Commentary

Cancer: Being or Becoming? A Whiteheadian Process Ontology Perspective

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Cancer research has traditionally approached the disease as a static entity, primarily explained through genetic mutations. However, this reductionist perspective fails to capture the dynamic, adaptive, and emergent nature of cancer. This paper proposes a paradigm shift in understanding cancer through the lens of process ontology, emphasizing "becoming" over "being." By framing cancer as a dynamic process influenced by molecular, cellular, and environmental interactions, this approach offers a more comprehensive understanding of the disease. Drawing on Alfred North Whitehead's process metaphysics, we argue that it provides a superior framework compared to other process perspectives, such as that of Dupré and Nicholson, for modeling cancer's complexity and opening new therapeutic avenues.

Introduction

Science and ontology are complementary fields. While science generates knowledge through observation and testable hypotheses, ontology provides the reflective and speculative foundation upon which scientific assumptions rest. Despite its claims to certainty, science relies on a priori assumptions rooted in ontological frameworks, such as the unobservable principles of mathematics and physics[1]. This interdependence underscores the need to integrate ontological perspectives into scientific inquiry for a holistic knowledge system.

Cancer research highlights the limitations of traditional substance-based ontologies, which treat entities as static and unchanging. In contrast, process ontology, notably advanced by Alfred North Whitehead, views reality as a system of dynamic processes rather than fixed substances. This paper argues that adopting Whitehead's process metaphysics offers a more coherent and comprehensive

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framework for understanding cancer's complexity, heterogeneity, and adaptability, surpassing alternative process perspectives like that of Dupré and Nicholson.

Substance Metaphysics vs. Process Metaphysics

Substance metaphysics posits that reality consists of discrete, self-contained entities defined by an immutable essence—the core attribute that determines an entity's identity across time and change. Rooted in Aristotelian philosophy, this view assumes that substances possess inherent properties that remain stable, with change occurring only as an external modification of these properties[2][3]. However, this framework faces significant ontological and epistemological challenges, particularly when applied to complex, dynamic systems like cancer.

Ontologically, substance metaphysics struggles to account for identity persistence amidst transformation. If an entity's essence is immutable, how can it remain "the same" when its properties —like a cancer cell's genotype or phenotype—undergo radical change? For example, a tumor may evolve from a benign state to a metastatic one. Substance metaphysics offers no coherent mechanism to explain this continuity, often relegating change to secondary accidents rather than an intrinsic feature of the entity[4]. This static view clashes with the fluid, adaptive reality of biological systems, where identity emerges from processes rather than fixed essences.

Epistemologically, the concept of essence is problematic because it is inaccessible to empirical verification. Essences are abstract constructs inferred rather than observed, rendering them speculative and untestable[3]. In cancer research, this manifests as a reliance on reductionist models that define tumors by static genetic mutations—such as BRCA1 or TP53 alterations—while sidelining the dynamic interplay of epigenetic, microenvironmental, and systemic factors. Robert Weinberg critiques this approach, noting that while reductionism has driven breakthroughs like targeted therapies, it falters against cancer's "endless complexity," as tumors adapt beyond their genetic blueprints[5]. The somatic mutation theory, a cornerstone of substance-based cancer models, assumes that cancer originates from a fixed set of genetic defects, yet it struggles to explain why genetically identical tumors exhibit diverse behaviors or why therapies targeting these mutations often fail due to emergent resistance[6].

In practice, substance ontology limits cancer research by framing tumors as isolated, static entities rather than relational systems. For instance, focusing solely on oncogene mutations overlooks how

the tumor microenvironment—hypoxia, stromal interactions, or immune responses—drives progression and adaptation[7]. This atomistic perspective fragments cancer into discrete components, ignoring the holistic dynamics that Whitehead's process metaphysics seeks to address. Whitehead critiques such frameworks for their "fallacy of misplaced concreteness," where abstract, static models are mistaken for the concrete, changing reality they aim to represent[8]. By reducing cancer to a collection of unchanging substances, this approach fails to capture its temporal evolution, emergent properties, and systemic interdependence—shortcomings that process ontology, particularly Whitehead's version, directly remedies.

