, rendering them "children of his imagination" (92). This is how the human type became universal: "faithful to his constant thought, man has never ceased to regard his own existence as the archetype of all other existences"[20] (94).

Already in the first chapter of the "Considérations" Germain had made several references to the faculty of imagination, stressing how it had served "as a guide to reason" (78) for the human mind. As we have already seen, imagination is not only important for poetic ideas (82), but also crucial for the mathematician, whose imagination "leaps" to seize results that "he cannot yet achieve" (83). Germain had first-hand experience of the importance of mathematical imagination. As Bucciarelli and

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Dworsky have pointed out about her work, she often had brilliant ideas, but due to her lack of rigorous mathematical education, her proofs were "awkward and clumsy when viewed against the background of available mathematics at the time" (1980, 7).

Germain demonstrated the importance of imagination for the mathematical mind in her "Pensées": "Depth of vision, accuracy of judgment, vivid imagination, these are the qualities of the mathematician"[21] (1896, 225), she wrote, particularly highlighting the connection between them: "what gives this depth, what exercises this judgment, is the imagination, not the one that merely playes on the surface of things, animating them with its colours, diffusing brightness, life, and movement, but an imagination that operates just as well inside bodies as it does outside them"[22] (1896, 226). It is only when imagination has done the difficult work of "penetrating nature" and forming "the anatomy of things," that the mathematician can proceed. Glesser and colleagues have particularly highlighted the importance of imagination "as the fundamental duty of being a mathematician" (2020, 219) in Germain's thought, making connections between her "Pensées" and Hardy's *Apology* (2004 [1940]).

In further developing the second chapter of her thesis, Germain engages with Kant's "transcendental idealism," positing that our knowledge is shaped by the structures of our own minds.[23] She thus raises the question of whether the conditions of possibility for knowledge and understanding are "the immediate result of the laws of being, or they derive only from a relation between any other reality and that of our existence"[24] (1896, 105). In pointing out that this is an area of debate between philosophers, she refutes Kant's thesis that "the most conclusive arguments can be attributed either to necessary relations, or to the forms of our understanding [since] in this regard, any rational decision seems to be forbidden to us"[25] (106).

Her Kantian critique notwithstanding, Germain considers the conditions of possibility for knowledge and understanding and engages with the problematics of a priori reasoning: "one cannot deny the legitimacy of philosophical doubt, for this doubt is founded on the impossibility of comparing any other judgment with that of man"[26] (106). She thus offers some preliminary observations, which are to be taken as inductions in her distinct method of mathematical logic and reasoning. Germain considers space and time as constant and measurable entities in their interrelation in her "Pensées": "space and time, this is what man sets out to measure; one circumscribes his momentary existence; the other accompanies his successive existence"[27] (196). Germain is still far from taking space/time as a continuum. And yet she points to movement as "a necessary relation" linking space and time, further suggesting that, unlike human beings who are continuously modified, "as soon as it is constant and uniform, space is known by time, time is measured by space"[28] (196). As Muller has noted there are three main ideas linking space and time in Germain's philosophical thought: "(1) space and time are measurable, (2) they are linked by motion, and (3) humans have no constancy nor uniformity" (2023, 88). Given that space and time are measurable "they play a role in the understanding and circumscribing of existence," Muller has further noted (89). Moreover, while humans have no constancy, their intellectual judgments function within the mathematical framework of order, proportion, and unity and so do space and time.

In the context of a priori reasoning, Germain observes that "our logic is composed of rules dictated by universal reason"[29] (1896, 106) and thus Kant's transcendental idealism "tends to undermine in its foundations the absolute reality of all the certainties that we can obtain"[30] (108). To ground her argument, Germain traces the universality of reason in the works of the antiquity and the Middle Ages: from the first astronomical knowledge up to the foundation of Cartesian geometry and Newton's discoveries, amidst

