

**On Membranes Within Disciplinary Entanglements: A Cognitive Framework**Dr Ioannis Bardakos<sup>1</sup>, Dr Malvina Apostolou<sup>2</sup><sup>1</sup>SCC, BNBU, Zhuhai, China<sup>2</sup>URM MAP-MAACC, ENSAPLV, Paris, Franceioannisbardakos@uic.edu.cn ORCID: <https://orcid.org/0000-0001-7039-0137>malvina.apostolou@gmail.com ORCID: <https://orcid.org/0000-0002-6904-3354>

**Abstract:** This paper proposes membranes as dynamic interfaces for x-disciplinary entanglements across inter-multi-, cross-, and trans-disciplinary practices. Membranes, arising transitional spaces, could reconceptualize the notions of in-between, the liminality, the uncanny and the non-places. Unlike static spaces, membranes can be dynamic structures with measurable properties defined by elasticity, tearability, porosity, and selective permeability. These characteristics enable membranes to mediate flows of knowledge, methods, as well as concepts between disciplines, and to operate through mathematical formulations that include functions, permeability coefficients and topological transformations. Multi-layered systems could enable simultaneous disciplinary distinction and hybrid emergence.

Extending this framework, we introduce multi-individuation, that is processes where disciplines maintain identity while generating novel forms through membranous interaction. This form(s) of interaction(s) and transformation(s) could bear cognition, emerging from recursive encounters between fields, producing methodologies and vocabularies irreducible to their constituent parts.

Through techno-artistic practice and computational humanities applications, we aim to demonstrate how membranous thinking could provide tools for experimentation and knowledge production. By illustrating how mechanisms of x-disciplinary exchange operate within intersecting scales and concepts of science, technology and arts, this framework could offer an approach to disciplinary hybridization and fusion beyond traditional models.

**Keywords:** membranes; multi-individuation; cognitive process; space; disciplinary hybridity

**1 Introduction. Rationale and objectives**

Contemporary research, design process and creative practice increasingly demand frameworks and integrative approaches that exceed the capacities of any single field, bearing the ability to mediate and invite emergence across disciplinary boundaries giving rise to a spectrum of collaborative practices. (Bardakos, 2023) Since the theoretical models for understanding the space of interaction between disciplines often rely on metaphors of 'bridging', 'weaving', or 'blending', they can imply a static connection between pre-formed, stable entities (Klein, 2010). Traditional models of interdisciplinarity often presuppose either porous borders that dissolve disciplinary identity or fixed boundaries that merely permit exchange.

This paper proposes a new conceptual framework: the membrane. As a model for x-disciplinary entanglement, this structure could permit selective transit, exhibit measurable and functional properties, and enable processes of co-emergence of artifacts, methods, or vocabularies. The membrane is posited as a dynamic boundary, a generative interface, a threshold of transformations and ruptures, an in-between space where encounters can occur. Thus, drawing from its definitions in biology, materials science, and mathematics, membrane is transposed into an analytical model for understanding x-disciplinary encounters.

The objective of this paper is to reconceptualize the liminal spaces between disciplines as active, membranous systems. To proceed, membranes are situated as a metaphor, a concept, and an analytical device for disciplinary permeability, grounded in architectural, biological and mathematical principle of behaviors. A link to a conceptual framework aims to interpretate the membranous sites of encounter. As membranes may be formalized with physical and mathematical variables (elasticity, permeability coefficients, porosity, topological transformations) they could model flows of knowledge and methods. The introduction of the concept of multi-individuation aims to demonstrate the membranous interface as a mediation towards a processual model where disciplines and practices co-evolve without dissolving their distinct identities, leading to cognitive and methodological interactions. To illustrate and enact this framework, practices and praxis in techno-artistic and computational humanities contexts will be demonstrated.

By framing disciplinary boundaries as active membranes, cognitive process of x-disciplinary design and productive x-disciplinary collaborations could be fostered.

Throughout this paper the abstract supplied by the commissioning symposium frames the inquiry: membranes as dynamic interfaces, multi-layered systems, and multi-individuation (Bardakos, 2024c) as a mechanism for hybrid cognitive emergence.