Process Metaphysics

Process metaphysics envisions reality as interconnected processes, where identity emerges from relationships and adaptive interactions rather than fixed essences. Change is intrinsic, as processes reorganize in response to their environment[8]. This shifts the focus from "Is this the same object?" to "How does this process behave?"—offering a framework that integrates regularity and transformation[3].

Traditional cancer models emphasize genetic mutations as the primary drivers, yielding valuable insights but failing to address cancer's heterogeneity and adaptability. Process ontology redefines cancer as a continuous "becoming," shaped by dynamic molecular, cellular, and microenvironmental interactions.

The Role of Dynamic Processes in Cancer

Cancer transcends genetic mutations, driven by epigenetic modifications, microenvironmental influences, and immune system interactions. The tumor microenvironment—a domain of hypoxia, inflammation, and stromal cell dynamics—either promotes or suppresses proliferation, highlighting cancer's adaptive capacity[7].

Cancer exhibits emergent properties like tumor heterogeneity, metastatic potential, and therapy resistance, arising from interactions between intracellular pathways and the microenvironment. These behaviors underscore that tumors exceed the sum of their parts[6].

Whitehead vs. Dupré and Nicholson: A Comparative Analysis

Among process ontologies, Whitehead's metaphysics stands out as particularly suited to modeling cancer, compared to the biologically focused process philosophy of John Dupré and Daniel Nicholson. Dupré and Nicholson argue that living beings are dynamic processes, not static substances, organized in a hierarchy of stabilized processes across timescales[9]. They note that processes are causally interconnected and vary in magnitude, intensity, and complexity, which aligns with cancer's dynamic nature and hierarchical interactions—from molecular signaling to systemic immune responses[9]. However, their framework lacks a method for explaining how these processes relate or generate novelty—key aspects of cancer's progression.

Whitehead's process metaphysics, in contrast, provides a comprehensive system. His concept of "concrescence" describes how processes—such as genetic alterations, epigenetic shifts, and microenvironmental cues—converge to form new entities, mirroring cancer's evolution through the integration of diverse influences[8], pp. 21-22]. His "theory of occasions" explains how processes interact across time, linking past events (e.g., initial mutations) with present conditions (e.g., immune responses) to shape future outcomes (e.g., metastasis)[8], pp. 194-195]. Moreover, Whitehead's emphasis on "creativity" and "novelty" directly addresses cancer's emergent properties—like normal to malign transformation, therapy resistance—offering a mechanism for how cancer adapts innovatively, a dimension absent in Dupré and Nicholson's work[8], p. 21].

While Dupré and Nicholson observe process interconnectedness and hierarchies, they do not specify how these interactions occur or why cancer exhibits creative adaptation[9], p. 13]. This gap limits their explanatory power for cancer's complexity. Whitehead, however, posits that ordered process relations, facilitated by a system of relational interplay, prevent randomness—a critical insight for understanding why cancer progresses systematically rather than chaotically[8], pp. 88-89]. Thus, Whitehead's approach not only captures cancer's dynamism but also models its relational and innovative nature more effectively than Dupré and Nicholson's biologically constrained perspective, which, while insightful for living systems, falls short in addressing cancer's emergent and adaptive complexity.

Process Ontology in Practice: A New Framework for Cancer Research

Adopting Whitehead's process ontology transforms how we approach cancer research by emphasizing its dynamic, relational, and emergent nature. This section explores practical applications through three key domains, leveraging Whitehead's concepts such as "concrescence" (the process of integrating diverse influences into a new entity), "creativity" (the generation of novelty), and the "theory of occasions" (how past processes inform present and future states) to reframe cancer as a state of "becoming" rather than a fixed "being."

The tumor microenvironment is not a passive backdrop but a dynamic domain that decisively influences cancer across all stages—from initiation to metastasis. Whitehead's process metaphysics provides a robust framework for understanding this interplay. He describes reality as a nexus of processes interacting through "prehension," where each process incorporates aspects of others into its becoming[8], pp. 23-24]. In cancer, immune cells, stromal support cells, and extracellular matrix proteins form a relational network that shapes tumor progression. For instance, hypoxia—a low-oxygen state—can trigger angiogenic processes that promote tumor growth, while inflammation may enhance cancer cell survival through cytokine signaling[10].

