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A Review of Body Temperature from Avicenna to Modern Medicine

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Abstract
Maintaining a body core temperature within the range of 36.5 to 38.5°C is crucial for proper bodily functions. Avicenna's Canon of Medicine emphasizes the role of temperament and humoral medicine, considering quadruple qualities including hotness, coldness, wetness, and dryness. This study delves into Avicenna's viewpoints on body temperature, exploring the diagnostic and medical interventions based on Hekmat, an Islamic approach to humoral medicine. Avicenna's work underscores the importance of innate heat (*Hararat-e-gharizi*) for maintaining life. The study compares different kinds of heat, distinguishing between innate heat essential for vitality and external factors leading to alien heat (*Hararat-e-gharibeh*) causing corruption/infection in the body. Avicenna's insights align with modern thermoregulation concepts. The article discusses the role of core temperature in longevity, the impact of thyroid hormones, and the connection between body temperature and diseases. Avicenna's emphasis on adhering to lifestyle rules and avoiding factors that diminish intrinsic heat echoes contemporary notions of health maintenance. Avicenna's holistic approach to body temperature provides a unique perspective on health. Aligning traditional viewpoints with modern findings can contribute to a comprehensive understanding of the intricate relationship between body temperature and well-being.

Key words: Avicenna, Persian Medicine, Temperament, Temperature, Traditional Medicine

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Introduction

Complete and proper functioning of the body is dependent on maintaining a body core temperature (Tc) of between 36.5 to 38.5°C. Malfunctioning of body systems occurs when Tc increases or decreases from these values; the greater the variance, the higher the malfunction (Moran and Mendal, 2002, pp. 879-885). The thermal regulation center of humans is located in the hypothalamus in the brain (Boulant, 2000, pp. S157-S161). Abstractly, this area of the brain can be considered as a thermostat, which begins heat loss responses when human body temperature is sensed as "too hot" and keeps heat or produces it when the temperature is sensed as "too cold" (Charkoudian, 2003, pp. 603-612). Fever, hyperthermia, hypothermia, and fatigue are various aspects of the thermal imbalance in the human body.

The importance of human body temperature and heat was well diagnosed in Persian medicines (Vaghasloo, Naghizadeh and Babashahi, 2017, pp. 3-8). Persian Medicine (PM) considers body temperature regulation as a balance of the four qualities—hot, cold, moist, and dry—a theory that is central to the understanding of health and disease in PM. While Avicenna's contributions are significant, it is important to recognize that these ideas were also present in the works of earlier physicians. Avicenna, however, provided a more structured and comprehensive interpretation of these principles, which has had a lasting impact on PM (Shirbeigi, et al., 2017, pp. 143-156; Jackson, 2001, pp. 487-489).

The regulation of body temperature is a critical aspect of human physiology, extensively explored in modern medical science. However, the historical perspectives provided by Persian Medicine (PM), particularly through the works of Avicenna, offer valuable insights that are often overlooked. This review aims to bridge the gap between these two paradigms by exploring body temperature regulation from Avicenna's writings to contemporary scientific understanding. Core body temperature (Tc) and its implications for health are central to both modern and traditional medical systems, and this review seeks to highlight the contributions of PM alongside modern scientific advancements (Jackson, 2001, pp. 487-489; Tipo, Khanam and Khan, 2019, pp. 31574-31577).

Methods

The leading medical textbook of Persian medicine authored during the 10th to 11th centuries, *Canon of Medicine* by Avicenna, was studied to derive all reported evidence and viewpoints on body temperature and health including. This book is not only a summation of other traditional medical system information but also a collection of its author's experiences (Khaleghi Ghadiri and Gorji, 2004, pp. 80-83).

To compare and contrast the medieval approaches recommended by this Persian scholar with the current findings, an additional search was performed using databases such as the Cochrane Library, Google Scholar, PubMed, and Scopus. As in PM, energy modification for the maintenance of health is called "*Hararat-e-gharizi*" (innate heat) and "*harārat*" (heat). It is considered the essence of well-being. Subsequently, we searched the exact term of lifestyle modifications (*Tadabir*) in the books. Then, we collected issues about temperament and health and classified the results based on the type of modification.

