

The Idea of a Vital Principle in Āyurveda and the Second Axiom of Thermodynamics*

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This inquiry joins the idea of a vital principle at work in two systems for spiritual liberation and medical treatment, South Asian Yoga and Āyurveda, to an interpretation of the second axiom of thermodynamics applied to open systems, a predictive mathematical account of matter. Though often first associated with philosophy or religion, Yoga and Āyurveda take human physiology as a function of the natural world, as does thermodynamics. The idea of “life force” or “vitality” emerges at the intersection of these two epistemologies. The religious or philosophical principle of prāṇa (succinctly, life energy) has its roots in a naturalist perspective, and a principle from mathematics and physical science yields the abstract concept of entropy (succinctly, energy loss). The discussion reconsiders the philosophical idea of a life force, or vital principle, and its potential application in health care.

Key words: longevity; health; Yoga; Āyurveda; healthcare

1 Introduction

The World Health Organization identified 2020-2030 as The Decade of Healthy Aging, calling attention to aging as a social as well as individual health issue.¹ In this context, one ongoing discussion has been whether aging should be considered a natural trajectory of decline or a disease in itself.² Both perspectives link aging to physical changes involving acute and chronic health conditions, from osteoporosis and diabetes to frailty and dementia. In one view, physical and mental decline is inevitable as people add years to their lives. Age-related diseases arise as the human body follows a trajectory of natural degradation. In the other view, curable diseases cause

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the decline and degradation associated with aging. Aging can be mitigated by treating the diseases.

The first view of aging places human bodies on a trajectory to disorder, following the classical form of the second axiom of thermodynamics (entropy does not decrease in closed systems). This form of the axiom undergirds the view that human bodies follow an inevitable pattern of irreversible decline as they age. For example, the Merck Manuals, a reliable reference source of medical information for medical professionals, consumers, patients, caregivers, and students includes a section on aging in its consumer version. Its “Overview of Aging” reinforces the view that “bodily functions begin to decline” in “early middle age.” Normal aging is presented as a universal process of biological changes occurring predictably over time:

These changes occur in everyone who lives long enough, and that universality is part of the definition of pure aging. They are to be expected and are generally unavoidable (Merck Manual 2024: n.p.).³

In this view, biological aging means predictable functional decline. Bodies will break down in a natural process involving conditions such as atherosclerosis, cognitive impairment, sarcopenia, diabetes, loss of vision and hearing, deterioration of internal organs, compromised immunity, and so on. Osteoarthritis, for example, is often described as “natural wear and tear” on joints over time, a consequence of years lived. The Arthritis Foundation notes the prevalence of this “wear and tear” narrative, even as it considers osteoarthritis a disease that is not necessarily age-related.⁴ The second view of aging follows the interests of aging populations seeking ways to live longer, healthier lives. A research-based, popular literature favors this view, in which people can influence their healthspan.⁵ Synthesizing medical studies for a general reader, this literature posits three general ways people can mitigate decline as they age: nutrition, exercise, and metabolic enhancement.

The idea of a vital principle may offer a fourth way to influence healthspan: lifestyle choices that result in entropy reduction. Continuum thermodynamics and the Indian medical system Āyurveda offer mutually relevant perspectives on the potential for a healthy human lifespan expressed in the second view. Their relevance to each other suggests entropy reduction, which can be cultivated based on Āyurvedic principles, as an unrecognized factor in current considerations of healthspan. Āyurveda’s recommendations for health and longevity depend on the concept of *prāṇa*, with a perspective on the human body as open to its environment, absorbing food and excreting waste. This perspective suggests a formulation of the second axiom of thermodynamics applied to open, rather than closed, physical systems. That form yields a perspective for interpreting Āyurveda’s dietary and lifestyle recommendations as lowering entropy system-wide.

A full consideration of Āyurveda’s complexity, historical variations in yogic practices, and the technicalities of the second axiom of thermodynamics exceed the scope of this paper. A level of

generalization in the discussions of the vital principle in South Asian thought (*prāṇa*) and the second axiom of thermodynamics formulated for open systems aims to show how they inform each other and suggest their importance in discussions of healthspan.

2 Vital Principle in Āyurveda and Yoga

Prāṇa, the vital principle in South Asian thought, is an extremely complex concept, but invariably associated with life. The word *prāṇa* translates as “constant motion,” motion being a primary characteristic of life. The prefix “*pra*” intensifying the noun “*ṇa*” (movement) gives the word *prāṇa* its sense of this ongoing movement (Zysk 1995: 33).⁶ In South Asian philosophy, *prāṇa* features in five of the thirteen major Upaniṣad-s in various ways. It may be a primordial source, a state of perfection, an origin, a property of the cosmos, or an irreducible essence (Mallinson and Singleton 2017: 128, 173; Connolly 1997: 26-27).⁷ In a wide field of meanings, *prāṇa* appears most consistently as one of five primary winds occurring in nature (*vāyus*), which is called *prāṇa*, and as the breath equated with life itself in living beings (Olivelle 1998: 23; Zysk 2007: 106).⁸

Peter Connolly summarizes a general understanding of *prāṇa* derived from the Upaniṣads and carried into the later Vedānta philosophical system (*darśan*) as “the primeval source of all and the immortal inner essence of individuals,” which manifests in the body as the *vayus* (Connolly 1992: 57).⁹ In this sense, *prāṇa* and other words denoting energy within the body such as *śakti*, invoke the quality of aliveness. English interpretations of *prāṇa* as “essence of life,” “vital breath,” “cosmic life force,” “soul-life force,” “breath of life,” “vital force” or “energy” capture this sense of a vital principle (Muelenbeld IA 2002: 32).¹⁰ *Prāṇa* is a key concept in Āyurveda and Yoga.

