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Hiding in Plain Sight-ancient Chinese anatomy

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Abstract

For thousands of years, scientists have studied human anatomy by dissecting bodies. Our knowledge of their findings is limited, however, both by the subsequent loss of many of the oldest texts, and by a tendency toward a Eurocentric perspective in medicine. As a discipline, anatomy tends to be much more familiar with ancient Greek texts than with those from India, China, or Persia. Here, we show that the *Mawangdui* medical texts, entombed in the Mawangdui burial site in Changsha, China 168 BCE, are the oldest surviving anatomical atlas in the world. These medical texts both predate and inform the later acupuncture texts which have been the foundation for acupuncture practice in the subsequent two millennia. The skills necessary to interpret them are diverse, requiring the researcher firstly to read the original Chinese, and secondly to perform the anatomical investigations that allow a re-viewing of the structures that the texts refer to. Acupuncture meridians are considered to be esoteric in nature, but these texts are clearly descriptions of the physical body. As such, they represent a previously hidden chapter in the history of anatomy, and a new perspective on acupuncture.

KEYWORDS

acupuncture, anatomical atlas, anatomy, Han era, meridian

1 | INTRODUCTION

Studying anatomy via direct dissection of the human body has been the "gold standard" in Western medicine since the Renaissance (1300–1600 CE) (Porter, 2017). There are records of even earlier anatomical dissections and physiological experiments by Herophilus (335–280 BCE) and Erasistratus (304-c.250 BCE), but their original works were lost in the fire of the library at Alexandria (von Staden, 1992). Galen (129-c.210 CE) followed in their footsteps, and his surviving animal-based works, which formed the basis of Western anatomy for the subsequent thousand years, indicate that he was familiar with theirs. Our histories of anatomy are highly Eurocentric. Great emphasis is placed on anatomical discoveries made in Europe (especially Greece), but there is usually very little mention of China (Shaw & McLennan, 2016), Persia (Alghamdi, Ziermann, & Diogo, 2017), or India (Wujastyk, 2009). This pattern persists even though these cultures have long and proud medical traditions. The first records of cataract surgery come from India in the fifth century BCE (Davis, 2016; Grzybowski & Ascaso, 2014) well before Herophilus. Prior to the flourishing of anatomy in Renaissance Europe, Chinese anatomical studies led to the creation of the Anatomical Atlas of Truth (*Cun Zhen Tu*) (Yang, 1106), and Ou XiFan's Anatomical Illustrations (*Ou Xifan Wuy Zang Tu*) (Chiang, 2015) in the Song dynasty (960–1279 CE) (The Song Dynasty (960–1279), n.d.). In

Persia, Ibn Sina (980–1037 CE) wrote the Canon of Medicine in 1025 CE (Koh, 2009), whereas in Europe Vesalius' famous De Humani Corporis Fabrica (On the Fabric of the Human Body) was only published in 1543 (Vesalius, 1543).

Here we argue that the ancient Chinese "*Mawangdui* texts" (dating to the second-third century BCE) (Yimou et al., 1988) constitute one of the very earliest anatomical atlases based on systematic human anatomical study comparable to that found in ancient Greece. Crucially, where the early Greek texts perished, the Chinese ones survived. The study of the *Mawangdui* medical texts thus offers us both a unique window into ancient Chinese anatomical knowledge, and a chance to rediscover this way of seeing and mapping the human body.

The establishment of these texts as an atlas also informs some of the most basic assumptions about the anatomical basis for acupuncture meridians and points. This has major implications for current scientific research into the mechanism(s) of acupuncture. It challenges the widespread belief that there is no scientific foundation for the "anatomy of acupuncture," by showing that the earliest physicians writing about acupuncture were in fact writing about the physical body.

2 | THE *MAWANGDUI* MEDICAL TEXTS

The *Mawangdui* medical manuscripts were entombed at the Mawangdui burial site in Changsha, Hunan Province, China in 168 BCE. This site comprises three separate tombs closed at different times, containing the bodies of the Marquis Dai, his wife Lady Dai, and their son (Harper, 1998). Many artifacts were found in the tombs including treatises on medicine, war, personal cultivation, materia medica, and recipes for foods that would be considered healthy or medicinal. There are three anatomical manuscripts which differ in their details but generally contain similar material (Changsha Mawangdui Han Dynasty Tombs Exhibition Hunan Provincial Museum, n.d.). They were written around 300–200 BCE (Yimou et al., 1988), broadly contemporaneously with the now-lost dissection-based texts of Herophilus and Erisastratus (Lloyd & Sivin, 2002).

