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From Non-Local pH Shifts to Bioengineered Brains: Latest Research of N. Rouleau & N. Murugan

Early Experiments with Persinger's Group: "Non-Local" pH Effects and Space-Memory

Both **Nicolas Rouleau** and **Nirosha J. Murugan** began their research careers in the 2010s under the late Dr. Michael Persinger at Laurentian University. In Persinger's **Neuroscience Research Group**, they participated in provocative experiments exploring whether electromagnetic fields could produce **"excess correlations"** or non-local effects in chemical and biological systems. For example, Rouleau (with T. Carniello and Persinger) reported that when two containers of spring water were exposed to the *same* rotating magnetic field pattern, adding a weak acid to one could induce an opposite pH shift in the distant, non-injected container [1] [2]. The direction of the pH change depended on the precise timing ("point duration") of the magnetic pulses, suggesting a possibly fundamental phenomenon behind the **distant coupling of chemical reactions** [2]. Murugan was co-author on a related 2013 study demonstrating that such **incremental pH shifts** in water could be "*stored*" and later retrieved – dubbed a form of *"space-memory"* – by reapplying the same magnetic field sequence [3]. In other words, water exposed to particular electromagnetic patterns seemed to retain information that allowed later **reproduction of pH changes** when the field was repeated [4] [3]. These intriguing findings, while *controversial*, laid the groundwork for their enduring interest in how **physical energies (electromagnetic, optical, etc.) interact with biological systems**.

Beyond water experiments, Persinger's group (including Murugan and Rouleau) also investigated ultraweak photon emissions ("**biophotons**") and electromagnetic influences on living tissues. For instance, they found dying melanoma cells emit shifting wavelengths of biophotons in patterns that could be predicted by Cosic's Resonant Recognition Model [5]. Murugan and colleagues showed that patterned magnetic and light stimuli could even affect **planarian flatworms**, causing enhanced or impaired regeneration and altering cell proliferation in melanoma models [6]. In one PLoS One paper, Murugan et al. (2013) reported *complete fragmentation* of planarian worms when exposed to specific temporally patterned magnetic fields [7]. These early **"fringe" experiments** – ranging from non-local chemical effects to photonic signaling in cells – reflect Persinger's influence: exploring the possibility that electromagnetic or quantum-like processes contribute to biological communication and consciousness.

Current Positions and Research Focus

Today, Rouleau and Murugan have transitioned to new institutions and have **mainstreamed** many of these ideas into cutting-edge biophysics, neuroscience, and bioengineering research. Both are now faculty members at Wilfrid Laurier University in Canada (after postdoctoral stints at Tufts University's Allen Discovery Center), where they **co-direct the Center for Tissue Plasticity and Biophysics** [8]. Each has carved out a distinct but complementary research program, earning prestigious positions: Dr. **Nicolas Rouleau** is an Assistant Professor of Health Sciences at Laurier (and adjunct in Biomedical Engineering at Tufts), while Dr. **Nirosha J. Murugan** is a Tier II Canada Research Chair in Tissue

Biophysics and an Assistant Professor at Laurier [9] [10]. In these roles, both scientists continue to probe the **interface of physics and biology**, but now with an emphasis on practical biomedical applications and rigorous model systems.

Nicolas Rouleau: 3D Neural Tissues, Minimal Cognition & Bioengineered Brains

Dr. Rouleau's latest work centers on **bioengineered brain tissue models** and the quest to understand the minimal requirements for cognitive functions. As Persinger's last PhD student, Rouleau was inspired by questions of the "electromagnetic bases of consciousness" [11]. His doctoral research showed that excised brain slices and even *post-mortem* neural tissues can still respond to stimuli (electrical or chemical) and emit photons in surprising ways [12] [13]. Building on that, Rouleau has shifted toward creating living **"brains-in-a-dish."** After joining David Kaplan's lab at Tufts in 2017, he helped develop three-dimensional (**3D**) neural cultures – tiny brain-like tissues grown on silk protein scaffolds – to model diseases like **Alzheimer's disease (AD)** and **traumatic brain injury (TBI)** [14] [15]. For example, Rouleau co-authored a 2020 *Science Advances* study that used a 3D human neural tissue infected with herpes simplex virus to replicate Alzheimer-like pathology (amyloid plaques and neuroinflammation) in the lab [16] [17]. This "brain-like" model provided direct evidence supporting a viral trigger for AD, a finding hailed as a *"very important paper"* by other Alzheimer's experts [18] [19]. Similarly, his group built a 3D tissue model of TBI on a bench-top, showing how chronic drug treatment could mitigate excitotoxic neural damage [20].