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"the thousand deviations" of reason that the history of science has pointed to (113). Here she highlights the importance of mathematics in offering truth and nothing but the truth: "From their birth, the mathematical sciences have offered the human mind the full realization of this type of truth, the object of its dearest affections"[31] (118). The reason is simple: while philosophical language was at times "even more obscure than the ideas it was intended to convey"[32] (122), the language of "the exact sciences" has always been precise and clear. In this light she is optimistic about the fallacies of the human mind, in the wider context of what I will further discuss as her process epistemology—an approach to knowledge which embraces open-ended inquiries and recognizes the provisional nature of knowledge, always subject to revision and refinement:

> One might have expected to go astray; and yet the errors of the human mind, seemingly inexhaustible, have all approached certain truths, and have not been as numerous as the defects of their methods might lead one to suppose. This is because the feeling of truth has never abandoned the authors of all these systems. This happy feeling has not been enough to preserve them from arbitrary and forced assumptions, but it has kept their imagination within certain limits.[33] (140)

Given the clarity of the language of the exact sciences and their consecutive prevalent position in seeking "the truth," it is no wonder that Germain made the study of science in general, and the mathematical sciences in particular, central to her philosophical propositions. Her historical account of the working of the human mind inevitably brings in mind Comte's law of the three different theoretical states (*états*): "the theological, or fictitious; the metaphysical, or abstract; and the scientific, or positive" that all branches of knowledge and principal conceptions pass through on the plane of his *Philosophie positive*. (1835, 3). Parallels between her work and Comte's positive philosophy were identified by Stupuy in his introduction of her philosophical work (1896), but also in a number of reviews that followed.[34] But it is clear that Germain does not follow Comte's paradigm, and as Stupuy has commented, "she does not distinguish between the logical processes which are specific to each category of knowledge; she does not indicate . . . the different destination of art and science, and her work is not exempt from all metaphysics" (1896, 54).

Most probably Germain would not have had time to read Comte's work, as the first volume of the *Philosophie positive* appeared in the end of 1829 and by then she was already suffering from cancer. Even considering the time earlier in the 1820s, we should bear in mind that Germain was moving in the mathematical circles of the Academy of Sciences in Paris and although she worked with many renowned mathematicians of her time, there is no evidence that she ever collaborated with Comte.[35] In this light, Germain's philosophical ideas not only precede the formulation of positive philosophy, but they also belong to a different strand in the history of thought, as I will further argue.

What is therefore important to consider while reading her work is its social, cultural, and philosophical context, which included August Comte and the rise of positivism in France, but also Hegel and German idealism. Paul Ritti, the editor of her posthumously published philosophical work, has actually argued that, since Germain had studied Kant, she would have read Hegel's philosophical work as well, and that she had probably met him during his visit to Paris in 1827, when the philosopher got to know many French intellectuals (Ritti 1890, 354). There is no evidence for this claim and there is no explicit reference to Hegel's philosophy in Germain's work, other than deploying the abstract notion of being, which is "the key to the vault of the Hegelian system," as Ritti has commented (354).

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Indeed the abstract notion of being recurs as an "absolute reality" in Germain's work: "will it be doubted that the archetype of being has an absolute reality, when we see the language of calculations springing forth from a single reality it has seized, encompassing all realities linked to the first by a common essence?"[36] she asks in her treatise (1896, 130). In thus following the route of mathematical logic she finally reaches the conclusion that "of all our ideas, the most abstract is that of being; for the idea of nothingness is entirely negative. Being belongs to us, it penetrates our intelligence and illuminates it with the torch of truth"[37] (138). In Ritti's reading then, "you have to be a metaphysician to be able to demonstrate that this being, which is, and which is not, becomes; and how becoming is a conciliation, of the two terms which seemed to exclude each other". (1890, 353).

It is precisely Germain's conception of being, its conditions and its laws, that "have a scent of German metaphysics and especially Hegelian," Pierre Lafitte had argued in a critical reading of her work (cited in Ritti 1890, 354). For some of her commentators then, Germain's Hegelian connections take her thought away from the field of positive philosophy.[38] As Ritti has further pointed out, Comte himself had acknowledged Germain's influence from German idealism and it is no wonder that, in devising his positivist calendar,[39] he placed her next to Hegel in the month named after Descartes and devoted to the modern philosophical trends of his time (1890, 352).

