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Rethinking Growth: A Bio-Inspired Take on Creative Processes

Introduction

Problem. The concept of *growth*, stemming from our understanding of the natural world, has played a crucial role in the perception and shaping of our material, social, and economic realities. As dystopian futures are unfolding in front of us, there is a growing concern about growth, which urges us to rethink some of our basic concepts around the matter to stand a chance in facing the current and future crises.

Objective. The presented work is a transdisciplinary effort to reflect on the concept of growth from a bio-inspired perspective, rethink it within the current discourse of New Active Materialism, and put it forward as an analytical tool as well as a creation strategy to address the urgencies of our time.

Approach. The approach of the work is to take the knowledge of activity of matter and material systems from materials science and biology; borrow the questions and concepts from various realms within humanities disciplines that are relevant to the *Active Materialism* discourse (cultural studies, feminist new materialism, information philosophy, and so on); weave the reflections on the interdisciplinary creative experiences into the mesh; and rethink the phenomena in light of these new transdisciplinary understandings, perspectives, and concepts, with the ultimate goal of bringing the new insights back into the various relevant realms of analysis and synthesis (e.g., interdisciplinary science and design research and education, sustainability discourse, and so on).

Outline. The most relevant place to start such a rethinking process is the realm of biology. By going through an example from biological material activity, the first chapter, "Active Materials Paradigm," opens up the current discourse around matter and material activity, paints a more performative picture of matter beyond the conventional paradigms, and looks at activity of matter through various *stances.* The second part, "Rethinking Growth as Sympoiesis," highlights some of the core principles in biological material systems and compares them to our industrial *fabrication paradigm*, and, based on those reflections, proposes a different take on growth that is rooted in and reflects the *creative nature of entangled dynamisms and performative structures.* The third chapter, "Rethinking Growth as Creation Strategy," summarizes the proposed model of growth and hints at how such a paradigm shift can serve a *creation methodology.* Chapter four concludes the argumentation and puts forth some *future* perspectives.

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Active Materials Paradigm—Activity through Various Stances

Case of an Active Material System

Consider the example of ice plants' hydro-actuated seed dispersal. Ice plants grow in arid areas and have evolved a sophisticated material strategy to ensure the seed dispersal in the right environmental conditions, namely upon rain. The underlying material architecture that enables the hydro-responsive actuation of the dead tissue is traced at various length scales in figure 1. The five seed-containing compartments are closed in a dry state (fig. 1A, top), and unfold and release the seeds only upon wetting (fig. 1A, bottom). The five hygroscopic muscles (keels) are folded inward and keep the valves closed in the dry state, and flex outward only upon hydration (fig. 1B, 1 – 2 and fig. 1, top right: schematic of flexing of the keels). The keels are made up of a network of hexagonal eye-shaped cells, filled with a highly swellable cellulosic inner layer, which would swell/ shrink upon hydration/drying cycles, resulting in the reversible opening/closing of the cells (fig. 1C–E, 4 – 5) and the expansion/contraction of the honeycomb structure (fig. 1C, 3). Presence of an inert backing tissue (fig. 1B, 2) hinders and resists the hydro-actuated deformation of the honeycomb structure, and, to compensate, the linear deformation translates into a bending one (fig. 1B–C, 1 – 3), which results in flexing of the keels and opening of the seed capsule (fig. 1A – B).[1]

To Narrate a Material's Activity

The common narrative of *Material* → *Property* → *Function* leans on the *Subject-Object-Property* paradigm: an inherently hylomorphic and patriarchal paradigm that takes matter as individuated and passive (fig. 2A).

