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Brain and Symmetry – A Principle Theory of Brain Function

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Abstract

The “Triggering Brain” hypothesis (Stueber, 2023) proposes brain function as a relational process based on biological equilibrium rather than absolute signal values. The present essay extends this model into a broader principle theory developed across physics, evolution, physiology, and the brain. In physics, symmetry, invariance, and relativity are examined as principles of stable order. In evolution, bilateral body plans and paired sensory systems are interpreted as selective pressures for relational neural processing. In physiology, homeostasis is reconsidered as a systemic principle in the sense of Bernard and Cannon rather than as a collection of local compensatory mechanisms. Within this framework, synchrony within the brain is proposed as the neurophysiological correlate of both biological equilibrium and invariance. “Triggering” is understood not as an occasional event, but as the fundamental mode of neural operation. The Kuramoto model provides a framework for interpreting EEG data in terms of phase coherence rather than signal amplitude. Several avenues for empirical falsification are proposed using EEG, MEG, and individualized anatomy-guided electrode placement (the “sulcal-fingerprint”). The hypothesis is presented as a principle theory in the sense of Albert Einstein and evaluated in light of Karl Popper’s criterion of falsifiability. Rather than competing with existing neuroscience, the hypothesis proposes synchrony as the biological state underlying stable neural function. Provided that this hypothesis is justified, identifying and measuring the biological “invariant” may significantly improve neurological diagnostics and therapeutic intervention.

Key Words: Triggering Brain, Symmetry, Relativity, Invariance, Evolution, Ediacaran, Homeostasis, Biological Equilibrium, Brain, Binding, Sleep, Synchrony, Kuramoto, Consciousness, EEG

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1. Introduction

The previously published hypothesis of the “Triggering Brain” (Stueber, 2023) proposes the brain as a system whose functioning may be based on the biological principle of equilibrium. The cortical columns are interpreted as structures in which a relation may be formed between an input “a” and a reference “b.” The input comes from the sensory organs, the body, or other cortical columns. The reference is created within the brain. The hypothesis expresses the ratio between the two as “a/b.” If the input signal is known, then the reference value corresponds (“a/b=1”). In the other case, there is a deviation. The ratio may provide a dynamic value regarding the existence of equilibrium between incoming signals and their correspondences stored in the brain. The cortical columns, which are also the nodes of the neural network, may thus be understood as places where signals are not simply forwarded, but where ratios are formed and evaluated. According to the hypothesis, the neural activity of the cortex may contribute to the major brain functions through the dynamic creation of ratios between “a” and “b.”

Activities during the day are associated with new neural connections (Hebbian learning) resulting in changes in “a.” Consequently, the relations gradually change as well. Their precision may decrease over the day and the result may approach a critical, non-physiological range. The brain gets tired and needs sleep. While there are no “a” inputs, “b” values can be recalibrated. The electromagnetic resting level of the brain has been proposed as a possible reference standard. After calibration, equilibrium may be restored. Since, within this framework, all cortical columns would be calibrated in the same way, they could operate within the same physiological range, and their outputs would be compatible with each other. From the perspective of a cortical column, it would therefore be irrelevant whether an “a” input originates from a sensory organ, the body, or another column. The equivalency of the inputs would therefore allow arbitrary relationships to be formed.

After calibration, the “b” values are adjusted so that the “a” inputs of the following day again lead to balanced relations. The brain learns about its environment and its body and is able to recognize what are typical inputs – what is known – and deviations thereof. The hypothesis differentiates: “a” is perceived information, “b” is stored information. “a/b=1” is information understood as known, and “a/b≠1” is information understood as new. The perception of information, the retrieval of the stored value, and the evaluation of their relationship are proposed to take place within the same neural structure, through the same process, and simultaneously. They are supposed to be due to a relational process, rather than sequential processing. According to this hypothesis, brain function may not be explained by absolute values but by relations.

The “Triggering Brain” hypothesis can be interpreted as describing a self-stabilizing system in which the typical characteristics of the environment are represented twice. First, “a,” in the form of neural connections, essentially the white matter. Second, “b,” within the gray matter. Each of these two may represent the living conditions typical for the brain. They are complementary to each other like an image and its mirror image. “Hebbian learning” and “b-learning” may therefore be understood as complementary processes.

The ratio “a/b” can be interpreted not only as a mathematical relation, but also as an expression of a principle of order. This ties in with “Biological Mirroring” as Konrad Lorenz introduced it into the biosciences. Biological mirroring creates principles of order that lead to biological stability and function. He wrote: “Objective reality exists for living beings only to the extent that it is mirrored in their cognitive structure” (Lorenz, 1973).

The understanding of “a/b” as mirroring in its biological dimension may be interpreted in analogy to the physical concept of symmetry. In physics, states that remain unchanged under a group of certain transformations are referred to as symmetrical. That is, when a structure retains its form and function even though the frame of reference changes. A bird's wings, for example, continue to function even though the reference frame for buoyancy constantly changes during flight. Hermann Weyl describes symmetry as the mental tool through which humans comprehend order in the first place: “Symmetry, as wide or as narrow as you may define its meaning, is one idea by which man through the ages has tried to comprehend and create order, beauty, and perfection” (Weyl, 1952).

The first essay was intended to provide an overview – a sketch – of this rather complex topic and to convey an impression of the physiological implications of the “Triggering Brain” model. The a/b-hypothesis was grounded in the “principle of biological equilibrium,” as expressed, for example, in Lorenz’s mirroring. The following sections aim to establish a broader theoretical foundation. The physical concept of “symmetry” serves as the guiding principle. The discourse is divided into four chapters: Physics, Evolution, Physiology, and Brain. The fifth chapter addresses the falsification of the theory.

The hypothesis of the “Triggering Brain” shall be understood as a principle-theoretical proposal in the tradition of Einstein’s distinction between principle and constructive theories (Einstein, 1919, 1954).

2. Symmetry in Physics

Classical Perspective

Physics owes its concept of “Symmetry” to the realization that the order and laws of nature are based on the existence of invariance and relativity.

“Invariance” was carefully examined by Henri Poincaré, who recognized at the beginning of the 20th century that our physical laws do not describe “Les faites bruts” (the brutal reality) in itself. Instead, they describe “Les faits scientifiques.” i.e. things that have been standardized in some scientific way. He concludes that our physical laws are nothing but relations (of the “fait scientifiques”) that describe the relations of the “fait bruts.” Therefore, physical laws are invariant in themselves (Poincaré, 1908).

Invariance means that a relationship remains unchanged under a certain group of transformations. This transformation invariance is the hallmark of every physical law. One example is the homogeneity of time: the fact that the laws of nature are the same today as they will be tomorrow expresses invariance with respect to time shifts. Similarly, the homogeneity of space: the fact that physical laws are the same everywhere is an expression of spatial transformation invariance.