As a medical system, Āyurveda was not traditionally invested in the yogic pursuit of liberation (Zysk 2001: 24; Birch 2018: 5).¹¹ However, by promoting a long, healthy lifespan, Āyurvedic medicine and its lifestyle recommendations served Yoga’s soteriological aims. Depending on the type of Yoga, these aims include transforming consciousness toward its independence from sensory stimulation and cognitive thought; releasing a person from the cycle of re-birth (*saṃsāra*); realizing the nature of the self; uniting the self with divinity; or recognizing divinity in the self. In the context of South Asian thought, Āyurveda and Yoga take *prāṇa* as a property of the physical world.

Āyurveda is codified in medical texts from about the first century of the common era, in a Vedic and Buddhist milieu (Zysk 2000: 38ff; Zysk 1995: 48).¹² The root *āyus* refers to life, specifically the life of a human body. As enumerated by the Sāṃkhya philosophical system (*darśan*) which informs Āyurveda and Patañjalian meditative Yoga, a human being is made up of matter. The material body includes the sense organs and the organs of action, the mind, ego, and a discerning

intellect (known collectively as *citta* in some texts), which are bound to a non-corporeal, immutable aspect (the *ātman* or *puruṣa*) (*Caraka Samhitā Sūtrasthāna* I: 46-47).¹³ *Āyus* mitigates the body's decay (*dhāri*) and sustains its life (*jīvita*) (*Caraka Samhitā Sūtrasthāna* I: 42).

Though not itself one of Sāṃkhya's 24 elements of matter (*tattvas*), *prāṇa* is understood to flow through the body as one of five winds or breaths (*vāyu-s*) (*Sāṃkhya Kārikā* 29).¹⁴ The *Maitrī Upaniṣad* (6.18) describes the five *vāyus* as essential to maintaining biological processes as well as sustaining a person's non-material aspect as long as it is attached to a body (Sarbacker 1962: 67).¹⁵ As a wind, *prāṇa* enables the body's organs of sense and action (*jñānendriyas*, *karmandriyas*) to function. In some interpretations, *prāṇa* contributes directly to the animation of matter as the "motions" of vitality, which give rise to action and intention (Daya Krishna 1968: 194; Maderey 2021: 88).¹⁶ *Prāṇa* also binds the immaterial, non-corporeal self (*ātman*, *puruṣa*) to the material body until liberation (*mokṣa*) or death. *Prāṇa* is less prominent in Sāṃkhya as a philosophy than it is in practices of meditative Yoga and Āyurvedic medicine (Connolly 1992: 164).

Prāṇa also features in a Vedāntic philosophical context (Ashton 2020: 34).¹⁷ The Vedānta school and its Advaita (non-dual) branch conceive the *ātman* in some relation to an ultimate reality (Brahman) or to a divinity. However, the role *prāṇa* takes in that relationship is not consistent across Vedānta's branches (Connolly 1997: 35). In the context of Vedānta, Haṭha and Tantric yoga developed techniques for moving *prāṇa* or *śakti* through channels (*nāḍīs*) and nodes (*cakrās*) in the body (Mallinson and Singleton 2017: 214-15). In yogic practices, the vital principle could be both breath itself and a property of the human body, both contributing to the aim of transforming consciousness (Døngart 2016: 45-6).¹⁸ Yoga thus developed techniques for inhaling, exhaling, and retaining the breath (*prāṇāyāma*) to cultivate *prāṇa*.

Āyurveda deals with how the body takes in and transforms *prāṇa* in food, water, and air, as well as the sensory stimuli that imprint on the mind as thought and memory (*saṃskāras*). A system of twenty qualities (*guṇas*) guides balancing the body's own qualities with the qualities of food and stimuli it takes in (*Caraka Samhitā Sūtrasthāna* I: 49, 51). In this way, Āyurveda's medical techniques aim to create internal conditions that allow *prāṇa* to move freely through subtle channels (*nāḍīs*), accumulating at points in tissues (*marmasthāna*). When evenly distributed, *prāṇa* fuels metabolism (digestion, respiration, and mental processes) and supports the body's tissues. Health (*svāstha*), then, is a steady state across a person's physical body (including mental processes), which influences a person's non-corporeal aspect:

He in whom the *doṣās*, *agni* (digestive power), *dhātus* (tissues), *malas* (waste products) and their activities are normal; his soul, sense organs and mind are calm/clear, is called *svāstha* (healthy person) (*Suśruta Samhitā Sūtrasthāna* XV 110, trans. Srikantha Murthy).¹⁹
Samadoṣa samāgniśca samadhātumalakriyah/Prasannātmendriyamanāh svāstha ityabhidhīyate.