## 2 Situating Membranes as a metaphor for disciplinary permeability

Membranes carry an ontological double-register: they are simultaneously boundary and interface.

In biological contexts the membrane separates intra and extracellular milieus while enabling controlled exchange; in architecture membranes can be surfaces that define inside/outside relationships while mediating light, wind, and perception; in network theory and knowledge systems, they can stand for translation layers, or interfacial processes that permit, filter, or reconfigure flows.

In architecture and media art and design, the space within space or liminal zone concept mirrors the membrane's function as spaces are not fully inside or outside, but allow transitional interactions that can produce emergent experiences, insights, relations. Such spaces highlight the interplay between constraint and openness, a principle applicable to the management of interdisciplinary knowledge flows.

The membranic metaphor lies in its capacity to combine qualitative, phenomenological insight with quantifiable properties and thus offering an analytic that is simultaneously phenomenological (liminality, uncanny, non-place) and operational (elasticity, permeability, topology).

This nature could allow membranes to model disciplinary permeabilities and x-disciplinary potentialities and exchanges. The membrane therefore could function as an epistemic device defining what kinds of methods, representations, and concepts pass, how they are transformed in transit, and what patterns emerge on either side. (Bardakos, 2024c) This could permit simultaneously the preservation of disciplinary identity and the generation of hybrid forms, encompassing the introduced multi-individuation process (see part 4.2).

Therefore, membranes could operate as both metaphor and method.

### 2.1 Conceptual Framework

Gaston Bachelard, in *The Poetics of Space* (1958), elevates the nook, the corner, and the drawer, spaces within spaces, as zones of intimate imagination, where geometry is imbued with psychology. Similarly, the threshold, not merely a line but a space of pause, transition, and potential, could be the physical instantiation of a membrane.

The concept of liminality as an in-between state, characterized by openness, could be transferable to the x-disciplinary encounter. It is a space where established disciplinary norms are suspended, and new structures can become possible. Liminality is generative: the suspended state contains the possibility of reconstitution into new forms. In an analogous way, membranic interfaces do not act only as borders, but as transformative filters in which disciplinary identities may be maintained and re-expressed. The membrane, in this sense, can be seen as a structural and functional element for these cognitive thresholds, where disciplinary ideas undergo recombination and selective passage.

This liminal state could also manifest as the uncanny, as explored by Anthony Vidler (1992) would emerge when a familiar concept from one's main discipline is deformed and recontextualized through its passage across a membranic boundary into another field, creating a hybrid entity that is both recognizable and estrange.

Michel Foucault's heterotopia (1986) can offer another analog to simultaneous isolation and permeability. A site that juxtaposes in a single real place several incompatible spaces, worlds within worlds that juxtapose incompatible orders and transformations (e.g., ships, gardens, cemeteries) and which can contain heterochronies or multiple temporality registers. Such environments serve as experimental membranes, where multiple temporalities and methodological protocols intersect, producing hybridities that cannot be reduced merely to their constituent parts.

Conversely, Marc Augé's non-places (1992), designating transitory infrastructures of supermodernity (as airports, motorways, shopping malls), are defined by their lack of identity, history, and relationality. A membrane, however, could bear the antithesis of a non-place as it is defined precisely by its relational and transformative function, actively generating new identities and histories through the flows it mediates. Membranes could transform potential non-places into generative zones by channeling interactions and creating relational networks.

Finally, Manuel Castells' dichotomy of the space of places and the space of flows (1996) could provide a macro-scale model. Disciplines can be seen as spaces of places within local, historically contingent contexts of meaning. The interactions between them could occur in a space of flows, that is a networked exchange. The membrane could be the interface at which the space of flows (data, concepts, methods) encounters and transforms the space of places (the localized discipline).

### 2.2 Interdisciplinarity and hybridization. Towards x-disciplinarity

The history of interdisciplinarity revealed through an evolution from simple collaboration to complex integration. It has been theorized in numerous ways, from boundary-crossing collaborations that remain

additive, to integrative modes that synthesize concepts into new shared frameworks, to transdisciplinary approaches that aim at problem-driven unity across knowledge.