The Conventional Materials Paradigm from material science and engineering visualizes the matters of material in a tetrahedron (fig. 2B) as an integrated way of addressing different perspectives of understanding and control of various aspects of materials.[2] One can take the perspectives of each of the interrelated four apices of the diagram: particular organization/ arrangement of materials (compositions) into structures over range of length scale; the synthesis and processing of those compositions and arrangements; the properties resulting from the compositions and their arrangements; and, finally, the performance of the material as a measure of its utility in a

1 Lorenzo Guiducci et al. 2016, "Honeycomb actuators inspired by the unfolding of ice plant seed capsules," *PLoS One* 11 (2016): e0163506, https://doi.org/10.1371/journal.pone.0163506.

2 National Research Council, *Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Age of Materials* (1989).

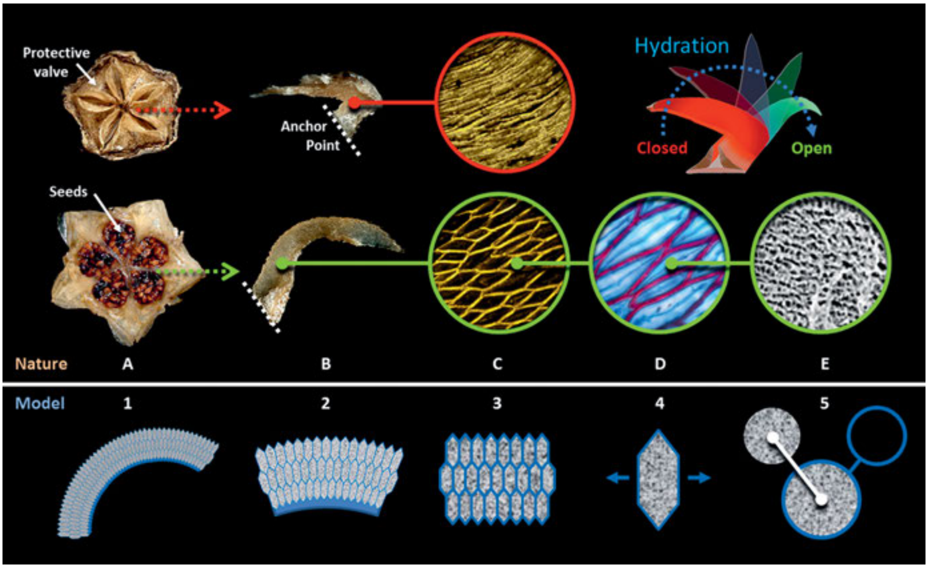

Fig. 1: Ice plant hydro-actuated seed dispersal: an active material system.