Results

Heat in modern science is defined as a quality that causes the mobility of molecules. It is measured by different methods and scales; the most common are Fahrenheit, Celsius, and Kelvin. For example, water has frozen at 0 degrees Celsius or centigrade and boils at 100 degrees. Survival depends on keeping the innate heat in a physiologic range to prevent any disturbance in normal functions of the body organs. Physiologic thermoregulation comprises thermal changes due to energy loss through vasodilation, perspiration, and heat production (shivering) reacting to different internal or external stimulants (Charkoudian, 2003, pp. 603-612). The normal function of the organs depends on keeping the central heat in a range between 36.5 and 38.3 degrees centigrade. More deviation from the physiologic range results in more disturbances in normal bodily functions (Moran and Mendal, 2002, pp. 879-885).

The preoptic part of the anterior hypothalamus is the main center of body temperature set-out (Boulant, 2000, pp. S157-S161). This area controls the body's thermostatic state; it wastes the extra heat when it perceives high temperature and produces heat with the perception of low temperature (Charkoudian, 2003, pp. 603-612).

Thyroid hormones also play an essential role in the control of body temperature. The action of thyroid hormones, secretion of norepinephrine, and the presence of free fatty acids activate uncoupling proteins in the skeletal muscles that play a role in skeletal muscle heat production (Sprague, et al., 2007, pp. 274-280).

Body Temperature

Body temperature control is located in the preoptic/anterior hypothalamus (PO/AH) in the brain (Lipton, 1973, pp. 890-897). Theoretically, this part of the brain can be related to a temperature regulator of the body, which initiates heat wastage responses when body temperature is sensed as "too hot" and heat conservation or heat generation when the temperature is sensed as "too cold" (Charkoudian, 2003, pp. 603-612). The local temperature of the skin also contributes significantly to the control of cutaneous blood flow at that site (Johnson and Kellogg Jr, 2010a, pp. 1229-1238). Vasodilation of heated-up areas is followed by local skin warming (Taylor, et al., 1984, pp. 191-196). The optimal local skin temperature to achieve maximal dilation of skin blood vessels in healthy individuals is 42°C, while local cooling of the skin can induce potent localized vasoconstriction that can even reduce skin blood flow to zero. (Charkoudian, 2003, pp. 603-612; 2010, pp. 1221-1228).

Body Thermoregulation

Thermoregulation of cutaneous blood flow is vital for the maintenance of core body temperatures (Charkoudian, 2003, pp. 603-612). Two groups of sympathetic nerves have unique effects on the human cutaneous circulation (Johnson and Kellogg Jr, 2010b, pp. 825-853). The sympathetic adrenergic vasoconstrictor nerves coexist with sympathetic vasodilator nerves, a less well-understood system that is activated during hyperthermia (Kellogg Jr, 2006, pp. 1709-1718). All areas of non-glabrous skin are innervated by sympathetic vasoconstrictor and vasodilator nerves, whereas glabrous skin areas such as palms, soles, and lips are innervated only by sympathetic vasoconstrictor nerves (Johnson, Minson and Kellogg Jr, 2011, pp. 33-89). Arteriovenous anastomoses (AVA) are another critical distinction between glabrous and non-glabrous skin, which are thick-walled, low-resistance conduits that allow high flow rates directly from arterioles to venules. In glabrous skin, AVA is numerous and richly innervated by sympathetic vasoconstrictor nerves. Therefore, opening or closing of this AVA in these areas can cause substantial changes in skin blood flow (Charkoudian, 2003, pp. 603-612). Cutaneous sympathetic vasodilator and vasoconstrictor systems play either in thermoregulation or blood pressure set-out, hereupon dysfunction in either of these systems could have significant consequences for both processes (Charkoudian, 2003, pp. 603-612; Charkoudian, 2010, pp. 1221-1228).

Core Temperature

Complete and proper operation of the body is dependent on maintaining a body core temperature (Tc) of between 36.5 to 38.5°C. Human body systems Malfunctioning occurs as the Tc increases or decreases from these values; the higher the variance, the greater the malfunction (Moran and Mendal, 2002, pp. 879-885). Tc above 41.5°C or below 33.5°C causes a rapid deterioration in the proper functioning of the body leading to severe complications or even death (Moran and Mendal, 2002, pp. 879-885; Hensel, 1981).

