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AGNI AND CELLULAR BIOENERGETICS: AN INTEGRATIVE PHYSIOLOGICAL PERSPECTIVE

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ABSTRACT

Background: In Ayurvedic physiology, Agni is regarded as the fundamental transformative force responsible for digestion, metabolism, tissue nourishment, and maintenance of life. Classical texts such as Charaka Samhita and Ashtanga Hridaya describe Agni as the central determinant of health, emphasizing that balanced Agni sustains vitality, strength, and longevity, whereas its impairment leads to disease. Despite its foundational importance, Agni has often been narrowly interpreted as digestive fire, limiting its broader physiological understanding.

Methods: A classical textual review was undertaken using primary Ayurvedic sources including Charaka Samhita, Sushruta Samhita and Ashtanga Hridaya. Descriptions of Jatharagni, Dhatvagni, and Bhutagni were analyzed and conceptually compared with contemporary knowledge of cellular metabolism, mitochondrial function, ATP production, and thermodynamic regulation. Correlative analysis was performed to identify physiological parallels between Ayurvedic and modern bioenergetic frameworks.

Results: The strong conceptual parallels between Agni and cellular bioenergetics. Jatharagni corresponds to digestive and absorptive metabolism, while Dhatvagni aligns with intracellular enzymatic reactions and mitochondrial energy production. The qualitative states of Agni—Sama, Manda, and Tikshna—reflect variations in metabolic rate and homeostatic efficiency. Ama parallels impaired metabolism and toxic by-product accumulation.

Conclusion: Agni may be understood as a multidimensional bioenergetic principle governing transformation, energy production, and metabolic equilibrium at systemic and cellular levels. This integrative perspective offers a scientific framework for bridging Ayurvedic physiology with modern metabolic science.

KEYWORDS: Agni, Cellular bioenergetics, physiology, digestive fire, dhatvagni

INTRODUCTION

A key and fundamental place in Ayurvedic physiology is held by the idea of Agni. According to classical literature, Agni is a whole transforming force that sustains life, vigor, tissue creation, immunity, and longevity rather than just being a digestive entity. The Charaka Samhita, one of the great compendia, emphasizes time and again that the state of health is determined by the balance of Agni, and that disease is caused by its disturbance. The famous saying "Rogāḥ sarve api mandāgnau" emphasizes that diseased processes are rooted in decreased Agni.[1] This claim emphasizes that the foundation of systemic equilibrium is metabolic integrity.

According to the Sushruta Samhita, Agni is a transformational power that controls tissue feeding, assimilation, and digestion.[2] Sushruta links the healthy development of Dhatus (tissues), preservation of strength (Bala), complexion (Varna), and lifespan (Ayus) to the functional integrity of Agni. The text goes on to explain that diseased situations are created when Agni is impaired since this results in an inadequate transformation of nutrients. Agni is thus portrayed as a regulator of systemic physiology in addition to being a catalyst for digestion.

According to the Ashtanga Hridaya, Agni is the sustaining metabolic power that transforms at three different levels: Dhatvagni (tissue-level metabolic activity), Bhutagni (elemental metabolic principle), and Jatharagni (main digestive fire).[3] According to Vagbhata, a healthy Agni provides Dosha balance, optimal Dhatus nutrition, appropriate Malas removal, and vitality maintenance. On the other hand, Ama, a pathogenic metabolic intermediate that serves as the foundation for illness manifestation, is produced by disordered Agni.[3] According to this multi-layered explanation, Agni functions at the systemic, biochemical, and potentially cellular levels.

From a physiological perspective, the classical representation of Agni is quite similar to the contemporary idea of metabolism, which is the culmination of all the anabolic and catabolic processes that keep life going. Cellular respiration and mitochondrial bioenergetics are acknowledged by modern biomedical science as essential for thermoregulation, tissue upkeep, and energy production. The biochemical foundation of life activities is the production of ATP via oxidative phosphorylation, the Krebs cycle, and glycolysis. Systemic disease, oxidative stress, inflammation, and metabolic abnormalities are caused by disruptions in these pathways.

