Chapter

The Role of Mitochondria in Consciousness and Cognition: New Insights from Feelings of Knowing-fundamental Interoceptive Patterns Theory

Holly Pollard-Wright and Mark T. Wright

Abstract

This chapter proposes that mitochondrial activity gives rise to a "cognitive force" linked to consciousness and interoception. The updated feelings of knowing-fundamental interoceptive patterns (FoK-FIP) theory holds that mitochondrial gene expression and energy production emit the cognitive force, or the bioenergetic perception underlying cognition. Further, through cellular frameworks, electromagnetic radiation occurs. According to the FoK-FIP theory, electromagnetic radiation is a form of consciousness. In this approach, the various physical components of mitochondria play different roles in consciousness and cognition. Through mitochondrial thermodynamics, the theory's constructs can be studied with empirical measures and research. The discussion section explores the connection between mitochondrial thermodynamics and the theory's constructs, as well as their measurement.

Keywords: cognitive broadcasting, mitochondrial dysfunction, consciousness, electromagnetic radiation, cognition

1. Introduction

The feelings of knowing- fundamental interoceptive patterns (FoK-FIP) system [1] may contribute to contemporary theory building, facilitating scientific progress. It is based on the FoK-FIP theory, which aims to address philosophical and scientific questions about the relationship between the intangible and tangible aspects of reality. In this process, multidisciplinary modeling involves the relationship between the mind, the nature of consciousness, and physical states and events in the body. Insights gleaned from quantum physics and consciousness research facilitated the modeling process. Notably, the possibility that the non-physical and physical aspects of reality are non-separable is a subject of ongoing discussion in philosophy and

science. In the initial stages of the FoK-FIP theory's development, abstract concepts were formulated. These concepts helped organize existing knowledge needed to investigate complex phenomena.

Importantly, this chapter represents the development of the theory and the need to link concepts with scientific inquiry. A broad model of thermodynamics will be used to connect theoretical concepts. *Thermodynamics* is a branch of physics that examines the relationships between heat, work, and temperature. It shows how they relate to energy, entropy, and the physical properties of matter and radiation. According to the FoK-FIP theory, there is an intimate relationship between thermodynamics and mitochondria. A brief discussion will be provided related to ongoing research methods that enable concepts to be empirically tested, validated, or refuted through observation and experimentation.

1.1. Brief methodology note

This chapter addresses theoretical developments of the FoK-FIP theory. The focus of the literature review was on identifying existing information and related empirical findings that are congruent and directly relevant to the theory, thereby facilitating conceptual development. The cited references in this chapter were identified through primary database searches using the following resources:

- PubMed/MEDLINE: Medical and health sciences literature
- Google Scholar: Multidisciplinary academic literature

The reference selection criteria included the following:

- The reference is available in English.
- The reference was published in a peer-reviewed journal.

2. Relativity modeling of the FoK-FIP theory

Albert Einstein's *Special Theory of Relativity* is a scientific theory that ultimately explains the relationship between space, time, mass, and energy. The special theory of relativity owes its origins to James Clerk Maxwell, specifically *Maxwell's equations* of the electromagnetic field [2]. Maxwell's equations are four fundamental equations that explain the relationship between electricity, magnetism, and light. These four equations describe how electric and magnetic fields are generated by electric charges and currents, and how these fields interact with each other. Notably, Maxwell's equations can be understood formally through the special theory of relativity [2].

The FoK-FIP theory expands the scope of the special theory of relativity. It does this by proposing that the relationships between space, time, mass, and energy are intimately connected to both physical and mental (psychological) processes. Essential to this concept are frameworks. Fundamentally, cellular frameworks consist of cells and are represented by living organisms. For example, there are cellular frameworks represented by humans in which the typical adult human body contains approximately 30 trillion cells [3]. Furthermore, within cellular

frameworks, complex cellular processes occur through interconnected mitochondria. Importantly, in the context of the theory's modeling linked with research, mitochondria are a system that produces electromagnetism, which Maxwell's equations can explain.

3. The endosymbiotic theory and the FoK-gene

In 1905, the Russian botanist Konstantin Mereschkowski first proposed the theory that mitochondria (and chloroplasts) originated as free-living prokaryotic cells. As such, the theory suggests these organelles arose from prokaryotes through (endo) symbiosis. In this process, mitochondria that were once free-living prokaryotic cells became part of eukaryotic cells. The endosymbiotic theory explains why mitochondria resemble free-living bacteria. It accounts for the physiological and biochemical similarities between these organelles and prokaryotic cells [4]. Furthermore, the single origin of mitochondria is supported by evidence related to protein import. Mitochondrial proteins are involved in a broad spectrum of pathways. Notably, there is a discrepancy between the number of proteins that mitochondria encode and the number of proteins they harbor. This discrepancy is generally explained by a corollary endosymbiotic theory involving gene transfer to the nucleus, also known as endosymbiotic gene transfer (EGT) [5]. As part of the evolution of mitochondria, many of their genes are transferred to their host cell's nucleus. During this early process, the transferred genes either became pseudogenes (non-functional genes) or were expressed as cytosolic proteins. The mitochondrial protein import apparatus came later as part of the evolutionary process. The mitochondrial protein import apparatus is a complex system. It is associated with mitochondrial biogenesis, import, sorting, folding, assembly, and degradation of proteins. Importantly, through the protein import apparatus, mitochondria can import proteins from the cytosol. Therefore, genes transferred from the mitochondria to the cells' nucleus are expressed, and the protein returns to the mitochondria [4].

The literature suggests that mitochondrial genes retained most tenaciously throughout evolution encode for (a) proteins involved in the electron transport chain and (b) the ribosome required for their synthesis [4]. The interdisciplinary modeling of the FoK-FIP theory includes the concept that the FoK-gene is also part of the mitochondrial genes retained tenaciously. In this concept, FoK-gene expression creates a bioenergetic relationship integral to perception. Through mitochondria, the FoK-gene is expressed in both prokaryotes and eukaryotes. The FoK gene expression occurs through a slightly different genetic code, distinct from the "universal" genetic code used by prokaryotic and eukaryotic cells. This is because the mitochondria's genetic system is separate and distinct from the cell's nuclear genome [6]. A genome refers to the organism's entire genetic blueprint. It is composed of deoxyribonucleic acid (DNA) arranged as pairs of chromosomes (nucleic acids and proteins) located in the cell's nucleus, and also DNA in the mitochondria. Mitochondrial DNA (mtDNA) represents a small fraction of the total DNA in cells. Like those of bacteria, mitochondrial genomes are usually circular DNA. Within a cellular framework, there is mitochondrial DNA in most animal cells (and in plant cells in the chloroplasts). Unlike other organelles, mitochondria have their own DNA that encodes ribonucleic acid (RNA), specifically transfer RNAs (tRNAs), ribosomal RNAs (rRNAs), and some mitochondrial proteins [6]. The mitochondrial translation apparatus refers to synthesizing a polypeptide chain from a messenger RNA (mRNA) template (e.g., tRNAs, rRNAs).

