

# Scientific exploration and hypotheses concerning the meridian system in traditional Chinese medicine

Wenchuan Qi<sup>1,2</sup>, Bin He<sup>1</sup>, Qingxin Gu<sup>1</sup>, Yongming Li<sup>3</sup>, Fanrong Liang<sup>1,2,4,\*</sup>

<sup>1</sup>School of Acupuncture-Moxibustion and Tuina, Chengdu University of Traditional Chinese Medicine, Chengdu, China; <sup>2</sup>Key Laboratory of Acupuncture for Senile Disease (Chengdu University of TCM), Ministry of Education, Chengdu, China; <sup>3</sup>American Traditional Chinese Medicine Society, New York, NY, USA; <sup>4</sup>Sichuan Clinical Medicine Research Center of Acupuncture-Moxibustion, Chengdu, China

## Abstract

The meridian theory is an important component of traditional Chinese medicine, playing a crucial role in disease diagnosis, treatment, and health preservation. Serving as the media for the effects of acupuncture, moxibustion, herbal medicine, and acupressure massage, meridians exert undeniable impact on the human body. However, the essence of meridians remains a topic of debate. Recent research has primarily focused on their anatomical structures, leading to numerous hypotheses. Simultaneously, other researchers have approached this subject from an energetic perspective, discovering information interactions within the meridian system. These findings suggest that meridians possess both physical and information dimensions, indicating that a singular approach to their study is insufficient. To bridge this gap, a shift from purely structural research toward an exploration of the information aspects of meridians is necessary. By integrating this information approach with traditional meridian theory, it may be possible to develop a new, modernized meridian theory that is aligned with contemporary concepts, making it more accessible and applicable in clinical settings.

**Keywords:** Communication, Information state, Meridian essence, Physical state

**Graphical abstract:** <http://links.lww.com/AHM/A133>.

## Introduction

On April 10, 2021, *Science* published a list of the 125 most concerning scientific questions in the world. In the field of medicine and health, the sole question related to traditional Chinese medicine (TCM) was whether there is a scientific basis for the meridian system. According to the *Yellow Emperor's Canon of Internal Medicine*, “Meridians are prone to various diseases, running *qi* and blood, and cannot be blocked.” However, the ancient depiction of meridians as “running *qi* and blood” is somewhat vague, making it challenging for us to fully comprehend their nature. Do meridians possess a tangible structure? If not, why can acupuncture at specific acupoints effectively treat corresponding illnesses, with some individuals even exhibiting notable phenomena such as propagated sensations along the channel (PSC)? Although recent research has illuminated the potential underlying mechanisms of acupuncture and moxibustion from neuroanatomical and biomolecular perspectives, the true essence of meridians remains unclear, awaiting further elucidation. In clinical practice, we frequently extol the outstanding efficacy of acupuncture and moxibustion, yet we remain perplexed by the underlying mechanisms that drive their

therapeutic benefits. Only by thoroughly understanding what meridians truly are can we utilize acupuncture and moxibustion techniques more effectively in clinical settings.

## The hypothesis of meridian essence

In ancient Chinese medicine, meridians were initially referred to as “pulses” and later subdivided into Jingmai (main meridians) and Luomai (collateral meridians), collectively known as meridians. The development of the meridian theory has undergone continuous refinement, evolving from observation to summarization, and from practice to theory. By observing pulses, inquiring about patients' sensations, and incorporating insights from ancient anatomical observations, early practitioners synthesized various factors to create the ancient “science of meridians.” This process was largely completed during the early Western Han Dynasty, laying the foundation for the meridian theory in TCM<sup>[1,2]</sup>. *Yin* and *yang* meridians hold particular significance within the TCM meridian system. *Yin* meridians are internally oriented, associated with internal organs, and are responsible for transporting nutrients and energy. They reflect the health of internal organs and help regulate the balance of *qi* and

\*Corresponding author. Fanrong Liang, E-mail: [acuresearch@126.com](mailto:acuresearch@126.com).