Given the clear conceptual similarities between ancient Agni and contemporary bioenergetics, Agni could be understood as a metabolic force that sustains life and regulates energy transformation and homeostasis. Sama Agni, which is equivalent to metabolic homeostasis in contemporary physiology, is a symbol of balanced metabolic activity in Ayurveda. Tikshnagni represents hypermetabolic circumstances, whereas Mandagni may be associated with hypometabolic states that are marked by decreased enzyme efficiency and energy generation. Additionally, the accumulation of harmful metabolic intermediates and oxidative byproducts brought on by mitochondrial dysfunction may theoretically mimic the creation of Ama as a result of deficient Agni.

Despite these seeming connections, a large portion of the modern understanding of Agni is still limited to gastrointestinal digestion, which restricts its wider physiological relevance. To understand Agni as a systemic and cellular regulation principle, a thorough bioenergetic interpretation is required. Comprehending Agni via the perspective of thermodynamics, specifically energy transformation and entropy, could offer a scientific framework that connects traditional Ayurvedic philosophy with contemporary metabolic physiology.

As a result, the current study suggests understanding Agni as a multifaceted bioenergetic entity that functions at the cellular, tissue, and digestive levels. This integrated method aims to extend the physiological knowledge of Agni beyond conventional bounds by establishing a correlation between classical textual accounts and contemporary ideas of cellular respiration, mitochondrial energy production, and metabolic equilibrium. In addition to bolstering Kriya Sharir's scholarly base, this interpretation might offer fresh perspectives on metabolic health and illness from an integrative standpoint.

Conceptual Framework of Agni in Ayurvedic Physiology

In Ayurveda, Agni is the basic transforming principle that governs metabolism, tissue creation, vitality, and disease prevention. It goes much beyond simple digestion. Agni's multifaceted physiological functioning is demonstrated by the meticulous descriptions of its various stages and functional states found in classical sources.4

Jatharagni

The main digestive fire in the Amashaya and Grahani is thought to be Jatharagni. Primary digestion and the conversion of consumed food into absorbable essence (Ahara Rasa) are its responsibilities. According to the Charaka Samhita, a balanced Jatharagni preserves health, but its deficiency becomes the underlying cause of illness.5 It controls how nutrients and trash are first broken down and separated. Jatharagni's hierarchical significance is further demonstrated by the Ashtanga Hridaya, which claims that it governs the operation of all other types of Agni.[3] Disruption of Jatharagni also compromises following tissue-level metabolic processes. As a result, it serves as the main metabolic regulator.

Dhatvagni

In addition to main digestion, Ayurveda identifies seven Dhatvagnis (Rasa, Rakta, Mamsa, Meda, Asthi, Majja, and Shukra) that reside within distinct tissues. These Dhatvagnis are in charge of tissue-specific metabolism and intracellular transformation.5 Each Dhatvagni produces metabolic waste (Malas) and secondary tissues (Upadhatus) while facilitating the transformation of nutrients into stable tissue components. The progressive metabolic reactions that take place inside cells are very similar to this layered metamorphosis. Pathological disorders arise from the improper tissue development caused by Dhatvagni impairment, which can manifest as either excess (Vriddhi) or depletion (Kshaya).5

Bhutagni

The five elemental metabolic principles that correlate to the five Mahabhutas are referred to as Bhutagni. Classical accounts state that each food component undergoes elemental transformation through its respective Bhutagnis following basic digestion. This guarantees that the elements of the body and the substances that are consumed are compatible. Thus, bhutangni is a micro-level metabolic modification that facilitates assimilation and bioavailability. Its function exemplifies the idea that metabolism entails qualitative alteration in accordance with the internal environment of the body rather than just mechanical digestion.

Functional States of Agni

Ayurveda categorizes Agni into four functional states based on its qualitative efficiency:

- Sama Agni – balanced and optimal metabolic activity
- Vishama Agni – irregular metabolic functioning
- Tikshna Agni – excessive or hyperactive metabolism
- Manda Agni – diminished or hypoactive metabolism

According to the Charaka Samhita, these differences determine physiological balance and the likelihood of disease.5 Sama Agni guarantees healthy tissue nourishment, absorption, and digestion. While Tikshna Agni induces quick depletion due to excessive metabolic activity, Manda Agni results in incomplete digestion and metabolic sluggishness. The metabolic results of Vishama Agni are erratic and unpredictable. These divisions show that long before hypo- and hypermetabolic states were defined by contemporary metabolic science, Ayurveda understood variations in metabolic rate and efficiency.