4. Core constructs

What is similar between the FoK-FIP theory's core constructs is their purpose. They act as a bridge for concepts gleaned from a broad range of scientific disciplines. In this regard, the FoK-FIP theory's constructs represent fundamental ideas and principles. Their purpose is akin to creating the concept of time, and thus, they aim to help scientists connect fundamental ideas within their respective domains [**Table 1**] [**Figure 1**].

Figure 1, as a conceptual diagram, illustrates how a single mitochondrion can function as a critical biological node within the feelings of knowing-fundamental interoceptive patterns (FoK-FIP) theoretical framework. It highlights consciousness-related processes modeled to emerge from and interact with mitochondrial bioenergetics.

5. Fundamental mitochondrial thermodynamics

The reader is encouraged to consider the thermodynamics model as a thread that connects the FoK-FIP theory's constructs to scientific inquiry and research. Important concepts associated with mitochondrial thermodynamics include energy conversion, the energy supply-demand problem, and heat production. Integral to these concepts is an understanding of (a) the structure of an atom and (b) a mitochondrion. An atom is the basic building block of all matter and has three main components: electrons, protons, and neutrons. Electrons are negatively charged particles that orbit the nucleus in a cloud-like formation. The atom's nucleus contains the protons and neutrons. Protons are positively charged particles, whereas neutrons have no electrical charge (thus neutral). Described very simply, a mitochondrion is a double-layered structure. It has a matrix, an inner membrane, an intermembrane space, and an outer membrane. The matrix is a space enclosed by the inner membrane. The inner membrane is folded, creating projections called cristae. The intermembrane space is the space between the inner and outer membranes. The outer membrane is the smooth outer layer of the mitochondrion (**Figure 2**).

5.1. Energy conversion

The literature suggests that the evolutionary emergence of photosynthesis led to the accumulation of oxygen in the atmosphere [18]. Therefore, living organisms needed to adapt to the environment. They did that through regularly occurring cellular oxidative reactions. Fundamental to cellular respiration are oxidation-reduction (redox) reactions. Cellular redox homeostasis is a dynamic process. It balances the reduction and oxidation reactions within cells. As such, homeostasis is closely tied to the evolving history of many regulated events and responses [19]. Oxidative metabolism is the process by which glucose and fatty acids are broken down through oxidation. It is the principal source of metabolic energy in animal cells. The following are key concepts associated with this process:

- The *mitochondrial electron transport chain* refers to a series of carriers that transport electrons from a higher to a lower energy state. It is integral to oxidative metabolism and involves the generation of free radicals. These are

• **Electromagnetic radiation (EMR) consciousness** The theory describes the EMR that occurs through a cellular framework as *EMR consciousness.* Mitochondrial metabolic activity and other cellular components contribute to the output of EMR consciousness. The theory's EMR consciousness correlates with other electromagnetic radiation consciousness theories [7–9].
• **FoK gene** This term creates a bridge between metacognition[10], genetics, and physics. The FoK gene [11] is a theoretical construct associated with mitochondrial deoxyribonucleic acid (mtDNA). It is modeled not to emit, absorb, or reflect light. This makes the FoK gene invisible to direct detection methods that rely on electromagnetic interactions. Despite its invisibility, the FoK-gene's presence is inferred through its association with perception. Specifically, FoK-gene expression causes the emergence of cognitive force, which, according to the theory, allows matter to become visible.
• **The cognitive force of cellular frameworks** The cognitive force is a hypothetical force linked to consciousness and interoception [12]. It arises from the expression of the FoK-gene. Notably, the cognitive force is not an inherent characteristic of the mitochondria themselves. As such, the cognitive force is unlike mitochondrial properties such as mass, volume, and density.
• **Awareness current** This term creates a relationship between the consciousness construct of awareness and the physics concept of current. In this abstraction, the awareness current [11] is a non-physical phenomenon of mitochondria. It occurs in conjunction with the movement of charged particles. For example, awareness current occurs when protons move across the mitochondrial inner membrane during oxidative phosphorylation.
• **Mitochondrial channels** Mitochondrial channels are a conceptualization of interconnected mitochondria that form a reticulum. Through this depiction, a better understanding of how mitochondria maintain health and cellular function may be facilitated. It is a concept that broadly correlates with depictions of mitochondrial channels in the literature [13–15].
• **A wavefront** A "wavefront" is a conceptualization of signals that the cognitive force will cognitively broadcast [1]. This construct consists of measurable electromagnetic fields that are synchronized patterns with linked points of activity. Through the wavefront, synchronized activity propagates across regions. Notably, signal propagation through the wavefront has a complex, interconnected nature. This means that signals do not propagate in a simple, uniform manner. Therefore, the FoK-FIP theory's wavefront concept differs from the one understood in classical physics [16].
• **Cognitive broadcasting** Cognitive broadcasting represents the processing of signals derived from the electromagnetic field of a wavefront. In this depiction, signals are broadcast cognitively by the cognitive force to create perception. This process involves organizing and interpreting signals as sensory information. "Sensation and cognition" includes sensation, attention, organization, interpretation, and response. In this process, signals are perceived as parts of the phenomenal world by the cognitive force. The theory's conceptualization of cognitive broadcasting broadly correlates with other cognitive theories of consciousness [17].
• **Interoception of FoK-FIP** The interoception of FoK-FIP (FoK-FIP interference and FoK-FIP feeling tones) serves as the foundation for cognitive broadcasting [11]. It refers to a process derived from the connection between the cognitive force and the mitochondrial network. This process yields a specific interoceptive experience. Further, the cognitive force has varying sensitivities to the interoception of FoK-FIP. In this modeling, the cognitive force can cognitively broadcast signals without awareness associated with FoK-FIP interference. In contrast, this same cognitive force can be aware that it is cognitively broadcasting signals through FoK-FIP feeling tones (pleasant, unpleasant, and neutral). FoK-FIP feeling tones are the foundation for awareness of reward-driven decision-making, arousal, reactivity to emotional stimuli, and somatic processing. They allow the perception of being "a self" that can feel the effects of mitochondrial function or dysfunction, for example, associated with fatigue or pain.

Table 1.
Core constructs of the FoK-FIP theory.