Crucially, Rouleau's research retains a focus on **electromagnetic and biophysical interactions** within these engineered brains. He has examined how patterned electrical stimuli or even mechanical rotation can influence the development and behavior of neural tissue. In one experiment, a rotating magnetic stirrer was used to induce **matrix deformation** and cell migration in a 3D neural culture, suggesting that physical motion/fields can organize cells in vitro [21]. This is reminiscent of the earlier rotating-field water studies, but applied now to tissue engineering. Rouleau explicitly lists **"bioelectromagnetism"** as one of his expertise areas [22], and he continues to investigate how neural tissues may *filter or transduce electromagnetic fields*, a concept directly descended from his PhD work [23] [24]. In fact, a 2017 paper he co-authored showed excised brain slices exhibit region-specific electrical responses to applied fields, behaving as if they can **process EM signals** even after death [25] [12].

Another through-line from Persinger's influence is Rouleau's interest in **biophotons** and unconventional markers of brain activity. In 2025 he and Murugan (with colleagues) published a study in *iScience* exploring **ultraweak photon emissions** from brain tissue as a potential optical readout of neuronal activity [26]. This bridges the gap between their early biophoton detection experiments and modern neuroscience: essentially asking if tiny light emissions from neurons could serve as functional signals or diagnostics [26]. Rouleau is also engaging with big-picture theoretical ideas about the brain. He wrote an **award-winning essay** on "transmissive consciousness" (arguing the brain might act as a filter or transceiver of mind, not just a producer) [27], and in 2022 he published *"A Transmissive Theory of Brain Function"* – a conceptual paper discussing how brain activity might be influenced by or integrated with fields beyond the skull [28]. These philosophical inquiries echo Persinger's questions about the brain and electromagnetic fields, but Rouleau now approaches them by combining engineering, neuroscience, and computation. As he describes, his lab (the **Self-Organizing Units Lab, or SOUL**) uses *"embodied hybrid neural-robotic systems"* and 3D tissues to test the **"multiple realizability"** of cognitive phenomena [24]. In practical terms, this means building *mini-brains* or brain–machine hybrids to see if memory, learning, or even rudimentary **"conscious"** behaviors can emerge in non-traditional substrates [29] [30]. By studying these minimal models, Rouleau aims to define what a brain *is* functionally, hoping to distill the essence of cognition. This ambitious program is supported by major grants (e.g. an NSERC Discovery Grant on neurostructural determinants of minimal cognition) and has yielded high-impact publications and reviews [31] [32]. In short, **Nicolas Rouleau's recent research transforms the**

exploratory spirit of his Persinger days into concrete bioengineering advances – creating living neural systems in the lab, probing their electromagnetic properties, and using them to test theories of mind, disease, and even synthetic intelligence [33] [34].

Nirosha Murugan: Biophysical Control of Regeneration and Cancer

Dr. Murugan's current research trajectory is equally rooted in the idea that **physical signals can orchestrate biology**, now applied to healing and disease. After completing her PhD at Laurentian (where she helped develop *"patented electromagnetic and optical tools to detect and manipulate cancer cell fates"* [35]), Murugan undertook postdoctoral work at Tufts' Allen Discovery Center and Harvard's Wyss Institute. There she delved into **regenerative medicine**, working with renowned biologists like Michael Levin and Donald Ingber. One of Murugan's landmark achievements came in 2022, when she was lead author on a *Science Advances* paper demonstrating **limb regeneration in adult frogs**. In that study, Murugan and colleagues applied a wearable bioreactor ("BioDome") containing a cocktail of 5 drugs to an amputated frog stump for just 24 hours – and remarkably, over the next months the frogs regrew leg-like structures with functional nerves, muscles, and even toes [36] [37]. *"It's exciting to see that the drugs... set in motion a months-long regeneration,"* Murugan noted, suggesting that even organisms (like frogs or humans) with limited regenerative ability have *"dormant capabilities that can be triggered into action."* [38]. This breakthrough in epigenetic reprogramming of tissue garnered widespread media coverage (e.g. *New York Times* and *Wall Street Journal* articles) [39], and it exemplifies Murugan's focus on **harnessing biophysical cues to induce complex biological outcomes**.