Agni–Ama Relationship

The development of Ama is a primary pathogenic consequence of compromised Agni. Ama is defined as a hazardous metabolic intermediate that is poorly digested and has obstructive, sticky, and weighty characteristics.5 Incomplete transformation caused by weak Agni (Mandagni) results in the buildup of Ama, which blocks channels (Srotas) and starts disease processes. The Sushruta Samhita also links inflammatory conditions and systemic dysfunction to decreased metabolic fire.2 As a result, many illnesses have the Agni–Ama axis as their pathogenic foundation. This connection highlights how crucial effective metabolic transformation is to preserving both structural and functional integrity.Together, the qualitative states of Agni, the idea of Ama, and the layered descriptions of Jatharagni, Bhutagni, and Dhatvagni depict a complex metabolic model in traditional Ayurvedic physiology. It portrays Agni as a tissue-specific, hierarchical, and regulatory principle that controls transformation on several levels.

Fundamentals of Cellular Bioenergetics

The processes by which living cells obtain, change, store, and use energy to maintain life are referred to as cellular bioenergetics. Cellular respiration, a finely synchronized sequence of enzyme processes that transform nutrients into useable chemical energy in the form of adenosine triphosphate (ATP), is the primary mechanism by which energy metabolism is mediated in contemporary physiology.6 To preserve thermodynamic equilibrium and metabolic homeostasis, cellular respiration combines mitochondrial and cytosolic processes.

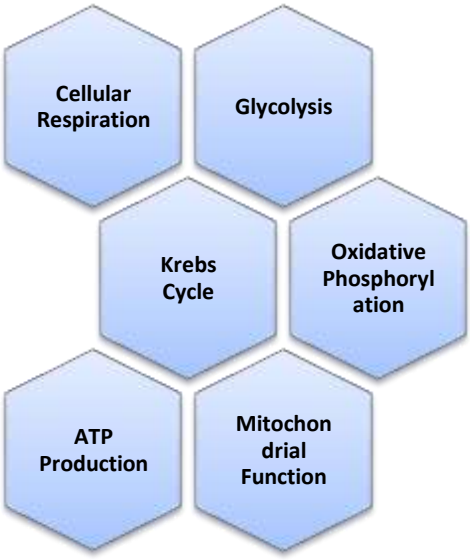


Figure 1 shows fundamentals of cellular bioenergetics

Cellular Respiration

The process by which glucose and other substrates are oxidized to produce ATP is known as cellular respiration. Glycolysis, pyruvate oxidation, the tricarboxylic acid cycle (also known as the Krebs cycle), and oxidative phosphorylation are its four main phases.6 Glucose is oxidized to produce carbon dioxide and water as part of the entire reaction, and energy is released and stored in ATP molecules. Maintaining structural integrity, membrane transport, biosynthesis, and cellular signaling all depend on effective cellular respiration.[7]

Glycolysis

The cytoplasm is where glycolysis, the initial step of cellular respiration, takes place. One glucose molecule is changed into two pyruvate molecules by a series of ten enzyme processes.6 Two ATP molecules and two NADH molecules are the net gains from this procedure. Because glycolysis doesn't need oxygen, it can occur in both anaerobic and aerobic environments.7 Glycolysis is a vital metabolic gateway that supplies substrates for the TCA cycle and intermediates for biosynthetic pathways, despite being energetically modest in comparison to later phases. Glycolytic enzymes including pyruvate kinase, phosphofructokinase, and hexokinase are regulated to maintain metabolic flexibility in response to cellular energy requirements.[8]

Krebs Cycle (Tricarboxylic Acid Cycle)

The tricarboxylic acid (TCA) cycle, another name for the Krebs cycle, takes place inside the mitochondrial matrix. Glycolysis-derived pyruvate is converted to acetyl-CoA via oxidative decarboxylation, which then enters the cycle.6 Acetyl-CoA is fully oxidized to carbon dioxide by a sequence of cyclic events, producing the reduced coenzymes $FADH_2$ and NADH. High-energy electrons that are later used in oxidative phosphorylation are stored in these reduced electron carriers. The TCA cycle connects catabolic and anabolic metabolism by supplying essential metabolic intermediates for the production of amino acids, lipids, and nucleotides.7 Maintaining cellular energy flux and metabolic homeostasis depends on the Krebs cycle operating efficiently.