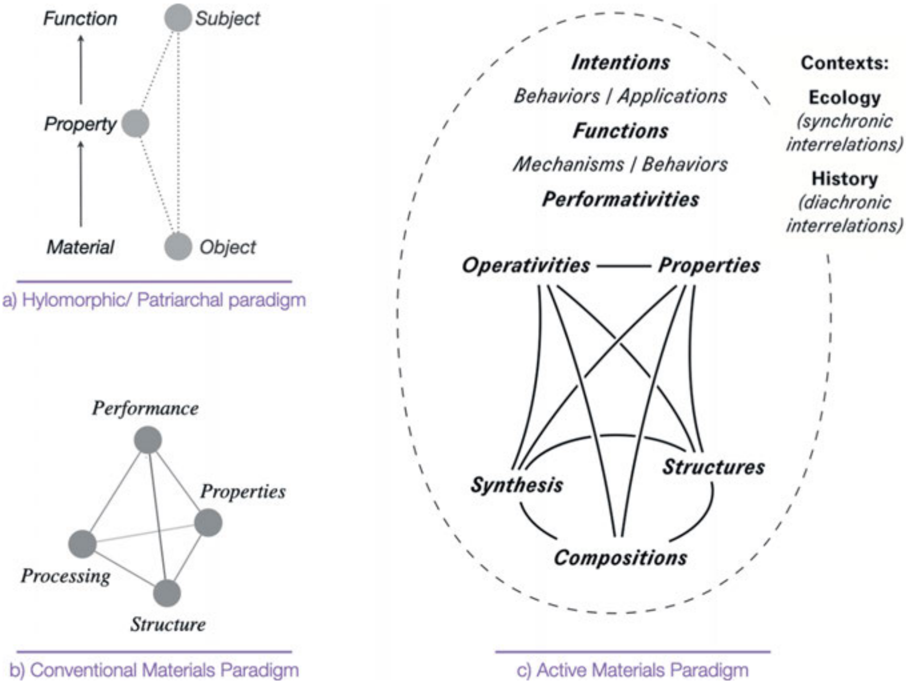

Fig. 2: Toward an Active Materials Paradigm: (2A) author's conception of hylomorphic paradigm; (2B) conventional materials science tetrahedron (National Research Council 1989); (2C) Active Materials Paradigm by Khashayar Razghandi, 2022.

given context. Nonetheless, the hylomorphic view of matter, as a passive building block to be tamed and shaped into forms and structures with specific functions, is also dominant in this conventional materials paradigm.

Going back to the ice plant hydro-responsive actuation, one can try to narrate the activity from various perspectives or stances as different yet entangled levels of description of the phenomena: various sugar molecules as composition; the process of how they are synthesized and put together; the structure and multiscale architecture they are synthesized into; and the role which this material architecture plays in defining the observed properties and functions. In this way we can construct some structure-function relationships. The whole system is made up of few basic components (cellulose, hemicellulose macromolecules, etc.), and the activity of the system (hydro-responsive actuation) is mainly due to the architecture of the material system at various length-scales. Ice plant and similar plant actuation systems are not a rare case; in biology, we encounter various forms of this structure-function or structure-activity relationship. Biology is based on only a few basic elements and building blocks, and the wide range of properties and functionalities we observe in nature are mainly achieved through diverse structures and material architectures.[3] In this narration of the ice plant actuation system, sensing, processing, and response to stimuli (rain) are integrated in one material system: we have "sense-action."[4] Material structure/organization is the key to relate matter, information, and energy.[5]

To continue with the narration, we can place composition, structure, and synthesis as the triad base of the material paradigm giving rise to various properties at various length scales of the system. However, one can take the same system, and narrate the system not only through the lens of composition, structure, and synthesis defining a specific property, but by following the chains of operations: "Water absorbs on sugar molecules the cellulosic inner gel swells, inflating the cells . . . pushing the cell walls from inside and opening the cells . . .," and so on. Looking at the system through the chains of operations can shed a different light on the matter, taking matter as operative. Property and operativity are two interrelated stances one can take to look at what emerges from the triad base of composition, structure, and synthesis.

3 See Peter Fratzl et al., *Active Materials* (Berlin: De Gruyter, 2021); Alexander H. King, "Our Elemental Footprint," *Nature Materials* 18, no. 5 (2019): 408 – 09, https://doi.org/10.1038/s41563-019-0334-3; Michaela Eder, Shahrouz Amini, and Peter Fratzl, "Biological Composites—Complex Structures for Functional Diversity," *Science* 362, no. 6414 (2018): 543 – 47, https://doi.org/10.1126/science.aat8297; Yuri Estrin et al., *Architectured Materials in Nature and Engineering* (Heidelberg: Springer, 2019); and Peter Fratzl, Christiane Sauer, and Khashayar Razghandi, "Editorial for the Special Issue: Bioinspired Architectural and Architected Materials," *Bioinspiration & Biomimetics* 17, no. 4 (2022): 1 – 4, https://doi.org/10.1088/1748-3190/ac6646.

4 Mohammad Fardin Gholami et al., 2021. "Rethinking Active Matter: Current Developments in Active Materials," in *Active Materials* (Boston: De Gruyter, 2021), 193 – 222, 212.

5 Gholami et al., "Rethinking Active Matter"; Fratzl et al., *Active Materials.*

Thus, we end up with a double-horned pyramid as the foundation of a new *Active Materials Paradigm* (fig. 2C).[6] This places *activity* at the core of the materials paradigm.