Received 3 February 2024 / Accepted 12 August 2024

**How to cite this article:** Qi WC, He B, Gu QX, Li YM, Liang FR. Scientific exploration and hypotheses concerning the meridian system in traditional Chinese medicine. *Acupunct Herb Med* 2024;4(3):283–289. DOI: 10.1097/HM9.0000000000000128

Copyright © 2024 Tianjin University of Traditional Chinese Medicine. This is an open-access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 (CCBY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.

blood. *Yang* meridians, on the other hand, run externally, involving the body surface, muscles, bones, and nerves. They regulate the functions of the body surface, reflect its health, and guide external treatment methods such as acupuncture. The interaction between *yin* and *yang* meridians maintains the flow of *qi* and blood, as well as physiological functions, which are of great significance for diagnosis and treatment in TCM. Through a comparative analysis of Han Dynasty bamboo and silk manuscripts and modern anatomical research, Li<sup>[1]</sup> discovered that, among the 74 symptoms studied, 39 were directly linked to the nervous system (52.7%), 33 were pain-related (44.6%), and 27 were associated with internal organs (36.5%). Remarkably, most of the pain symptoms and nervous system disorders originate from the *yang* meridians, while nearly all visceral diseases occur within the *yin* meridians. Nervous system disorders or pain symptoms originating from *yin* meridians are rare, with the exception of ischemic angina. These findings suggest that the *yang* meridians described in the Han Dynasty silk medical texts likely correspond to the structures, physiology, and pathology of the modern nervous system as observed by doctors at that time, while the *yin* meridians primarily refer to the structure, physiology, and pathology of the large arteries in the upper and lower extremities [Supplementary Table S1, <http://links.lww.com/AHM/A135>]<sup>[1]</sup>. This anatomically based understanding offers new perspectives and evidence for understanding the essence of meridians.

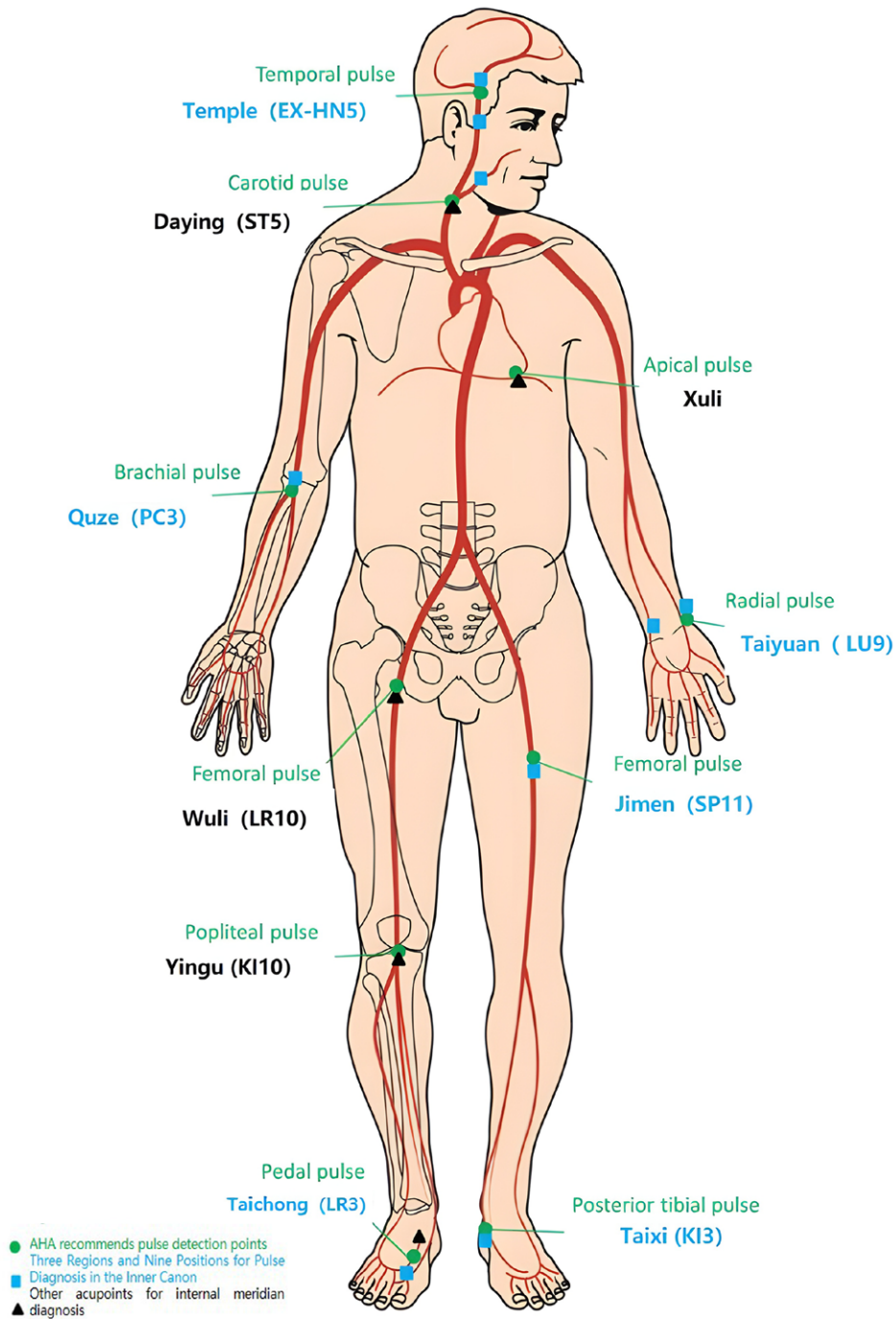
In recent decades, significant research on the essence of meridians has been conducted both domestically and internationally, leading to the formation of several key hypotheses. The “vascular hypothesis” suggests that the foundational structure of meridians may correspond to blood vessels, particularly the arterial network. Some perspectives propose a resemblance between the depiction of meridians and the vascular system, especially in the arrangement of arteries<sup>[3]</sup>. The observation of sensory conveyance along meridians could be attributed to the unique configuration of blood vessels, implying that the abundance of blood vessels within tissues along the meridians may serve as the material basis for meridians<sup>[4]</sup>. The literature has proposed the hypothesis that “*yin* meridians correspond to arteries”<sup>[5]</sup>. Through a comparative analysis of Han Dynasty bamboo and silk manuscripts and modern anatomical research, Li<sup>[1]</sup> discovered that the original anatomical basis for the six *yin* meridians described in the Han Dynasty manuscripts likely corresponds to the major arteries of the four limbs. Notably, the inclusion of the Hand Jueyin Pericardium Meridian is highly consistent with the modern anatomical discovery of the persistent median artery, further supporting the correlation between *yin* meridians and arteries. Interestingly, the commonly used pulse detection points in modern medicine are all located on the 12 meridians of TCM. These critical pulse points already have corresponding acupoint names in Chinese medicine and are categorized as pulse diagnosis acupoints. This is not a coincidence but rather evidence that TCM identified these pulse points more than 2,000 years ago<sup>[1]</sup>. Through practical experience, the significance and meaning of pulse diagnosis were summarized, and these points were incorporated into the meridian and acupoint