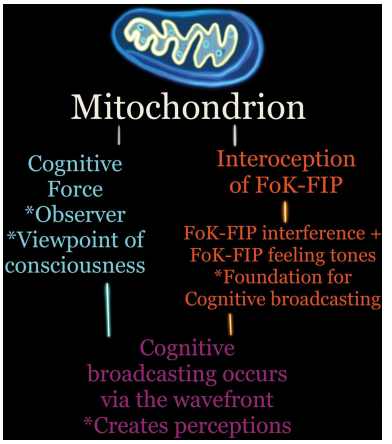

Figure 1.
Highlights of the FoK-FIP theory.

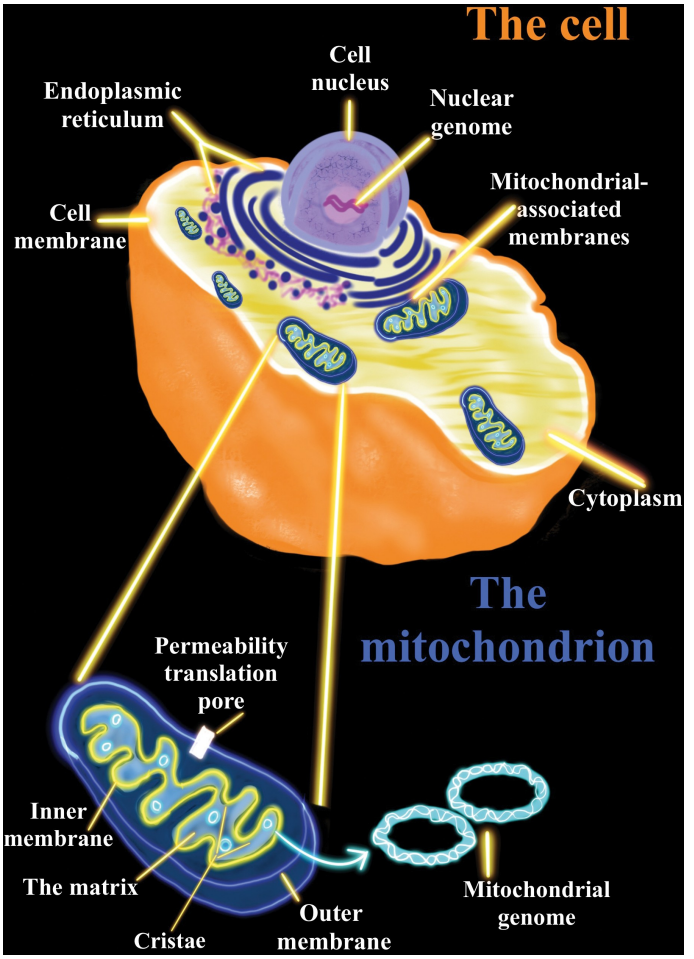

Figure 2.
The cell and the mitochondrion.

byproducts of the electron transport chain. Importantly, free radicals can damage cellular components if not adequately managed [20].

- *Oxidative phosphorylation* is a thermodynamically driven process. In this process, chemical energy is converted into adenosine triphosphate (ATP). ATP is the cell's primary energy currency, meaning it serves as the primary energy source for cellular use and storage [21]. Through oxidative phosphorylation, ATP is generated. Driving ATP synthesis is a proton gradient across the inner mitochondrial membrane. The proton gradient is established when protons are pumped out and into the intermembrane space before flowing back through the ATP synthase.

- *ATP synthase* is a molecular machine found in mitochondria (and chloroplasts). It has a key role in cellular energy production (and photosynthesis). It exists within the cristae folds of the mitochondria's inner membrane. Notably, the ATP synthase is closely linked but not technically considered part of the electron transport chain [22]. Instead, ATP synthase acts as the final step in the process of oxidative phosphorylation. A mitochondrial ion gradient refers to a difference in the concentration of positively or negatively charged ions across a membrane. Ions are atoms or molecules that have gained or lost electrons, resulting in a net electrical charge. An uneven distribution of ions (primarily hydrogen ions) across the inner mitochondrial membrane creates a concentration difference. In this process, more protons are in the intermembrane space than in the mitochondrial matrix. As part of this process, the ATP synthase rotates at a speed that depends on temperature and ATP concentration. For example, ATP synthase rotates about 230 times per second at room temperature. In contrast, it rotates up to 650 times per second at 45 degrees Celsius [23–25]. Notably, the literature suggests that the ATP synthase rotational rate is independent of the nature of cellular demand. This means that the ATP synthase can function solely in an on/off manner [26]. In summary, ATP synthesis and the efficiency of the electron transport chain are closely linked to thermodynamics, with a direct dependence on ATP synthase. Through ATP synthase-related processes, the efficiency of the electron transport chain can be influenced by factors such as a proton leak. This leak can reduce the net proton flux and lower the overall efficiency.

5.2. The energy supply-demand problem

Cellular metabolism can be functionally organized into supply and demand [27]. The energy supply-demand problem refers to energy production in the cell. It is a process where energy needs of the cell are matched with delivery of components needed to create energy. This problem underlies flux in intracellular metabolic homeostasis. Notably, the function of ATP synthase has been hypothesized to play a vital role in demand. Functioning ATP synthase helps explain how cells that require extra energy send signals to their mitochondria [28].

5.3. Heat production

Mitochondria are "hot" and are warmer than the cytosol of cells [29]. Mitochondrial function generates a significant portion of the heat that contributes to cellular and organismal temperature regulation, a process known as thermogenesis.

Notably, the actual values of thermogenesis in mitochondria are a matter of debate [30]. Nevertheless, thermogenesis includes the dissipation of a proton gradient. In this process, the difference in proton concentration and electrical potential across a membrane (generated by the electron transport chain) is reduced or eliminated. Through this process, energy in the form of heat is released. For example, mitochondria generate most of the heat in endotherms (warm-blooded animals). This process includes some impedance to heat transfer across protein-rich bioenergetic membranes. Therefore, mitochondria must operate at a higher temperature than body temperature in mammals and birds [31].

6. Conceptual elaboration of the core constructs of the FoK-FIP theory

In this section, the reader will be introduced to the modeling that underlies a specific set of core constructs from the FoK-FIP theory.