The first thing this paradigm shift does, is that the boundaries and interfaces within and in between material systems become blurry. If you follow the chain of operations, you will find yourself facing with porous, blurry, and fluid interfaces and event-based boundaries signified by the intra-activities at various scales.[7]

Following this path, *function* turns out to be not just a *telos* at the macro scale, but can be taken as a stance situated within various interrelations in the architecture of the system: a sugar molecule can be a functional unit of the swelling gel inflating the cell, or single cells can be taken as the functional unit of the honeycomb structure, and so on. Here, we have structural and functional interrelations not only throughout the material architecture (between larger or smaller length scales), but also with the surrounding environment.[8]

Ice plants open in response to rain and have evolved to do so: material systems are situated within ecologies and histories.[9] This brings the performativity stance into the materials paradigm (fig. 2C).[10] Biology is the realm of entangled dynamism and performative structures. *Things* are always situated in an entangled interwoven meshwork of things (ecologies), and things are dynamic: they have histories and futures. In this sense, *ecology context* highlights the synchronic sense of interrelations, and *history context* highlights the diachronic interrelations. Looking from the performativity stance, matter can be seen as performative in the meshwork of ontological relations and relevance. We are not dealing with subjects, objects, and their properties; rather, we are dealing with co-beings and co-becomings.

We are dealing with entangled dynamisms and performative structures.

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6 Khashayar Razghandi, "Rethinking Materials Paradigm: Towards an Active Understanding of Gestalt," in *Design, Gestaltung, Formatività*, ed. Patricia Ribault (Berlin: Birkhäuser, 2022).

7 Khashayar Razghandi and Emad Yaghmaei, "Rethinking Filter: An Interdisciplinary Inquiry into Typology and Concept of Filter, Towards an Active Filter Model," *Sustainability* 12, no. 18 (2020): 7284, https://doi.org/10.3390/su12187284.

8 Gholami et al., "Rethinking Active Matter."

9 Razghandi, "Rethinking Materials Paradigm."

10 Karen Barad, "Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter," *Signs: Journal of Women in Culture and Society* 28, no. 3 (2003): 801–31; Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham, NC: Duke University Press, 2007); Jens Hauser and Lucie Strecker. "On Microperformativity," *Performance Research: A Journal of the Performing Arts* 25 (2020): 1–7; Razghandi, "Rethinking Materials Paradigm."

Rethinking Growth as Sympoiesis—Bio-inspired Analysis of Creative Processes

Makings of Biology vs. Fabrication Paradigm

The whys and ways of biology making things are paradigmatically different from the whys and ways we design and manufacture things. This has to do with the difference in the boundary conditions or constraints that shape the *making*.

In biology, things are mainly made through growth processes. Making in biology looks more like following a recipe: it is approximate. Our manufacturing paradigm is more like a blueprint: identical, exact materials, parts, and processes (think of the production lines of early cars or today's smartphones). Situated within specific ecologies (thermodynamical, physiological, evolutionary, developmental, and so on), biology is "poor." It has to make do with available resources: ambient temperature, relatively low forces, and so on. It also has to make do with whatever is available as building blocks to make. All life (on earth) uses only few basic elements (fewer than thirty) from the whole periodic table. Our smartphones use around seventy of the 118 known elements.[11] We are "rich" with "abundant resources"!

Life makes a variety of properties and functionalities possible by playing with material structure. It makes use of a variety of biologically or thermodynamically controlled processes to shape those structures. These processes of making are fundamentally different from the energy- and resource-heavy fabrications that shape the making paradigm of our time. "Heat beat treat" is not just a faint memory of the blacksmiths, or a foggy factory of an old industrial area. Even our most advanced 3D-printing technologies follow the same hylomorphic logic: extract, assemble, and shape the passive matter into the desired forms and functions. We are "rich" with "abundant resources"!