In the light of these debates and given that Germain's work weaves into different philosophical trends of her time, what I therefore argue is that her take on the dynamic nature of being and reality situate her philosophical work in the wider field of process philosophies. In mapping the history of process philosophy, Johanna Seibt (2023) has identified "pockets of process thought" in the wider area of Western substance metaphysics: "a special branch of process thought opened up in late 18th and early 19th century German Idealism, when Johann G. Fichte, Friedrich W. J. Schelling, and Georg W. F. Hegel responded to Immanuel Kant's system of a transcendental idealism." All these philosophers Seibt notes "focused on the process by which the world of knowable appearances, including reflective reasoning, is generated" and Hegel in particular "postulated that reality is the self-unfolding of dynamic structures or templates."

Germain's critique of Kantian epistemology and ontology does not therefore come out of the blue, nor does it simply follow the trend of her times as, Bucciarelli and Dworsky have commented (1980, 111). What I argue is that her treatise can be included in "the pockets of process thought" that Seibt has identified in the wider area of Western substance metaphysics. While considering the context of Hegelian dialectics within which her work was read, even by the positivist philosophical circles of the nineteenth century, I further make connections between her take on a process approach to cognition and Whitehead's process philosophy (1985). In doing so I follow Seibt's apt remark that Hegel's dialectics is "the hallmark of speculative process metaphysics" (2023) and that Whitehead's philosophy of the organism is the most rounded take on this speculative process metaphysics (Seibt 2023). Here I have to clarify that, given its unfinished and fragmented nature Germain's philosophical thought can only be considered in terms of its processual aspects, namely her dynamic take on reality and the human mind, as well as her unique notions of "feelings" (*sentiments*) and "happy ideas" as I will further discuss. My argument is that what derives from her work and particularly her transdisciplinary approach is not a holistic processual view of reality and the cosmos, as in Whitehead, but rather a process epistemology, which considers and examines the dynamic nature of knowledge formation and understanding, as I have already noted.

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3. Adventures in processual thought

"The actual world is a process and process is the becoming of actual entities", Whitehead famously wrote in his major philosophical work *Process and reality*. (1985, 22). Process is a fundamental fact of experience for Whitehead and "involves the notion of a creative activity belonging to the very essence of each occasion." ([1938] 1968, 151). As Steven Shaviro has perceptively pointed out, Whitehead's understanding of reality as process moves the analytical interest from the philosophical question of "why is there something rather than nothing" to the more sociologically driven one of "how is it that there is always something new?" (2012, x).

This transition from the "why" to the "how" has also been highlighted in Germain's philosophical work: "doubtless, the impression produced by reading an imaginary work does not resemble that which results from the study of a treatise on geometry"[40] (1896, 80) she wrote, in considering connections between mathematics and literature. And yet, she goes on to observe, "let us not hasten however to conclude that there is no common bond between works which initially appear so different."[41] (80–81). It is only when we consider the process of their creation and follow the different phases of their composition that "it will become evident that the highest literature, like the discoveries that enrich science have been inspired by a feeling of order and proportion which is the regulator of all intellectual movement"[42] (81). In his commentary to her work, Stupuy has underlined Germain's interest in the "how," tracing its genealogy to Diderot's thought: "to seek the how and no longer the why, this is, in fact, what marks the philosophical progress outlined by the school of Diderot" (1896, 56), he emphatically noted. In thus seeking "the how" and not "the why", Germain's process epistemology rejects static and fixed views of knowledge and understanding and emphasizes instead that knowledge is dynamic, constantly evolving, as well as shaped by ongoing processes of wonder, exploration, and discovery. In this light, she also embraces open-ended inquiries and acknowledges the provisional nature of knowledge, as we have already seen.