system, further solidifying the meridian theory of TCM to guide clinical practice (Figure 1)<sup>[5]</sup>. Nevertheless, further scientific investigation is imperative to validate this hypothesis and to elucidate specific characteristics of meridian phenomena, such as the rate of sensory transmission along meridians and the complexity of bidirectional transmission.

The “neural hypothesis” regarding the essence of meridians primarily suggests that the phenomenon of meridians is intricately linked with the functionality of the nervous system<sup>[6-7]</sup>. This theory underscores a notable alignment between the pathways of meridians and the distribution of nerves, proposing that the manifestation of meridians may be a functional expression of the nervous system. Essentially, the neurological perspective maintains that sensory transmission along meridians is a consequence of excitation propagation between neurons<sup>[8]</sup>. When exploring the essence of *yang* meridians, Li<sup>[1]</sup> suggested that they may correspond to certain structures and pathological phenomena of the nervous system as observed by medical practitioners of the time. For instance, many diseases associated with *yang* meridians are linked to nervous system disorders in modern medicine, and *yang* meridians are primarily distributed along the outer side of the human body, which is consistent with the distribution patterns of nerves<sup>[1]</sup>. This finding offers a new perspective on the nature of *yang* meridians. While the neural hypothesis provides an explanation for certain meridian phenomena, it does not fully account for all the attributes and functions of meridians. For instance, the TCM theory includes concepts such as the circulation of *qi* and blood and the interconnection between organs, which are complexities that neuroscience alone finds challenging to elucidate.

The “myofascial hypothesis” has gained prominence in recent years as a theory exploring the fundamental nature of meridians. It proposes that the essence of meridians may be intricately linked to the structure of the human myofascial membrane. This theory aligns closely with the concept of myofascial chains in terms of material composition, holistic nature, and pathological manifestations, thus offering modern anatomical support for the theory of meridians and tendons<sup>[9]</sup>. The fascia system, primarily composed of connective tissue, forms a comprehensive tension network that interconnects the entire body, echoing the concept of meridians as channels for the circulation of *qi* and blood, extending throughout the body. The myofascial hypothesis offers a plausible explanation for the essence of meridians, particularly given the fascia’s fluidity, its clinical applications, and its association with acupuncture points.