Following these *boundary conditions* and constraints of growth, biology ends up with diverse material architecture and multi-functionalities. Multi-scale structure of material systems gives rise to various properties and operativities and addresses multiple functionalities simultaneously.[12] The core of the fabrication paradigm is about picking of the "right" material (material selection), design and fabrication of different parts, and assembly of those parts into systems and devices.[13]

Thinking along Borgmann's distinction of "things" and "devices," biology is more "thingy," more open and entangled, while our fabrication more often seeks and results

11 King, "Our Elemental Footprint."

12 Eder, Amini, and Fratzl, "Biological Composites"; Estrin et al., *Architectured Materials*; Peter Fratzl, "Biomimetic Materials Research: What Can We Really Learn from Nature's Structural Materials?," *Journal of the Royal Society Interface* 4, no. 15 (2007): 637–42, https://doi.org/10.1098/rsif.2007.0218; Fratzl, Sauer, and Razghandi, "Bioinspired Architectural and Architected Materials."

13 Fratzl, "Biomimetic Materials Research."

Fig. 3: Makings of biology vs. fabrication paradigm, inspired by Peter Fratzl, "Biomimetic Materials Research: What Can We Really Learn from Nature's Structural Materials?," *Journal of the Royal Society Interface* 4 (2007): 637–42, doi: 10.1098/rsif.2007.0218.

in "devices" as closed and protected systems.[14] *Things* in biology are open and entangled material systems, with fluid interfaces and event-based boundaries, where matter, energy, and information flow within the entangled dynamisms and performative structures.

Biology is the realm of entangled intra-activities,[15] within meshworks[16] of entangled dynamisms and performative structures, with interwoven yarn-balls of ontological cares and significances which we call things. Fabrication relies mainly on imported activity. It is about shaping passive matter into forms, parts, devices, and systems, and then bringing the activity into those systems (e. g., cables of energy and information) to serve a certain function for a certain amount of time. Fabrication follows a paradigm of closed and protected, secure and fixed design with imported activity.

The boundary conditions and constraints are the key to emergence of organizations structures. Biology and information philosophy point to the potentiality and contingency of the constraints.[17] The potentiality of not just what happens but also what

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14 Albert Borgmann, *Technology and the Character of Contemporary Life: A Philosophical Inquiry* (Chicago: University of Chicago Press, 1987); James Auger and Julian Hanna, *Reconstrained Design* (Madeira: M-ITI, 2019).

15 Karen Barad, "Posthumanist Performativity" (see note 10); Karen Barad, *Meeting the Universe Halfway.*

16 Tim Ingold, "Toward an Ecology of Materials," *Annual Review of Anthropology* 41 (2012): 427–42, https://doi.org/10.1146/annurev-anthro-081309-145920.

17 Terrence W. Deacon, *Incomplete Nature: How Mind Emerged from Matter* (New York: W. W. Norton & Company, 2011).

could happen and could have happened, is defined through the boundary conditions and constraints. The entanglements and coupling of the different constraints of different material systems are, on the one hand, maintaining the organizations and structures that matter, and, on the other hand, the loci of the emergence of new structures, organizations, and creations.[18]

This paints a meshwork model of entangled co-beings and co-becoming. The structures are in becoming and the emergence and sustenance of structures/organizations are to be traced in the entangled dynamisms and constraints. These can be imposed by physical, thermodynamic, evolutionary, and developmental processes, among others, and interactions across various scales and stances. Biologically or thermodynamically controlled processes that realize the makings in biology are shaped by the boundary conditions of entangled material systems at various scales and stances. The coupling of the constraints and boundary conditions of different materials' organization results in dynamic fluxes of matter, energy, and information into and in between such entangled structures. Structure is the key to biological material solutions. Structures have open, fluid, and event-based boundaries, entangled with various other structures at smaller and larger length scales of the system, and expanding out into other structures of other dynamisms.