In her theorem from 1918, Emmy Noether formulated the crucial connection between the invariance of physical laws, and their significance for “stability”: every physical system leads to a conserved quantity. Time independence, for example, leads to energy conservation. Position independence leads to momentum conservation, etc. (Noether, 1918). This suggests that stability is a direct consequence of invariance.

A conceptual analogy may be drawn to neurology, although this transfer should be understood as heuristic rather than literal: The relationship between the brain and its environment needs to be stable (invariant) at all times and in all places in order to ensure a stable life. As a result, the brain may not primarily respond to constantly changing, absolute values, but rather seeks to maintain relationships within a physiological frame. Applied to the present hypothesis, the a/b-ratio may be interpreted as an expression of biological invariance.

In an autobiographical text, Albert Einstein described “Symmetry” as one of the foundations that accompany our normal everyday life. Every child knows that something can fall down or that an action leads to a change, and so on. All these “truths” prove the existence of a fundamental relationship between the physical conditions of reality. “Symmetry” is fundamental in this sense. Its covariance is so fundamental that its recognition does not require explanation by a physicist. However, the combination of these three fundamentals – symmetry, invariance, and relativity – is not trivial (Einstein, 1946).

Biological processes never violate physical laws. For example, animal limbs must obey the law of leverage, enzymatic reactions must obey the law of mass action, etc. In all biological objects, our theories follow the symmetry, invariance, and relativity of physics. Only in the case of the brain – in terms of perception, behavior, or consciousness – we have not yet succeeded in pinning down this principle. With the “a/b” hypothesis, the “Triggering Brain” model suggests a tangible functionalism that combines symmetry, invariance, and relativity and may help to bring us closer to this goal.

Modern Perspective

In today's fundamental research, symmetry is no longer regarded solely as a formal principle of order, but also as a constitutive element of dynamic reality. It can be understood as an expression of the conservation conditions of nature (Gross, 1996). Invariance is often interpreted as a constitutive element of a world that can be understood as a collection of events rather than a collection of things (Rovelli, 2016). Symmetry is thus considered an epistemological condition. It may enable different observers to describe the same world in the same way. This relationalist view can be seen as corresponding to the idea of the “Triggering Brain,” according to which neural processes may not primarily represent absolute states, but rather relationships. Consequently, the brain may not primarily strive for the stability of things, but for the stability of relationships.

Thinking in terms of symmetries and invariants can also be observed at the interface between modern physics and theoretical biology. Ilya Prigogine described living systems as “dissipative structures” that maintain their order through a continuous flow of energy. This creates local states of order that remain stable only if fluctuations are “compensated” within certain limits (Prigogine & Stengers, 1984). In the “Triggering Brain,” such “fluctuations” are interpreted as being due to changes in the “a/b” ratio throughout the day. They may be “compensated” in two ways: systematically by calibrating “b,” or dynamically by thoughts and behavior.

Stuart Kauffman describes evolution as a permanent “dance on the edge of chaos.” Systems are creative when they are neither too rigid (symmetrical) nor too chaotic (asymmetrical) but operate in an intermediate range in which “symmetry breaks” give rise to new stable orders (Kauffman, 1993). In the present hypothesis, the brain may be described as in this intermediate state: It “dances” between symmetry (equilibrium → a/b), asymmetry (perception → a'/b), and renewal of symmetry (calibration → a'/b').

In theoretical physics and biology, symmetry is often understood not as a geometric property, but as a phenomenon of stabilizing relationships. This does not result from nothing happening, but rather from changes that are so intertwined that, within a certain range, their relationships remain symmetrical. In modern physics, changes that disturb symmetry (“Symmetry Break”), are understood as instances that lead to the transition from current symmetry to new possibilities. They connect the physical ideal of invariance with the real dynamics through change. (Anderson, 1972; Prigogine, 1980; Laughlin, 2005).

Following Weyl and Einstein “invariance” characterizes the law (Yang, 1962). Hermann Weyl explains that invariance of any physical law, essentially requires the system to stay within a certain “group of allowed transformations” (Weyl, 1952), otherwise the symmetry breaks. Applied to the “Triggering Brain” hypothesis, this implies that the symmetry of the proposed a/b-relation may have its own group of allowed transformations for maintaining biological invariance.

3. Symmetry in Evolution

Biological systems are subject to physical laws and are shaped by them. Organisms cannot escape the realities of mechanics and optics. They are required to develop architecture to translate physical laws into biological functions. In biomechanics, for example, muscle forces act via levers around joints. The efficiency of each movement depends on the ratio between input force and lever length. As Niven & Farris (2012) argue, neural control of motor performance must be capable of processing relational information. Without such calculations, effective locomotion would not be possible, especially with larger and mechanically more complex animals.

Something similar applies to vision. Binocular depth perception arises from geometric relationships between angles and axes described by the law of sines and the intercept theorem. The nervous system integrates the two slightly different images from the eyes by deriving distance, depth, and direction from their disparities. Poggio & Poggio (1984) provided evidence that neurons in the visual cortex perform such relational calculations and convert sensory disparities into geometrically meaningful signals. Taken together, these parallels suggest that neural function may not be limited to the encoding of raw signals. Instead, neurons may embed physical relationship patterns into biological calculations and convert noisy sensory inputs into information that is directly relevant for orientation and locomotion. Thus, relational neurons may be interpreted as reflecting the continuity between physical laws and the biological requirements of perception and movement.

Evolutionary research has provided indications that the ability to process neural signals in a relational manner may have emerged as early as the Ediacaran Period, approximately 635–543 Ma ago (Ma = million years) (Knoll et al., 2006). The Ediacaran represents a turning point in the history of life because it marks the transition from largely microbial ecosystems to the emergence of complex, multicellular organisms. Before this period, mechanical forces were mainly managed at the cellular level. Single-celled organisms with their spherical-ellipsoidal shapes were able to cushion external forces through cell walls or flexible membranes. Their floating lifestyle allowed them to convert external forces into kinetic energy, preventing them from causing structural or internal damage. However, with the emergence of larger, multicellular organisms, such static solutions may no longer have been sufficient. The increasing body size and differentiation likely required new strategies to counter mechanical stresses.

The emergence and spread of benthic microbial mats in the late Ediacaran and early Precambrian (approx. 550 Ma) provided a new, stable, and rich source of nutrients (Seilacher, 1999; Gehling & Droser, 2013). New morphologies evolved to exploit these resources. Flat, dorsoventrally compressed, bilateral body shapes lying flat on the ground enabled the animals to graze on the microbial mats while resisting currents by allowing them to flow over them (Laflamme et al., 2009). Cilia lining the edges of these bodies stabilized their position and enabled subtle gliding movements across the sea floor. In later bilaterals, these structures evolved into paired appendages that improved both locomotion and stabilization (Budd & Jensen, 2017).