The “humoral channel” hypothesis offers an interpretation of the essence of TCM meridians, positing that meridians may potentially serve as conduits for tissue fluids, particularly those involved in fluid dynamics. This hypothesis aligns with the TCM concept of *qi* and blood flow within the meridian theory. Researchers have identified the anatomical structure of the “human tissue fluid circulation network” using magnetic resonance tracing imaging and high-resolution biological imaging techniques, suggesting that this network may represent one of the physical foundations of meridians<sup>[10]</sup>.



**Figure 1.** Comparison of the arterial pulse points to pulse diagnosis acupoints<sup>[6]</sup>. The commonly used human arterial pulse detection points on the body surface are recommended by medical institutions such as the AHA. The pulse diagnosis acupoints are derived from the Nine Pulses in Three Parts theory in the Inner Canon of Huangdi and other literature from the same period, where the arteries are merely illustrative. AHA: American Heart Association; EX-HN5: Taiyang acupoint; KI3: Taixi acupoint; KI10: Yingu acupoint; LR3: Taichong acupoint; LR10: Zuwuli acupoint; LU9: Taiyuan acupoint; PC3: Quze acupoint; SP11: Jimen acupoint; ST5: Daying acupoint.

In the field of TCM meridian research, the “functional complex hypothesis” offers a theory that seeks to explain meridian phenomena by integrating multiple systems and functions. According to this hypothesis, the essence of meridians may be a three-dimensional structure that integrates multiple systems and functions, rather than being limited to a single structure or function<sup>[11]</sup>. The hypothesis suggests that the meridians could represent a tangible three-dimensional network involving nerves, bodily fluids, energy transmission, and other systems. In TCM,

meridians are believed to play an important role in promoting blood and *qi* circulation, balancing *yin* and *yang*, influencing life and death, and treating various diseases. The functional complex hypothesis aims to capture the regulatory role of meridians in both physiological and pathological processes of the human body. While this hypothesis provides a comprehensive theoretical framework for understanding the diverse roles and forms of meridians, it remains in the exploratory stage and requires further scientific evidence for validation and refinement.

There are significant differences between the meridian theory of TCM and the theoretical framework of modern medicine. TCM emphasizes holistic concepts, including the theories of *yin-yang* and the five elements, as well as the theory of *qi* and blood. In contrast, modern medicine places more emphasis on research within the realms of anatomy, physiology, and molecular biology. These differing theoretical frameworks make it challenging to fully explain and verify the essence of meridians using contemporary medical approaches. To better align with current medical practices, we propose, based on existing research, two common states of meridians: physical form and information form.

### The physical form of meridians

A wealth of interdisciplinary research has been conducted to investigate meridians, leading to several significant findings. In addition to examining the vascular and nervous systems, studies have explored the structure of meridians from various perspectives, including the microcirculation system, lymphatic system, immune system, and connective tissue structures. Research has focused on elements such as blood vessels, neurotransmitters, cells, inflammatory factors, and proteins<sup>[12,13]</sup>. Theories, such as the “neural-endocrine-immune” and “cell-vascular-neuronal” network structures have been proposed<sup>[14-17]</sup>, highlighting the role of neural excitatory reflexes in PSCs<sup>[18]</sup>. This phenomenon originates from the central nervous system when acupuncture is applied at distal acupoints in the limbs<sup>[19]</sup>. Furthermore, researchers have demonstrated that stimulating meridians with sound waves can enhance recovery from peripheral nerve damage<sup>[20]</sup>. Despite these advancements, the precise physical form of meridians has not been fully elucidated and remains to be widely accepted.

### The information state of meridians

Information within the body serves as a crucial connection that integrates various parts of the organism, reflecting and regulating the functional status of the organs and body systems. This implies that meridians are capable of collecting and transmitting information from different body regions, facilitating coordinated bodily functions. Through their roles in communication, transportation of *qi* and blood, and the perception, loading, and transmission of information, the meridian system helps regulate the functional activities of the organs, enabling the complex physiological functions of the body to work in harmony and maintain the dynamic balance of *yin* and *yang*. The meridian system can be viewed as a synthesis of biological, physical, and chemical systems. Meridians and acupoints exist objectively and possess diverse structures, which can generate various biological signals through acupuncture and moxibustion. These signals can propagate from localized areas to the entire body. The flow of biological information in meridians is associated with the phenomenon of sensation along these pathways. The human body, a material system composed of numerous molecules and ions, is fundamentally an intricate physical and chemical system. Acupuncture and moxibustion act on meridians to generate physical and chemical signals.

Therefore, the information essence of meridians encompasses biological signals generated by physical and chemical reactions, including molecules, ions, electron flow, heat, electricity, magnetism, light, and pressure<sup>[21]</sup>.