6.1. Consciousness as electromagnetic radiation

According to the FoK-FIP theory, consciousness refers to electromagnetic radiation (EMR) produced through cellular frameworks. The FoK-FIP theory's version of EMR consciousness has aspects that correlate broadly with other theoretical models of consciousness [32]. The conceptualization of EMR consciousness includes mitochondria generating electromagnetic fields. For example, the mitochondrial membrane potential is associated with a strong electromagnetic field. In the context of this model, the mitochondrial network's ion and electron gradients are crucial for maintaining the integrity and function of EMR consciousness. In cellular frameworks represented by animals, the collective firing of neurons allows communication through electrical impulses. In this process, electromagnetic fields are created and modeled as part of EMR consciousness. Notably, the central nervous system is believed to have evolved under the control of genes that are often conserved both structurally and functionally [33]. Research findings indicate that the central nervous system evolved from the skin of invertebrates. This suggests consciousness originated in the body's (rather than the brain's) physiologic makeup [34].

6.2. The cognitive force of cellular frameworks

The cognitive force of the FoK-FIP theory is the "viewpoint of consciousness" (in which consciousness is EMR). Linked by mitochondria are the concepts of the "observer" and the concept of consciousness. Through each mitochondrion with FoK gene expression, cognitive force emerges. It then interacts with the system of connected mitochondria. By doing so, the cognitive force becomes the "observer" of the mitochondrial system. Importantly, through the interaction of cognitive force and mitochondria, the cognitive force is capable of making measurements. In this process, the interactive cognitive force creates a relationship between observing and influencing mitochondrial functioning. Aligned with the theory, the act of observation by the cognitive force can affect the mitochondrial system being observed. This modeling broadly correlates with the "observer effect" of quantum mechanics. The observer effect in physics refers to the phenomenon where what an observer sees can

differ from what would be observed in their absence. The results of the double-slit experiment [35] famously illustrated this concept. In this experiment, observing electrons or photons as they pass through slits causes them to behave like particles rather than waves. Notably, this experiment suggests that the state or quality of having existence or substance (reality) may be intimately connected with measurement. As such, the intuitions about the phenomenal world might be more a product of measurement rather than of perceiving fixed, pre-existing, or independent entities.

6.3. Awareness, a current of the mitochondria's inner membrane

The FoK-FIP theory suggests that awareness is a current. As such, the concept of "current" is an idea that broadens the physics concept of "current", such as that produced in a wire. Based on the theory, awareness current is a nonphysical phenomenon connected with an electrical potential difference. Integral to awareness current is the inner mitochondrial membrane, a continuous equipotential structure [36]. As implied by the theory, the inner membrane stores the oxidation energy of respiratory substrates as electrical potential and the potential for awareness. In this process, the inner membrane acts as a coupling membrane. It can generate an electric potential, which is coupled to awareness. As part of this process, the movement of electric charges generates low-frequency magnetic fields. The theory models these to represent FIP. This modeling adds a new dimension to discussions about the effects of low-frequency magnetic fields on mental function [37, 38]. Notably, magnetic fields created by a single mitochondrion are extremely small and therefore not directly measurable outside the cell. However, through interconnected mitochondria, an aggregated activity within a tissue might produce detectable low-frequency magnetic fields.

6.4. Mitochondrial channels

The theory's inclusion of mitochondrial channels intends to expand understanding of the mitochondrial reticulum, also known as the mitochondria-associated endoplasmic reticulum membranes (MAMs). The mitochondrial channels are a broader term encompassing the entire interconnected network of mitochondria within cells and underlying intercellular mitochondrial transfer. Essential to understanding the channel concept is the fact that mitochondria are not static structures. Instead, they are constantly being remodeled through the process of mitochondrial fission and fusion. A single mitochondrion can be divided into two (mitochondrial fission). In contrast, two mitochondria can merge to form one larger mitochondrion (mitochondrial fusion). Aligned with the theory, mitochondrial channels facilitate the distribution of energy, which includes cognitive force. In this representation, mitochondrial channels are dynamic and communicate both within and outside cells. The following explains the distinctive features of mitochondrial channels connected to physical, behavioral, and cognitive function:

- There is a relationship between the movement of the cognitive force and the proton-motive force. Through oxidative phosphorylation, mitochondria generate an electric potential difference. In this process, an electromotive force (EMF) is produced across their inner membrane. The cognitive force, therefore, is transmitted through mitochondrial channels formed by the movement of

protons (H+) across the inner membrane. Integral to this process is an electrochemical gradient that drives the synthesis of ATP.

- The cognitive force moves between cells through (a) tube-like membrane structures (tunneling nanotubes), (b) vesicles that are taken up by recipient cells (extracellular vesicles), (c) sharing of cellular components (cell fusion), and (d) recipient cells that take up free mitochondria released into the extracellular environment (endocytosis).

The mitochondrial channels form a regulatory system that is connected to organ function. This modeling broadly aligns with the meridian and channels concept of Traditional Chinese Medicine (TCM) [39]. Through cellular frameworks represented by animal models (e.g., human and non-human) with mitochondrial channels, the cognitive force flows. There is an *outflow,* an *inflow*, and a *surrounding flow* [40] associated with the cognitive force of cellular frameworks:

- *A stream of outgoing* (outflow) *cognitive force:* In this process, connected mitochondrial networks, as part of channels, result in the cognitive force being pulled towards the cell membrane.

- *A stream of ingoing (*inflow) *cognitive force*: Through mitochondrial channels, the cognitive force propagates from body parts to the central nervous system and peripheral nervous tissue.

- *A surrounding flow of cognitive force*: The cognitive force flows through mitochondrial channels intimately connected to the brain and spinal cord, and central nervous system function.

6.5. A wavefront for chunking and stimulus organization

The wavefront is a nuanced way to appreciate the richness and subtlety of signal processing through cognitive broadcasting. This concept connects mitochondrial communication within the central nervous system to a broad understanding of wavefronts, rather than the classical understanding of wavefronts from physics. Within the wavefront, signal propagation does not occur uniformly and thus differs from light propagating from a point source. Therefore, this conceptualization does not directly follow the understanding of a "wavefront' according to classical physics. Instead, the wavefront associated with cellular frameworks represented by animals (humans and non-human) refers to electromagnetic fields that connect the brain and other body structures. In the brain and spinal cord, mitochondria are intricately interrelated through the wavefront. Notably, the spinal cord neurons (nerve cell bodies and their neurites) are considerably more concentrated than elsewhere in the body [33]. Key concepts about the wavefront include: (a) it is generated through mitochondrial dynamics, and (b) it is not the primary means of communication between the brain and spinal cord. Instead, the wavefront serves as a system for cognitive broadcasting by the cognitive force. As such, the wavefront allows signals derived from the electromagnetic field to be broadcast cognitively. Further, the initial stages of cognitive broadcasting involve the cognitive force radiating through the wavefront. It does this before binding to parts of the electromagnetic field.