The evolutionary relevance of mechanical forces has already been highlighted by D'Arcy Wentworth Thomson (1917). In "On Growth and Form," he argued that geometry, currents, and physical forces shape the form and function of animals just as profoundly as genetic variations. This perspective, which was initially overshadowed by Darwin's theory of selection and therefore received less attention, has experienced a strong revival in modern evolutionary developmental biology (“Evo-Devo”). Contemporary research integrates mechanical influences as constant constraints that channel developmental processes (Kirschner & Gerhart, 2005; Müller, 2007; Briscoe & Kicheva, 2017). Although these forces are difficult to quantify precisely, they are increasingly considered a crucial factor in explaining evolutionary and developmental dynamics (Forgacs & Newman, 2005; Dudley, 2002).

While mechanical adaptations shaped morphology, the emergence of paired eyes presented a new challenge for the nervous system. The bilateral body plan, coordinated by HOX genes and gene regulatory networks (GRNs) (Martindale & Hejnol, 2009), led to the development of paired motor and paired sensory structures in the Ediacaran. The neural challenge was to merge the slightly divergent inputs from both eyes into a unified neural availability. Neurons capable of relational processing may have enabled early animals to compare these paired inputs, allowing for rudimentary depth perception and directional orientation (Nilsson, 2009). Fossils from southern China, such as Yilingia spiciformis (~550 Ma), show bilateral segmentation and anterior densification of nerve tissue consistent with such sensory integration, although functional statements about fossils are limited (Chen et al., 2019). Relational neurons may therefore have initially developed in the service of vision. This assumption is supported by the concentration of ganglia, which are considered to represent earliest primitive brains, in the anterior part of the body, near and between the later eyes (Strausfeld & Hirth, 2013).

Another innovation of the Ediacaran was the emergence of carnivory. Many benthic organisms grazed on microbial mats with the help of ventral feeding organs (Budd & Jensen, 2017; Xiao et al., 2019). In *"In the Blink of an Eye,"* Andrew Parker explains: “When one organism moved over another, it could ingest and digest the tissue of the animal beneath it. In this way, neighboring organisms became a new source of energy” (Parker, 2003). Fossil finds from the Gaojiashan biota in southern China document feeding traces that are consistent with such interactions (Xiao & Laflamme, 2009). This change is understood to have transformed ecological dynamics dramatically, as animals themselves became a resource for the first time. Predator-prey relationships emerged. Prey organisms were under pressure to detect and avoid attacks, while predators benefited from improved sensory perception and agility. Optical systems became crucial for detecting potential attackers and potential prey. Mechanical systems have become crucial for initiating attacks or escape. The resulting race likely led to increasing demands on both sensory integration and motor coordination. Neurons capable of linking the symmetry of sensory inputs and coordinating the symmetry of motor outputs may have offered a decisive adaptive advantage. Fossil finds, for example from Chinese deposits such as Chengjiang, show not only morphological diversification but also remarkable sensory and neural innovations (Shu et al., 2003; Ma et al., 2012).

The convergence of these factors may have constituted the formative ecological and biological conditions at the beginning of the Cambrian Explosion. The physiological capabilities may have been early manifestations of the a/b-principle proposed by the “Triggering Brain”. This may explain the continuity of brain evolution and its wide universality within the animal kingdom.

4. Symmetry in Physiology

The discussion of the a/b-hypothesis of the “Triggering Brain” requires the perspective of physiology. Symmetry and equilibrium can be understood as being closely linked to the concept of “homeostasis.” This concept, however, gives rise to misunderstandings.

Since Walter B. Cannon coined the term in 1932, its meaning has changed profoundly. Cannon used homeostasis to describe an emergent system state that arises from the interaction of many physiological processes (Cannon, 1932). Today, his definition is often phrased as follows: “The term homeostasis refers to the maintenance of balance in the body through coordinated physiological processes.” Cannon emphasizes that this is “a condition which may vary, but which is relatively constant.” The term was thus clearly meant to be relational and systemic: homeostasis did not refer to a specific mechanism, but rather to an equilibrium that is jointly produced by many adaptive mechanisms. Claude Bernard, whose ideas Cannon referred to, emphasized the character of relationality, for which he used the word “milieu,” as a condition for life. He wrote: "La fixite du milieu interieur est la condition de la vie libre" (Bernard, 1865). ("The stability of the internal milieu is the condition for free life.")

During the 20th and 21st centuries, there has been a significant shift in meaning, which has led to a semantic erosion of the term. Cannon referred specifically to circulation, respiration, blood sugar, body temperature, and hormones, and understood homeostasis as a systemic property of the organism (“...in the body...”) for regulating these conditions. He did not explicitly exclude the cell and its processes, which may explain why in modern neuroscience the term homeostasis has increasingly been applied to individual cellular mechanisms. Nowadays, the term is often used as a kind of label for local processes such as synaptic scaling or ion channel compensation. The original idea of systemic-emergent states appears to take a back seat in favor of processual explanations. Marder and Goaillard, for example, write: “Neurons use a variety of homeostatic processes to maintain stable activity patterns” (Marder & Goaillard, 2006). The word “homeostatic” here does not refer to the equilibrium itself, but to the processes involved in it. Gina Turrigiano refers to “homeostatic synaptic scaling” as “a form of plasticity that adjusts synaptic strengths to stabilize neuronal firing” (Turrigiano, 1999 and 2008). In doing so, she narrows the term down to a specific molecular mechanism. Another example can be found in Graeme Davis, who writes: “Homeostatic plasticity refers to mechanisms that stabilize synaptic function in response to perturbations” (Davis, 2013). In all three examples, homeostasis is not used to describe a higher-order state, but an individual operational activity. This carries the risk of a categorical error: the result of a multitude of cooperating processes – the (homeostatic) equilibrium – is confused with the processes themselves that jointly enable it.

It has been shown by Harold Modell and colleagues that this conceptual distortion is not only anchored in research, but also at the level of university education. The authors investigated how students in the US understand the concept of homeostasis and found that the term is almost exclusively identified with negative feedback mechanisms. They write: “Students tend to equate homeostasis with negative feedback and fail to understand the emergent system-level nature of the concept” (Modell et al., 2015). At the same time, they show that textbooks contribute to the confusion, as they often define homeostasis inconsistently and rarely convey the systemic perspective originally described by Bernard and Cannon. The authors conclude that the classical understanding of the term has largely been lost in the curriculum. This didactic evidence suggests that the semantic erosion of the term is already effective at the level of basic learning, which can only continue at the level of scientific theories.