But there is another important term in Germain's philosophical focus in the short extract above, the notion of feeling (*sentiment*), which is recurrent in her "Considérations," as well as her "Pensées." What is important to highlight here is that the main thrust of Germain's take on feelings is very different from the common understanding of feelings as affects or emotions. Throughout her treatise she refers to feelings as the precursor of human understanding, the first stone in the long process of reasoning and knowledge production, as well as the path to the ethics and aesthetics of the human existence. Whether she refers to "a profound feeling of order and proportions" (78), which is the regulator of all intellectual movement either in the works of high literature or the rich discoveries in science (81), "a feeling of continuity," "a feeling of analogy" (112), or "a feeling of freedom" (135), Germain configures a universal feeling, which corresponds to a universal type of truth and has given rise to the creations of the human mind, as we have already noted.

As a matter of fact, whenever we get pleasure from a stroke of genius or a touch of eloquence in sciences, in fine arts, or in literature, it is because through them we can discern previously unseen relations and we are transported in a realm where we discover "an unexpected order of ideas or feelings,"[43] she wrote (81). Feelings also emerge in her *Pensées* connected to movement and power: "force is in the body the faculty to move and to move others; it is in us *the feeling* of power"[44] (209, emphasis added). Feelings are in short connected to the focus of Germain's philosophical work, namely investigating the

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"how" of intellectual processes, but they are also framed within her process epistemology in terms of recognizing the embodied nature of knowing. While emphasizing feelings, Germain argues that knowledge is entangled with our experiences, emotions, and affects.

In a parallel way, Whitehead's way of looking at the "how" of becomings goes through the work of "prehensions", a notion he uses to denote understanding not necessarily linked to cognition: "I will use the word prehension for uncognitive apprehension: apprehension that may or may not be cognitive" (1967, 69). Prehensions for Whitehead are "ways of grasping the world" ([1938] 1968, 151); they are used to configure how an "actual entity" becomes through the awareness, that is, the feeling of its environment.[45] In this light "prehensions" in Whitehead's vocabulary could be rendered as feelings. However, Whitehead's insistence on using "prehensions" instead of "feelings" derives from the fact that he wants to differentiate his approach from a subject-centred understanding of feelings. For Whitehead it is not subjects who have feelings, it is actually in the process of feeling the world that subjects as actual entities are being constituted.

It goes without saying that subjects pre-exist feelings in Germain's approach, rather than emerging as effects of them as in Whitehead. However, the conception of feeling as a pre-cognitive understanding—in terms of sensing the true as a starting point in the long process of investigating, formulating, and understanding—is what defines her approach. Recall how, in the first chapter of the "Considérations," all intellectual movements either in literature, science, or the fine arts start from a chaotic exploration in the world of abstract ideas, unmodified hypotheses, or blurring forms:

> ideas crowd the poet's imagination; he remains uncertain for a while; a multitude of different sources seem capable of giving life to his composition; he follows its development, then abandons it. He makes a new choice, his mechanism becomes more complicated; he is not happy with it, he stops, he retraces his steps.[46] (82)

In the same backdrop of "a chaos of thoughts" (83) the mathematician eventually grasps "the fruitful idea" as already discussed above. We know next to nothing of these intellectual adventures Germain notes as "the poet will not give us an account of the subtle discussions that preceded the adoption of the emblems he has chosen"[47] (88). Similarly, "the genius, who has glimpsed one of the secrets of the natural order, will not tell us either how many times his imagination has wandered around the path, which was to lead him to the certain knowledge of a truth, which he is now able to demonstrate"[48] (88–89). It is precisely the concealment of this process, argues Germain, that has led to the historical separation of imagination from reason. (89)

In the midst of these "adventures of ideas" as Whitehead (1969) would call them, "events" appear in the natural order of the world and therefore in the mind, which is part of it. And here emerges another analogy I want to draw between Whitehead's concept of the "event" and Germain's notion of "the simple [and happy] idea." For Whitehead, "the world is made of *events*, and nothing but *events*: happenings rather than things, verbs rather than nouns, processes rather than substances," Steven Shaviro has succinctly pointed out (2012, 17). Taking nature as "a structure of evolving processes" (Whitehead 1967, 72), Whitehead argues that events appear as spatio-temporal unities encompassing the present through contemporary ideas, the past through memories and the future through anticipation (1967, 72). In this complex configuration, events as entities—and not as merely collages of parts—are ultimately "the things prehended" (74). If we transfer this conceptualization of the "event" to the symbolic realm, "events" as