Oxidative Phosphorylation

The last and most energy-producing phase of cellular respiration is oxidative phosphorylation. It involves the electron transport chain (ETC) and takes place along the inner mitochondrial membrane.6 After passing through a number of protein complexes (Complex I–IV), the electrons provided by NADH and $FADH_2$ finally reduce molecular oxygen to water.

The proton motive force is an electrochemical gradient created when the energy released during electron transport propels proton pumping across the inner mitochondrial membrane. This gradient is used by ATP synthase (Complex V) to convert ADP and inorganic phosphate into ATP.8 Most of the ATP produced during aerobic respiration is attributed to this chemiosmotic process.

ATP Production

The universal energy currency of the cell is ATP. It supplies energy for cellular repair, biosynthesis, active transport, muscular contraction, and thermoregulation.6 Under ideal circumstances, the full oxidation of a single glucose molecule produces roughly 30–32 ATP molecules.8 The availability of substrates, oxygen supply, enzymatic efficiency, and mitochondrial integrity all have a significant impact on ATP generation. Cellular dysfunction and a number of metabolic and degenerative disorders are caused by disruptions in ATP production.[7]

Mitochondrial Function

The core organelles of bioenergetics, mitochondria are frequently referred to as the "powerhouses" of the cell. In addition to producing ATP, mitochondria control the creation of reactive oxygen species (ROS), calcium homeostasis, apoptosis, and redox balance.[7] Their evolutionary and functional uniqueness is highlighted by the fact that they replicate autonomously and have their own DNA.

ATP production is decreased, oxidative stress is increased, and oxidative phosphorylation is hampered by mitochondrial malfunction. Age, cardiovascular disease, neurological diseases, and metabolic problems are all linked to this dysfunction.[8] Thus, maintaining systemic metabolic balance and cellular bioenergetic stability depend on mitochondrial integrity.

Agni and Thermodynamic Principles

The thermodynamic laws that control biological systems can be used to explain the idea of Agni. Open thermodynamic systems, living things constantly exchange matter and energy with their surroundings. According to the First Law of Thermodynamics, sometimes known as the law of energy conservation, energy can only be changed from one form to another; it cannot be created or destroyed. Physiologically speaking, metabolic processes convert the chemical energy obtained from food into ATP, mechanical work, heat, and biochemical intermediates. This transformational ability is similar to the Ayurvedic view of Agni as the principle that transforms ingested substances into their useful biological essence (ahara rasa) and subsequent tissue elements (parinama). Contemporary bioenergetic research describes this transformation primarily through mitochondrial oxidative phosphorylation and substrate-level phosphorylation, reinforcing the analogy of Agni as a systemic energy-transforming force.[9-11]

Entropy is introduced by the Second Law of Thermodynamics, which highlights that inefficiency and heat loss are a part of all energy transformations. Entropic effects of biological events are reflected in cellular metabolism through incomplete oxidation, the production of reactive oxygen species (ROS), and the buildup of metabolic intermediates. This idea is consistent with the Ayurvedic concept of Ama, which is defined as a metabolic residue that has been poorly digested as a result of decreased Agni. New research links mitochondrial malfunction and oxidative stress to systemic metabolic illnesses, offering a scientific foundation for comprehending Ama as oxidative and biochemical byproducts of ineffective metabolism.[12–14]

The metaphor of metabolic fire is further supported by the fact that heat production is an essential byproduct of oxidative metabolism. Measurable indicators of biological heat generation include basal metabolic rate, brown adipose tissue thermogenesis, and mitochondrial proton leak. From an integrative standpoint, Agni represents controlled thermogenesis and metabolic intensity at the cellular and systemic levels in addition to digestive fire.[10, 11]

Agni and Metabolic Homeostasis

The dynamic maintenance of internal stability in the face of external perturbations is known as homeostasis. Tightly controlled feedback systems involving the endocrine system, autonomic nervous system, and intracellular signaling pathways are how modern physiology explains this. Insulin, glucagon, thyroid hormones, and cortisol are among the hormones that affect energy balance, substrate use, and metabolic flux. Optimal ATP synthesis and reduced oxidative stress are guaranteed by balanced mitochondrial efficiency and enzymatic accuracy.[11–15]