Murugan's lab at Laurier now integrates **tissue biophysics, stem cell biology, and cancer research**. Her core philosophy is that cells receive not only chemical signals, but also **mechanical, electrical, and optical/magnetic cues** from their environment – and by modulating these *biophysical signals*, we might direct cell fate and tissue patterning [40] [41]. This concept directly echoes her Persinger-era work (where magnetic fields altered cell behaviors), but she now investigates it in cutting-edge contexts like **reprogramming cancer cells** and **promoting regeneration**. For instance, Murugan recently co-authored a comprehensive review in *Cellular and Molecular Life Sciences (2024)* on the **"biophysical control of plasticity and patterning in regeneration and cancer."** In it, she and collaborators outline how forces like electric fields, mechanosignaling, and photostimulation can induce cells to switch states (e.g. cancerous to non-cancerous) or tissues to rebuild, drawing links between developmental biology and tumor biology [42] [43]. One practical arm of her research examines how the **tumor microenvironment** and even distant organs (like the brain) communicate with cancers – for example, how certain brain changes ("chemo brain," cognitive impairment) might be tied to signals from cancerous tissues [44]. This reflects a systems-level approach ("cell-to-society," as she calls it [45]) that she uses to tackle pathological states.

Notably, Murugan hasn't abandoned the *"fringier"* measurements from her early career – she's incorporated them with more rigorous methods. In a 2020 paper (*Cancers* journal), Murugan (with Persinger as a co-author, one of his last collaborations) demonstrated that **ultraweak photon emission** could serve as a non-invasive early detection method for malignancy [46]. This study continued her interest in biophotonic signals from cancer cells, showing that different cancer cell lines emit distinct photon signatures, potentially usable as optical biomarkers of cancer [46]. Likewise, Murugan has explored *synergistic effects of combined magnetic fields and light* on biological targets – e.g. a 2017 experiment using temporally coordinated pulses of magnetic fields and LEDs to inhibit melanoma cell growth and influence planarian regeneration [47]. These investigations of **"electromagnetic therapy"** are early steps toward what her lab now pursues in a more translational guise: using controlled energy inputs (fields, light, mechanics) to *guide stem cell differentiation, tissue repair, or cancer cell reversion* [35] [40]. For example, one ongoing project in her lab examines how **magnetic field exposure might alter cancer cell metabolism or proliferation**, effectively "reprogramming" tumor cells to a benign state.

Another line of research looks at **aneural organisms** (organisms with no nervous system, like slime molds) to understand primitive decision-making purely through physicochemical signaling. In a 2021 *Advanced Materials* paper, Murugan and colleagues (from the Wyss Institute) showed that a slime mold-like organism can use **mechanosensation** to navigate and make long-range decisions without any neurons [48]. This study provided evidence that **intelligent behavior can emerge from physical cues** and feedback, reinforcing the idea that cognition isn't limited to brains – a concept that parallels the "minimal cognition" theme in Rouleau's work.

In summary, **Nirosha Murugan's latest research extends the Persinger-era ideas of electromagnetic and quantum biology into the realms of regeneration and cancer treatment**. By leveraging biophysical signals – much like those she once studied for subtle pH shifts or planarian puzzles – Murugan now aims to **control complex biological outcomes**: regrowing organs, restoring healthy cell function, and decoding the physical "language" cells use to coordinate growth and healing [40] [49]. Her recognition as a Canada Research Chair in Tissue Biophysics underscores how this interdisciplinary approach has gained credibility. It's a striking evolution from exploratory *NeuroQuantology* experiments to leading-edge biomedical research.