High Core Temperature

Although an increase in Tc in the body may be due to two different mechanisms, the result of both can be fatal (Moran and Mendal, 2002, pp. 879-885). Firstly, it may be due to the failure of one or more organ systems in the body, accompanied by possible infection or pollution, resulting in fever (Moran and Mendal, 2002, pp. 879-885; Brekhman, 2013). Secondly, by a disturbance in the sensitive balance between the total body heat production and the amount of heat emitted from the body, mainly by sweating (Moran and Mendal, 2002, pp. 879-885).

Although the mechanisms of these beneficial responses of fever, as a nonspecific acute-phase response, are poorly understood, it has been associated with improved survival and shortened disease duration in infections (Jiang, et al., 2000, pp. 1265-1270). Internal body temperature may be increased due to fatigue during exercise in the heat. Endotoxins and heat shock proteins released from the internal organs may be associated with fatigue by inducing hyperthermia. Alternatively, hyperthermia, by influencing the motor control center in the brain, might reduce the central drive for exercise (González-Alonso, et al., 1999, pp. 1032-1039). Skeletal muscles can use both lipid and glucose as fuel, depending on their need and accessibility to proper fuel (Li, et al., 2015, pp. 23-35).

Body Heat in Persian Medicine

The diagnostic approach and medical interventions in Persian medicine (PM) are very different from conventional medicine because of different basics. Some concepts in PM are considered principles of PM School. Every physician who wants to practice in PM should learn these basics. Despite the importance of “innate heat” in PM, it is less paid attention to because of its complexity either theoretically or practically. The innate heat, as mentioned in PM resources, is very different from heat and temperature in general meaning. The innate heat is the source of energy for body organ function. However, in PM, four elements (fire, air, water, and earth) are presented as the essential elements of every creature including inanimate, plants, and animals, but the reality is that the definition of the Iranian sages from these elements are very different from what we know from fire, air, water, and earth. They considered fire, air, water, and earth as the presentative of quadrupled qualities, including warm-dry, warm-wet, cold-wet, and cold-dry. Warm and cold are active and wet and dry are passive qualities (Ibn-abbas, 2008). Neither living nor nonliving things could be considered free from one of these quadruple-paired qualities. Avicenna believed that heat as the first quality is the source of life and all motions and activities throughout the universe (Avicenna, 2007).

Human beings have a unique constitution among all animals. Deviating from the average constitution or temperament risks his health. Four elements with different qualities including hotness, coldness, wetness, and dryness counteract each other to make human beings balance in temperament. Balance in qualities does not mean the same quantity of the elements but keeping them in a ratio, proper to human constitution for health maintenance and normal body function. Each body organ possesses its unique temperament. The heart regarding the brain is considered hot-dry, the brain regarding the heart is cold-wet, and the liver is considered hot-wet (Jackson, 2001, pp. 487-489). The skin possesses a temperament of average regarding the other organs. Every organ has the best functionality in its specific temperament, and if it loses its average temperament, its function is disturbed. Generally, all organs are hot-wet in temperament, and the description, as mentioned earlier of paired qualities for them, is comparative. The organ function is disturbed if it loses its real innate heat and turns toward coldness (Avicenna, 1978).

Different Kinds of Heat

The concept of heat is different in modern medicine comparing PM, and it is considered just a physical notion that is measured by physical instruments. In terms of modern science, the heat that ripens the fruits, and one that spoils them are the same, and the only difference between these two processes is the function of microorganisms on the second one. On the contrary, in PM the innate heat is a vital energy, similar to Chi in Chinese medicine, that conveys vital forces throughout the body.

The surface temperature of the body and its core temperature are different because the body's surface is in direct contact with the external environment and accordingly is affected by the outside temperature changes. The core body temperature is usually higher than the skin temperature or the temperature of the surrounding environment, except in extreme climatic conditions, and its range of variation is more limited to protect the internal organs and maintain normal body function. The opening of the skin pores, due to attenuation of sympathetic activity, is a compensatory mechanism to dissipate the extra heat out of the body. Closing the pores, which is usually because of cold exposure and heat loss prevention, is a body-defending mechanism against external environmental changes (Johnson and Kellogg Jr, 2010a, pp. 1229-1238).