In order to sustain vitality (bala), complexion (varna), and longevity (ayush), Ayurveda defines Sama Agni as the state in which digestion, absorption, assimilation, and tissue feeding take place in a balanced and timely manner. In this stage, anabolic and catabolic processes are in balance, which is very similar to metabolic equilibrium. Mandagni, on the other hand, is comparable to hypometabolic conditions like hypothyroidism or metabolic syndrome, which are marked by slow metabolism and the buildup of metabolic byproducts. Tikshnagni is similar to hypermetabolic disorders that include tissue depletion, elevated thermogenesis, and excessive catabolism.

Enzymatic balance plays a pivotal role in this integrative interpretation. Enzymes regulate reaction velocity, substrate specificity, and metabolic channeling. Impairment in enzymatic or mitochondrial function leads to dysregulated metabolic networks, analogous to disturbed Agni. Thus, Agni can be conceptualized as a systemic regulatory intelligence coordinating hormonal, enzymatic, and mitochondrial activities to maintain metabolic homeostasis.

Conceptual Correlation Model

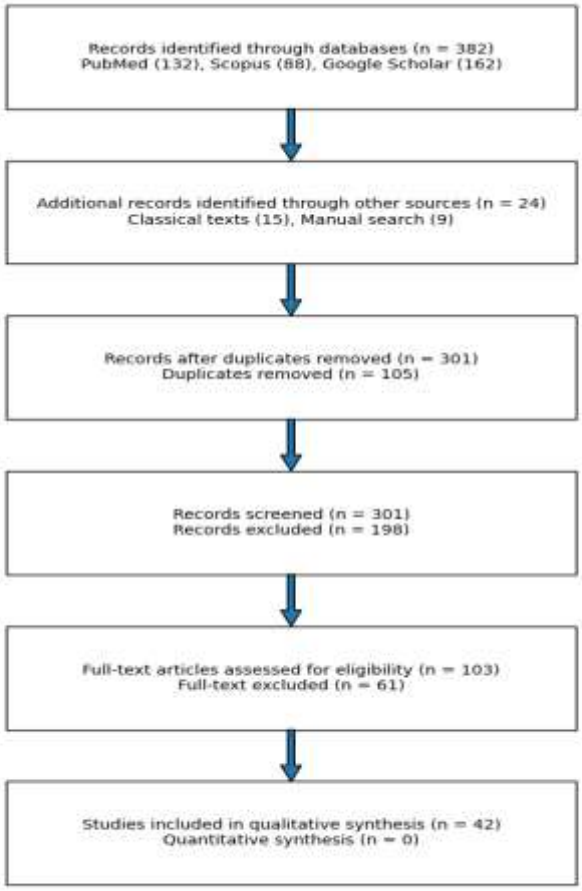
An integrative physiological model may be proposed to align Ayurvedic categories with contemporary bioenergetics:

Agni Concept	**Bioenergetic Equivalent**
Jatharagni	Digestive and absorptive metabolism
Dhatvagni	Cellular enzymatic reactions and tissue-specific metabolism
Tejas	Mitochondrial oxidative energy and cellular thermogenesis
Mandagni	Reduced metabolic rate / mitochondrial inefficiency
Tikshnagni	Hypermetabolic state / increased catabolic flux
Ama	Metabolic intermediates, oxidative stress, inflammatory by-products

Jatharagni is associated with nutrient absorption and gastrointestinal digestion that is controlled by enzymes and the metabolic integration of the gut and liver. Dhatvagni stands for metabolic changes at the tissue level that are comparable to anabolic pathways, glycolysis, and cellular respiration. Tejas, which are frequently connected to the subtle aspects of fire, can be understood as the redox potential and bioenergetic capability of mitochondria.[9–11]

Instead than reducing Agni to a single biochemical route, this correlation model presents it as a multi-level, hierarchical regulating system that encompasses cellular metabolism, digestion, thermogenesis, and redox balance. A paradigm like this promotes multidisciplinary research that connects Ayurvedic physiology with contemporary systems biology,

especially in the study of metabolic illnesses associated with oxidative stress, mitochondrial dysfunction, and decreased metabolic flexibility.[12]



DISCUSSION

According to the current integrative investigation, Agni is a regulatory metabolic intelligence that governs the body's energy control, transformation, and absorption. Agni is the fundamental factor that determines health, energy, and longevity, according to traditional Ayurvedic literature. According to the Charaka Samhita, healthy Agni promotes life, whereas imbalanced Agni causes illness.[19] This conceptual centrality is in line with current theories of cellular bioenergetics and metabolic control.