Several researchers<sup>[1,5,22]</sup> believe that meridians are a conceptual combination of anatomical structure and physiological function. They serve as vital executors in controlling, operating, and regulating *qi*, blood, and body fluids, while aiding in the conversion of material energy within the body. They do not refer to a single anatomical structure but rather “to an overview and summary of the entire physiological function.” Nerves serve as important carriers for information transmission in the body. The neural hypothesis, when explaining the essence of meridians, tends to focus excessively on local neural structures and functions, and cannot fully encompass all the characteristics and functions of meridians. For instance, in the TCM theory, meridians involve the circulation of *qi* and blood as well as the connections between organs and meridians. Brizhik et al.<sup>[23]</sup> propose that even if meridians do not have specific anatomical structures, they are part of the dynamic when local and global systems interact. Kong et al.<sup>[24]</sup> introduced the quantum principal theory of the meridian system, which postulates that the influence of different parts of the human body on each other arises from the macroscopic quantum coherent state of the meridians. By administering tuina, acupuncture, moxibustion, and other traditional Chinese therapies to acupoints, the symptoms in the corresponding organ can be effectively adjusted with the aid of the quantum meridian state. The holistic view of *yin* and *yang* complementarity is the intersection of quantum physics and TCM<sup>[25]</sup>. This holistic approach suggests that meridians primarily serve as carriers of biological information. From an information theory perspective, this suggests that there exist various channels and circuits within the human body for transmitting information, and corresponding circuits must be established to exchange information between cells, tissues, and organs—the fundamental units that maintain life.

### The root of meridians lies in communication

As carriers of information, meridians not only reflect the physiological and pathological states of the human body but also serve as links between humans and the natural world. The concept of correspondence between heaven and humanity has always been a core tenet of TCM. The author posits that meridians establish the connection between heaven, earth, nature, and the human body. The celestial system and the human body's *qi* and blood both follow their own patterns of movement—a function enabled by the meridian system in the latter. The principles of treatment—“treating the excess with purging, treating the deficiency with supplementing, treating subsidence with moxibustion, and treating neither an excess nor a deficiency with acupuncture”—are used to stimulate the meridians and bring them back to a neutral physiological state. In their exploration of the human body, ancient Chinese people discovered and summarized these natural laws, aligning them with philosophical ideas of their time and expressing them through concepts such as *yin* and *yang*, the five elements, *qi*, blood, *ying*, and *wei*,

which together form the meridian system that we know today. Therefore, meridians provide us with information about life and the key to maintaining our health.

Under the influence of the emphasis of the Western scientific model on empirical evidence, modern individuals seek to comprehend the nature, structure, and underlying mechanisms of the meridian system. It is undeniable that modern thinking methods, when used to analyze the essence of the meridians, will facilitate the ongoing development of the theoretical framework of TCM and contribute to effective clinical practice. This line of research holds significant value. However, there is not necessarily one form of truth, and meridians do not necessarily have only one specific form. The meridians may be in a state that is visible or invisible. Of course, the essence of meridians cannot be explained by a single organ or tissue, but rather involves a complex network of multiple systems and structures. In particular, the correlation between *yin* meridians and arteries, and the similarity between *yang* meridians and nerves, also provide new perspectives for understanding the essence of meridians<sup>[1]</sup>. Our analytical paradigm should not be limited. Momentary changes in the human body include changes in information, and different manifestations of changes indicate different states of life.

### Prospects for the study of meridians

There have been many studies on the essence of meridians in recent decades, but the specific structure of the meridian system has not been clearly identified thus far. Despite numerous attempts to validate the accuracy of the hypothetical organizational structures of the meridian system, minimal progress has been made. Perhaps it is time to reassess our research approaches. The description of meridians in the ancient classic of Chinese medicine, Yellow Emperor's Inner Canon, poses a challenge; Professor Huang Longxiang once expressed the following doubt: the "meridians" or "collateral channels" mentioned in the classics clearly refer to blood vessels, but in some cases, they do not refer to blood vessels. Or they are like blood vessels, but not like blood vessels<sup>[26]</sup>. For thousands of years, interpretations of meridians by ancient people have been subjective and vague. The author believes that to make meaningful progress in the experimental research on meridians, a comprehensive review and synthesis of the related existing literature is essential. By analyzing the intricate descriptions of meridians in ancient texts from diverse perspectives, we can reconstruct the theoretical framework behind the meridians. This theory should subsequently be tested, validated, and refined through clinical trials and experimental studies. This process can be approached from two perspectives:

#### *Meridians as carriers of various kinds of information*

The meridians serve as vehicles for information, encompassing both the physiological and pathological states of the human body, which are intricately linked to the natural laws of the universe. The physiological state of the human body is a product of natural selection and an embodiment of these natural laws. Aligning the body with these laws leads to wellness, while deviation results

in disease and pathological states. Therefore, when studying the human body, it is essential to consider not only the body itself but also the meridians, which exist and undergo informational changes extending beyond material forms, regardless of their state. Current research often assumes material forms for the meridians and primarily investigates meridians from neuroanatomical and biomolecular perspectives using advanced technology, and clinical and animal experimental methods are generally used to identify the underlying mechanisms. While such research outcomes offer singular insights into specific aspects of the meridian system, they fail to capture its true essence. TCM posits that humans are interconnected and interdependent, with this theory reflecting and summarizing natural laws in the human body. The meridian system itself is considered an information field that connects the universe and humanity. Applying Western scientific methods to the study of TCM and meridian systems in a simple way may grossly misrepresent their true nature. In future research, it might be fruitful to initiate investigations with a holistic perspective derived from TCM's understanding of constant movement and the unity between nature and humanity. This approach might facilitate the identification of crossover points with modern medical research and offer fresh angles for exploring concepts of TCM, potentially leading to innovative ideas and breakthroughs.

#### *Meridians possess multiple physical structures*

The meridian system encompasses the entire structure of the human body. In addition to the findings of previous studies on structures such as blood vessels and nerves, researchers have recently discovered a potential interaction system within the meridians. This system is composed of cells and the extracellular matrix, which is widely distributed between organs, tissues, and cells, and may constitute a unique type of connective tissue<sup>[27]</sup>. Recent findings<sup>[28,29]</sup> have illuminated the ultra-structures of the channels responsible for the circulation of *qi* and blood within meridians—tissue microchannels formed by skin collagen fiber bundles and their components. These advancements have provided insight into the essence of the meridians, yet collagen studies constitute only a fraction of the vast ocean of meridian research. If we can liberate ourselves from the constraints of current research approaches and utilize existing findings to investigate unproven yet interconnected anatomical structures within the human body, we may discover new research angles rather than solely relying on known anatomical systems. This approach could lead to a deeper understanding of the material structure of the meridian system, potentially propelling forward research in related fields.

#### *More technical methods are needed for exploring the essence of meridians*

The modern scientific technologies and methods for the research of the essence of meridians cover many fields, including physics, chemistry, biology, and medicine. They include typical physical detection methods: exploring the relationship between meridian phenomena and physical quantities by measuring physical quantities such as

resistance, conductance, and magnetic fields on meridian lines<sup>[30]</sup>. This method helps reveal the physical properties of meridian phenomena. In recent years, with the continuous development of science and technology, some new technologies and methods have also been applied to the research of the essence of meridians, such as fluorescent tracer technology. By injecting sodium fluorescein as a contrast agent and using a laser to excite and photograph it, the migration trajectory of the fluorescent agent in the body can be obtained. This method helps to understand the flow characteristics of meridians<sup>[31]</sup>. Through the use of neuroimaging methods, the biological and physiological basis of meridian phenomena can be explored, by studying the relationship between meridians and physiological systems such as the nervous and endocrine systems. For example, neuroimaging technology is used to study the relationship between meridians and the nervous system. Currently, the quantum theory is used to explain meridian phenomena, and the quantum principle of meridians has been proposed<sup>[23]</sup>. Based on the concept of macroscopic quantum states of ion channels, researchers have proposed a quantum coherent state model of meridians. This model can explain the role of meridians in regulating organ symptoms. It is believed that with the continuous progress of modern science and technology, there will certainly be appropriate research tools to accurately and comprehensively reveal the essence of meridians.