Growth is situated within various entangled histories and ecologies with specific boundary conditions and constraints imposed on it at various scales and stances. Situatedness of growth in biology urges adaptation, not only at the level of evolution, but also at the systems and materials level. The growth of biology, entangled with the historical and ecological contexts, begets adaptations of materials, structures, and functions to the changing entangled dynamisms and conditions. Adaptations is biology's way of dealing with uncertainty and openness.

In the light of this analysis of the whys and ways of making in biology, and through the lens of the active materials paradigm, I propose to reimagine growth along the background of the creative nature of entangled dynamisms and performative structures (fig. 4).

Rethinking Growth as Creation Strategy—A Bio-Inspired Synthesis of Creative Processes

Growth as a Creative Methodology

Complex problems are in essence systemic and dynamic. *Systemic* nature entails that there are multiple actors involved that are in an entangled interrelation with each other: dealing with an ecology rather than mere causal relations of subjects, objects,

18 Ibid., *Incomplete Nature.*

and properties. *Dynamic* aspect points out to the fact that any structure is essentially a structure in becoming: the relations defining the synchronic aspects are, in fact, a snapshot of an ever-changing relation in a diachronic dimension. In dealing with such problems, which are multifaceted and ever-changing, a suitable creative approach is one that is simultaneously integrative and adaptive. The proposed bio-inspired model of growth can serve as a methodology that can address these various aspects both in analytical and synthetical practices.

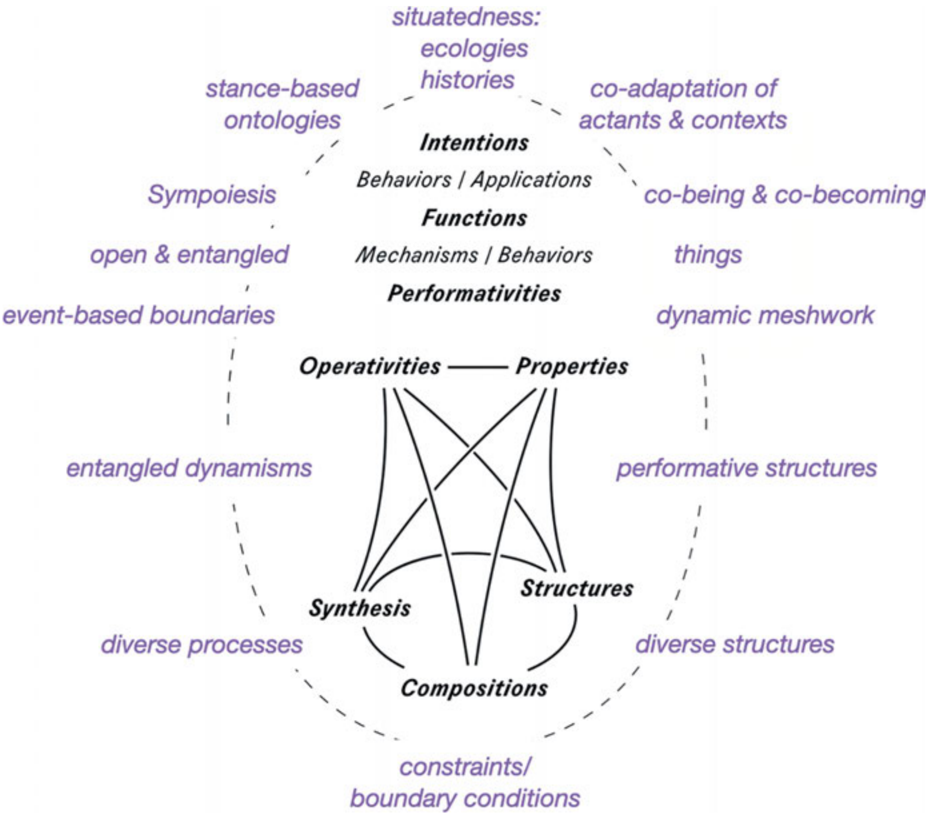

Fig. 4: Rethinking growth: creative nature of entangled dynamisms and performative structures.