Early models of multi-disciplinarity involved disciplines working in parallel on a common problem, with minimal interaction. Interdisciplinarity implied a greater degree of interaction, often resulting in a borrowing of methods or concepts. Transdisciplinarity aims to create a unified framework that transcends and encompasses the disciplinary perspectives.

The proposed framework does not require the dissolution of disciplinary boundaries. Instead, it focuses on the dynamics at the boundary itself, the liminal space, the in-between. This state is of generative potentialities, a spontaneous, unstructured operating phase. Hybridization, a concept borrowed from biology and cultural studies, describes the creation of new forms by combining elements of different origins. The membrane is the site where this hybridization is negotiated.

### 3 Membranic framework and analogical correlations

Membranes can be modeled mathematically. Their behavior can be described by functions, permeability coefficients and topological transformations. In physics membranes are characterized by mechanical parameters (bending rigidity, in-plane elasticity), transport properties (permeability coefficients, selective channels), and morphological features (porosity, thickness, topology).

In building science and engineering, membranes are thin, flexible structural elements that carry loads primarily through tensile stresses. The works of Frei Otto on lightweight tensile structures demonstrated how minimal material could define maximal space through complex curvature and pre-stress (Otto and Rasch, 1995). Contemporary research focuses on 'smart' or 'adaptive' membranes (Paech, 2016) (Zanelli and Campioli, 2006). These are dynamic systems that can respond to environmental stimuli, changing their porosity to regulate light and air, or their shape, to modulate structural performance. This embodies the transition from a static boundary to a responsive interface. Such systems can generate architectural performances that are emergent and behavior-based, rather than predetermined. (Hensel and Menges, 2008) (Hensel et al, 2010)

#### 3.1 Frei Otto's experiments

'For Otto, 'technology' always implies 'multimedia technology'. He constantly submits himself to the physical laws of membrane surfaces, systematically researches their geometric properties and accurately explores the possibilities of the respective construction methods using media techniques, in the sense of Friedrich Dessauer, the technical sphere appears here as 'being real and becoming real through ideas'' (Vrachliotis, 2020, 74)

Model and machine together formed an experimental system, uniting observation, manual precision, and theoretical inquiry. Otto's experimental culture depended on the interaction of eye, hand, and instrument, where design was both an individual process of knowledge production and a collective scientific discourse. The fragility and temporality of the materials were essential to the experiments' epistemic value as failures were part of the process. Frei Otto's work centered on the fundamentals of structural efficiency, drawing on modern technology and materials, such as high-tensile steel cables and synthetic membranes.

Historically, architecture depended on gravity and heavy mass for stability. Otto reversed this paradigm by exploiting tensile stress rather than compression. His research into tensile structures revealed that stability could be achieved through tensioned membranes and cables, whose anticlastic, saddle-like curvatures form minimal surfaces, the smallest possible surfaces bounded by given curves.

His early practical research focused on mast- and cable-supported membranes, which became foundational to his concept of minimal structures. Beginning with the Kassel Bandstand (1955), Otto developed a series of tensile pavilions based on saddle-shaped surfaces. These included the Dance Pavilion in Cologne (1957), the Wave Hall and Small Pavilions in Hamburg (1963), and the Swiss National Exhibition tents in Lausanne (1964). Otto also introduced ridge-type and arch-supported membranes, and later high- and low-point tents supported by enlarged mast heads, producing sculptural, undulating forms. (Glaeser, 1972)

He extended these principles into retractable roofs, treating membranes as movable elements guided by cables and winches. Beginning with a small tent in Cannes (1965), he created larger, automated retractable roofs for venues such as the Open-Air Theater in Bad Hersfeld and swimming pools in Paris and Lyons. These lightweight, translucent structures offered flexible enclosures adaptable to changing weather and seasonal conditions, approaching Otto's ideal of 'non-structures' that minimize environmental intrusion.