#### *Studying meridians with related pathological manifestations*

Through in-depth research on pathological manifestations related to meridians, we gain a more comprehensive understanding of the complex role of meridians in human health and disease. When the physiological functions of meridians are imbalanced, tangible subtle substances or metabolites in the blood, tissue fluid, or body fluid can precipitate in the gaps, forming specific abnormal manifestations such as nodules or masses<sup>[32]</sup>. These abnormalities can intuitively reflect the deficiency or excess of *qi* and blood in the meridian to a certain extent, providing objective evidence for disease diagnosis. For abnormal manifestations such as nodules or masses caused by imbalanced meridian functions, physical therapies like acupuncture, massage, and cupping can stimulate meridian points to promote the circulation of *qi* and blood, while herbal formulas can regulate organ functions, improve fluid metabolism, and remove phlegm and dampness to dredge the meridians. With regard to the development and application of meridian diagnosis, modern meridian medicine expert Wang Juyi<sup>[33]</sup> recorded the contents of meridian diagnosis, meridian differentiation, meridian selection, and acupoint selection and matching in his book *Introduction to Meridian Medicine* which is applied in modern clinical medicine. Meridian diagnosis is the first step in clinical acupuncture and moxibustion diagnosis and treatment. Attention should be paid to the diagnosis of meridian acupoints to find the reaction points of diseases, in order to better identify the location of diseases, select acupoints, and improve the effect of treatment, providing a basis for further meridian syndrome differentiation and guiding the diagnosis and treatment of diseases<sup>[34]</sup>. Through modern anatomical research, a new interpretation of the “Nine Pulses in Three

Parts” pulse diagnosis method has been provided, pointing out that pulse diagnosis points are all located on important arteries, which further confirms the scientific nature of meridian diagnosis<sup>[5]</sup>.

#### **Conclusion**

The essence of meridians is complex and profound, which cannot be fully explained by a single structure. It interweaves a network of multiple physiological systems. Meridians are not only closely related to anatomical structures such as blood vessels and nerves, but also perform the critical function of transmitting and processing biological information. This unique dual attribute—the integration of the physical form and information form—collectively shapes the complete image of meridians. In general, the meridian system possesses a functional structure that can be considered as superior anatomy. The traditional meridian theory is primarily based on functions, yet these functions are derived from material structures. Therefore, a comprehensive understanding of the essence of meridians necessitates a substantial accumulation of experimental and clinical data. By combining these foundational research materials with the classical meridian system, it is possible to establish a new meridian theory that aligns with evolving international practices in modern acupuncture and moxibustion. Liberating ourselves from the constraints of previous anatomical studies and approaches to the study of meridians for the sake of adopting the perspective of information exchanges between nature and humanity could lead to a fresh perspective and new insights in medicine.

#### **Conflict of interest statement**

Fanrong Liang is the editorial board member of this journal. The other authors declare no conflict of interest.

#### **Funding**

This research was supported by the National Natural Science Foundation of China (82205286) and the National Natural Science Foundation of China (82074556). The regional cooperation program of the National Natural Science Foundation of China (U21A20404) and the Natural Science Foundation of Sichuan Province (2023NSFSC1819).

#### **Author contributions**

Wenchuan Qi, Bin He, and Qingxin Gu: Conceptualization, writing—original draft preparation. Yongming Li: Review and editing. Fanrong Liang: Writing, review and editing, funding acquisition. All authors have read and agreed to the published version of the manuscript.

#### **Ethical approval of studies and informed consent**

Not applicable.

#### **Acknowledgments**

None.

## Data availability

Not applicable.