Figure 4 highlights the core concepts around the proposed model of *growth as creation strategy* which can be summarized as follows.

The proposed *active materials paradigm* (figs. 2, 4) invites thinkers and makers to address and engage with matter through the lens of a diverse range of stances of *composition, structure, synthesis, property, operativity, performativity, function, intention.* The active materials paradigm diagram can be used as a tool to cultivate a more systemic and dynamic understanding of making:

> "Acknowledging and paying attention to the proposed conceptions, as well as following a dynamic shift of perspective between these stances, can serve as a tool for engaging with these various levels of descriptions of a phenomenon, the relevant realms of ontologies and boundary conditions associated with these stances and the interrelation between them. The hope is that such an engagement helps with our thinking, questioning, explaining, or making and nurtures a more comprehensive picture of Gestaltung throughout analysis and synthesis."[19]

Things are systemic and dynamic. Things are situated within ecologies and histories (fig. 4). In various realms of making (e. g., chemistry, biology, engineering, design, etc.) we usually deal with things rather than isolated subjects or objects. This serves as a reminder that things are situated in open and entangled dynamic meshworks of interrelations and intra-actions.

Taking the operativity stance—and following chains of operations—invites us to take a different perspective of borders, interfaces, and boundaries of things. The assumed solid boundaries suddenly seem much more porous, more fluid, blurrier, and we find event-based boundaries assumed, signified, or made through the intra-activities at various scales.

It is important to notice that various stances—as various interrelated levels of description of things—are situated within different historical and ecological contexts (fig. 4). The emphasis lies in engaging with various stances; one deals with—entangled yet different—constraints and boundary conditions. For instance, in engaging with the material composition of a system, one deals with histories and ecologies, which are (entangled yet different) from the ones that one has to take into account as an *intentional stance*. Consequently, paying attention to—and shifting in between—the different constraints and boundary conditions that are acting at each stance becomes a crucial part of the creation process (fig. 4).

Another critical point is that in engaging with different stances one faces entangled yet different ontologies. Figuring out the things that things care for depends on the level of description of the system. The graph of ontological interrelations of a material system can be very different depending on whether the loci of attention is on the *synthesis stance* or the *function stance*. They involve different actants, constraints, ontologies, ontological interrelations, and so on. Thinking of things through these *stance-based ontologies* helps to have a clearer understanding of various actants and boundary conditions through the creation process (fig. 4). Keeping aware of stance-based ontologies, event-based boundaries, and so on, helps to question and rethink some conceptions such as unit, borders, inside/outside, passive/active, and so on.[20]

Things are and happen within entangled dynamisms and performative structures (fig. 4). The performativity stance invites to take a dynamic meshwork understanding of *things*, which allows us to practice seeing things through the lens of *co-beings* and *co-becomings*. In this light, growth—reimagined as the creative nature of such entangled

19 Razghandi, "Rethinking Materials Paradigm."

20 Gholami et al., "Rethinking Active Matter"; Razghandi and Yaghmaei, "Rethinking Filter."

dynamisms and performative structures—can be thought of and implemented as a methodology for co-creative processes among human and nonhuman actants.

In such an entangled and dynamic view of things, adaptation—at various stances —becomes an essential feature of the creation strategy (fig. 4): adaptive materials, structures, properties, designs, etc., as well as adaptive processes, collaboration modes, dynamics, and so on.[21] The evolutionary tree (coral) of the creation process can be traced as a tool to: a) follow the growth of the ideas, creations, and the projects as a whole; b) help to signify the adaptations and the constraints and rationales behind them; c) highlight the failures, dead ends, etc., and the constraints and rationales behind them; d) notice complementary ideas across branches; and so on.[22] As such, adaptation becomes one of the key features of growth as creative methodology, and prepares one to notice and address the co-adaptation/co-evolution of various actants and contexts within the creation process. Such *sympoietic* understanding of things serves as a reminder-tool to distance oneself from seeing creations as individuated, closed, and passive objects.