Agni as Regulatory Metabolic Intelligence

According to Ayurveda, Agni is more than just digestive fire; it is a systemic regulating force that coordinates the transformation of nutrients at the elemental (Bhutagni), tissue (Dhatvagni), and digestive (Jatharagni) levels.20 In a similar vein, modern physiology acknowledges metabolism as a highly coordinated network controlled by cellular signaling processes, endocrine regulation, mitochondrial efficiency, and enzymatic pathways.[21]

The relationship between Agni and metabolic control has been highlighted by recent integrative analyses that have been published in journals like Integrative Medicine and the Journal of Ayurveda. These analyses reveal that Agni is not a literal digestive entity but rather reflects functional metabolic capacity.22 Similar to the systemic regulating role assigned to Agni, studies indexed in PubMed show that mitochondrial bioenergetics influences cellular energy sensing, redox balance, apoptosis, and inflammatory signaling.[23]

The division of Agni into Sama, Manda, Tikshna, and Vishama states is similar to how metabolic phenotypes are interpreted today. Sama Agni, which is defined by optimal ATP synthesis and effective substrate utilization, is equivalent to metabolic homeostasis. Tikshnagni is similar to hypermetabolic states characterized by excessive catabolism and oxidative stress, whereas Mandagni is similar to hypometabolic disorders like hypothyroidism or metabolic syndrome.[24]

Mitochondria as "*Agni-sthana*": A Proposed Model

The physical and functional seat of metabolic fire, mitochondria, may be conceptualized as "Agni-sthana" in a revolutionary interpretive framework. Although cellular organelles are not mentioned in classical writings, Dhatvagni is mentioned as the principle that governs metabolism at the tissue level.20 By facilitating oxidative phosphorylation and ATP generation, mitochondria play a crucial role in modern bioenergetics.[21]

Thermogenesis, the generation of reactive oxygen species (ROS), and apoptotic signals are all regulated by mitochondria.[25] The Ayurvedic description of Agni as Ushna (heat-producing) is poetically consistent with controlled heat

creation during oxidative phosphorylation. Moreover, it is now understood that metabolic and degenerative diseases are largely caused by mitochondrial malfunction.[23]

Agni is discussed in the Indian Journal of Ayurveda Medicine in relation to integrative therapies and metabolic correction techniques. It is suggested that enhancing tissue-level and digestive metabolism improves systemic physiological resilience.[26] Comparable to mitochondrial redox imbalance, theoretical investigations in the Journal of Natural Remedies link oxidative stress and inflammatory cascades to deficient Agni.[27]

In accordance with the second law of thermodynamics, mitochondria convert chemical energy into useable ATP while releasing some energy as heat.[21] The Ayurvedic belief that Agni maintains homeostasis by regulating transformation rather than optimizing energy output is philosophically consistent with this controlled inefficiency, which guarantees entropy creation and maintains biological order.

Agni, Ama, and Oxidative Stress

Additional conceptual convergence is provided by the Agni–Ama link. Ama in Ayurveda refers to substrates that have been incorrectly digested as a result of diminished Agni.[28] In biomedicine, oxidative stress and the buildup of reactive metabolites are caused by incomplete oxidation, poor mitochondrial respiration, and metabolic excess.[23] Cellular damage, insulin resistance, and inflammation are all exacerbated by these byproducts.

According to studies listed in PubMed, mitochondrial failure causes redox signaling to be disrupted, produces more ROS, and encourages chronic inflammatory illnesses.[25] These results lend credence to the idea that Ama is equivalent to harmful metabolic intermediates or indicators of oxidative stress.