As described in the published literature on the FoK-FIP system, this process creates "cognitive pixels." Pixels in this context refer to both a unit of meaning (through their association with cognitive broadcasting) and a physical unit (through their association with the electromagnetic field). Resulting from a complex process, the cognitive force is intimately connected with cognitive pixels. Connected with the function of the wavefront, the cognitive force can "pull itself together" in a mental process. By doing so, it brings cognitively aligned pixels together through the wavefront, regardless of their spatial separation. This describes the chunking and stimulus organization components of cognitive broadcasting. This mental processing depiction broadly rather than directly correlates with the cognitive binding process described in the neurology literature. This modeling aims to contribute to the scientific understanding of the role of electromagnetic fields in brain and spinal cord function, a topic that is still evolving. Importantly, because the cognitive force is a part of pixels, it cannot separate itself from the cognitive broadcasting process. This means that the cognitive force will never see itself directly and will only see what it cognitively broadcasts to create the objects of the phenomenal world.

6.6. The foundation for cognitive broadcasting: The interoception of FoK-FIP

A core concept associated with cognitive broadcasting is that each mitochondrion with cognitive force acts as a self-contained information system. This modeling has aspects that correlate with other theories that describe cellular self-organization [41]. Further, interoception, as described in the literature, refers to the internal world and body perception [42]. The FoK-FIP theory modeling differs from the literature regarding the concept of interoception. The cognitive force cognitively broadcasts a myriad of different signals by reacting to the same foundation (the interoception of FoK-FIP). By doing so, it can foster bodily self-awareness [43] and emotional regulation [44]. This conceptualization broadly aligns with the idea of an ordered sense of self, in which the multisensory, interoceptive body summary plays a significant role in regulating and maintaining internal dynamics in balance [45]. Consistent with the theory, the interoception of FoK-FIP arises from mitochondrial components required for oxidative phosphorylation. Based on this modeling, the inner mitochondrial membrane (including ATP synthase), the intermembrane space, and the outer membrane are interconnected through thermodynamics. The thermodynamics model can explain how the cognitive force has varying degrees of sensitivity (e.g., heightened, decreased, or neutral) to the interoception of FoK-FIP. This sensitivity has effects related to the cognitive force's ability to identify, access, understand, and respond appropriately to the patterns of internal signals.

- *FoK-FIP interference* is a process that occurs at the molecular (sub-cellular) level. It acts as the foundation for cognitive broadcasting below the level of conscious awareness. It is a process that begins within the mitochondrial matrix and is linked with FoK-gene expression and mitochondrial energy production (e.g., oxidative phosphorylation and the electron transport chain) [46].

- *FoK-FIP feeling tones* are processes that act as the foundation for the awareness of the cognitive broadcasting process. They act as a precursor (an antecedent) to

the processing of signals to create emotions. The cognitive force can perceive FoK-FIP feeling tones as being pleasant, unpleasant, or neutral. In this process, perception may include emotions and metacognitive reflection upon sensory signals. Importantly, through FoK-FIP feeling tones, a specific interoceptive experience is linked to the awareness of changes within the mitochondrial structure. Therefore, a difference in the concentration of ions across a membrane or in the concentration of electrons across a membrane is felt. Further, FoK-FIP feeling tones are intimately connected to the impression of the senses (sense impressions). As previously mentioned, a core concept is that FoK-FIP feeling tones are associated with regions and organs. The terms "triggering," "cognitive binding", and "propagating" are part of the theory's modeling that aims to facilitate envisioning new ways of thinking about interoception. The "triggering" FoK-FIP feeling tone can be perceived as coming from the chest (thoracic region) and associated with the heart and lungs. The "cognitive binding" FoK-FIP feeling tone can be perceived as originating from the head and is associated with specific areas of the brain. The "propagating" FoK-FIP feeling tone can be perceived as coming from the abdominopelvic region and associated with organs such as the spleen, liver, pancreas, intestines, stomach, pelvic floor, and skin. The core idea behind FoK-FIP feeling tones is that they enable the cognitive force to perceive its existence by a very particular interoceptive feeling [11] [**Figure 3**].

The "triggering" FoK-FIP feeling tone is associated with the heart and lungs. The "cognitive binding" FoK-FIP feeling tone is related to the brain. The "propagating" FoK-FIP feeling tone is linked with the spleen, liver, pancreas, intestines (top row from left to right), stomach, pelvic floor, and skin (bottom row from left to right).

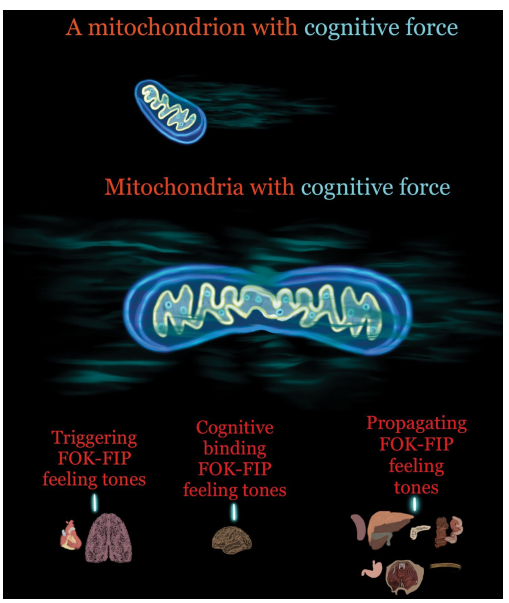

Figure 3.
The intricate relationship between the theory's concepts of FoK-FIP feeling tones and their association with mitochondrial triggering, cognitive binding, and signal propagation.

6.7. Cognitive reactions

Cognitive reactions by the cognitive force are connected to mitochondrial-derived bioelectrical potentials. The core concepts about these cognitive responses, therefore, are that (a) they are bioelectric potentials used by all cells with cognitive force and (b) are essential for chunking and stimulus organization through the wavefront. Described in the published literature and mentioned here to facilitate understanding, cognitive broadcasting includes the cognitive force responding to the interoception of FoK-FIP using three cognitive reactions: automatic, impulsive, or with forethought. In this process, automatic cognitive reactions can lead to impulsive cognitive reactions, which may or may not result in cognitive reactions with forethought. Furthermore, the cognitive reactions of the cognitive force are linked to a natural tendency of mitochondria to change or fluctuate within themselves. Therefore, cognitive broadcasting can be construed as being "intrinsically dynamic."