I propose that such entangled and intra-active conception of growth (fig. 4) can serve as a co-creation methodology in various realms of making.

Conclusion and Outlook

Rethinking Growth: Interdisciplinary Co-Creation Methodology

Some realms where the proposed growth model can particularly serve as a co-creation methodology are the realms of science-design interdisciplinary research, education, and innovation practices.[23] Taking growth as creation methodology can help to cultivate such interdisciplinary in-between spaces where diverse range of knowledges can encounter and weave into open, complex, and adaptive co-creation processes. In such interdisciplinary settings, various stages of exposure, inquiry, exploration, creation, adaptation, etc. can be facilitated through the proposed growth methodology (fig. 4). Such open and adaptive co-explorations can provide a fertile ground for nucleation of various new questions and research or design projects within natural sciences,

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21 Or Ettlinger and Khashyar Razghandi, "Speculative Inquiry and Growth: A Methodological Approach for Creative Knowledge Generation and Interdisciplinary Problem-Solving," *Creativity Research Journal* (forthcoming).

22 Facundo Gutierrez and Khashayar Razghandi, "MotorSkins—A Bio-Inspired Design Approach towards an Interactive Soft-Robotic Exosuit," *Bioinspiration & Biomimetics* 16, no. 6 (2021): 066013, https://doi.org/10.1088/1748-3190/ac2785.

23 Ettlinger and Razghandi, "Speculative Inquiry and Growth"; Khashayar Razghandi et al., *Scaling-Nature – A Reflection on an Interdisciplinary Design-Science Studio* (Bielefeld: transcript Verlag, forthcoming); Gutierrez and Razghandi, "MotorSkins."

humanities, and design disciplines: a playground for realization of *research through education* and *education through research.*[24]

Rethinking Growth: Uncertainties, Urgencies and Open Futures

As dystopian futures unfold in front of us, the powerful yet blurry image of "future as a horizon that is approaching us" holds various uncertainties and urgencies. *Rethinking growth* hopes to offer a different understanding and a way to deal with this *openness.*

Rethinking growth emphasizes a paradigm shift from individual subjects and objects with properties and autopoiesis, to performativity and sympoiesis within active and entangled meshworks. Future-makings are rooted in these co-beings and co-becomings.

The image of the entangled dynamisms and performative structures embraces the diversity and activity of various actants and agencies, and growth can be re-understood within this image. The categorization and dichotomies of the patriarchal dominators—the subject/object, subject/property, organisms/environment, active/passive, and so on—are failing the reality of the entangled dynamisms and performative structures.

Futures cannot follow this prediction-control paradigm of domination and exploitation. The normative discourses of atomization, alienation, universalism, and dominance are the prevailing conceptions and logics of the current passive conception of matter, buttressing the foundations of patriarchy and capitalism. A less hierarchical, more interrelational, more diverse, a more intra-active and performative conception of growth seems to be the way to reflect and face the current ecological and socioeconomic crisis.

Open futures need co-creation paradigms: to pay attention, to care for, and to co-work. We need to acknowledge the diversities—of agencies, of ontological relevance and concerns, of constraints, and of encounters, the entangled dynamisms and performative structures, with multitudes of agencies and relations, colliding and intertwining, bonding and so on.

Rethinking growth hopes to highlight the entangled and performative nature of creative processes, and put forward a new conception of growth to inspire new interdisciplinary and intersectional approaches toward a more comprehensive creation paradigm: growth as co-creative future-makings.

24 Ettlinger and Razghandi, "Speculative Inquiry and Growth"; Razghandi et al., *Scaling-Nature.*