Clinical Implications in Metabolic Disorders

There are important ramifications for metabolic disorders from the Agni-centered paradigm. Chronic low-grade inflammation, altered substrate consumption, and mitochondrial dysfunction are characteristics of conditions like obesity, type 2 diabetes mellitus, metabolic syndrome, and non-alcoholic fatty liver disease.[23]

Enhancing mitochondrial efficiency and metabolic flexibility may be the goal of Ayurvedic treatments meant to restore Sama Agni, such as herbal interventions, lifestyle correction (Vihara), and nutritional regulation (Ahara).24 According to research published in integrative publications, several Ayurvedic remedies decrease oxidative stress indicators and increase insulin sensitivity, which may be a reflection of improved cellular bioenergetics.[26]

Additionally, the Tikshnagni lens can be used to interpret hypermetabolic inflammatory conditions, in which tissue depletion is the outcome of excessive metabolic activation. On the other hand, lower metabolic rates and the buildup of metabolic waste are associated with Mandagni-like conditions.[24] These similarities imply that in integrated clinical practice, Agni-based evaluation can provide a paradigm for functional metabolic phenotypes.

The idea that mitochondria are Agni-sthana should not be taken literally, but rather as a heuristic paradigm. In Ayurveda, agni has physiological, biochemical, and regulatory aspects, while mitochondria are cellular organelles with specific molecular roles. However, conceptual mapping offers a useful interdisciplinary discussion that connects systems biology with traditional Ayurvedic thinking.

Toward an Integrative Bioenergetic Paradigm

The convergence of Ayurvedic Agni theory with contemporary mitochondrial science underscores a shared emphasis on regulated transformation, energy balance, and systemic equilibrium. Both paradigms acknowledge that life is sustained not merely by energy production but by intelligent regulation of metabolic flux.

Biochemical profiling of metabolic states according to Agni evaluation methods and association with mitochondrial biomarkers such oxidative stress indicators, oxygen consumption rate, and ATP output should be part of future study. Multidisciplinary research like this could support integrative metabolic models.

To sum up, Agni can be understood as a bioenergetic regulating principle that controls transformation and metabolic balance. In this integrative paradigm, Agni-sthana has a believable physiological connection in mitochondria, which are the cellular sites of oxidative metabolism. In addition to enhancing theoretical knowledge, this model creates new opportunities for the integrative treatment of metabolic diseases.

CONCLUSION

Agni may be interpreted as a multi-layered bioenergetic regulatory principle governing digestion, cellular respiration, and metabolic equilibrium. While traditionally described as the transformative force responsible for digestion and tissue nourishment, its broader interpretation suggests a systemic regulatory intelligence that coordinates metabolic processes at multiple biological levels.

At the gross level, Agni reflects digestive and absorptive efficiency, ensuring proper breakdown and assimilation of nutrients. At the tissue and cellular levels, it parallels enzymatic activity, substrate oxidation, ATP generation, and mitochondrial function. Through this lens, Agni represents not merely the production of energy, but the regulation of metabolic transformation, distribution, and utilization.

The concept also encompasses qualitative aspects of metabolism—efficiency, balance, adaptability, and resilience. Balanced (Sama) Agni corresponds to metabolic homeostasis, where energy production matches physiological demand and waste products are effectively cleared. Impaired states such as Mandagni or Tikshnagni may be understood as dysregulated metabolic conditions characterized by reduced efficiency or excessive catabolism. The formation of Ama conceptually aligns with metabolic by-products, oxidative stress, or incomplete substrate utilization resulting from compromised regulatory mechanisms.

Using a bioenergetic framework to interpret Agni emphasizes its integrative and systemic nature rather than reducing it to a particular biochemical route or organelle. The functional expression of Agni at the cellular level is reflected in this model through the combined effects of thermodynamic balance, enzymatic regulation, hormonal modulation, and mitochondrial bioenergetics. Agni can therefore be seen as a dynamic principle of controlled change that upholds

metabolic balance, vigor, and structural integrity. By providing a conceptual link between traditional Ayurvedic physiology and modern biomedical science, this integrated understanding creates opportunities for more in-depth multidisciplinary studies of metabolic health and illness.

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Data Availability
This study is a conceptual review based on classical Ayurvedic texts and published scientific literature. No primary datasets were generated or analyzed during the current study. All references used are cited within the manuscript.

Conflict of Interest
None

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process.
During the preparation of this manuscript, the authors used an AI-assisted language tool to improve clarity, grammar, and organization of the text. The authors reviewed and edited the content critically and take full responsibility for the final version of the manuscript.

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