Continuity and Evolution: Connecting Past and Present Research

Despite the shift in experimental focus and scale, Rouleau and Murugan's current work **bears a clear family resemblance to their earlier research** with Persinger. Both scientists have maintained a fascination with how information might be carried and stored in physical substrates beyond conventional biochemical pathways. In Persinger's lab they asked, *can water "remember" electromagnetic exposures? Can two separated systems communicate via shared fields?* Today, Rouleau and Murugan are applying these questions to practical ends: *Can we use electromagnetic or mechanical signals to "instruct" a tissue to heal or a cell to change fate?* Their recent review articles explicitly invoke these connections – for example, noting that **information as EM energy can be stored in water and later affect biology**, as demonstrated in the 2013 space-memory experiments [3]. Now they seek unifying principles by which **biophysical energies orchestrate cell behavior**, whether in a petri dish "brain" or a regenerating limb [42] [43].

Another through-line is the study of **ultraweak signals** at the edge of measurability. Previously, the team detected tiny pH changes and photon emissions; now they measure subtle electrophysiological and optical signals in lab-grown tissues to gauge health or function [26]. In a forthcoming 2025 paper (Casey *et al*., *iScience*), Rouleau and Murugan demonstrate monitoring of **photon emission from neural cultures as an optical marker of brain activity** [26]. This directly builds on their early biophoton work, but translated to neuronal contexts. Likewise, their **philosophy of science** has carried forward. Persinger often espoused non-traditional models of the mind (e.g. that consciousness might relate to electromagnetic patterns in the brain and beyond). Rouleau and Murugan, now writing in high-profile forums, continue to explore such ideas – from Rouleau's transmissive brain hypothesis [28] to their joint discussions on **sentience in unconventional substrates** [50]. Crucially, they approach these ideas with the added rigor of modern experimental techniques and collaborations with mainstream scientists.

In practical terms, both researchers have **broadened their toolkits** far beyond what was available at Laurentian. Murugan's lab uses stem cell technology, regenerative biology assays, and advanced imaging; Rouleau's lab employs biomaterials engineering, optogenetics (e.g. using light to modulate cell behavior) [51], and neuroengineering platforms. Yet, the *spirit* of their Persinger days – an openness to phenomena like **electromagnetic information storage, field-mediated communication, and cross-disciplinary thinking** – remains a driving force. It's evident in how they framed the mission of Laurier's Center for Tissue Plasticity and Biophysics: to investigate *"the biophysical language of cellular* *communication"* and the *"fundamental, scale-invariant properties of cognitive systems"* [40] [52] . Terms like "scale-invariant" and "language of cells" harken back to the idea that the same physical principles might apply from water molecules to brains, which is a theme Persinger cultivated.

To illustrate the continuity: in 2014, Rouleau and Persinger wrote about **electromagnetic fields as "structure–function zeitgebers"** that could influence morphogenesis and consciousness [53] . In 2023, Rouleau, Murugan, and Kaplan wrote about **"functional bioengineered models of the CNS"**, essentially using controlled environments to study how structure and function emerge in neural systems [32] . Both efforts share a common question: how do patterns (whether magnetic fields or tissue architecture) shape biological function and information processing? The difference is largely one of context and acceptance – what was once speculative in *Journal of Biophysical Chemistry* or *NeuroQuantology* is now tested in *Nature Reviews Bioengineering* and *Science Advances* with tangible models and reproducible methods.

Finally, it's worth noting that **their collaboration has come full-circle**. After independently venturing through postdocs, Rouleau and Murugan have reunited at Laurier, pooling their expertise. They co-author many of their recent publications, blending Rouleau's neural engineering perspective with Murugan's biophysical and biomedical focus. For instance, their 2024 article in *Advanced Intelligent Systems* discusses the *"risks and rewards of embodying AI with cloud-based laboratories,"* exploring how AI and *in vitro* life systems might interface [54] . This kind of forward-looking, boundary-crossing topic reflects the intellectual adventurousness fostered in Persinger's group, now applied to emerging tech and biology. Both are also mentoring new students in these interdisciplinary areas, ensuring that the lineage of ideas – from non-local pH anomalies to synthetic bioengineered cognition – continues to evolve.

In summary, **Nicolas Rouleau and Nirosha Murugan's latest research spans a remarkable spectrum**: from building *"mini-brains"* to regenerating frog limbs, and from decoding cell communication to redefining consciousness. While the applications are cutting-edge and often biomedical, the underlying thread can be traced back to their early experiments with Michael Persinger. They have taken the *seed concepts* of those early 2010s studies – that unconventional physical processes might underlie biological phenomena – and **grown them into rigorous, peer-reviewed science in multiple domains**. This progression showcases how youthful, exploratory research (even if speculative) can lead to innovative science when combined with new tools and broader vision. As they continue to publish in high-impact journals and present at international conferences, Rouleau and Murugan are effectively translating the *"Persinger-esque"* questions into mainstream scientific discourse, enriching our understanding of both fundamental biology and its potential futuristic applications [27] [40] .