Prāṇa is responsible for maintaining this well-regulated state. *Sama*, translated by Murthy as “normal,” implies evenness or equanimity and can also be translated as balance.²⁰ As we will discuss below, the quality of balance implied by the word *sama* suggests an aspect of Āyurveda’s relevance to the second axiom of thermodynamics applied to open systems. *Doṣā*, *agni*, *dhātu*, and *mala* are also key. *Doṣa* is what Āyurveda seeks to balance to achieve health.

The concept of *doṣa* shares similarities with the Greek Hippocrates’ *physis* and the humors (Zysk 1995: 48). Āyurveda’s three *doṣas* (*vāta*, *pitta*, *kapha*) pair the qualities of the five natural elements: earth, air, fire, water, and ether (*mahābhūtas*). *Vāta doṣa*, for example, combines air and ether. *Doṣa* literally means that which can go awry in a body, that is, what becomes disordered and causes disease (*Caraka Samhitā Sūtrasthāna* I: 57-61). A *doṣa* can become disordered by diet and living patterns that put a body in an adverse relationship with its environment. For example, a body in which *vāta doṣa* is prominent will have delicate bones, dry joints, and dry skin. Dry, cold foods or climate will exacerbate *vāta*’s qualities of lightness, dryness, and airiness, causing disorders such as osteoarthritis or eczema. These disorders would be treated by re-balancing the body’s synchronicity with its environment.

Organism-wide balance also includes the mind and the sensory input it processes. Mental clarity depends on three qualities understood to constitute all of nature, as described in verse 13 of the *Sāṃkhyakārikā*. These *maha* or “great” *guṇas* can be described roughly as clarity and serenity (*sattva*), activity and transformation (*rajas*), and darkness and inertia (*tamas*). Āyurveda associates *rajas* and *tamas* with unbalanced mental processes. The *Caraka Samhitā*’s chapter on the body, *Śārīrasthāna*, describes a yogic mental state, for example, as increasingly unaffected by sensory stimuli, thus *sattvic* (*Charaka Samhitā Śārīrasthāna* I: 136-37). As in yoga, serenity and clarity in the mind through the cultivation of *sattva* and practicing non-violence (*ahiṃsā*), allow for release of the latent impressions on the mind (*samskaras*) that bind a person’s *ātman* to re-birth (Wujastyk 2012: 34).²¹

Agni is also essential to organism-wide balance. *Agni*, like *prāṇa*, is a prominent theme in South Asian thought. The first word of the *Rg Veda* is *agni* and its first hymn is devoted to the sacrificial fire (*yajñā*) (*Rig Veda* I.1; Jamison and Brereton I: 89).²² *Agni* is also a god in the Vedic pantheon, and a manifestation of *rajas*, the quality of energetic activity. Āyurveda conceives of digestion as fire (*jatharagni*), the vibrant (*rajasic*) process that transforms food and stimuli from the environment. Well-stoked, steadily burning, strong digestive fire means the body expends little energy in the process of converting food and stimuli into its seven tissues (*dhātus*): plasma (*rāsa*), red blood (*raktā*), muscle and skin (*māṃsa*), adipose tissue (*meda*), bone (*asthi*), bone marrow (*majjā*) and reproductive tissue (*śukra*). Weak or intermittent digestive fire results in undigested substances (*ama*) accumulating throughout the body. Accumulated *ama* blocks the circulation of *prāṇa*, resulting in inflammatory conditions such as rheumatoid arthritis.

Ayurveda's core technique for maintaining *svāstha* is dietetics (*aharatattva*), which bring *prāṇa* into the body via combinations of foods, herbs, and beverages (*Caraka Samhitā Mātrāsītīyasthāna* I: 1-14). Health depends on taking in foods and sensory stimuli high in *prāṇa*, digesting efficiently to absorb *prāṇa*, and expelling waste (*ama*) low in *prāṇa*. Efficient, thorough digestion depends on attention to a *doṣa*-appropriate diet (*ahara vihara*) and life practices that maintain the body's inherent order.

Āyurvedic food combinations are complex, but broadly, Āyurveda advocates fresh, mildly spiced foods appropriate to a person's *doṣa*, eating regularly in moderation, and filling the stomach with equal parts of food, liquid, and air. Life activities such as sleep and meals should be aligned with daily time cycles (*dinacharya*) and adjusted to the seasons (*ritucharya*) (*Aṣṭāṅga Hṛdaya Sūtrasthāna* I: 2-3).²³ Practices such as oil massage (*abhyanga*) are advised to reduce physical and mental tensions, which expend energy unnecessarily inhibiting the circulation of *prāṇa*.

Simplified examples illustrate how Āyurveda restores balance when a person's *doṣa* goes awry. Someone experiencing depression (a *tamasic* mental state) whose constitution has a high proportion of *kapha doṣa* (earth and water) might be prescribed a light diet with dry or spiced foods with physical activity to reduce the heaviness of *kapha* and increase the vibrancy of *rajas*. Heartburn indicates an imbalance in *pitta doṣa* (fire and water). The imbalance might be due to an excess of *rajasic* foods eaten in inappropriate proportions, at the wrong time of day, quickly in agitated conditions. Mild foods and changes in eating patterns might rebalance *pitta*, allowing the body to process food and stimuli without excess acid which taxes digestion. Balance enhances the mobility of *prāṇa* and reduces resistance in metabolic processes, resulting in overall health.