The texts describe the organization of the human body in the form of divisions or pathways, each of which has associated disease patterns. These 11 pathways carry the same names as the acupuncture meridians described in the later *Huangdi Neijing* or Yellow Emperor's/Yellow Thearch's Classic of Internal Medicine (henceforth "the *Neijing*") (Huangdi Neijing, 2010). The *Neijing* is the canonical text of ancient Chinese medicine and has great status in Chinese history and culture. It is recognized as the repository of medical thought at the time of the Han dynasty (206 BCE–220 CE), and contains the earliest exposition of acupuncture theory, points and clinical practice, and we have discussed the anatomical content found in it in other papers (Shaw, 2014; Shaw & Aland, 2014; Shaw & McLennan, 2016). Unlike the entombed *Mawangdui* texts, the *Neijing* was copied and recopied over time, has volumes of commentary associated with it, and remained current throughout Chinese history to the present. There are sections from the *Mawangdui* texts copied verbatim into the *Neijing*, suggesting that the older texts became subsumed into the bigger, more detailed compendium. The key difference in content between the two is the addition of an extra meridian (*arm jue yin*) to the *Neijing* that is not found in *Mawangdui* (Unschuld, 1985, p. 81). There is also no mention of either acupuncture, or acupuncture points found in *Mawangdui*. This information is all contained in the later *Neijing* text, which clearly indicates that mapping the body was an area of active anatomical research in the Han era, with a progression of ideas over time.

Both the *Neijing* and *Mawangdui* describe a system of meridians or pathways through the body in which *Qi* (vital energy) circulates. How this description was arrived at, however, is the subject of considerable debate. In ancient China, the development of anatomy is generally considered ***not*** to have involved dissection (Harper, 1998; Lloyd & Sivin, 2002), in contrast to what was broadly contemporaneous in the West. This is because Han-era China was governed by Confucian law. Under Confucian law, each person had their place and the stability of the state and social order was maintained through a rigid social structure. One of the laws underpinning that structure was that of "filial piety" (Confucianism, 1996), under which it was a child's duty to respect and worship their parents and ancestors. The human body was considered sacred, and dissection was seen as a mutilation of one's ancestor, and therefore forbidden (Lloyd & Sivin, 2002). For this reason, it is widely assumed that the anatomy described in *Mawangdui* and the *Neijing* was arrived at through some means that did *not* involve direct examination of the body (Lloyd & Sivin, 2002; Unschuld, 1985).

However, the *Han Shu* (Book of Han) records the dissection of the criminal Wang Sun-Qing in CE16 (Schnorrenberger, 2008). The *Han Shu* is a complete history of the Han Dynasty from 206 BCE-23 CE, and this record of dissection forming part of Wang Sun-Qing's punishment shows that in the case of criminals, the law of filial piety did not apply. The penal system at the time included the "5 Punishments": tattooing of the face, cutting off the nose, chopping off the feet, castration, and the death penalty(Yang, 2015). The death penalty could be carried out by strangling, decapitation, or slicing. Decapitation was a more serious penalty than

strangulation because it mutilated the body, thereby humiliating the person and denying them a fate for their mortal remains that was in compliance with the law of filial piety. Death by slicing was more severe still, as the offender was tied to a post and cut whilst still alive, until they died. The record of dissection would fit with a punishment system that considered mutilation of the body the most severe form of the death penalty (Kim & LeBlang, 1977). We argue here that the *Mawangdui* texts record anatomy arrived at via dissection (as does the succeeding *Neijing*). If this assessment is correct, they are not only the oldest Chinese anatomy texts, but also the oldest surviving anatomical atlases in the world, predating Galen by a thousand years.

3 | (CON)FUSING MEDICAL PARADIGMS

The *Mawangdui* medical texts were only discovered forty years ago. Nobody has yet proposed that they are an anatomical atlas (Liu, 2016). We suggest that the primary reason for this is not that Confucianism renders anatomical study through dissection inherently implausible, instead, we propose that reading these texts requires the ability to view the anatomy of the body through a naive lens that is significantly different to our modern perception of science and medicine.