Otto also explored pneumatically inflated membranes. Supported by air pressure, these structures achieve weightlessness, their limitations being economic rather than structural. From 1959 to 1961, Otto conducted intensive research on pneumatic systems. He devised numerous configurations combining spherical forms, modifying plan geometry, and integrating restraining cables or nets to control shape and drainage. These

experiments bridged theory and practice, leading to proposals ranging from inflated grain silos to large-scale greenhouse enclosures.

Frei Otto expanded the relationship between model, media, and material by experimenting with thin membranes made from water and detergent. From the late 1950s, he and others, such as Robert Le Ricolais, used soap bubbles to study structural behavior and teach principles of form and equilibrium. These soap-film models naturally generated minimal surfaces determined by boundary conditions and uniform surface tension, revealing forms of efficiency and aesthetic spatial characteristics.

Otto and his collaborator Larry Medlin later developed controlled environments and specialized soap-film machines to measure these minimal surfaces more precisely, especially during preparations for the German Pavilion at Expo 1967. The apparatus included systems for air regulation, lighting, measurement, and imaging, combining technology with material, optical, and recording processes.

Frei Otto described the phenomenon of ‘self-forming’ as a foundational principle in the experimentation with membranes, shells, and related structural systems. He designated it as the process through which a given form emerges naturally within a system that achieves equilibrium between external forces and internal resistances, the latter being intrinsic to the material’s physical properties. In this approach, the designer’s role is not to impose a predetermined geometry but to define key parameters and material conditions, tensile strength, elasticity, boundary constraints, within which the system autonomously resolves itself into a state of structural balance, thereby generating its own specific form. This method of form-finding stands in contrast to design practices predicated on top-down geometric prescription, proposing instead a material-driven mode of morphological genesis.

‘Otto’s architectural models, if we can still refer to them as models in the traditional sense, function not only as static objects, but also as dynamic objects, i.e. as models of environmental processes generated by media technology tools. In all their poetic fragility, Frei Otto’s models tell the story of an operative aesthetic that oscillates between the precision of scientific instruments and the imagination of works of art.’ (Vrachliotis, 2020, 75)

#### **4 From material to conceptual membranes**

##### **4.1 Membranes as systems of boundary conditions**

Transposing these principles, a conceptual or disciplinary membrane can be defined as a system of boundary conditions that actively regulates exchange to maintain systemic identity while enabling adaptation and growth. In architecture, boundaries could organize enclosure, light, thermal exchange and movement, in epistemics, boundaries could set the conditions for encounters, discourse, methods, and evidence. Membranes are characterised by parameters, permeability, porosity, elasticity, tearability. They are boundary-condition systems with parameters that can be made porous, layered, perforated, or create localized hybrid zones. A multi-layered membrane system could model complex x-disciplinary interactions.

##### **4.2 Constructing individuations. From individuation to multi-individuation**

The concept of individuation, developed by Gilbert Simondon (1992), as an ontological process, describes the process by which something comes into existence and acquires a self. For Simondon, the individual is not a pre-given substance but a phase in a process of becoming, always in a metastable relation with its ‘pre-individual’ milieu. He also extended this framework to psychic and collective individuation, explaining how individuals and societies co-develop through shared processes of transformation and exchange of information. (Simondon, 1958) (Bluemink, 2021) In Jungian psychology, individuation is the process of becoming a whole and authentic self by integrating the conscious and unconscious parts of the psyche. It requires shedding the social mask (persona) and confronting unconscious influences. Rather than leading to isolation, it fosters connection with humanity through self-understanding. (Jung, 1972) It seems that in his theory spectrum individuation incarnates an inward synthesis of the fragments eventually with the goal to a psychological process towards a state. In contrast, in Simondon terms the concept is an ongoing becoming process-relational and processional-towards a process. In our case Simondon’s approach is approached, where the user becomes a participatory multiplicity.

#### **5 Techno-artistic practices**

Techno-artistic (Ascott, 1996) practice operates at the interface between art and technology. Art used as a technology for transforming consciousness can be a site for observing membranous cognitive thinking within x-disciplinarity.