In Yoga, *prāṇa* serves the soteriological work of liberation (*mokṣa*). We might think of the yogic body as conducting "energies that awaken consciousness," and the Āyurvedic body as a doctor's map of physiological processes (Wujastyk 2003: 260).²⁴ Broadly speaking, yogic practices can be thought of as moving *prāṇa* to transform consciousness (*parinama*), whereas Āyurvedic medicine transforms *prāṇa* to support the body (Zysk 2007: 108).

With a common intellectual foundation in the Upaniṣads, Yoga and Āyurveda share a vocabulary for health, understanding the human body as simultaneously material and non-corporeal (Birch 2018: 12). Yoga shares with Āyurveda the concept of disease (*vyādhi*) as imbalance in the five elements comprising the physical body (*Caraka Samhitā Śārīrasthāna* I: 27-8; Birch 2018: 3-4). Patañjali's *Yoga Sūtras*, for example, views poor health as a hindrance to meditation (I:30).²⁵ Yoga also takes internal fire as essential for processing food and sensory stimuli. The *Yogayājñavalkya*, for example, describes strong internal fire moving *prāṇa* upward through the body (IV: 11-5; VI: 65-75; Birch 2018: 21).²⁶

While Yoga seeks the non-corporeal *ātman*'s immortality apart from the body, Āyurveda deals with bodies that die. For Āyurveda, living a long healthy life is a basic human desire supported by

diet and lifestyle (*āyushkāmiya adhayāya*) (*Caraka Samhitā, Tisraisanīyasthāna*, I: 3; *Aṣṭāṅga Hṛdaya, Sūtrasthāna*, I: 1). *Jara*, rejuvenation, one of Āyurveda's eight branches, thus focuses on conditions of advanced age (*Aṣṭāṅga Hṛdaya, Sūtrasthāna*, I: 1; 39ff). As in the Merck Manual, this branch of Āyurveda views aging as a natural process that cannot be halted or reversed. However, treating the body in a continual exchange with its environment, Āyurveda approaches aging therapeutically (*Caraka Samhitā Śārīrasthāna* I: 115). The approach to sustaining health over time is based on cultivating vitality in the body by attending to how it exchanges *prāṇa* with its environment.

3 Mutual Relevance

Āyurveda/Yoga and the second axiom of thermodynamics may be considered mutually relevant in that each posits a principle for sustaining a system's life based on its exchange with its environment. Exploring this mutual relevance is not unproblematic. In conventional Eurocentric thought, metaphysics and physics are different systems of knowing in part because they establish knowledge differently (White 2014: 25).²⁷ This distinction suggests entropy production in thermodynamics and the idea of a vital principle operate in different epistemological frameworks. *Prāṇa* derives from centuries of South Asian philosophical inquiry into the essence of life that informed medical and soteriological practices, whereas the axioms of thermodynamics derive from historically recent European experiments aimed to provide a mathematical account of how matter behaves.

If this distinction holds, considering Āyurveda/Yoga and the second axiom of thermodynamics together raises a comparison that concerned Austrian physicist Erwin Schrödinger (Bitbol 1999: 4).²⁸ For Schrödinger, the apparent perception of congruence between Indian and European ideas potentially blurred speculative thinking and logic, mixing analysis of matter with subjective experience (Schrödinger 1964: 92-3).²⁹ Kenneth Zysk extends this perspective, acknowledging that Āyurveda and bio-medicine differ in their conceptual understandings of the human body (Zysk 2001: 26).³⁰

That *prāṇa*, like gravity, is understood as a property of the material world, not a metaphysical proposition, is a reminder that these concerns are nuanced. Similarly, the connection between system longevity and entropy in living bodies is not obvious. For example, how much increase in entropy is sufficient to cause a single cell to lose viability, when evolution has endowed living cells with resilience to mutations and other disruptors? While analysis of such questions is not necessary for this paper's general thesis, these complexities must be acknowledged.

Adhering to Schrödinger's caution, this inquiry explores how two accounts of matter inform each other, rather than seeking congruence or using one as an explanatory framework for the other. Āyurveda and the second axiom of thermodynamics each suggest a principle for sustaining life, but by different methods. Their mutual relevance depends on the formulation of the second axiom for open rather than closed physical systems, following Belgian chemist Illya Prigogine's observation that South Asian philosophy synchronizes the body's interior with its environment (Prigogine 1977: 59).³¹ Based on the experimental conditions from which it is derived, the conventional form of the second axiom of thermodynamics assumes a physical system is closed, not in exchange with its environment. Applied to human life, this assumption leads to the perspective expressed above in the Merck Manual: human life span is limited by an unavoidably increasing system-wide entropy. Āyurveda assumes human bodies to be open systems, exchanging *prāṇa* with the environment. This assumption points to a limitation in the conventional closed system formulation of the second axiom if it is applied to living bodies. European scientists in the early twentieth century recognized that limitation and considered the implications of adapting the axiom to open systems.

In South Asian thought, received knowledge (*śruti*) constitutes a method of knowing (*prāmaṇa*). By that means, *prāṇa* is known as a property of the physical world that imbues matter with life. The *Taittirīya Upaniśad*, for example, describes *prāṇa* as life itself moving through the body with inhalations, exhalations and pauses in breathing and the non-corporeal aspect of a person (*ātman*) residing in the lungs. *Prāṇa* also connects the physical body, the non-corporeal self, and an ultimate reality (Brahman) (2.2):

For lifebreath is the life of beings,
So it's called 'all life.'
A full life they'll surely live, when they
worship *Brahman* as lifebreath.
For lifebreath is the life of beings,
So it's called 'all life' (*Taittirīya* 2.3, trans. Olivelle).