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prehended entities in Whitehead correspond to Germain's image of "simple [and happy] ideas" that emerge and decisively change the flow of thinking about the world. As we have seen, she remarked: "in the midst of this tumultuous struggle between conflicting projects, a simple idea finally emerges. Whether it has already been glimpsed, or it presents itself to him for the first time, the author feels that this idea is the one he had been pursuing"[49] (1896, 82).

Further transposed to the socio-political sphere, "*events*" or "simple [and happy] ideas" stick out from the ordinary, mark historical discontinuities and open up the future to a series of differentiations. In all cases, both "events" and "simple ideas" chart points at which existing laws change and new ones are created, whether in nature, science, poetry, society, and/or history. In the development of her philosophical discourse, Germain is thus adamant that science, literature, and the fine arts "were born out of one and *the same feeling*" (90, emphasis added) and their intellectual processes obey the same laws and run in parallel. This basic principle of her philosophical thought fits with Whitehead's (1964) famous argument that "the bifurcation of nature," taken as an imposed separation of reality between what is conceived by science and what is experienced by human beings, is one of the major epistemic fallacies of modernity.

Indeed, taken as an erroneous conceptualization of the relation between science and the world, the bifurcation of nature forms a serious impediment in how we approach important philosophical questions around the nature of the mind, the evidence of experience, the value of interpretations, and most importantly the coherence of knowledge. In her long engagement and dialogue with Whitehead's philosophical work, feminist philosopher and scientist Isabelle Stengers has pointed to the effects of this critique in reconceptualizing causality and subject–objects relations in scientific research and beyond:

> Nature bifurcates when we assert that there exists on one side a causal, objective nature—for instance the molecular mechanisms explaining the functioning of neurons and the interactions between neurons—and on the other side a perceived nature full of sounds, odours, enjoyments and values, all these so-called secondary properties being subjective ones, attributed to nature by the perceiving subject. (Stengers 2008, 98)

Whitehead's bifurcation theory was an attempt "to exhibit natural science as an investigation of the cause of the fact of knowledge," (1964, 30), but he carefully pointed out that "we can only know the 'what' and not the 'why' of knowledge" (30). In this light, we can only analyze the content of knowledge as produced and retained in our mind, "but we cannot explain why there is knowledge" (32). Germain made a similar observation in the first chapter of the "Considérations," when observing that, while "the superior knowledge" of penetrating the nature of things and therefore tackling the ultimate cause is "forever forbidden to us" (1896, 78), we should nevertheless focus on investigating the work and function of our intellectual processes and, therefore, "the content of knowledge as produced and retained in our mind", as in Whitehead's note above (1964, 30). In thus surpassing the question of "why", both Germain and Whitehead automatically invalidate the split between causal and perceived nature and immerse themselves in understanding the complexities of the world that human beings emerge from and are part of.

It was precisely in addressing the "what and the how" of knowledge beyond the fallacy of bifurcation that Whitehead initiated the philosophy of process. Very much in

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accordance with Germain's principle—although never mentioning her work in his citations—Whitehead's thesis was that the world is one reality within which material and mental interrelations emerge and that this reality "is the process" (1967, 72), as already noted above. Moreover, his famous statement that "we think in generalities but we live in detail" (1948, 26) is crucial not only for understanding history as process reality, but also for appreciating the importance of Germain's unfinished historical investigation of "the state of science and letters at the different periods of their culture" (1896, 91) in the second chapter of her discourse. Despite its brevity, as well as its fragmented and unfinished state Germain's philosophical work is an unrecognized trace of processual approaches to epistemology in the nineteenth century, by highlighting the dynamic, holistic, embodied, and relational nature of knowledge and thus embracing open-ended and provisional inquiries, as well as pointing to the pragmatic orientation of knowledge in guiding action and facilitating further research. Her processual epistemology is further a rare exemplar of transdisciplinary thought, at a time when sciences were defining and defending their borders. It is thus with some notes on transdisciplinarity that I would like to conclude this paper.