## References

- [1] Li YM. Anatomical basis of transition from eleven to twelve meridians in Han dynasty. *Chin Acupunct Moxibustion* 2021;41(10):1153–1158.
- [2] Ma JX. Ancient medical books unearthed from Mawangdui. *Chin J Med Hist* 1980;10(1):41–46.
- [3] Xing YR. Research on the conceptual framework of vessel in Chinese medicine. *J Beijing Univ Tradit Chin Med* 2024;47(2):175–180.
- [4] Chen Q, Wo Y, Cui W, et al. Study on relationship between interstitial fluid circulation system and meridians of TCM. *J Guizhou Univ Tradit Chin Med* 2023;45(5):1–4.
- [5] Li YM. Scientific basis of meridians: new interpretations of nine pulses in three parts. *Chin J Integr Tradit West Med* 2021;41(10):1168–1173.
- [6] Longhurst JC. Defining meridians: a modern basis of understanding. *J Acupunct Meridian Stud* 2010;3(2):67–74.
- [7] Shen Y, Wang L, Zhang E, et al. The relationship between nervous system and meridians. *Highlights Sci Eng Technol* 2023;36:509–516.
- [8] Wang RX, Mao ZN, Wang RR. Discussion on the correlation between the phenomenon of transmission and the transmission of nerve impulses. *Asia-Pac Tradit Med* 2020;164:197–199.
- [9] Liu JW, Yu XP, Zou W. Correlation between meridian and myofascial in terms of acupoint localization. *J Clin Acupunct Moxibustion* 2021;37(6):97–101.
- [10] Li HY, Wang F, Chen M, et al. An acupoint-originated human interstitial fluid circulatory network. *Chin Med J (Engl)* 2021;134(19):2365–2369.
- [11] Xue XQ, Ma X, Li XH, et al. Research progress of meridian essence hypothesis in China. *World Sci Technol* 2020;22(6):2068–2073.
- [12] Wu Z, Cai R, Wu S, et al. *The Meridian–Viscera Correlation: Theory and Mechanisms of Heart Meridian–Heart–Brain Interactions*. Cham: Springer International Publishing; 2022:311–344.
- [13] Zuo YJ, Shi YB. Research progress on physiological basis and physical characteristics of meridians. *Tradit Chin Med* 2022;11(4):641–647.
- [14] Cai T, Ma XC, Chen CL, et al. Discussion of intestinal flora from TCM viscera and meridians theory. *J Liaoning Univ Tradit Chin Med* 2019;21(7):118–120.
- [15] Huang ZJ, Wu J, Zhang WC. Study on the correlation between five zang organs and meridians based on Terahertz wave spectroscopy. *China J Tradit Chin Med Pharm* 2022;37(1):348–352.
- [16] Yin N, Dai YY, Xu GZ. Alpha-wave cerebral cortex functional networks of magnetic stimulation on acupoints of different meridians. *Chin J Rehabil Theory Pract* 2018;24(12):1438–1445.
- [17] Feng WL, Wu HT. Interpretation of the meridian perspective of the role of the brain-gut axis in the pathogenesis of irritable bowel syndrome. *Lishizhen Med Materia Medica Res* 2015;26(12):2970–2971.
- [18] Tan CY. Essence of meridians based on neural electric field. *Chin Acupunct Moxibustion* 2010;30(10):835–839.
- [19] Zhang WB, Wang YP, Li HY. Analysis on correlation between meridians and viscera in book the yellow emperor's internal classic. *Acupunct Res* 2018;43(7):424–429.
- [20] Xu JZ, Zhang B, An HJ, et al. Clinical observation of acoustic meridian resonance therapy in the treatment of diabetic peripheral neuropathy. *World J Integr Tradit West Med* 2016;11(6):812–4 + 8.
- [21] Zou HB. Theoretical pattern and action mechanism of bio-signal: physical chemistry in meridians and collaterals acupoints. *World Chin Med* 2022;17(4):543–552.
- [22] Wang XX, Wang XT, Liu DN, et al. Theoretical reduction and current situation reconstruction of meridian essence research. *Clin J Tradit Chin Med* 2022;34(2):199–203.
- [23] Brizhik L, Chiappini E, Stefanini P, et al. Modeling meridians within the quantum field theory. *J Acupunct Meridian Stud* 2019;12(1):29–36.
- [24] Kong XY, Xiang M, Fang J, et al. The connection between meridians and physiological functions: a quantum principle. *Nano Res* 2023;16:12817–12820.
- [25] Meng JY. Introduction to the overall view of quantum physics and traditional Chinese medicine. *Chin J Basic Med Tradit Chin Med* 2013;19(12):1471–1472.
- [26] Huang LX. *Restoration and Reconstruction theory of Meridians Outline*. Beijing: People's Health Publishing House; 2016.
- [27] Huang CL. *Investigation into Electro-Osmosis Flow Model in Human Meridian System*. Nanjing University of Traditional Chinese Medicine; 2017.
- [28] Bai XB, Wu RZ, Zhang Y, et al. Tissue micro-channels formed by collagen fibers and their internal components: cellular evidence of proposed meridian conduits in vertebrate skin. *Microsc Microanal* 2020;26(5):1069–1075.
- [29] Shi YH, Wu RZ, Zhang Y, et al. Telocytes in different organs of vertebrates: potential essence cells of the meridian in Chinese traditional medicine. *Microsc Microanal* 2020;26(3):575–588.
- [30] Wang GJ, Ayati MH, Zhang WB. Meridian studies in China: a systematic review. *J Acupunct Meridian Stud* 2010;3(1):1–9.
- [31] Li T, Tang BQ, Zhang WB, et al. In vivo visualization of the pericardium meridian with fluorescent dyes. *Evid Based Complement Alternat Med* 2021;2021:5581227.
- [32] Li Z, Li L, Xu F, et al. Analysis in five steps of meridian syndrome differentiation. *J Clin Acupunct Moxibustion* 2022;38(4):80–85.
- [33] Wang JY. *Introduction to Meridian Medicine*. Beijing: China Traditional Chinese Medicine Press; 2016:224–355.
- [34] Bao YF, Ding HK, Zhang ZH, et al. Intelligent acupuncture: data-driven revolution of traditional Chinese medicine. *Acupunct Herb Med* 2023;3(4):271–284.