### 5.1 General computational creativity

The field of computational creativity can provide a laboratory of experimentation under the aforementioned prism, at the intersection of artificial intelligence, human-machine interaction, digital art and design and their interpretive contexts thereby contesting the traditional separation between human creativity and machine automation. Within techno-artistic research, computational creativity can operate as a critical zone where algorithmic procedures and human intentionality enter recursive negotiation, articulating an epistemic shift in which creativity becomes a distributed, membranic process of co-individuation between human and machine.

The artist's/designer's input, a prompt, a dataset, a set of parameters, undergoes a translation from semantic intent into a dimensional mathematical topology of the model's latent space (Boden, 2009). This latent space is the membranic in-between: a structured yet fluid domain where concepts are encoded as vectors (White, 2016). This in-between is the membrane through which meanings, probabilities, and aesthetic choices traverse. When the artist manipulates this space, they become both participant and modulator of permeabilities, constructing places.

The co-creations of generations is a process of emergent individuation from this latent milieu. The resulting artifact is a hybrid object, a product of the multi-individuation of human artistic intention and the AI's statistical models. This interaction is recursive. The cognitive framework of an artist is deformed by the uncanny relation with the novel juxtapositions or formal qualities of the computational output, that acts within a recursive interaction, as a new input can alter the human's creative trajectory and design process. (Ascott, 1990)

Computational creativity systems can act as membranes between disciplinary domains: for example, between design heuristics and algorithmic generation, or between artistic intention and computational execution.

In practice, even if computational creativity has raised questions about the nature of novelty, value and domain specificity, techno-artistic systems do not simply generate outputs from one discipline to another but rather induce processual transformations. In the design studio, these processes mediate between architectural practice and algorithmic logic, and the resulting artefact is hybrid; multi-individuation occurs.

The membranic frame can bring into view not only flows of methods/concepts but also the channels, filters, and feedback loops that foster the alchemic correlations across disciplinary encounters.

From a cognitive perspective, the recursive exchanges embodied in computational creativity function as a feedback membrane externalizing latent mental operations, rendering them visible, editable, and re-ingestible into the creative loop. In artistic practice, the membrane becomes an epistemic instrument, a technology of thinking-through-technology, where speculation, error, and mutation are complex generative tools.

Thus, general computational creativity embodies a methodological elasticity analogous to the physical properties of membranes, stretching, filtering, recombining epistemic material. By conceiving it as porous, selective structures rather than deterministic mechanisms, techno-artistic practice transforms computation into an interface. It is within this recursive, semi-permeable milieu that exploration continuously *becomes* through translations and transformations.

### 5.2 Traveling within moistmedia

Roy Ascott's concept of 'moistmedia', the convergence of the dry, digital systems world of data (bits) with the wet, biological world of material (atoms and genes) is a strand of techno-artistic practice (Ascott, 2000). In this view, the space of art-technology hybridisation becomes an interface: neither pure digital nor purely organic, but a transitional zone: a material/immaterial interface with porosity, elasticity, selective channels (bits/atoms, code/organism). Moistmedia is both a philosophy of material interconnectivity and a technological condition of hybridity.

Techno-artistic works that operate in moistmedia traverse multiple disciplinary layers: biology, computation, art, architecture, activism. In each case the membrane metaphor is tangible: the interface between living system and digital system has measurable properties (response time, permeability to signals, adaptability) and qualitative features (liminality, uncanny). Moistmedia installations act as hybrid zones of knowledge flow: artist, scientists, biologists, computational designers and data scientists traverse methods and generate novel aesthetics and epistemologies. Moist-media thus becomes both substrate and metaphor for x-disciplinary entanglements between biology, computation, art, philosophy, producing a material-discursive zone of becomings.

The moist condition reinterpretes dichotomies between subject and object, machine and organism, replacing them with topologies of co-evolution. The membrane here serves as an operational boundary condition, mediating informational exchange through gradients, resonating with the biological function of membranes as regulators of flows.

Moistmedia also functions as an epistemic environment for cognitive extension where the fusion of organic and digital substrates enables a form of distributed cognition, within a cognitive and ontological traversal. In this

milieu, the membrane extends the architectural and biological understandings of membrane into a philosophy of relational becoming, where the in-between is the condition for emergencies and transformations.