PM sages believed in different kinds of heat including *gharizi* – the innate heat – which maintains body health and *gharibeh* – alien heat – which corrupts the body. *Hararat-e-gharibeh* – alien heat – is produced by *Ajram-e-gharibeh*– malicious microorganisms- while the immune system is attenuated by any cause.

According to Aghili Shirazi, there are two types of heat in the body: *Hararat-e-gharizi* –instinctive (innate) - belonging to the animal soul which is essential for life, and "*ostoghosi*," which belongs to the natural soul, and is essential for normal body functions including nutrition, growth, and reproduction that it needs the instinctive heat to accomplish its duties (Johnson and Kellogg Jr, 2010a, pp. 1229-1238).

"*Hararat-e-gharizi*" is a soft steam of the physical soul which conveys the natural warmth throughout the main body organs including the heart, brain, and liver, to maintain life. The warmth of intrinsic heat does not have burning, infectivity, maliciousness, or corruption, and it is the sign of life appearing in time of birth and vanishing with death. It is in counter-part of *Hararat-e-gharibeh* and it is not produced by foods and drinks and when it is extinguished by any causes, the physical existence is not possible anymore (Taylor, et al., 1984, pp. 191-196).

Avicenna mentions in the *Canon of Medicine* that intrinsic heat protects the internal body organs against the thermal changes of the external environments. Accordingly, any factors that attenuate the intrinsic heat endanger normal body homeostasis and vice versa (Lipton, 1973, pp. 890-897). Philosophically, *hararat-e-gharizi* is regarded as substantive while the other sorts of body heat are considered accidental.

The accidental heat, which comes from the foods and drinks, takes the place of energy which is lost in the process of normal body function and physical activities. However, the accidental heat does its tasks properly just under the establishment of the main source of life which is the intrinsic heat, otherwise, it would degenerate into the alien heat - *Hararat-e-gharibeh* - and corrupt the body.

Measurement of Heat

There are several ways to determine body temperature, including oral, dermal, axillary, rectal, oesophageal, tympanic membrane, and urinary bladder catheter (Moran and Mendal, 2002, pp. 879-885). Peripheral thermometers do not have adequate accuracy to be used for measuring body temperature in clinical decisions (Niven, et al., 2015, pp. 768-777).

In Persian medicine, the physician who takes the temperature of the patients by checking the hand'palpation should be moderate in mezaj or know the temperance *mizaj* of the community. Hence, the measurement of heat is qualitative in Persian medicine while it is quantitative in modern medicine. One way to determine the temperature of every body organ is palpation (*malmas*) of the skin covering that specific organ. For example, palpation (*malmas*) of the head, liver, and stomach helps the physician for the determination of the heat intensity of that organ. Meanwhile, the passive (*monfa'eleh*) qualities including wetness and dryness may also be estimated further than the active (*fa'eleh*) qualities warmth and coldness. The physicians should not be limited to palpation to determine *mizaj* and qualities, but it is essential to apply other ways including thorough history taking and physical examination. The most important issues in history taking that help the physician for better evaluation of *mizaj* and estimating true intrinsic heat include the climate, accommodation, quality, and quantity of sleep, physical activity, bowel habits, mental states, and how the patient is affected by environmental and climatic changes.

Body Temperature and Health

Blood flow thermoregulation in the skin is vital for establishing normal homeostasis and maintenance of normal body temperature (Charkoudian, 2003, pp. 603-612). All animals use the same mechanism for survival by maintaining body heat and minimizing energy loss. Winter sleep, migration to tropical areas, and increasing adiposity or piloerection are considered the ways of keeping the body heat (Hauton, Coney and Egginton, 2009, pp. 514-522).

Fever is a rapid response to the acute phase of the disease and generally leads to a decrease in the infectious disease period (Jiang, et al., 2000, pp. 1265-1270).

Local warming causes dermal vasodilation. At 42 degrees centigrade, a rapid increase in temperature happens in the first minutes, then a moderate increase, and finally, it sets in a constant point. Capsaicin in the pepper acts similarly by attaching to the vanillic receptors in the nerve endings, depolarizing them, and producing a local heat in the applied area (Charkoudian, 2003, pp. 603-612).