System dynamics further reveal cancer's complexity. Whitehead's "theory of occasions" posits that processes integrate past events into present configurations, projecting toward future possibilities[8], pp. 194-195]. Applied to cancer, the microenvironment's history—such as prior immune exposures or chronic inflammation—conditions its current state, influencing whether it suppresses or accelerates tumor growth. This temporal relationality suggests that modulating the microenvironment (e.g., targeting stromal cell signaling or reducing hypoxia) could disrupt cancer's trajectory. By viewing the microenvironment as a Whiteheadian process system, researchers can identify novel therapeutic targets that address these dynamic interactions rather than static components[10].

A New Perspective on Therapeutic Approaches

Traditional cancer therapies often target static genetic mutations, such as inhibiting oncogenes like KRAS. However, Whitehead's process ontology shifts the focus to cancer's dynamic adaptability, advocating treatments that address its relational and transformative nature. His emphasis on

"creativity" highlights how cancer generates novel responses—such as therapy resistance—through the interplay of processes[8], p. 21]. For example, tumors may adapt to chemotherapy by upregulating efflux pumps or altering signaling pathways, behaviors that emerge from the integration of genetic, epigenetic, and environmental influences.

This perspective aligns with emerging strategies like immunotherapies, which leverage the immune system's dynamic interactions with cancer cells. Immune checkpoint inhibitors (e.g., anti-PD-1 therapies) enhance T-cell responses, disrupting the tumor's ability to suppress immunity—a process-driven approach that mirrors Whitehead's relational framework[11]. Similarly, modulating the tumor microenvironment—such as targeting stromal cells with anti-fibrotic agents—addresses cancer's systemic adaptability rather than isolated mutations. Whitehead's "concrescence" suggests that therapies should aim to alter the convergence of processes (e.g., immune evasion, angiogenesis) that sustain cancer, rather than focusing solely on static endpoints like DNA repair[8], pp. 21-22].

This approach also encourages longitudinal strategies. Since Whitehead's "theory of occasions" links past, present, and future processes, treatments could target cancer's evolutionary path—for instance, preempting resistance by combining therapies that disrupt multiple process pathways simultaneously[11]. By embracing cancer as a becoming process, Whitehead's framework inspires therapies that evolve with the disease, offering a more resilient response to its adaptability.

Epigenetic mechanisms—such as DNA methylation, histone modifications, and microRNAs—play a pivotal role in reprogramming cellular behavior, driving cancer's adaptability. Whitehead's process ontology frames these as dynamic processes of "becoming," where cellular identity emerges from ongoing relational transformations rather than fixed essences[8], pp. 23-24]. For instance, hypermethylation of tumor suppressor genes silences their expression, while histone acetylation alters chromatin accessibility, enabling cancer cells to shift phenotypes[12]. These changes are not static but evolve through interactions with the cellular microenvironment, reflecting Whitehead's concept of "prehension"—the incorporation of external influences into a process's development.

Whitehead's "creativity" further illuminates how epigenetic modifications generate novelty in cancer. MicroRNAs, for example, can regulate multiple gene networks, enabling rapid adaptation to stressors like chemotherapy[12]. This emergent behavior aligns with Whitehead's view that processes produce new realities through relational interplay[8], p. 21]. Understanding epigenetics as a Whiteheadian

process reveals why targeting single epigenetic alterations often fails—cancer's adaptability stems from a dynamic system of converging influences, not isolated events.

Practically, this suggests therapies that modulate epigenetic dynamics holistically. Inhibitors of DNA methyltransferases or histone deacetylases (e.g., azacitidine) can reverse silencing, but combining these with microenvironmental interventions—like immune activation—could disrupt the broader process network sustaining cancer[12]. Whitehead's framework encourages researchers to map these temporal and relational dynamics, identifying critical convergence points (concrescence) where interventions can shift cancer's trajectory toward suppression rather than progression.

Conclusion

Viewing cancer through Whitehead's process ontology reveals it as a complex, ever-changing state of becoming, shaped by environmental, systemic, and dynamic interactions—not merely a molecular disorder. Compared to Dupré and Nicholson's framework, Whitehead's metaphysics offers a more robust model by addressing process relations, creativity, and emergent properties essential to cancer's nature. This perspective moves cancer research beyond reductionism, fostering comprehensive therapeutic strategies that target its dynamic essence.

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