Parallel to this development in science, the term has undergone a significant expansion across disciplines and is used in economics, psychology, politics, ecology, sociology, and other fields as a metaphor for stability and self-regulation. As a result, the term has become polysemous. It has several meanings at the same time, some of which differ from each other and some of which are contradictory. The term is certainly one of the most successful terms of the past century, having found its way from science into broader society. As a result, it has become popularized, which has reinforced its semantic erosion. The definitional precision that would be necessary for a basic scientific term has been lost. The same term is now used both for molecular compensation reactions in individual neurons and for the stability of entire political systems. This is a conceptual span that inevitably undermines its scientific precision.

Denis Noble criticizes this from a systems biology perspective. Noble opposes the reductionism that attributes biological regulation solely to molecular mechanisms. He argues that homeostasis can only be appreciated if it is understood as an emergent result of higher-level organizational constraints (Noble, 2006). Noble sees a fundamental flaw in the way this concept is currently handled in modern physiology, without, however, abandoning the term itself: a relational, systemic concept is narrowed down to a collection of local processes, thereby losing sight of its actual meaning.

Sterling and Eyer go further and criticize the homeostasis model in general as “too static” and “too poor” (Sterling & Eyer, 1988). They emphasize that biological regulation does not aim to maintain fixed values, but rather to continuously adjust the relationships between relevant variables. As early as the 1980s, they diagnosed a conceptual exhaustion of the classical understanding of homeostasis in the life sciences.

Antonio Damasio is one of the authors who has preserved Cannon's original relational meaning. For decades, he has used homeostasis not in the narrow, mechanistic sense of many neurobiologists, but in the organismic, systemic sense of Bernard and Cannon. For him, homeostasis is a “fundamental principle of life” by which organisms regulate processes and maintain stability (Damasio, 2010). He explicitly relates the term to the entire regulatory structure of the organism. He extends it to the functions of the brain and develops a theory of emotions and consciousness that encompasses the entire nervous system and therefore extends far beyond the brain.

J. Scott Turner is another proponent of a systemic concept of homeostasis. He understands homeostasis as an emergent, organismic capacity, not as a molecular mechanism. In regard to brain function, he describes “homeostasis as a fundamental principle for a coherent theory of the brain.” (Turner, 2019). Turner also emphasizes the active, constructive role of organisms and shows that homeostatic functions often extend beyond the body into the environment, for example in the architecture of termite mounds. Turner has proposed a concept he called the “Bernard machine,” which can help bridge the gap between Bernard's historical-romantic view and modern neuroscience (Turner, 2007).

The authors mentioned are examples of many researchers who keep alive the systemic concept of homeostasis in the tradition of Bernard and Cannon. The work of Denis Noble, Antonio Damasio, J. Scott Turner, and others makes it clear how biological stability must first be understood at the level of the entire organism. The authors view their research subject from completely different perspectives but come to the same conclusions: Life is the emergent result of an order that arises from the interaction of many relational processes. Damasio and Turner take this organismic perspective and focus on the brain. For Damasio, the central regulatory mechanism is equilibrium generated by the organism. He shows that the phenomenological representations of this equilibrium – feelings – play a crucial role because they indicate whether the organismic milieu is in balance or not. In this way, they connect somatic regulation with mental processes.

The double shift that the term “homeostasis” has undergone since Cannon, the “reduction” in modern neuroscience and the metaphorical expansion in social discourse lead overall to a considerable loss of precision. For a theoretical model based on the analysis of relational structures, such as “a/b” proposed by the “Triggering Brain,” such a term is therefore problematic. It is too narrow when limited to specific molecular processes in the scientific literature, and too broad when used in everyday language to describe almost any form of higher order.

For these reasons, I decided to avoid the term “homeostasis” in the first presentation of the “Triggering Brain” (Stueber, 2023). I used the expression “biological equilibrium” instead. Even without a formal definition, the expression seems scientifically rigorous, intuitive, and justified. “Biological equilibrium” is supposed to simultaneously insinuate the equilibrium to which individual processes are aligned and the equilibrium of any higher order that arises anew through the interlocking of these processes. The term may therefore be considered independent of the respective semantic level of integration and combines the two common anticipations of the concept of homeostasis. In my eyes, this was sufficient for a “sketchy” description of the a/b-hypothesis at that point in time.

The present essay aims to go deeper as the underlying a/b-principle of the “Triggering Brain” shall be justified and examined. This makes clear semantic differentiation essential, which concerns processes that operate locally within the cell, and the systemic, cross-cellular “milieu” that emerges from their joint activity.

Basically, all processes at the cellular level are relational processes and proceed according to the physical laws. Each operates in a specific, physiologically favorable range. They mutually adjust their activities through cascade-like, hierarchical, or cyclical interlocking. Mechanisms of inhibition, amplification, active or passive control of concentration and charge distributions, and, last but not least, control of the genetic apparatus determine the nature, strength, and direction of these processes. They control relational references but they never change the relational – symmetrical – character of the processes themselves. In a physical sense, the metabolism of a cell may be understood as a system of many individual symmetries. In a physiological range, they are invariant. They jointly create and maintain the overall symmetry within the cell, and, because cells are open systems, also between the cell and its environment.

This system may largely have been developed during the first 2,000 Ma of evolution. With the development of multicellular organisms around 550 to 600 million years ago, the need potentially arose for intercellular coordination (Yuan et al., 2011). Homeostasis ("Milieus" in the sense of Bernard) for controlling extracellular conditions is supposed to have evolved in the context of the evolution of multicellularity (Özbek et al., 2017.)

The analysis shows that "Homeostasis" may be understood as a milestone in the course of evolution. It is therefore important to preserve the conceptual precision of the term. Rather than remaining a purely descriptive label, the concept may require further theoretical development to capture its systemic and organizational significance. Homeostasis contributes not only to the accumulation of knowledge but also to a deeper understanding of biological organization.

The essay aims to use philosophical methods to examine the justification of the a/b-hypothesis. "Philosophy…" – to use the words of Hannah Arendt – "…looks at the truth" (Arendt, 1964) and attempts to identify universal laws. About "homeostasis" one truth, as shown above, is obvious: there are different ideas about it. The six authors cited are all highly respected figures who have made significant contributions to neuroscience. Is it possible that 50% of these renowned scientists are wrong? That is very unlikely. It rather points to a deeper aspect: different fields of expertise and perspectives, coupled with the intuition of different personalities lead to different ideas. However, this does not mean that different ideas must lead to different solutions or are even wrong. But what may be the overall synopsis?