The *Taittirīya* articulates the idea of *prāṇa* as a vital principle, which Yoga and Āyurveda cultivate in practice.

In physical science observation, experiment, and mathematical prediction constitute a method of knowing how the physical world behaves. Based on experiments conducted on closed physical systems, the second axiom of thermodynamics predicts mathematically that a physical system will increase in entropy, losing energy until its molecular motion eventually stops. For a living system, increasing entropy means functional decline toward death, the cessation of movement. When the second axiom of thermodynamics is applied to open systems, however, the prediction changes. That change links mathematical prediction of entropy production and the idea of a vital principle.

In open physical systems, the second axiom admits the possibility that entropy can decrease across the system, mitigating the system's decay by delaying cessation of molecular motion. An open system can sustain molecular motion longer (though not indefinitely) depending on its exchange of entropy with the environment. Āyurveda and Yoga, as we have seen, assume the movement of *prāṇa* as the vitality of life, the word *prāṇa* itself conveying motion as the essential quality of life. For Schrödinger, too, matter is alive when

it goes on 'doing something,' moving, exchanging material with its environment, and so forth [...] for a much longer period than we would expect an inanimate piece of matter to 'keep going' under similar circumstances (Schrödinger 1944: 69).³²

In principle, sustaining a body's order by taking in and cultivating *prāṇa* to sustain life resonates with the prediction of sustaining an open system via entropy reduction as permitted by the open system formulation of the second axiom (Schneider and Kay 1995: 162ff).³³ While physical science may not prove a vital principle, as Ludwig von Bertalanffy concludes, the second axiom of thermodynamics extended to open systems does not preclude the possibility (Bertalanffy 1950: 25). Indeed, the correctness of axioms cannot be proved through experiment, only disproved. The potential for decreasing total system entropy to mitigate functional decline over a lifespan predicted in the open system form of the second axiom thus links it the idea of a vital principle, discussed here as *prāṇa*.

4 Life and the Second Axiom of Thermodynamics

Thermodynamic axioms first showed how changes in energy give rise to associated forces as a closed system does work. This classical thermodynamic paradigm is essentially Newtonian: the momentum of an object is constant until a force changes it; conversely, if momentum changes, a force has been applied. Changes in momentum are thus associated with force, giving rise to observable cause and effect. Common translations of *prāṇa* into English as "life force" and "life energy" use the language of physical science. Like the concept of force, *prāṇa* is known by its effects. We cannot see gravitational force, for example, but we see its effect when a ball rolls off a table. Similarly, we cannot see *prāṇa*, but we can see its effects when a body responds to an Āyurvedic treatment, or moves during inhalation and exhalation.

However, whereas Newtonian physics accounted for the movement and momentum of matter, thermodynamics accounts for the transformations of energy that occur as matter moves and chemically reacts. Thermodynamics defines energy as the potential that gives rise to a force that effects a change in a system. In a closed physical system, energy is conserved. It can be transformed, as when friction transforms kinetic energy to thermal energy. The cost for that

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transformation is entropy: entropy accounts for the dissipation of energy when it is not conserved, without having to specify exactly where the energy went.³⁴ A closed system dissipating energy produces entropy (a state variable) as it becomes disordered.

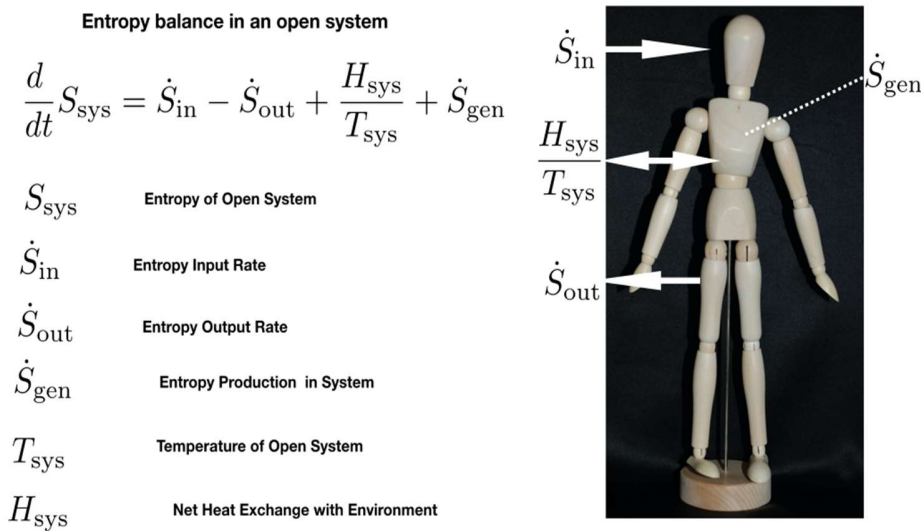
Fire is a helpful metaphor for understanding dissipating energy and entropy production. A fire, in which fuel burns up as its stored energy transforms into heat, goes out because the energy expended in consuming fuel has no way to replenish itself (the condition of a closed system). First, a force is needed—the strike of a match—to start the fire. As the fire catches and burns, it releases chemical energy stored in fuel—wood or paper. The fuel’s chemical energy transforms into heat energy. The burning fuel radiates heat, but that heat does not re-fuel the fire; it dissipates. Because the fuel cannot take in new energy, its available stored energy degrades and unless new fuel is added the fire goes out. The fire becomes disordered leaving ashes, which having expended their stored chemical energy do not burn. The transformation of wood or paper to ash is irreversible. Entropy, then, is the mathematical measure of energy that was rendered unavailable in the transformation of fuel to heat as the fire burns. The production of entropy represents this process of energy dissipation and system disorder in a closed system, ending in system-wide stasis (equilibrium). An open system, which can take in fuel from the environment, transform its free energy, and excrete what is left over, can preserve its order (a steady state). Biological organisms, here the human body, are one type of open system.