4. Transdisciplinarity *avant la lettre*

As Christina Hughes has aptly noted, "there is a long history in feminist thought that has been concerned with the shortcomings of disciplinary knowledge," further adding that "disciplines cut and chunk human, more-than-human and other-than-human experiences into separate and hierarchised knowledge fields" (2020, 1). Considering transdisciplinarity in the field of philosophy, Stella Sandford has pointed out that "transdisciplinary theory and its concepts are not necessarily identifiable with any specific disciplinary fields, either in their origin or application" (2015, 160). In this light Sandford considers philosophy, "the most tightly policed discipline in the humanities," and its rejection of the transdisciplinary concepts, methods, and practices of feminist theory, a transdisciplinary area par excellence.

Looking back in the history of philosophy and science we know of course that, although distinctions between disciplines did exist, science and philosophy were interconnected and the *savants* in the early modern period were active in a wide range of disciplines including mathematics, physics, the natural sciences, as well as philosophy and literature (see Smith 2009). In Germain's time however, disciplines had definitely become much more bounded and specialized, and we have already seen Germain's particular tribute to mathematics as the science of truth par excellence in the previous section.

In this context Germain's adventures in philosophy were indeed a bold transdisciplinary move, particularly considering that not only did she attempt to engage in the philosophical debates of her time, but she also tried to transpose concepts from mathematics and physics to philosophical reasoning. Muller has suggested that Germain's dream was "to apply the language of numbers to moral and political issues" (2023, 85). What I have argued in this paper is that, apart from her input to moral and political philosophy, Germain has made an important contribution in the field of process epistemologies. While I see the merit of Muller's assertion that Germain was trying "to apply the language of numbers to moral and political issues," I think that her stance was much more complicated than just the mathematization of the social.

Transposing concepts is not synonymous with transferring, but rather includes radical changes or perhaps mutations, both in the concepts and the fields they are being transposed to. Rosi Braidotti has influentially theorized the importance of

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"transpositions," searching for its roots in music and in genetics. The concept of transpositions "indicates an intertextual, cross-boundary or transversal transfer, in the sense of a leap from one code, field or axis into another, not merely in the quantitative mode of plural multiplications, but rather in the qualitative sense of complex multiplicities," Braidotti has noted (2006, 5). As a musical term transpositions can be taken as variations on a theme, non-linear, but non-chaotic, while in genetics transpositions refer to processes of mutation, neither random, nor arbitrary: "transposable moves appear to proceed by leaps and bounds, but are not deprived of their logic, or coherence" (5). In the field of epistemology, transpositions facilitate the emergence of other ways of knowing and offer "a contemplative and creative stance that respects the visible and hidden complexities of the very phenomena it attempts to study," notes Braidotti (6). It is precisely here that Germain's innovative and pioneering work on transdisciplinary thought lies. In being transposed to the philosophical field Germain's language of calculus creates transdisciplinary connections between science, philosophy, and the arts, opening up new vistas wherein socio-political realities can be seen and understood, and philosophical inquiries can further be unfolded.

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Notes

1 "Le temps ne conserve que les ouvrages qui se défendent contre lui."

2 For a discussion of Germain's contribution to pure and applied mathematics, see Bucciarelli and Dworsky 1980; Del Centina and Fiocca 2018; Musielak 2020.

3 For a comprehensive overview of the literature around Germain, see Musielak 2020.

4 Germain's philosophical work was discussed at the time of its posthumous publication, mostly among positivist philosophy circles (see Stupuy 1896). For contemporary engagements with her philosophical work see Musielak 2020, particularly ch. 10; Glesser et al., 2020; Muller 2023.

5 For more details about Libri's passion for collection see Maccioni-Rujo and Mostert 1995, esp. ch. 9; Del Centina and Fiocca 2018; Musielak 2020, esp. ch. 11.