We humans basically think in terms of processes and logic. Understanding causal relationships is essential: There is (1.) the process that we look at, and (2.) the understanding that we aim to develop. The key here may be "activity." Activity is required first, understanding follows. "Homeostasis," in this picture, is nothing very active. As it results from different processes, it is a somewhat passive artefact and may not be our main concern. For that reason, homeostasis might be an "**u**nderappreciated and far too often ignored central organizing principle of physiology" (Billman, 2020)**.**

Let me discuss this topic from a physical perspective. In physics, we understand symmetry, relativity, invariance, equilibrium, and symmetry breaking as the physical foundations of reality. Within this framework, there is no distinction between "active" and "passive," since everything is related to everything else in a symmetrical way. In physics, it took centuries to realize that "symmetry" is not a consequence of physical laws, but a "fundamental, intrinsic property." The present theory assumes that something similar might also apply to homeostasis. Certainly, homeostasis is generated by biological processes, yet at the same time it also mirrors the symmetry of these processes. Homeostasis may therefore be understood as a "fundamental, intrinsic property" of biological reality, similar to symmetry. Regarding brain function, the a/b hypothesis of the "Triggering Brain" supports this view. The following chapter, "Symmetry in the Brain," aims to explain why.

5. Symmetry in the Brain

This chapter examines the a/b-hypothesis of the "Triggering Brain" at the systemic and the cellular level of the brain. As discussed previously, the analysis will focus on the electromagnetic properties of cortical columns (Stueber, 2023). With reference to physics and given the required invariance of a/b, it is necessary to determine the group of allowed transformations: The conditions under which changes of "a" and/or "b" will not disturb their symmetry (a/b). In terms of wave physics, two phenomena may come into question here: interference and synchrony.

Interference results in the superposition of waves and leads to new patterns in terms of amplitude, wavelength, and frequency. It alters local deflections and can lead to amplification or attenuation. This may result in a change in any or all three dimensions of both, "a" and "b." Interference therefore may change the symmetry of "a" and "b," which is not allowed under the requirement of invariance.

Synchronization, on the other hand, corresponds to a state of temporal order in which the individual characteristics of "a" and "b" may be preserved. This means that the incoming signal "a" and the reference value "b" may be combined with each other in their temporal appearance without losing individual characteristics and preserving their symmetrical relation.

Consequently, and according to this hypothesis, "synchrony" meets the invariance requirements of allowed transformations for processing a/b while "interference" fails.

In the first presentation of the hypothesis, complete destructive interference was mentioned in a side note as a possible wave-physical phenomenon for the relational normalization of "a" and "b" (Stueber, 2023). Upon closer inspection, however, this analogy proves to be untenable.

Yoshiki Kuramoto (1975) described synchrony mathematically as follows:

$$\mathrm{r}e^{i\Psi} = \frac{1}{\mathrm{N}}\sum_{j=1}^{\mathrm{N}} e^{i\theta j}$$

Here, “θ_j“ represents the phase of an oscillator “j.” “Ψ“ represents the reference phase. “N” represents the size of the oscillating ensemble. The model describes synchrony as the mean value of phase differences. The factor “r” serves as a “Global Order Parameter”. It expresses the degree of synchrony: ($\mathrm{r} \approx 1$) synchrony is at the highest degree; ($\mathrm{r} \approx 0$) at the lowest. It is important to note that the contribution of inputs towards synchrony lies in the phase difference they add to the system, not in their strength. (Kuramoto, 1975).

It has been shown that the synchronous coupling of oscillators is aligned with three essential factors. First, a large ensemble of individual oscillators is necessary, which, second, must be in closed proximity. Third, the oscillators must exhibit a high degree of physical similarity. (Kuramoto, 1975 and 1984; Strogatz, 2000 and 2003; Breakspear et al., 2010).

Synchrony can be illustrated well with the example of applause after a performance. At first, the applause is chaotic because each person follows their own clapping rhythm. After a short time, spontaneity often sets in, with everyone clapping in the same rhythm. This happens without external control and without conscious coordination. If we look at the movement of a single hand, it can be described approximately as a periodic, wave-like movement. With the onset of synchrony, the hands of different people move along similar temporal trajectories. The decisive factor here is not the form of the movement itself, but its temporal coordination. At any given moment, the hands are in the same phase, while the individuality of the movements is preserved. Synchrony bundles the underlying dynamics into a new, collective pattern without disturbing them.

The three decisive prerequisites for synchrony have already been mentioned: a large number, spatial proximity, and physical similarity. All three prerequisites are generally met in many neural tissues. The cortex or the cerebellum are examples of very large ensemble of biochemically similar and densely packed cells. To develop synchrony, they need sufficient electromagnetic similarity. Empirical findings suggest that different strategies may be effective for adjusting the bioelectrical properties of cells towards synchrony. Examples may include synaptic downscaling (Tononi & Cirelli, 2014), neuromodulatory state changes (Aston-Jones & Cohen, 2005), structural-biophysical changes in neural coupling properties (Craddock et al., 2012), and others.

I would like to highlight the findings of Eve Marder and colleagues in this context. In their lobster model, a specific neuron (the pyloric dilator neuron, PDN) generates a physiological spike pattern for controlling the pylorus if it is integrated into its natural network. If the dendritic connections from surrounding neurons are experimentally disturbed, the physiological pattern disappears. However, the PDN can recover, so that the physiological signal can reappear after a rest period of about 6 to 8 hours. Marder et al. found that during this time, the cell changes its configuration of various ion channels. The researchers observed seven different charging processes for four cations and noted that the cells develop quite different, individual settings until the physiological spike pattern regenerates. They conclude that "similar network activity can be generated by widely different combinations of ion channel conductances." (Marder and Goaillard, 2006) and, somewhat more abstractly: "There are many solutions to the problem of producing a particular neuronal output." (Marder, 2011). More recently the scientists refer to this finding, following Edelman and Gally, as: "The Brain's Best Kept Secret is its Degenerate Structure" (Albantakis et al., 2024; Edelman & Gally, 2001).

Such findings may be interpreted as a triggering of the electromagnetic properties of the cell. It does not matter how exactly this happens. The only thing that matters is that physiological conditions are reestablished. Following the Kuramoto model and the present hypothesis, such findings may serve as examples of how neurons may act to maintain synchrony. Synchrony, as soon as established, may mark the endpoint of the adaptation because physiological conditions are reestablished as soon as oscillations are in synchrony. The oscillators are required to be physically similar – not identical. Kuramoto's "r" therefore has a kind of "degenerate" character and may serve as theoretical explanation for Marder's "…many solutions…" hypothesis.

Remodeling the "Triggering Brain"

The "Triggering Brain" model described so far may now be understood as a special case description of the sleep–wake cycle. During wakefulness the system undergoes changes due to Hebbian Learning. This is supposed to disturb the ability of maintaining synchrony. The calibration during sleep is supposed to adjust cellular settings so that synchrony, within the system's new frame, can be reestablished. Following the discussion of the present paper, it may become obvious that synchrony may not only be the baseline attractor state when the brain awakes, but evidently a fundamental condition for its general functioning. Consequently, a more general definition of the a/b-hypothesis may be required.