Using cold press causes local vasoconstriction via stimulation of adrenergic nerves and could be neutralized by noradrenergic such as bretylium (Charkoudian, 2003, pp. 603-612).

The cerebral temperature has been recognized as an influential factor in ischaemic brain damage. Many reports indicate that systemic temperature may be quite different from brain temperature, and the pathophysiological basis of such differences is not fully understood. Fever is persistent after acute cerebral damage, and the cerebral temperature is significantly higher than the body's core temperature. Studies showed that the temperature rise is associated with derangements of intracranial volume homeostasis documented by increases in ICP (Rossi, et al., 2001, p. 448).

Low HRV reflects a failure of command-and-control mechanisms to the heart or cardiac uncoupling. The autonomic nervous system is a likely candidate for this failure (Mowery, et al., 2011, pp. 534.e9-534.e17).

The appearance of mood disturbances in patients with acute stroke is due in part to thermoregulatory mechanisms triggered by acute brain injury (Prasad, 2009, pp. 226-227).

Therapeutic hypothermia maintained at a target temperature of 33°C ± 1°C over 18 hours independently correlated with favorable neurological outcomes (Shinozaki, et al., 2012, pp. 1838-1844). Lower body temperatures contribute to the enhanced metabolic efficiency of the obese state (Landsberg, et al., 2009, pp. 871-876).

Keeping patients who suffered a heart attack ventricular arrhythmia at 33 degrees Celsius will reduce the chance of future neurologic complications (Li, et al., 2015, pp. 23-35). It seems that obese people decrease their body heat to put the body in a state with more metabolic efficiency. In other words, the consumed calories are used to produce fat tissues rather than convert them to heat (Ibn-abbas, 2008).

Studies have shown that maintenance of the internal temperature (Core temperature) increases longevity in animals. Calorie restriction in humans maintains weight and micronutrient supply and reduces the internal heat level. The decrease of Triiodothyronine seems to have a role in reducing the internal heating caused by dietary restriction (Avicenna, 2007).

According to Avicenna's belief, the main factors contributing to longevity include maintenance of the innate heat and avoiding retention of the wastes - alien moistures –in the body that is acquired solely by regarding the six essential rules for life including air (climate), food and drink, sleep and waking, movement and stillness, retention and release, and finally mental states or moods. Non-compliance with the aforementioned rules puts the body at risk of various diseases and premature extinguishing of the intrinsic heat that is death. Some examples that diminish the intrinsic heat and attenuate the immune system are overindulgence in food and drink, plethora, sleep disturbances, and inability to handle stress (Johnson and Kellogg Jr, 2010a, pp. 1229-1238).

From the perspective of Persian medicine, intrinsic temperature plays a significant role in proper food digestion as well as normal growth and development. Any disturbance in liver homeostasis leads to a mismatch in the humors (phlegm, sanguine, bile, black bile) produced by the liver and increases wastes in the body. Disposal of these wastes would not be possible without the help of intrinsic heat, and these both will lead to more exhaustion of the intrinsic heat and predisposition to disease and shortened life span.

Heat-Related Diseases

Fatigue in hot weather is due to increased heat in the body (Vaghasloo, Naghizadeh and Babashahi, 2017, pp. 3-8). Hyperthermia causes the secretion of more endotoxin and heat shock proteins in internal organs, which may contribute to fatigue and decrease the inclination for activity by affecting the related center in the brain (Vaghasloo, Naghizadeh and Babashahi, 2017, pp. 3-8). Temperatures below 33.5 and over 41.5 quickly cause irreversible damage to the body and, finally, death (Boulant, 2000, pp. S157-S161).

Brain temperature is an essential factor in the creation of brain damage is known. Many studies have shown that the temperature inside the body (core temperature) varies with the cause is not known so far. Fever after the acute brain shot is a common finding, and brain temperature is higher than body temperature. Clinical studies indicate that the increase in brain temperature is associated with disturbances in homeostasis of intracranial volume that are accompanied by increased intracranial pressure after acute brain injury (Johnson, Minson and Kellogg Jr, 2011, pp. 33-89). Raising temperature may decrease heart rate variability in patients who suffer from physical activity. It seems that in trauma patients, a disorder of the central nervous system results in decreased proper response to stimuli and heart rate fluctuations not controlled by the heart (Avicenna, 1978). Mood disorders in individuals after a stroke may be due to decreased blood flow to the brain through automatic thermal regulation to control bleeding (Niven, et al., 2015, pp. 768-777). In a group of patients who are undergoing surgeries, anesthetic gases cause the release of calcium in skeletal muscle, leading to a dangerous increase in body temperature that may be fatal without a fast proper intervention (Eltit, et al., 2012, pp. 7923-7928).