In the mid-twentieth century, some European scientists, among them Illya Prigogine, Erwin Schrödinger, and Ludwig von Bertalanffy, suggested that the laws of nature governing energy transformation might be applied to biological organisms. In his famous essay “What is Life?” Schrödinger hints at the idea of a “life energy” implied by an open system formulation for the second axiom of thermodynamics in a continuum setting. Schrödinger considers the second axiom in relation to biological organisms rather than purely physical systems. He considered that as an open system, the human body can mitigate increasing entropy if it takes in substances lower in entropy than what it excretes. Prigogine envisioned this exchange as a “new dialogue of man and nature” (Prigogine 1982: 46). What Prigogine recognized as a deeper understanding of the relationship between humans and nature is foundational to the Sāṃkhya philosophy on which Āyurveda is based.

Schrödinger’s insight is that by absorbing “negative entropy” a human body can balance the entropy its metabolic processes produce over time. “Negative entropy” here is a metaphor for the net exchange of entropy between an open system and its environment; in its definition as a physical quantity, entropy cannot actually be negative. That balancing sustains the body’s internal energy for regeneration and repair, which extends its life (Schrödinger 1944: 72). This process represents a transformation in which the less the entropic cost of the exchange, the less the expenditure of energy for the system to do its work. Bertalanffy, drawing on the work of Prigogine and Schrödinger to identify principles governing such systems, considered this

exchange and transformation of energy a “necessary condition for the continuous working capacity of the organism,” in other words, its life (Bertalanffy 1950: 23).

The diagram of this transformation below represents the change $\Delta S = \Delta Q/T$, where S represents entropy, Q is the heat transfer and T is temperature. The expression d/dt is the rate of change of entropy. Prigogine’s extension of thermodynamics to open systems and states of non-equilibrium provides an important nuance to this equation. In the entropy balance equation, the first two terms on the right-hand-side of the equation account for the mechanism by which the total system entropy can decrease. The last term in this equation accounts for the rate at which entropy is produced by the internal processes of the open system. In his 1977 Nobel Prize Lecture in Chemistry, *Time, Structure and Fluctuations*, Prigogine argues that a natural way to extend the second axiom of thermodynamics for closed systems to the setting of open systems is to require that the last term in the entropy balance equation of Figure 1 be nonnegative (265, line 2.2).³⁵ This implies that life would not be possible if a cell were a closed system.



“Low entropy in, high entropy out” in this balance equation suggests a principle similar to Āyurveda’s dietary recommendations for balancing a body according to its constitution (*doṣa*). Āyurveda takes wholesome, fresh foods to be high in *prāṇa* (*Caraka Samhitā, Mātrāsītīyasthāna* 10-3). Strong digestive fire digests these foods efficiently, releasing the stored *prāṇa* for circulation throughout the body. The waste eliminated has less *prāṇa*, resulting in a balanced,

ordered system. Āyurveda's recommendations are strikingly similar to Bertalanffy's description of living systems "maintaining themselves in a steady state by the importation of materials rich in free energy." Drawing on Schrödinger's expression "negative entropy," Bertalanffy holds that the human body as an open system maintains balance by "importing complex organic molecules, using their energy, and rendering back the simpler end products into the environment" (Bertalanffy 1950: 26).

Bertalanffy considers food in its molecular composition, whereas Āyurveda's range of substances a body takes in extends to impressions left on the mind. These, like food, carry *prāṇa* and must be digested. In Āyurveda's philosophical context, the mind is part of the physical body, which is not the case in European physical science. While a perspective that sees a disembodied mind might not consider the metabolic cost of processing sensory stimuli, memories, emotions and thoughts, Āyurveda accounts for their digestion in the cultivation of a *sattvic* mentality: a clear, serene state of mind free of impediments to perception.

Insofar as efficient digestion of food, sensory stimuli, and mental activity can be considered an ongoing energy transformation through metabolic processes, the second axiom applied to open systems yields a physical principle that accounts mathematically for prolonging life and maintaining health by balancing entropy. In thermodynamic terms, metabolizing food and sensory stimuli with low entropy and lowering resistance would result in little net loss of energy. In this model, a human body could maintain and possibly even increase available free energy. That free energy would then be available for transformation into other kinds of irreversible energetic work—mechanical, electrical, or chemical—to heal disease, retard degradation and sustain optimal health. When a body functions with less entropic cost (less entropy produced in metabolic processes), it maintains the condition of health that prolongs life: homeostasis or *svasta*. This is a human body's healthspan (Rao 2018: 225).³⁶

The idea of a vital principle appears as a relationship between energy transformation and sustaining the life of an open physical system or living organism in both Āyurveda/Yoga and the thermodynamic prediction of entropy reduction. Thermodynamic balance laws, like Āyurveda's principle of *prāṇa* recognize system-wide balance, with minimal resistance in the working of metabolic processes as key to sustaining life. In practice, cultivation of "low entropy in, high entropy out" would yield the longer, healthier lifespan Āyurveda attributes to the circulation of *prāṇa*. This mutual relevance has implications for discussions of healthspan.