The cognitive reactions of the cognitive force have correlates that broadly align with the existing literature. For example, the literature suggests that individuals often make sense of their feelings and surroundings by relying on the automatic sequence of physiological sensations, significance, awareness, and interpretation [47]. According to the FoK-FIP theory, when the cognitive force reacts to the interoception of FoK-FIP, interoceptive signals can be processed as anticipated. This cognitive broadcasting enables the cognitive force to trust the body signals it processes. When the cognitive force perceives the interoception of FoK-FIP mentally, this represents reliable interoceptive signals. In this regard, the foundation for cognitive broadcasting serves to achieve and maintain homeostasis, supporting overall health and wellness. Awareness of this process, correlated with pleasant, unpleasant, or neutral FoK-FIP feeling tones, involves the cognitive broadcast of a particular interoceptive experience. Therefore, perception in general results in establishing a sense of safety that is felt. This concept broadly correlates with the literature where interoception supports the freedom to participate in meaningful activities while trusting one's body to generate consistent, relevant sensations [48].

7. Mitochondrial dysfunction and problematic cognitive broadcasting

The theory's conceptualization of the mitochondrial network dynamics is that it is both a consequence and an initiator of disease. This concept has aspects that broadly align with the mitochondrial cascade hypothesis, which states that mitochondrial dysfunction is the primary cause of Alzheimer's disease [49]. Related to ongoing FoK-FIP theory research, Canis lupus familiaris (domestic dogs) can exhibit deficits similar to those observed in humans with Alzheimer's disease, including disorientation, memory loss, and behavioral changes. This is associated with the development of brain amyloid plaques in the extracellular space and around blood vessels [50]. Canine cognitive dysfunction syndrome (CCDS) is a syndrome characterized by a progressive deterioration in cognition, associated with amyloid deposition and cortical atrophy. The literature suggests a high prevalence of CCDS in aging dogs [51, 52]. Notably, domestic dogs have a long history of co-evolution with humans [53]. This has resulted in dogs mirroring behaviors based on the perceived threat [54]. Included in this process is the ability of dogs to recognize body language and scent. When dogs experience fear, they do so in a manner similar to humans.

In this process, brain regions such as the amygdala process threats, triggering fear responses and behaviors (cowering, hiding, or fleeing).

Importantly, mitochondrial dysfunction is also observed in a range of other disorders. There are hundreds of different mitochondrial enzymatic defects, both genetic and environmental in origin [55]. Mitochondrial dysfunction is associated with immune system dysfunction [56], heart failure [57], and cellular senescence [58]. It is connected to neuropsychiatric conditions (e.g., Parkinson's disease, Huntington's disease, anxiety, and bipolar disorder) [59]. The modeling of the FoK-FIP theory for problematic cognitive broadcasting includes the concept that it occurs with one or more of the following:

- Mitochondrial modifications

  Mitochondrial modifications encompass changes in calcium homeostasis and mitochondrial morphology, as well as an increase in reactive oxygen species (ROS) production. Mitochondria are a primary source of ROS in most cells. Under normal conditions, approximately 1–2% of the cell's oxygen consumption is estimated to be converted into ROS [60]. Notably, higher organisms have evolved to utilize ROS and nitric oxide (NO) as signaling molecules for various physiological functions [61]. They regulate vascular tone, monitor oxygen tension in controlling ventilation and erythropoietin production, and play roles in signal transduction from membrane receptors (in various physiological processes).

- Mitochondrial permeability transition pore (mPTP) repetitive gating transitions

  The mPTP is a channel within the inner mitochondrial membrane. It is associated with mitochondria exhibiting sharp, transient depolarizations caused by local ROS. Modification of ROS includes the opening of the mPTP. According to the FoK-FIP theory, PTP gating affects the cognitive force's sensitivity to the interoception of FoK-FIP. In this process, an individual mitochondrion exhibits sharp, transient depolarizations caused by local ROS. This results in the cognitive force becoming aware of a particular interoceptive experience (FoK-FIP feeling tones). Based on this modeling, there is a relationship between the sensitivity of the cognitive force to FoK-FIP feeling tones (pleasant, unpleasant, or neutral) and mPTP repetitive gating transitions (stochastic flickering and synchronous). Integral to this concept is the ATP synthase complex. ATP synthase's c-subunit may form the mPTP [62].

- Circadian rhythms and ATP synthase function

  According to the FoK-FIP theory, gravitational perturbations (gravitational force between molecules) are part of the recognition component of perception. Through the rotation rate of the ATP synthase, the subjective awareness of FoK-FIP feeling tones by the cognitive force is linked to measurable gravitational signatures. The FoK-FIP theory builds on concepts found in the literature that (a) the ATP synthase rotation rate is integral to circadian rhythms and (b) the ATP synthase is functionally related to the geomagnetic field [26]. Circadian rhythms are the body's internal clock that regulates physiological patterns such as sleep, temperature, and hormone release [63]. Research suggests the Earth's magnetic field can influence circadian rhythms [64]. Notably, domestic dogs are sensitive to minor variations of the Earth's magnetic field [65]. They can sense

weak thermal radiation through the naked and often moist skin of their nose tip [66].

- Cardiac reflexes

  The FoK-FIP theory suggests that when the energy supply-demand match is violated, problematic cognitive broadcasting is linked with cardiac, brain, and other cellular and organ pathologies. In this conceptualization, mitochondrial dysfunction and problematic cognitive broadcasting can be initiated through reflexes originating in the heart. The heart is an organ where significant spontaneous depolarization of the mitochondria can occur. The role of reflexes through the mitochondria is to maintain cardiovascular homeostasis [67]. In this process, myocyte contraction and signal transmission related to cardiac reflexes result in fast-acting reflex loops between the cardiovascular system and the central nervous system. Integral to this process is the autonomic nervous system, where the sympathetic and parasympathetic systems interact in complex ways.

8. Discussion

The FoK-FIP theory seeks to establish a connection between physics and consciousness concepts, thereby facilitating avenues for research. FoK gene expression is one of the theory's constructs that allows mechanistic modeling to do that. Through FoK gene expression, mitochondrial physical characteristics are linked to the non-physical cognitive force. Further, cognitive broadcasting involves mitochondrial properties, including thermal behavior, elasticity, and kinetic characteristics. Thermodynamics is a broad model that allows for testing to validate aspects of the FoK-FIP theory.

8.1. The proposed study components

In brief, a research study involving domestic dogs owned by individuals is proposed. Approval from the Institutional Animal Care and Use Committee (IACUC) will be obtained. All owners will review and sign an informed consent form. In this research, vitamin B12 refers to an aqua-acupuncture intervention for mitochondrial dysfunction associated with B12 deficiency in dogs with conditions such as exocrine pancreatic insufficiency or inflammatory bowel disease. As part of this process, the FoK-FIP theory suggests that deficiencies in B12 may indirectly affect the rotational speed of ATP synthase. The dogs will be randomly assigned to one of two groups: a control group and an experimental group. The control group will consist of dogs who do not receive any B12 aqua-acupuncture. They only receive dry needling. B12 aqua-acupuncture will be administered to the dogs in the experimental group. The owners will not be privy to which group their dog is assigned to.