6 Si les hommes qui ont avancé les sciences par leurs travaux, si ceux à qui il a été donné d'éclairer le monde, veulent revenir sur le chemin qu'ils ont fait, ils verront que les idées les plus belles, les plus grandes, sont les idées de leur jeunesse, mûries par le temps et par l'expérience. Elles sont renfermées dans les premiers essais, comme les fruits dans les boutons du printemps.

7 … un sentiment profond d'ordre et de proportions devient pour nous le caractère du vrai en toutes choses …

8 Les oracles du goût et les arrêts de la raison se ressemblent; l'ordre, la proportion et la simplicité ne cessent pas d'être des nécessités intellectuelles. Les sujets sont différents, mais le jugement est constamment appuyé sur ce type universel qui appartient également et au beau et au vrai.

9 L'esprit exige de la clarté; il veut que les diverses parties soient liées entre elles, avec assez d'art pour que leur rapport s'aperçoive d'un coup d'œil; il demande un ordre facile à saisir; il se complaît dans la simplicité, source de l'élégance.

10 … l'esprit humain est guidé dans toutes ses conceptions par la prévision de certains résultats, vers lesquels se dirigent tous ses efforts.

11 … l'esprit humain obéit à des lois; elles sont celles de sa propre existence …

12 Et, en effet, un trait de génie, un trait d'éloquence, dans les sciences, dans les beaux-arts, dans la littérature, nous plaisent par une seule et même raison : ils dévoilent à nos yeux une foule de rapports que nous n'avions pas encore aperçus.

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13 Il entrevoit des résultats qu'il ne peut encore atteindre; son imagination s'élance, pour les saisir, dans les routes qu'elle s'est frayées; il craint de s'être égaré, il doute de ses premiers aperçus, il rétrograde et cherche à ressaisir les indications qui l'avaient d'abord guidé; un grand nombre d'idées se sont jointes à celles qui furent les premières; elles compliquent le sujet, partagent l'attention et suspendent le jugement. Mais, à travers ce chaos de pensées, le génie distingue une idée simple; son choix est irrévocablement fixé, il sait que cette idée sera féconde.

14 En traçant son plan, le poète ne perdra jamais de vue l'idée principale. Elle donnera à son travail l'unité d'intérêt et d'action, source de toute beauté véritable.

15 … le géomètre porte une attention soutenue vers l'idée heureuse qui dirige ses recherches.

16 L'homme de lettres s'occupera du choix des mots, de leur arrangement, de l'harmonie du vers ou de celle de la phrase.

17 La langue des calculs peut donner lieu à des corrections qui lui sont propres; car elle a aussi son style, et tous les auteurs ne l'écrivent pas avec le même degré de perfection.

18 Ah ! n'en doutons plus, les sciences, les lettres et les beaux-arts sont nés d'un seul et même sentiment.

19 … l'unité d'action, l'unité d'intérêt, la clarté de l'exposition.

20 Fidèle à sa pensée constante, l'homme n'a jamais cessé de regarder son existence propre comme le type de toutes les autres existences.

21 Profondeur de vue, justesse de jugement, imagination vive, voilà les qualités du géomètre.

22 Mais ce qui donne cette profondeur, ce qui exerce ce jugement, c'est l'imagination, non celle qui se joue à la surface des choses, qui les anime de ses couleurs, qui y répand l'éclat, la vie et le mouvement, mais une imagination qui agit au dedans des corps comme celle-ci au dehors.

23 "Transcendental idealism," a crucial concept in Kant's philosophy, with an important body of scholarship around it, cannot be covered within the limitations of this paper. See Stang 2023 for a recent overview of this important philosophical notion.

24 … le résultat immédiat des lois de l'être, ou si elles dérivent seulement d'un rapport entre toute autre réalité et celle de notre existence.

25 …les arguments les plus concluants peuvent être attribués ou à des rapports nécessaires, ou aux formes de notre entendement ; en sorte que, à cet égard, toute décision rationnelle paraît nous être interdite.