There are several points of convergence between conventional medicine and PM regarding the clinical manifestations and complications associated with abnormally elevated body temperature. In Persian medical literature, any substantial alteration in the four primary qualities—heat, coldness, moisture, and dryness—is believed to disturb the organ's temperament (*Soo-e-mizaj*), and, if sustained, may ultimately culminate in overt disease. For example, persistent predominance of coldness in the brain is thought to impair its normal function and may be associated with cognitive decline or mental underperformance. Likewise, when coldness and moisture prevail in the stomach, impaired digestion and a sense of postprandial heaviness are frequently observed. Conversely, excessive heat in any organ can disrupt its physiological function. For instance, an excess of heat in the head has been linked to tremors of the hands, whereas increased heat in the stomach is commonly associated with dyspepsia or heartburn. When the body is exposed to intense exogenous heat, this external thermal load can dissipate and deplete the body's intrinsic moisture. Over time, such a process may result in reduced or absent sweating (anhidrosis), along with non-specific symptoms such as fatigue and general malaise. The brain, in particular, is considered highly sensitive to heat. In contrast to the heart—which is inherently adapted to a relatively warm environment—the brain is described in Persian medicine as requiring a cooler and more humid milieu in order to maintain its normal activities. Accordingly, sustained exposure to excessive heat in the brain is regarded as a major factor that can significantly compromise its functional integrity.

Body Heat and Foods

According to PM sources, people with negative energy balance are bothered by thermogenic foods and spices such as pepper and green tea. However, Reinbach, et al. found the benefit of these compounds in decreasing the appetite of people with positive energy balance (Reinbach, et al., 2009, pp. 260-265), which is in line with PM notions that hot-dry medicines. i.e., mustard and pepper, improve digestion in people with the dominance of GI tract phlegm suffering flatulence and dyspepsia (Avicenna, 1978).

Conclusion

Avicenna's contributions to the understanding of body temperature and its relation to health remain a significant foundation in Persian Medicine. While these principles were present in earlier works, Avicenna's structured approach has provided a lasting framework that continues to resonate with modern scientific advancements. This review highlights the importance of integrating historical perspectives from PM with contemporary research to enrich our understanding of body temperature regulation. Four qualities is a neglected issue among modern physicians, however, some aspects of it, such as the relation between abnormal heat and health are partly studied in modern nutrition and sports medicine. Acute infectious illnesses, such as fever and malignant hyperthermia after injection of anesthetics, are subjects of debate in recent literature, however, PM looks to the quadruple qualities as more comprehensive and basic. In Persian Medicine, foods that increase body temperature are often discussed within the framework of their *mizaj*, meaning their inherent quality, which influences the body's overall temperament. Functional foods, with their specific *mizaj*, contribute additional qualities to the body's internal environment, affecting temperature regulation. PM sages believed that the innate heat (energy) affects the ingested foods first in the GI tract and then in the liver and through the three processes of digestion in GI, liver, and blood vessels, the components diverted from the food may generate the aforementioned additional qualities. This issue may be comparable with the kinetics of primary and secondary metabolites in the context of functional foods in modern literature.

The role of internal temperature homeostasis in longevity has recently been experimented with using various physiological and environmental factors. On the other hand, in PM, innate heat preservation is the most important factor for increased longevity. Tailoring new clinical trials about the influence of dietary habits and body temperature can reconcile traditional and modern viewpoints in this field of study.

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Authors' Contribution

Babak Daneshfrad reviewed, edited, and finalized the paper. Faranak Alembizar contributed to the investigation and editing the paper. Majid Nimrouzi conceived the idea of this study, conducted the investigation, and provided the primary draft. All authors read and approved the final version of the work.

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Conflict of Interest

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