Additionally, reading ancient Chinese is a specialist skill. The creation of a single Chinese script that is consistent across all the different Chinese languages and dialects was a key part of the unification of China in the Han era. Formation of the written text was a crucial step that allowed for central governance. Traditional Chinese script is highly complex, and was simplified during the 1950s and 1960s to encourage literacy and make printing easier. The ideas contained within it are from a historical era that was underpinned by the philosophy of *yin/yang* (described below). To read these texts therefore requires not only the ability to read the traditional script, as well as modern simplified script. It also represents a substantial paradigm shift for scholars, especially those from the West accustomed to explanations of the universe that are based in modern science. Traditional Chinese Medicine is based on the doctrine of *yin* and *yang*. This is a broad philosophical concept of complementary opposites that has underpinned the Chinese understanding of the universe since the Han dynasty and before. The paradigm continues to the present day, and the *yin/yang* symbol (Figure 1) has been adopted into some parts of Western culture that have been influenced by Eastern spiritualism.

FIGURE 1 The *yin/yang* symbol. In this image, the dark is *yin*, and the light is *yang*. Within the dark is the seed of the light, and vice versa. Both flow into each other, as day flows into night, and night flows through to become day again

Yin 陰, 阴 is defined as "the dark negative feminine principle in Chinese dualistic cosmology," with additional connotations of overcast (weather), cloudy, shady, moon, implicit, hidden (*yin*-Chinese-English Dictionary; Thesaurus - YellowBridge, n.d.).

Yang 陽, 阳, is defined as "the bright positive masculine principle in Chinese dualistic cosmology," with additional connotations of; positive, sun, male principle (Taoism) (*yang*-Chinese-English Dictionary; Thesaurus - YellowBridge, n.d.).

The terms *yin* and *yang* are also used to describe human anatomy, in ways that fit with these general principles but have different English translations depending on context. For example, they can be used as relational terms to describe location: the head is *yang* (superior) in relation to the abdomen; the abdomen is *yin* (inferior) in relation to the head. The back is *yang* (dorsal/posterior) in relation to the front; the front is *yin* (ventral/anterior) to the back. The skin is *yang* (exterior) in relation to the bone; bone is *yin* (interior) in relation to the skin.

Being able to interpret, based on context and deep philosophical understanding, which of the meanings of *yin* is being used in a given text can be challenging. In this case, we also have to add the complexity of describing a body in symbolic terms, based on presumably limited (and variable) source material, and the fact that any anatomy based on cadavers is missing significant functional information. In modern anatomy, for instance, it is

taken for granted that we distinguish between nerves, arteries, and veins. However, this knowledge was arrived at through investigation of the living, not examination of the dead. When looking at these structures in a cadaver, all that can be seen are a collection of tubes which travel through the body together, which the naïve viewer will interpret according to their own understanding.

For example, in the cadaver, arteries have an open lumen and are empty of blood. This led the ancient Greeks to conclude that air (*pneuma*) flowed through arteries, and blood only flowed in veins (Aird, 2011). There is no way to tell simply by looking that blood travels toward the heart in veins, and away from the heart in arteries. Nerves in a cadaver are dense white structures with neither lumen nor blood. It is impossible to tell that electrical impulses are conducted via the nerves both to and from the brain. All that can be deduced by their position is that they must have something in common with the empty tubes (arteries), and the blood-filled ones (veins). All three structures tend to travel together as neurovascular bundles, often wrapped in a common fascial sheath, and pass along the same fascial planes in between muscles. Without knowledge of the physiologically different functions that they perform, there is no reason to differentiate between them beyond the purely structural.

Finally, a substantial shift of paradigm like that required to merge ancient Chinese and modern Western world-views also requires that we learn to see the strange in the familiar and the familiar in the strange (ideas with a long history in anthropology and sociology) (Willermet & Catherine, n.d.). Our modern tendency to describe the body as a series of functional systems—nervous, respiratory, circulatory etc.—although so familiar that we may not even notice it, is by no means "obvious" or objective. Seeing the anatomy in the *Mawangdui* texts thus requires an effort to shift out of our familiar paradigms and explore the body from a viewpoint that to us is new.