Sources:

- Rouleau & Persinger (2014), *Journal of Biophysical Chemistry*: non-local pH shifts in water under shared angular-velocity magnetic fields [1] [2] .
- Dotta, Murugan, Persinger *et al.* (2013), *NeuroQuantology*: water "space-memory" of pH changes under rotating magnetic fields [4] [3] .
- Murugan *et al.* (2018), *Biochem. Biophys. Reports*: biophotonic markers distinguishing cancer cells [6] .
- Murugan *et al.* (2022), *Science Advances*: induced limb regeneration in adult frogs via bioelectric device [37] [38] .
- Murugan *et al.* (2021), *Advanced Materials*: mechanosensation-based decision-making in an aneural organism [48] .
- Rouleau *et al.* (2020), *Science Advances*: 3D human brain-like tissue model of herpes-induced Alzheimer's disease [16] .

- Rouleau & Murugan (2023–2025), various publications: reviews on CNS tissue engineering [32], iScience study on ultraweak photon signals in neural tissue [26], and more – as detailed in their faculty profiles [55] [56].
- Faculty Profiles – Wilfrid Laurier Univ.: **N. Rouleau** (Health Sci) and **N. Murugan** (Health Sci) – research overviews, background, and lists of recent publications [9] [55] [40] [48].
- Allen Discovery Center at Tufts profiles: background of Rouleau and Murugan postdoctoral work (neural tissue engineering; regenerative biology and cancer) [57] [35].
- Selected media coverage: *Sci.News* on Murugan's frog limb regeneration [37]; *STAT News* on Rouleau/Kaplan's herpes-Alzheimer's 3D brain model [18] [19].

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[1] [2] (PDF) Non-Local pH Shifts and Shared Changing Angular Velocity Magnetic Fields: Discrete Energies and the Importance of Point Durations
https://www.researchgate.net/publication/276040075_Non-Local_pH_Shifts_and_Shared_Changing_Angular_Velocity_Magnetic_Fields_Discrete_Energies_and_the_Importance_of_Point_Durations

[3] [4] The absolute shift in pH for baseline condition (black), "encode"... | Download Scientific Diagram
https://www.researchgate.net/figure/The-absolute-shift-in-pH-for-baseline-condition-black-encode-condition-grey-and_fig3_266838412

[5] [6] [7] [21] [39] [40] [41] [44] [45] [46] [47] [48] [56] Nirosha Murugan | Wilfrid Laurier University
https://www.wlu.ca/academics/faculties/faculty-of-science/faculty-profiles/nirosha-murugan/index.html

[8] [9] [11] [14] [15] [16] [17] [20] [22] [23] [24] [26] [27] [29] [30] [31] [32] [33] [34] [52] [55] Nicolas Rouleau | Wilfrid Laurier University
https://www.wlu.ca/academics/faculties/faculty-of-science/faculty-profiles/nicolas-rouleau/index.html

[10] [35] [49] Nirosha Murugan, Ph.D. - Allen Discovery Center at Tufts UniversityAllen Discovery Center at Tufts University
https://allencenter.tufts.edu/nirosha-murugan-ph-d/

[12] [13] [25] [42] [43] [50] [51] [53] [54] Publications | My Site
https://www.rouleaulab.com/publications

[18] [19] Study using human brain tissue shows herpes link to Alzheimer's | STAT
https://www.statnews.com/2020/05/06/researchers-show-herpes-link-to-alzheimers/

[28] A Transmissive Theory of Brain Function: Implications for Health, Disease, and Consciousness
https://www.mdpi.com/2673-4087/3/3/32

[36] [37] [38] Researchers Successfully Regrow African Clawed Frog's Lost Leg | Sci.News
https://www.sci.news/biology/biodome-10494.html

[57] Nicolas Rouleau, Ph.D - Allen Discovery Center at Tufts UniversityAllen Discovery Center at Tufts University
https://allencenter.tufts.edu/nicolas-rouleau-ph-d/