5 Vital Principle in Discussions of Healthspan

The idea of a vital principle is not foreign to philosophical thought associated with the European intellectual tradition. Aristotle's animating soul, the biblical breath of God (*ruach, pneuma*), and vital heat in ancient Greek medicine (*calidum innatum*) find their way into later European concepts such as *vis essentialis corporis*, *élan vital*, and vitalism. Philosophies of vitalism, however, failed the test of scientific experiment in Europe by the end of the eighteenth century, becoming in the words of Christopher Donohue and Charles T. Wolfe "the most misunderstood and reviled philosophy of life" (Donohue and Wolfe 2023: 1).³⁷ British biophysicist Francis Crick stands as an example of the rejection of vitalism in scientific inquiry in the 1960s with his forceful assertion of vitality's irrelevance to biology.³⁸ Amid the rejection of vitality in scientific discourses, the idea of a vital principle derived from South and Southeast Asian thought traditions found traction in Europe and the United States as internal bio-energy cultivated in wellness practices. These include *prāṇa*, *kundalinī* and *śakti* from South Asian Yoga, and *chi* from Japanese martial arts (*ki*) and Chinese medicine, *t'ai chi chuan* and *qigong (qi)*.

Paradoxically, the idea of a vital principle in Europe and the United States owes some of that traction to the very discourses on science that rejected vitality. Early efforts to promote Yoga in the United States for example, fused physical science and philosophy by describing *prāṇa* as electrochemical and electromagnetic energy (Singleton 2010: 71-5; De Michelis 2004: 119-20).³⁹ In the late nineteenth century, Swami Vivekananda deliberately presented meditative yoga as a science of the mind, casting *prāṇa* as electricity, making meditation compatible with physical science (White 2014: 115; Vivekananda 1956: 53-5).⁴⁰ In the same era, Helena Blavatsky's occult interpretations of *prāṇa* spiritualized electro-magnetism, intertwining it with "cosmic electricity" in resistance to scientific materialism (White 2014: 107; Rudbøg 2012: 289).⁴¹ The quasi- or pseudo-scientific use of "energy" as a synonym for vitality persists today in popular wellness practices (Barcan 2013: 224).⁴²

The mutual relevance of Āyurveda/Yoga and thermodynamics is situated in this complex history, which sometimes blurs and sometimes reinforces boundaries between cultures and zones of knowledge. In this context, how might the second law of thermodynamics applied to open systems conceive of energy transformation in a way that suggests something like a vital principle? And how might the assumption of a vital principle in Āyurveda and Yoga inform an understanding of the open system form of the second axiom? What value might a vital principle add to current interest in healthy aging, longevity, and healthspan?

Both Āyurveda/Yoga and the second axiom of thermodynamics in open systems suggest time-related degradation in a physical body can be mitigated with attention to system or organism balance with the environment. While recognizing degenerative changes as an inevitable, natural if unwelcome process, the idea of a vital principle in Āyurveda allows for a holistic approach to

healthspan, in which people have agency to affect their trajectory. In Āyurveda, specific lifestyle modifications mitigate decline by re-establishing balance (*sama*) in a body's tissues, internal heat, innate qualities, and waste elimination (Rao 2018: 227). As a medical system, Āyurveda bypasses the closed-system form of the second axiom with the idea of a vital principle to create order across the body.

In practice, a person can influence their healthspan over time by balancing what their body takes in, transforms, and excretes. The more efficiently physiological processes work, the less entropy they produce and the more resilient the body becomes. In Āyurveda, this is a process of replenishing and circulating *prāṇa* while trying to reduce the amount of energy a body expends to do the work of staying alive. In thermodynamic terms, a balanced body's organism-wide entropy could potentially decrease over time, thereby sustaining its health and extending its physical life, depending on the entropic cost of a body's internal transformations.

One way Āyurveda reduces entropic cost is by stoking strong digestive fire (*agni*). The emphasis on digestive fire (*agni*) in Āyurveda explicitly links metabolism to energy transformation. Biological processes at work in staying alive may be mechanical, biochemical, kinetic or electromagnetic, all of which can be transformed and can produce entropy. The important feature, however, is not the form of the energy itself, but the processes that transform it. For Āyurveda, a healthy body with strong digestive fire transforms food with minimal energy expenditure. In thermodynamic terms, if digestive fire is weak a body cannot make use of the fuel it takes in. In that condition, the body functions in effect like a closed system. Unable to transform what it takes in, it will go to greater entropy (disorder).