8.2. The hypothesis

Mitochondrial network changes associated with B12 deficiency can be modulated through aqua-acupuncture using vitamin B12. In this context, modulation refers to

regional and distal cellular mitochondrial dynamics, which are suggested to underlie problematic cognitive broadcasting.

8.3. The predictions

There are three predictions associated with the proposed research study involving domestic dogs owned by individuals:

- The temperature of the lacrimal caruncle in the right eye [68] of the same dog with B12 deficiency will decrease over time, following B12 aqua-acupuncture treatment.

- Gait parameters will change in a way that indicates improved health over time for the same dog with B12 deficiency that receives B12 aqua-acupuncture [69].

- A standardized and validated client-based survey score for osteoarthritis severity is expected to decrease for dogs with B12 deficiency that respond beneficially to the B12 aqua-acupuncture intervention [70].

8.4. The intervention to treat mitochondrial dysfunction: Vitamin B12 aqua-acupuncture

In this proposed aqua-acupuncture intervention, vitamin B12 is injected into the spinalis muscle associated with renowned Chinese physician Hua-tuo's paravertebral acupoints. The classical Hua-tuo-jia-ji involves 19 acupoints located bilaterally along the dorsolateral aspect of the thoracolumbar spine, from the T1 to L7 vertebrae [71]:

- The spinalis muscle is located on the medial aspect of the erector spinae column of spinal muscles at the cervical, thoracic, and lumbar vertebral levels. It assists in extension, flexion, and rotation of the spine (e.g., bending backward and to the side).

- Vitamin B12 is a water-soluble vitamin that acts as a cofactor or coenzyme for mitochondrial enzymes essential for cell function [72]. It plays a critical role in energy metabolism and mitochondrial function. This vitamin protects against mitochondrial toxicity and oxidative stress.

Based on the theory's modeling, B12 injection along Hua-tuo's paravertebral points triggers a somatovisceral reflex with autonomic effects. In this process, acupuncture represents tonic and burst spinal cord stimulation [73]. This results in beneficial waveforms that converge with visceral efferents. Through connecting mitochondrial channels, reflexive interactions transmit sensory information from the body to the brain. In this conceptualization, the autonomic nervous system sends information to areas such as the amygdala and hypothalamus, as well as to internal organs and regionally located referred pain regions (e.g., a spinal segment, a joint, or viscera).

8.5. Empirical measure

It is hypothesized that measuring eye temperature, gait analysis, and a validated questionnaire about osteoarthritis severity can be used to indirectly assess the

theory's constructs associated with mitochondrial health in animals (both human and non-human).

8.5.1. Monitoring of mitochondrial dynamics using infrared thermal imaging

This modeling aims to facilitate research that explores the role of physical phenomena and quantum effects in mitochondrial energy transfer and regulation. The FoK-FIP theory assumes that mitochondria exhibit observable random motion, which is produced by "thermal motion." As such, thermal motion is intimately linked with the "perceiver" (or "observer"), the cognitive force. Notably, a phonon can be thought of as a discrete unit of vibrational energy [74]. It is a quantum of energy associated with the vibrational motion of atoms [75]. In this modeling, phonons are used to describe the collective vibrations of mitochondrial atoms. Phonons, therefore, are "particles" of heat within mitochondria. Through the previously described wavefront, a relationship exists between nanoscale-range phonon scattering and cognitive broadcasting events.

Thermal motion is closely tied to the field of thermodynamics and directly related to infrared radiation (the heat signature emitted by objects). In this conceptualization, the cognitive force is a thermodynamic quantity associated with "hot" mitochondria. Through cognitive broadcasting, the cognitive force creates synergy between heat and other forms of energy (e.g., mechanical, electric, or chemical). Within cellular frameworks, cognitively broadcasted signals are distinguished by their occurrence within a narrow temperature range. Cognitive broadcasting is a process that encompasses energy transfer, heat dissipation, and signaling within cells. In this research, infrared thermography is the modality used to measure surface temperature. The proposed study investigates the application of IRT as a non-invasive method to indirectly infer the relationship between cognitive broadcasting events linked with ocular temperature (OT):

- The lacrimal caruncle (the inner corner of the eye) is an unmistakable landmark that has the highest temperature on the eye [76]. It is a highly vascular area innervated by the sympathetic nervous system. Furthermore, research has shown that the right eye and lacrimal caruncle are the most effective indicators of temperature changes in dogs after a stressful event [68]. In the proposed study, the lacrimal caruncle serves as a thermal window, allowing for the monitoring of mitochondrial dynamics associated with physiological status, stress levels, and health conditions. Specifically, if B12 deficiency is causing fever or impacting thermoregulation, then the proposed B12 intervention could lead to a decrease in the temperature of the right lacrimal caruncle.

Importantly, this research includes the necessary steps to facilitate the validation of findings. IRT will be conducted in a testing environment with climate control. This is important because changes in humidity (high and low) can influence OT. Additionally, this research will utilize the Teletherm Tiger4 Cub Model 640, a palm-held infrared camera featuring a Focal Plane Array detector system with video-rate capture for live-action studies. It provides for single or continuous snapshot capture into the TIFF file format. The system is powered through a USB connection, eliminating the typical battery charging required by other similar camera systems. Focus control enables detailed thermal imaging of the subject at varying distances.

Thermal sensitivity is less than 40 mK or 0.04°C. As such, this radiometric system allows for the pinpointing of specific temperature values within the resultant image. It utilizes a changeable 33 × 25 degree lens that operates in the – 20-100 degree C range. Coordinated software processing enables a comprehensive analysis of images in various color palette formats and the identification of key elements within them. Remote control operation of the camera allows for hands-free use (G.L. Rockley, personal communication, June 26, 2025).

In sum, based on the theory's conceptualization, cognitive broadcasting is closely linked to cellular nanoscience. The temperature of the right medial caruncle, analyzed using IRT, has potential applications in indirectly measuring the theory's constructs:

- Phonon scattering affects thermal conductivity.
- Temperature distribution is linked to mitochondrial processes, including cognitive force.
- Temperature can affect both phonon behavior and cognitive broadcasting.