4 | RESULTS

4.1 | The *Mawangdui* meridians in the flesh

The *Mawangdui* arm meridians are much simpler than those of the leg, so we treat them first. Arm and leg meridians are each split into *yin* and *yang*. The patterns each set displays are themselves useful illustrations of the naming conventions and paradigms of ancient Chinese anatomical studies, as represented in the *Mawangdui*.

In what follows, we are dealing with three discrete but inter-related sets of information: the original Chinese texts (characters), direct translations of those texts that are as literal as possible (in English), and the anatomical descriptions that we believe align most closely with the pathways described.

The Table of Translations (found in the Supplementary Information) gives the original Chinese texts and our translations of them. As there are usually three texts per meridian, we also provide a collated translation which is a summary of the combined texts for each meridian.

In the main body of our results section, we take these detailed documents as the basis for our interpretation. Tables 1–11, and Figures 2–12, therefore act to unify and integrate the text, translation and anatomical structure. We name the physical structures that we have identified through dissection and anatomical examination as the most likely structures being described in the *Mawangdui*. These sections summarize our evaluation of the physical actuality of the meridians described. In the main text, we alternate between modern anatomical terminology and references to the translations. For clarity, the original Chinese terminology is given in italics and our translations of the texts are referred to in quotation marks. The translations are included where they are relevant to understanding the reasons for our interpretations.

The contextual information is about how these structures relate to the translated texts, and the overall patterns that emerge. Where we name a meridian but do not specify a single version (e.g., where we describe "the arm meridians"), the text that follows describes points of congruence between translated text and physical anatomy. In the case of the arm meridians in particular, there are

TABLE 1 Arm *tai yang*

Name	Test description
Arm *tai yang* (ear vessel)	Greater *yang* meridian of the arm, ear vessel—"it rises up from the little finger/back of hand, goes along the space on the outside of the two bones. It goes up the bone to the lower corner to the Centre of the elbow. It passes along the soft muscle ridge up to the shoulder, and passes along the back of the neck to join into the eye and the ear."
Anatomical pathway	A. This is the most medial of the three *yang* meridians, and starts on the little finger. It passes along the arm on the extensor surface of the forearm as the basilic vein. B. It joins with the cephalic vein as the median cubital vein in the elbow, and continues along the edge of biceps brachii to the shoulder as the cephalic vein. C. It progresses up along the neck as the external jugular and branches to the eye and ear as the auriculotemporal vein.

TABLE 2 Arm *shao yang*

Name	Test description
Arm *shao yang* (shoulder vessel)	Lesser *yang* meridian of the arm, shoulder vessel– "It rises up from behind the ear, goes below (into) the shoulder, exits along the upper arm along the outside ridge, goes along the outside of the bicep, goes to the upper ridge of the (middle) finger."
Anatomical pathway	The pathway of this vessel is very similar to the ear vessel of arm *tai yang*, and all three of the manuscripts also mention the shoulder vessel starting at the ear. The name of the vessel is however "shoulder" so we interpret this pathway as following the same route along the external jugular vein as the ear and tooth vessels. D. It then differs in that this pathway includes specific mention of the veins which pass from the external jugular into the shoulder. It then passes along the cephalic vein in the arm, as do the other two *yang* meridians. E. It passes into the hand where it finishes on the middle finger.

TABLE 3 Arm *yang ming*

Name	Test description
Arm *yang ming* (tooth vessel)	Brilliant *yang* meridian of the arm, tooth vessel—"it rises from the second finger (index) and from the big finger (thumb), goes to the upper ridge of the arm, joins in the Centre of the elbow, follows bicep, to the cheek, joins into the teeth Centre and connects with the nose."
Anatomical pathway	F. This vessel starts from the lateral dorsum of the hand at the thumb and index finger, and continues along the forearm as the cephalic vein. G. It joins with the basilic vein at the median cubital vein in the elbow, and then continues along the edge of biceps brachii to the deltopectoral groove as the cephalic vein. H. It passes up along the external jugular vein to the face and goes to the mouth as the facial vein.

many places where the individual meridian descriptions seem to have large amounts of overlap, so we adopt an approach that highlights both congruence, and difference.