The hypothesis will now differentiate:

- “a” – inputs being able to disturb synchrony
- “b” – inputs being able to restore synchrony
- “a/b” – relational process of maintaining synchrony
- “Synchrony” – preferred physiological state (“Homeostasis”)

The distinction between “a” and “b” shall not be interpreted as a distinction between two separate classes of signals. “a/b” is a mirroring process: the same input may function as “a” or as “b” depending on the relational state of the system at a given moment. What defines an input is therefore not its intrinsic nature, but its effect on synchrony. If a signal increases phase deviation and drives the system away from coherence, it functions as “a”; if it contributes to restoring phase alignment and supports the return to a stable homeostatic state, it functions as “b”. In continuous brain activity, they are inseparable and may often occur simultaneously. A visual edge onset, for example, might function as “a” in an unexpected location (phase perturbation), but as “b” when it confirms a spatial relation in the oscillating neighborhood (phase restoration).

Every perturbation of synchrony contains the condition for its own compensation, and every stabilizing process emerges only in relation to a preceding disturbance. The a/b-relation should therefore not be understood as a temporal sequence, but as a dynamic equilibrium in which disturbance and restoration are complementary aspects of the same ongoing regulatory mechanism. Consequently, phenomena such as event related desynchronizations (ERD) (e.g. Pfurtscheller and Lopes da Silva, 1999) may not be explained as a breakdown of function, but as perturbative activity of (“a”).

Because synchrony is not a fixed state but a continuously maintained dynamic equilibrium, triggering cannot cease as long as the brain is in a physiological condition. Every incoming signal, whether external sensory input or internally generated activity, produces phase deviations and requires compensation. The brain therefore does not switch back and forth between phases of function and phases of correction because it is “trapped” in this ongoing process of synchrony disruption and restoration. Even in conditions of apparent rest, spontaneous oscillatory activity continues to generate fluctuations that must be integrated into the existing relational order. Complete inactivity would imply the absence of regulation and therefore the loss of functional stability. In a healthy brain, according to the present hypothesis, this would be expected to be physiologically unstable or highly unlikely.

The model aims to explain how coherent functional states may be preserved through permanent, relational balancing of homeostasis. It may therefore be understood as the underlying principle on how this system may be able to generate and control relational outputs such as coordinated movement, spatial orientation, or adaptive behavioral responses. In this sense, the hypothesis does not describe consciousness, but a biological process by which stable neuronal conditions may be achieved, providing the physiological basis from which conscious contents may emerge.

Because the “Triggering Brain” hypothesis proposes a fundamental principle of neural information processing, it may be speculated that the a/b-principle may not be limited to the cortex but may also be found throughout the nervous system, including the cerebellum, the mid-brain, and ganglia throughout the body.

6. Falsification

The causal argument of the “Triggering Brain” starts with symmetry as a general organizing principle and leads to synchrony as its neurophysiological manifestation. At first glance, this appears to be a circular argument: symmetry explains synchrony, while synchrony serves as empirical evidence for the underlying principle of symmetry. However, such a circular argument does not necessarily constitute a theoretical weakness. As Albert Einstein (1919, 1954) emphasized, principle-based theories differ from constructive theories in that they do not start from mechanistic elementary causes, but rather from general invariants and relational constraints that limit possible processes. In this sense, the present theory describes “symmetry” not as a local mechanism but as a principle of stable order, while “synchrony” is intended to represent its observable biological form.

This distinction is equally relevant with regard to Karl Popper’s criterion of falsifiability (Popper, 1963). Popper did not reject principle-based theories because of such recursive structures; rather, he demanded that they yield empirically testable consequences. The scientific validity of the “Triggering Brain” therefore does not depend on eliminating the apparent symmetry-synchrony cycle (which is not possible), but on deriving testable predictions from it: for example, that functional brain activity systematically correlates with phase coherence, that sleep contributes to the recalibration of synchrony, or that disruptions in synchrony cause reproducible cognitive deficits.

To develop falsification proposals, it is necessary to consider certain conditions associated with the theory:

EEG

The Kuramoto model provides a suitable framework for interpreting EEG data in terms of the a/b-hypothesis. An a-input may act as a disturbance to synchrony because it alters the system’s phase coherence. When interpreting EEG data, therefore, it is not primarily voltage amplitudes that may be decisive, but rather phase relationships, losses of coherence, differences in phase length, and the speed with which the system returns to a harmonious state. These dynamics may be understood as expressions of the adaptation through which the brain maintains synchrony.

One may argue that phase-amplitude coupling (PAC) represents the primary functional unit of neural computation, PAC does not replace this framework; rather, it is readily accommodated within it. For instance, cross-frequency interactions – such as high-frequency gamma bursts nested within a slower theta phase – can be mathematically conceptualized within an extended Kuramoto architecture as the explicit physiological mechanism driving “b”. Thus, amplitude modulations remain intrinsically bound to, and guided by, the underlying phase.

Harmonic scaling

Rhythms such as alpha or beta bands in the EEG may be understood as harmonic transposition of homeostasis. Synchrony is as most stable when frequencies are in rational proportions relative to a baseline (“Arnold Tongues”). Taking the Alpha-Band of the EEG as a reference baseline (1:1), the harmonic synchrony intervals range downwards for sleep to 1:4 (Delta) and 1:2 (Theta), and upwards for activity to 2:1 (Beta) and 4:1 (Gamma).

This harmonic scaling could allow the brain to utilize different operating modes without losing phase coherence. A shift in the harmonic level alters the system’s “headroom” for restoring synchrony. During sleep, for example, frequencies are low and phase length is high. This allows for more precise fine-tuning compared to high frequencies and favors slower (cellular) processes. In the waking state, due to the higher speed, harmonic adjustments require faster (neuronal) processes.

The size of the oscillating ensemble

The Kuramoto model includes the scaling factor (1/N), which means that the global order parameter (r) depends on the size of the ensemble (N). As the number of oscillators increases, the contribution of a single unit to the mean decreases, making synchronization increasingly independent of individual inputs. This leads to a fundamental biological trade-off between ensemble size and sensitivity. The hypothesis posits that the anatomy of the brain may have evolved to optimize this relationship. Sulci may be interpreted as biological solutions that spatially subdivide the oscillating ensemble into smaller and more sensitive groups, while gyri optimize macro-scale structural connectivity and core processing throughput. It could follow from this that the reproducibility of EEG measurements may be improved by optimizing the position of the electrodes according to the individual “sulcal fingerprint.” Recent research findings on the optimization of EEG procedures show that electrode placement has a significant impact on reproducibility (e.g., Formica et al., 2025).