Āyurveda also reduces entropic cost by regulating the quality of food or stimuli a body takes in. Āyurveda's food recommendations hinge not on nutrients in foods or their molecular structure but on the metabolic transformation of food and its nutrients. Regardless of *doṣā*, recommended foods would be fresh vegetables or meat, cooked lightly to preserve their structure. Following Bertalanffy, Āyurveda recommends highly ordered, large molecular, low entropy foods (Bertalanffy 1950: 26). In thermodynamic terms, taking in lower entropy foods and stimuli, transforming them efficiently, and excreting higher entropy waste reduces system-wide entropy.

Organism-wide entropy is therefore a dynamic, spatially inhomogeneous field, for which both Āyurveda and thermodynamics account. Āyurveda allows for local fluctuations of *prāṇa* in *marmasthāna*, points throughout the body where *prāṇa* collects, as well as in the system of channels (*nāḍīs*) through which *prāṇa* circulates. Continuum thermodynamics models the entropy of a human organism as a density field defined at each point of the Euclidean volume occupied by the body. (The total entropy of the body at any given time would be the integral of the entropy density over the volume occupied by the body at that time.) In general, even if the total entropy of the body is either increasing or decreasing (monotonic in time), it can be fluctuating (nonmonotonic) at each point in the body. For example, the total entropy of the body

could be decreasing, but the entropy of individual organs could be increasing or decreasing in complex dynamic patterns. Organism-wide entropy is therefore a dynamic, spatially inhomogeneous field, which Āyurveda accounts for in its system of *marmasthāna*.

Each of the two frameworks for energy transformation discussed here—one assuming a vital principle and the other not—suggests a strategy for influencing human healthspan. Thermodynamics does not assume, prove, or disprove a vital principle as a property of matter or human physiology. It does, however, predict mathematically the kind of exchange with the environment Āyurveda cultivates in treatments and practices to circulate *prāṇa* effectively. Without compromising scientific logic or dismissing an idea of vitality that so far resists proof by controlled experiment, Āyurveda/Yoga and the second axiom applied to open systems may be viewed as approaching the idea of a vital principle in different ways. That reciprocity has implications for thinking about healthspan in a bio-medical framework.

German hermeneutic philosopher Hans Georg Gadamer observes that modern bio-medicine treats what goes wrong with a body, rather than promoting health as the foundation for extending life (Gadamer 1996).⁴³ Health for Gadamer is a condition in which a body “sustains its own proper balance and proportion,” in an “immeasurable state of proportion.” Gadamer describes health as a “condition of inner accord, of harmony with oneself that cannot be overridden by other, external forms of control” such as language, medical standards, and imposed measurements (Gadamer 1996: 108). Gadamer calls this inner accord the “hidden character of health,” its “mystery” (Gadamer 1996: 107). His phrases evoke the idea of *prāṇa* as the “hiding place of Brahman” in the human body in the *Taittirīya Upaniṣad*. They also evoke Schrödinger’s reckoning in the last section of his essay “What is Life” that “we must be prepared to find [life] working in a manner that cannot be reduced to the ordinary laws of physics” (Schrödinger 1944: 76).

The idea that a body might “sustain its own balance” to prolong its state of “inner accord” echoes the *Suśruta Samhitā*’s expression of health (*svāstha*) as well-functioning bodily processes, balanced qualities and digestive fire, well-formed tissues, efficient elimination of waste, and a joyful attitude quoted above. Gadamer, writing in the context of bio-medicine based on physical science, envisions this balance as the basic condition of health. Gadamer’s refutation of a model in which physical degradation cannot be mitigated, as the closed system form of the second axiom predicts, opens space in bio-medicine for the idea of a vital principle. The mutual relevance of Āyurveda/Yoga and the open system form of the second axiom enters that space with implications for current discussion of healthspan.

In both frameworks, life is a function of transformations in a physical system in a regulated exchange with its environment. The open systems form of the second axiom applied to human biology takes that exchange into account predicting entropy could decrease and sustain a body’s life and health over a longer span of time. Āyurveda’s cultivation of system-wide balance through efficient digestion of food, mental activity, and sensory stimuli expresses that prediction in

medical practice. Healthspan, then, can be understood as the effect of an internally balanced body in favorable energetic and entropic balance with its environment. To the second axiom of thermodynamics in open systems, Āyurveda contributes a practical approach to reducing entropy. To Āyurvedic guidance for maintaining health and extending lifespan based on the circulation of *prāṇa*, the second axiom of thermodynamics in open systems adds an empirical tool for supporting human healthspan. To nutrition, exercise, and metabolism, the idea of a vital principle offers a fourth way to influence healthspan: reducing entropy across the body by regulating food and stimuli the body takes in and processes. This approach reinforces the view that chronological aging can be mitigated by treating disease.

6 Summary

In the context of current discussions of human healthspan, this paper has put the South Asian medical system Āyurveda in conversation with the second axiom of thermodynamics formulated for open systems. Each of these approaches to sustaining physical life supports a conception of a vital principle, directly in Āyurveda and indirectly in thermodynamics. Āyurveda offers practices for health based on the idea of a vital principle in the environment and in a human body. The second axiom formulated for open systems offers a mathematical account of internal processes that use energy in physical systems. Attention has been given to differences in their philosophical orientations, epistemological foundations, and applications. Rather than concluding that these two approaches are congruent, we have argued that each provides insights into the idea of a physical principle that sustains life. We have suggested how those insights might influence current thinking about the relationship between health and chronological age.

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