8.5.2. Gait as a measurable variable connected to mitochondrial dynamics

According to the FoK-FIP theory, the ability to objectively measure gait parameters has significant value in indirectly measuring core constructs. In this approach, analyzing gait parameters measured by a pressure-sensitive walkway provides insights into the underlying mitochondrial function (including cognitive force) and its impact on gait performance. Studies investigating the relationship between mitochondrial function and walking performance in older adults have been conducted [77]. The literature suggests that higher mitochondrial function is associated with faster gait speed. Importantly, the fundamental principles of muscle function and energy metabolism derived from human studies are generally applicable to other mammals, including domestic dogs.

A central pattern generator (CPG) is a neural circuit in the central nervous system. It is associated with the spontaneous firing of interneurons in the cervical and lumbar spinal cord. Notably, the CPG can generate rhythmic motor patterns without requiring continuous sensory or brain input. The CPG is integral to gait, which refers to the specific manner in which an animal moves its legs when ambulating (e.g., walking, running, or trotting). Mitochondrial disorders can manifest as myopathy associated with muscle weakness and gait disturbance [78]. Further, there is a link between mitochondrial dysfunction and issues with the CPGs [79]. The theory's modeling suggests that CPG mitochondrial disorders are linked with problematic cognitive broadcasting.

The proposed research investigates the use of gait analysis using the GAITFour system. This system is a portable, electronic pressure-sensitive walkway that measures temporal and spatial quadruped gait parameters, combined with software that controls the walkway's function, processes the data, and calculates the gait parameters. As the subject ambulates the walkway, the system continuously scans the sensors to detect and record sensor activity. Sensor activity is recorded by the GAITFour software, which separates and identifies the paw strikes and calculates gait parameters.

In sum, according to the FoK-FIP theory, mitochondrial dysfunction affecting walking ability is linked to the functioning of the cognitive force. The modeling of

the FoK-FIP theory suggests a relationship exists between cognitive broadcasting and neurological disorders, musculoskeletal disorders, and injuries:

- Mitochondrial dynamics (ATP production linked with cognitive force) are integral to muscle contraction and nerve impulses involved in movement, including walking.

- Walking efficiency is determined by how effectively energy is used and thus governed by thermodynamic principles.

8.5.3. The Liverpool osteoarthritis in dogs (LOAD) questionnaire: An objective measure for osteoarthritis in dogs

LOAD is a method for assessing mobility scores based on the owner's responses to questions about their dog's osteoarthritis (OA) [80, 81]. Notably, owners are not aware of the numerical value associated with each response in the scoring section. They select individual responses for each question based on their experiences and observations. The proposed research utilizes LOAD scores to determine the presence or severity of mitochondrial dysfunction, suggested to underlie OA [82]. Furthermore, according to the FoK-FIP theory, problematic cognitive broadcasting includes heightened or decreased sensitivity of the cognitive force to the interoception of FoK-FIP. In this process, pain is perceived. A definition of pain derived from the literature [83] is as follows: Pain is an aversive sensory and emotional experience. It represents an awareness of damage or threat to the integrity of tissues. In this conceptualization, the questionnaire serves as a tool for monitoring treatment response to the B12 aqua-acupuncture intervention in dogs with B12 deficiency. The questionnaire also serves as an indirect tool for monitoring problematic cognitive broadcasting.

9. Study limitations and strengths

While this study design has certain limitations that may influence the interpretation of results, it also offers several methodological strengths. The following analysis examines both the challenges that warrant careful consideration and the aspects that strengthen the validity of the research framework.

9.1. Limitations of the study

This study includes some theoretical and methodological limitations that could limit its validity and generalizability. The theoretical foundation of the study is the unvalidated "FoK-FIP theory," which includes concepts like "cognitive broadcasting" and "cognitive force," which lack established scientific support and may conflate physics terminology with biological processes inappropriately. The study's outcome measures may not accurately reflect the proposed mechanisms – infrared thermography of the eye, gait analysis, and owner-reported questionnaires provide only indirect evidence of mitochondrial function changes. The sample is restricted to dogs with specific conditions, limiting generalizability to broader populations. Additionally, the study design lacks controls such as a placebo injection

group (the control receives dry needling rather than a true placebo), and the complex theoretical framework makes it difficult to isolate which components of the intervention, if any, are responsible for observed effects.

10. Strengths of the study

The study includes several methodological strengths that enhance its scientific rigor and practical applicability. The randomized controlled design with dog owner blinding helps minimize bias, while the use of validated instruments like the LOAD questionnaire and standardized gait analysis equipment (GAITFour system) provides objective, reproducible measurements. The multi-modal approach to outcome assessment – combining thermal imaging, biomechanical analysis, and clinical questionnaires – offers an evaluation of treatment effects from multiple perspectives. The study appropriately addresses ethical considerations through IACUC approval and informed consent procedures. The use of precise infrared thermography equipment with high thermal sensitivity (0.04°C) in controlled environmental conditions demonstrates attention to measurement accuracy. The focus on domestic dogs provides a clinically relevant animal model.

11. Conclusion

This chapter proposes new perspectives on the foundations of science, including the science of interoception, which was established over 100 years ago [42]. Mechanistic interdisciplinary modeling is a method that may facilitate research and new avenues for scientific exploration, disease treatment, and prevention.

Acknowledgments

The authors would like to thank Dr. Huisheng Xie, DVM, PhD, for serving as an expert source in validating the acupuncture protocol developed by these researchers to treat anxiety disorders in dogs. Dr. Huisheng Xie's input was invaluable as he is a third-generation Chinese herbalist and founder of Chi University with over 30 years of personal clinical experience.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this chapter.

Funding

No organization supported the authors in preparing this chapter; no funding, grants, or other support was received.

Consent procedures

During post-screening (occurs if the dog passes the screening tests), the consent is reviewed with the owner and signed.

Data availability statement

There is no data from the study participants to report at this time. For further inquiries, please contact the corresponding authors.

Ethics approval

Feelings of Knowing-Fundamental Interoceptive Patterns-Disorder (FoK-FIP-D) in the Canine Model PLAVS IACUC Number: C001. APPROVAL DATE: May 4, 2023
EXPIRATION DATE: April 30, 2026

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors utilized Google's AI Gemini and summarization tool as an aid to support clarity rather than replacing the authors' work and intellectual contributions. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published chapter.

Author details

Holly Pollard-Wright[1*] and Mark T. Wright[2]

1 Institute of Electrical and Electronics Engineers (IEEE), New York, USA

2 Clinical Associate Professor, Department of Clinical Science, Kaiser Permanente Bernard J. Tyson School of Medicine, Pasadena, USA

*Address all correspondence to: drhmp1@gmail.com

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