For the interpretation of EEG data according to this hypothesis, the transitioning from abstract phase coherence in the Kuramoto model to empirical Phase-Locking Values (PLV) on the scalp requires accounting for three biophysical confounding factors: volume conduction, source mixing, and – most importantly – reference-dependency. To address the reference problem, Yao (2001) introduced the “Reference Electrode Standardization Technique” (REST), which mathematically relates EEG recordings to a neutral reference at infinity.

To broadly resolve these intertwined spatial and reference artifacts, a unified approach is proposed that integrates the REST framework with the individual’s unique sulci fingerprint rather than standard 10–20 grids. By embedding personalized cortical folding directly into the biophysical forward model, this method may minimize anatomical estimation errors while simultaneously reducing inter-subject source-mixing variance. Consequently, aligning the physical sensor array with person-specific anatomy may provide a better veridical reconstruction of true Kuramoto phase dynamics.

7. Proposals for the Falsification of the Theory

Proposal 1: Gyro- and Sulcal Fingerprinting

Objective: Verify whether cortical folding supports synchronization through localized phase-coherent ensembles. Method: Measure the signal-to-noise ratio (SNR), phase-locking value (PLV), and coherence of subjects performing standardized tasks using EEG with two electrode layouts: (1) a standard electrode grid and (2) an individualized layout aligned with the subject’s individual sulcal fingerprint (SF-EEG). Prediction: Signal quality, phase coherence, and synchronization precision should be significantly higher using the individualized layout, because it better captures anatomically localized synchrony. Falsification: If no significant difference in synchronization measures is observed between standard EEG and SF-EEG, the hypothesis that cortical macro-anatomy is optimized for localized synchrony must be rejected.

Proposal 2: Sleep as Recalibration of Synchrony

Objective: Test whether sleep functions as a biological recalibration process restoring baseline synchrony. Method: Subjects undergo selective deprivation of synchronization-relevant sleep phases, such as partial SWS suppression (e.g., acoustic stimulation during slow waves), while EEG/SF-EEG measures the stability of phase coherence and recovery dynamics in response to standardized stimuli on the following day. Prediction: Impaired recalibration should result in higher residual deviations from synchrony, faster fatigue, reduced adaptive capacity, and diminished tolerance for new inputs.

Falsification: If behavioral precision, phase coherence, and recovery capacity remain unaffected despite selective suppression of recalibration-relevant sleep phases, the hypothesis that sleep serves as synchrony restoration must be rejected.

Proposal 3: Synchrony during Multisensory Integration

Objective: Verify whether cortical synchrony represents the functional integration of linked a/b-states during multisensory processing. Method: Use MEG and EEG/SF-EEG to measure phase coherence, PLV, and the Kuramoto order parameter (r) between distinct cortical regions during tasks requiring integration of disparate sensory information, such as audio-visual cue binding. Prediction: Successful integration should correlate with increased phase coherence and stable increases in the Kuramoto order parameter, reflecting the restoration of a coherent relational state. Falsification: If successful multisensory integration occurs without a corresponding increase in measurable synchrony, the claim that functional integration depends on synchrony maintenance must be rejected.

Proposal 4: Hemispheric Load-Sharing and Sleep Recovery

Part I: Hemispheric Asymmetry during Wakefulness

Objective: Determine whether the brain maintains synchrony through interhemispheric compensation when one hemisphere is disproportionately loaded. Method: Apply a hemispheric overload protocol, such as high-intensity linguistic processing combined with neutral visual input. Measure interhemispheric synchrony using EEG/SF-EEG or MEG. Prediction: Increased local asynchrony in the loaded hemisphere should induce compensatory interhemispheric coupling, preserving overall functional stability. Falsification: If local overload produces cognitive failure or pathological desynchronization without compensatory interhemispheric recruitment, the hypothesis of unified synchrony regulation must be rejected.

Part II: Hemispheric Recovery during Sleep

Objective: Verify whether sleep calibration acts selectively on previously disturbed regions. Method: Measure sleep-associated synchronization activity, especially slow-wave activity (SWA), in subjects from Part I during the following sleep cycle. Prediction: Calibration signals should show asymmetrical intensity, with stronger restorative activity in the previously overloaded hemisphere. Falsification: If sleep-related recalibration is distributed uniformly regardless of prior asymmetrical wakeful load, the hypothesis that sleep calibration is a targeted relational restoration process must be rejected.

Proposal 5: Quantitative Compensation of Intrinsic Activity

Objective: Test whether intrinsic brain activity serves as a compensatory mechanism preserving synchrony under reduced external input. Method: Gradually reduce external sensory stimulation down to a Ganzfeld environment (near-complete sensory deprivation) while monitoring resting-state synchronization, intrinsic oscillatory activity, and Kuramoto order parameters using EEG/SF-EEG. Prediction: As external input decreases, internally generated activity should increase proportionally to preserve global synchrony and phase stability. Falsification: If intrinsic activity occurs independently of sensory deprivation, or if synchrony collapses without compensatory internal activity, the hypothesis of permanently maintained synchrony must be rejected.

8. Discussion

A central objection to the "Triggering Brain" hypothesis may concern the question of whether neuroscience requires a new organizing theory at all. Many researchers would argue that no fundamentally new principle is necessary because the essential mechanisms of brain function are known and identified: neurons, synapses, oscillations, plasticity, predictive coding, and large-scale networks. The remaining task for neuroscience is primarily one of resolution: to describe these mechanisms with increasing precision until higher-order phenomena such as cognition and consciousness become fully explainable. The well-known wager between Christof Koch and David Chalmers illustrates this divide. Koch has argued that the neural correlates of consciousness may be empirically identified within a foreseeable time frame (Koch, 2019), whereas Chalmers has emphasized that the explanatory gap between neural activity and subjective experience may not be closed by mechanistic accounts alone (Chalmers, 1996).

This disagreement may reflect a deeper methodological divide. One side assumes that understanding emerges through the progressive completion of mechanistic descriptions. The other suspects that the relation between local mechanisms and global functional organization may require an additional conceptual framework. The "Triggering Brain" hypothesis belongs to this perspective. It does not deny the validity of established neurophysiological findings, but questions whether the current inventory of mechanisms is sufficient to explain how the brain preserves functional unity under permanent change.

This question becomes particularly relevant considering the reproducibility crisis in neuroscience. Many findings – especially in functional imaging and EEG research – show considerable variability across laboratories, tasks, and analytical methods (e.g. Eklund et al., 2016; Botvinik-Nezer et al., 2020). Differences in preprocessing, electrode placement, reference selection, averaging procedures, mathematical models, and statistical thresholds can lead to substantially different interpretations of the same underlying activity. EEG, in particular, often provides highly sensitive but theoretically underconstrained measurements: amplitudes, oscillations, and connectivity patterns are observed, but their systemic meaning remains difficult to define. Without a principled framework, interpretation risks becoming descriptive rather than explanatory.