### 5.3 Technoartistic flâneries

The figure of the flâneur/flâneuse, as expressed by Charles Baudelaire and later Walter Benjamin, the observant wanderer of the modern city, finds a new incarnation in the techno-artistic domain. The contemporary flâneurs extend their perceptual reach into data environments, algorithmic architectures, hybrid physico-digital spaces. They move not only through urban spaces but through media-spaces too, as sensorial wanderers within hybrid spaces. This techno-artistic flânerie is a practice of moving through informational and physical spaces with a permeable, receptive awareness, allowing the environment to permeate and transform one's perception. The navigation is not just through physical arcades but involves data streams, virtual topologies and algorithmic spaces as well.

The contemporary hybrid flâneur/flâneuse can act as an orchestrator of sensory, technological, and locative practices, curating steps, co-walkers, and technologies in a city that is both physical and data-mediated. (Psarras, 2018)

They move along and across disciplinary entanglements and inhabit the liminal zones: threshold spaces between art, technology, biology, architecture and computation. Their walking becomes an epistemic performance, indexing flows of methods and hybrid vocabularies. (Bardakos, 2024b)

The experience of crossing that surface is both physical and cognitive: one crosses from architecture into interactive media, from standing observer to agent in a knowledge-flow system. The techno-artistic flâneur/flâneuse thereby becomes a node in the complex network of disciplinary layers, participating in multi-layered exchanges and cross-contextual alchemies.

Porous spaces within spaces where difference and simultaneity coexist reflect an openness that regulates flows of sensory and informational stimuli, transforming movement into cognition negotiating the thresholds. These forms of derive triggers recursive multi-individuations between bodies, urban/rural/virtual-scapes, codes, and digitalities.

They challenge the disembodied visions of the digital observer by reinstating the corporeal, affective, and temporal dimensions of experience, with techno-artistic flâneurs re-appropriating the in-between spaces of the networked -scapes as zones of poetic resistance and creative speculation. Thus, these flâneries perform the membrane as an elastic, porous, reflexive experience. They transform mobility into a generative process of sensing, interpreting, and re-imagining the hybrid territories giving rise to individuations of perception and representation.

### 6 Anti-conclusions, more questions

In the realm of techno-artistic research and praxis, where disciplines intertwine, the membranic multi-individuation ontology may serve as a framework, allowing for the separation by connecting, enabling the regulation of flows of ideas, creations, or methodologies. (Bardakos and Apostolou, 2024) It can act as an instrument, a technology of thinking the in-between with and through desire, as a neo-alchemic practice: a meta-interface where opposing elements could interact under conditions, their essences selectively permeating, reacting and giving rise to novel individuations within cognitive transformations. This leads to operational processualities through which we multi-individuate our own minds and become other.

Within such a system, the membrane thinking operates as a speculative instrument, a cognitive and aesthetic apparatus for experimentation. Through this lens, techno-artistic practices become meta-alchemic laboratories, wherein material and conceptual opposites coexist in dynamic tensions and relations, reacting towards individuations and cognitive configurations. Membranic thinking inherits this orientation by cultivating transitional zones of invention, permeable liminal spaces between known and unknown encounters, producing uncertainties, consciousness transformations and unforeseen systemic correlations. This speculative -scape, can cope with totalization through the constant genesis of sub-spaces and sub-places reinterpreting, reinventing potentialities.

Rather than presenting the membranic thinking as fixed, we resist closure and invite continued experimentation, reflexivity, curiosity, invention, critique. Liminalities invite us to wander, to flâneur, to traverse, to explore potentialities. (Bardakos, 2024a)

We thus offer the membranic thinking where the in-between space becomes a place of alchemic operations, a fertile ground of cognitive operations challenging the potentialities of interactions and forms of knowledge, in an analogy to Whitehead's organ of novelty (Whitehead, 1929), the adventurous thrust of speculative reason that introduces possibilities of interpretations and correlations of the understandable(s).

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