TABLE 4 Arm *tai yin*

Name	Test description
Arm *tai yin*	Greatest *yin* meridian of the arm—"it starts in the Centre of the palm, goes along the forearm between the two bones following straight along the tendons, travels below the sinew into the bicep, to the armpit, and connects with the heart."
Anatomical pathway	I. This is a description of the ulnar artery starting in the palm of the hand, and passing along the ulnar side of the forearm to the elbow. J. It passes under the bicipital aponeurosis, and joins into the brachial artery on the medial side of the arm, in the fascial plane formed between brachialis muscle and biceps brachii. From here, it passes up through the axilla, subclavian artery, brachiocephalic artery (right) or arch of the aorta (left), ascending aorta to join into the left ventricle.

TABLE 5 Arm *shao yin*

Name	Test description
Arm *shao yin*	Lesser *yin* meridian of the arm—"it travels straight from the lower corner of the sinews (at the wrist), to the upper ridge of the lower bone. It passes below the sinew, along the bicep of inner *yin* to the armpit, exits the armpit and assembles in the flank."
Anatomical pathway	K. This is the radial artery from the point where it passes under brachioradialis tendon at the wrist to travel along the radial side of the forearm to the elbow. L. It passes under the bicipital aponeurosis to join into the brachial artery, and travels along in the plane between brachialis and biceps brachii to the armpit. M. From the axillary artery as it passes into the subclavian to leave the armpit. There are also multiple branches that connect between the armpit and the side of the thorax.

4.2 | Arm meridians

4.2.1 | *Yang*

The three *yang* meridians of the arm (*tai yang, shao yang, yang ming*) do not each describe discrete structures (Tables 1–3). Rather, together they describe the network of veins in the arm starting from the back of the hand and travelling to the face. These veins flow initially from

TABLE 6 Foot *tai yang*

Name	Test description
Foot *tai yang*	Greatest *yang* meridian of the foot—"exits at the cavity outside the ankle, goes up in the Centre, penetrates up, exits at the hip, wraps around the backbone, exits along the back of the neck, to the corner of the head, goes down the face, wraps around (X) to the inner corner of the eye."
Anatomical pathway	N. The venous return for the lateral foot flows into the short saphenous vein, which is found in the Centre of the posterior leg, and which connects into the neurovascular bundle in the popliteal fossa. From here, the text is describing the pathway of the sciatic nerve which travels straight up through the posterior thigh to the gluteal region. O. The sciatic nerve passes through the greater sciatic notch into the pelvis where it becomes the lumbosacral plexus and disappears through the intervertebral foramina into the spinal cord. The extensor muscles fan out either side of the spine, until they reach the neck where the combined splenius capitis muscles and ligamentum nuchae join the thorax and ribcage to the occiput. P. Temporalis muscle covers the lateral aspect of the head and goes under the zygomatic arch into the face and the corner of the eye.

TABLE 7 Foot *shao yang*

Name	Test description
Foot *shao yang*	Lesser *yang* meridian of the foot—"it goes out in front of the ankle; a branch goes to the gap in the bone, goes straight up to the outside of the knee and connects. It goes out along the outside of the thigh/rump, along the ribs and sends out a weak branch to the shoulder. It goes straight to the armpit, goes out to the nape of the neck, to the ear; exits. It goes to the pillow bone and to the outside of the eye where it seeps into the eye socket."
Anatomical pathway	Q. This meridian starts with superficial fibular nerve which becomes the fibular nerve running in the interosseous space between the tibia and fibula. At the knee, the nerve passes around the head of the fibula to connect into the sciatic nerve. From the head of the fibula, the iliotibial tract runs along the lateral aspect of the thigh to become tensor fascia lata muscle, passing over the gluteal muscles to form a tendinous attachment into the iliac crest. R. Latissimus dorsi attaches along the iliac crest, and covers the back medially to the spinous process in the midline. It rises to the level of the inferior border of the scapula, and attaches laterally into the humerus, forming the posterior border of the axilla. S. Trapezius muscle overlays the more superior part of latissimus dorsi, and also attaches to the spinous process in the midline. It runs out to the shoulder along the spine of the scapula, and rises along the neck to attach to the occiput. From here, the meridian continues into temporalis as with foot *tai yang*.

either the little (*tai*) (Figure 2), middle (*shao*) (Figure 3), or index (*yang ming*) (Figure 4), fingers of the hand to the elbow, where they connect with each other via the median cubital vein. From here, the veins of the arm (as defined in modern anatomy) have two possible pathways. The cephalic vein remains on the surface, and continues to the top of the shoulder before joining into the subclavian vein. The brachial vein travels deep in the plane between biceps brachii and brachialis before flowing into first the subclavian, then the brachiocephalic veins, and thus into the heart.