The “Triggering Brain” hypothesis may contribute at this level. By interpreting EEG rhythms as expressions of synchrony and harmonic regulation rather than isolated signal events, it offers a unifying principle for their interpretation. Measures such as phase coherence, phase-locking value, and the Kuramoto order parameter may then be understood not merely as technical descriptors, but as indicators of the system’s relational stability. This could improve reproducibility by shifting attention from isolated amplitudes toward invariant properties of synchronization and recovery dynamics, which may be more directly linked to functional regulation.

Evolutionary biology and physiology provide strong reasons for such a perspective. Living systems are self-maintaining systems whose primary problem is the preservation of stability under continuous perturbations. Homeostasis is therefore not a secondary feature but a constitutive principle of biological existence. In nervous systems, this problem becomes especially pronounced because information processing itself constantly generates structural and functional changes. Learning modifies connectivity, sensory input perturbs ongoing oscillatory states, and internal activity continuously alters the system’s own reference conditions. A rather mechanistic account of biochemical pathways may not be sufficient to explain how coherence is preserved across these recursive disturbances.

From this perspective, the search for a principle such as symmetry-driven synchrony is not an attempt to replace existing neuroscientific findings, but to provide a higher-order constraint comparable to principle theories in physics. Just as Albert Einstein did not reject known physical laws but reorganized them through invariance principles, the “Triggering Brain” hypothesis proposes that synchrony may function as an organizing condition that links local processes to systemic stability. It addresses not what neurons are made of, but how neural systems may remain functionally integrated despite constant deviation from equilibrium.

Consequently, the hypothesis shows clear conceptual connections to established lines of research in neuroscience and theoretical biology. Giulio Tononi’s “Integrated Information Theory” (Tononi et al., 2016) defines consciousness through the degree to which a system generates irreducible integrated information (Φ). Its central question is why certain neural states are experienced subjectively rather than remaining purely functional. The “Triggering Brain” hypothesis addresses a prior level of organization: it asks how neural systems maintain the stable relational order required for such integration to occur at all. Stanislas Dehaene’s “Global Neuronal Workspace Theory” describes consciousness as the large-scale broadcasting of information (Dehaene et al., 1998). The present hypothesis provides the homeostatic explanation of how such a coherent neuronal workspace can emerge and remain stable over time. Wolf Singer's work on temporal binding and cortical synchrony provides direct neurophysiological support for the central role of phase coherence in functional brain organization (Singer, 2007).

Antonio Damasio places homeostasis at the center of cognition and consciousness, providing strong support for the idea that neural processing is fundamentally organized around the preservation of systemic stability (Damasio, 2010). Denis Noble's concept of biological relativity supports the view that neural function cannot be fully explained from a single privileged causal level but requires a system-wide understanding of multilevel regulation and homeostasis (Noble, 2006). Karl Friston's "Free Energy Principle" describes living systems as continuous processes of error correction and stability preservation (Friston, 2020), closely corresponding to the a/b-relation as the permanent balancing of disturbance and restoration. Roger Penrose emphasizes that biological organization necessitates an explanation rooted in deeper physical principles and formal structures (Penrose, 2016). He posits that quantum-level biological processes are fundamentally influenced by space-time geometry. Under this framework, neural synchrony can be understood as a space-time system: "space" is represented by phase relationships and lengths, while "time" is defined by the velocity of synchronization. For such a system to function, the state of synchrony must be transduced into cellular regulatory processes. Penrose proposes a framework for this interface via microtubules, which are increasingly being studied for their potential role in intracellular signal transduction.

The "Triggering Brain" hypothesis therefore does not stand in opposition to contemporary approaches. It may be understood as an attempt to unify current perspectives under a principle-theoretical framework.

It is equally acknowledged that such a principle theory ultimately requires a rigorous mathematical framework if it is to move beyond conceptual plausibility and become scientifically robust. Concepts such as symmetry, synchrony, relational balancing, and mirrored rotations cannot remain purely descriptive if they are to serve as explanatory principles; they must be translated into formal relationships that allow precise prediction and empirical testing. Approaches such as the Kuramoto model, phase-coherence analysis, and system-level dynamical models may provide initial methodological entry points, but they may not yet constitute a complete formalization which, at present, is limited by several fundamental problems that remain unresolved at both the biological and physical level.

First, it is unclear whether synchrony should primarily be understood as a biologically determined phenomenon or as a physically determined one. The central question is not merely whether synchrony exists, but why it emerges as a preferred state of neural systems. Is synchrony mainly driven by biological regulation – through evolutionary selection, synaptic organization, and homeostatic adaptation – or is it the consequence of more fundamental physical constraints such as phase coupling, energetic minimization, and invariance principles? Determining which of these represents the primary driving force is essential before a rigorous mathematical framework may be established.

Second, reliable measurement remains a major limitation. We currently lack sufficiently precise data both for the biological side of the problem – such as the exact structural and functional dynamics of white matter adaptation, local phase restoration, and system-wide calibration – and for the physical side, namely the direct measurement of synchrony as a dynamical electromagnetic process. EEG and MEG provide indirect access to oscillatory behavior, but they do not yet offer a sufficiently stable or spatially resolved description of the underlying phase relations needed for formal principle derivation.

Third, the absence of a mathematical framework also results from the difficulty of translating the concept of invariance from physics into biology. In physics, invariance refers to stable relations that remain preserved despite changing conditions and thereby constrain what processes are possible. For a principle theory of brain function, the corresponding question may ask about which biological organizing condition plays an equivalent role. The eye, for example, does not determine what we see, but it defines the structural conditions under which seeing becomes possible – and we understand how this works. Likewise, the digestive system does not determine what we eat, but it provides the stable biological organization that makes digestion possible – and we know how this works. In the same sense, neuroscience must ask what corresponding biological principle allows the brain to maintain coherent function despite continuous perturbation, plasticity, and structural change. The "Triggering Brain" proposes that this "invariant" is not a single anatomical or cellular structure, but a dynamic property of the system. In this framework, the biological invariant is not synchrony as a static state, but the system's capacity to continuously restore synchrony under perturbation. Synchrony itself is therefore not the invariant, but its observable expression. However, because this "biological invariant" has not yet been clearly identified, operationalized, or measured, it cannot yet serve as the basis of a rigorous mathematical formalization. The present theory therefore remains conceptual. Its mathematical proof depends on future advances in neurophysiological measurement and theoretical formalization. For mathematical modeling, the three dimensions of "information" may be defined by phase length (syntax), the difference in phase lengths (semantics), and the speed of synchronization (pragmatics).

Provided that the present hypothesis is justified, the identification of this “biological invariant” may prove to be of fundamental importance for neuroscience. Understanding its nature – and developing reliable methods to measure it – could significantly improve our interpretation of brain function and have major implications for neurological diagnostics and therapeutic interventions.

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