26 … on ne saurait nier, en effet, la légitimité du doute philosophique; car ce doute est fondé sur l'impossibilité de comparer aucun autre jugement avec celui de l'homme.

27 L'espace et le temps, voilà ce que l'homme se propose de mesurer; l'un circonscrit son existence momentanée; l'antre accompagne son existence successive.

28 … l'espace est connu par le temps, le temps est mesuré par l'espace.

29 Notre logique se compose de règles dictées par la raison universelle.

30 … tend à saper dans ses fondements la réalité absolue de toutes les certitudes que nous pouvons obtenir.

31 Dès leur naissance, les sciences mathématiques ont offert à l'esprit humain l'entière réalisation de ce type du vrai, objet de ses plus chères affections.

32 … langage plus obscur encore que les idées qu'il était destiné à rendre …

33 On devait s'égarer; et pourtant les erreurs de l'esprit humain, qui sembleraient inépuisables, se sont toutes rapprochées de certaines vérités, et n'ont pas été aussi nombreuses que le vice des procédés pourrait le faire présumer. C'est que le sentiment du vrai n'a jamais abandonné les auteurs de tous ces systèmes. Cet heureux sentiment n'a pas suffi pour les préserver des suppositions arbitraires et forcées, mais il a retenu leur imagination dans de certaines limites.

34 See the annexes of Germain's *Œuvres philosophiques* (1896, 358–93).

35 For a detailed exposition of Germain's teachers, mentors, friends, and rivals, see Musielak 2020, esp. ch. 11.

36 Doutera-t-on que le type de l'être ait une réalité absolue, lorsqu'on voit la langue des calculs faire jaillir d'une seule réalité dont elle s'est emparée toutes les réalités liées à la première par une essence commune?

37 De toutes nos idées, la plus abstraite est celle de l'être; car celle du néant est toute négative. L'être nous appartient, il pénètre notre intelligence et l'éclaire du flambeau de la vérité.

38 See Goering, cited in *La Neue Freie Presse,* published in Vienna on August 22, 1888. An extract of this article is included in the annexes of the *Œuvres philosophiques* (Germain 1896, 373–78).

39 See Comte's calendar at https://gallica.bnf.fr/ark:/12148/bpt6k21868f.texteImage and Sarton 1952 for a discussion of Comte's positivist calendar.

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40 Sans doute, l'impression produite par la lecture d'un ouvrage d'imagination ne ressemble pas à celle qui résulte de l'étude d'un traité de géométrie.
41 Ne nous pressons pourtant point de conclure qu'il n'existe aucun lien commun entre des œuvres qui semblent d'abord si différentes.
42 Il deviendra évident que la littérature la plus élevée, comme les découvertes dont s'enrichit la science, ont été inspirées par un sentiment d'ordre et de proportions qui est le régulateur de tout mouvement intellectuel.
43 un ordre inattendu d'idées ou de sentiments
44 La force est dans le corps la faculté de se mouvoir et de mouvoir les autres; elle est en nous le sentiment de la puissance.
45 See Whitehead 1985, part III, ch. 1.
46 . . . les idées se présentent en foule à l'imagination du poète; il reste quelque temps incertain; une multitude de ressorts différents semblent pouvoir donner la vie à sa composition; il en suit le développement, puis il y renonce. Il fait un choix nouveau, son mécanisme se complique; il n'en est pas content, il s'arrête, il revient sur ses pas.
47 . . . le poète ne nous rendra pas compte des discussions pleines de finesse qui ont précédé l'adoption des emblèmes qu'il a choisis . . .
48 . . . l'homme de génie qui a surpris un des secrets de l'ordre naturel, ne nous dira pas non plus combien de fois son imagination s'est égarée autour de la route qui devait le conduire à la connaissance certaine d'une vérité qu'il est à présent en état de démontrer.
49 Du milieu de cette lutte tumultueuse entre des projets contraires surgit enfin une idée simple. Soit qu'elle ait déjà été entrevue, soit qu'elle se présente à lui pour la première fois, l'auteur sent que cette idée est celle qu'il avait poursuivie.

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