In the *Mawangdui* anatomical paradigm, however, these three arm meridians are defined as *yang*—best translated in this context as "superficial." The pathway described therefore follows the cephalic vein along the arm. At the shoulder, it connects *not* with the subclavian, but instead with the external jugular vein. From here, the veins travel along the neck with three main branches; the suprascapular vein to the shoulder (*shao yang*), the auriculotemporal vein to the ear (*tai yang*), and the facial vein to the mouth (*yang ming*).

4.2.2 | *Yin*

The *yin* pathways of the arm also describe blood vessels (Tables 4 and 5). The ulnar artery (*tai*/greater *yin*) (Figure 5) is the most direct, starting in the palm of the hand and passing out along the ulnar side of the forearm. The radial artery (*shao*/lesser *yin*) is not as prominent in the hand, and continues through the forearm on the radial side. Both connect into the brachial artery at the elbow. *Tai yin* continues to the heart presumably via the subclavian artery and the arch of the aorta, whereas *shao yin* (Figure 6) finishes in the armpit where there are multiple vascular connections into the thorax.

TABLE 8 Foot *yang ming*

Name	Test description
Foot *yang ming*	Brilliant *yang* meridian of the foot—"it follows the Centre of the calf/ the tibia, goes up to the Centre of the knee and the kneecap. It exits along the fish thigh, wraps around the lower belly, goes up and joins to the inside of the nipples/breast. It goes up to the throat, encircles the mouth, goes up to the nose."
Anatomical pathway	T. his is the pathway of the anterior tibial neurovascular bundle, which connects into the popliteal vein at the back of the knee. The pathway passes through the adductor hiatus as the femoral artery, and continues on the anterior surface of the thigh to the ramus of the pubis. U. From here, there is a connection with the epigastric vessels which form a network over the belly, and connects with the vascular network of the internal thoracic vessels to join with the subclavian vessels. V. The vessels continue to rise up to the mouth and face, in the same way as the *yang* vessels of the arm also continue from the cephalic veins upward until they terminate.

TABLE 9 Foot *shao yin*

Name	Test description
Foot *shao yin*	Lesser *yin* meridian of the foot—"it exits in the space between the Achilles tendon and the ankle, runs through the inside of the calf, joins into (the knee), goes through the thigh to the abdomen. From here, it passes into the Centre of the body and the liver and gallbladder. It connects with the kidneys, penetrates the backbone, and passes to the tongue."
Anatomical pathway	W. These are the veins that travel with the posterior tibial artery in the deep compartment of the leg. They are variable, and so are known as venae comitante (veins that travel with). As in *yang ming*, these now become the popliteal vein, and pass through the adductor hiatus to become the femoral vein. Here they pass over the pelvic rim and descend into the pelvis as the external iliac and common iliac veins. X. The common iliac veins join to form the inferior vena cava which rises on the right-hand side of the vertebral column to seemingly disappear into the liver. The renal veins also connect into the vena cava just below the liver. The rest of the pathway up to the face is referred to without any further detail as it rises to the tongue.

4.3 | Leg meridians

4.3.1 | *Yang*

The leg meridians are longer, starting at the feet/ankles and finishing at the head. By comparison to the arm meridians, they are both more complex and more diverse. They do not describe single continuous structures like veins or arteries, but rather are composed of a series of different structures, some neurovascular and some muscular. These have fascial connections with each other, creating visual rather than functional connections to form diverse yet continuous pathways through the body.

The *yang* meridians are concerned with what lies in the most superficial layers of the body. *Foot tai yang* (big/greater *yang*) (Table 6) describes the short saphenous vein as it drains the lateral side of the foot and joins into the popliteal vein (Figure 7). From the back of the knee, the pathway continues by following the sciatic nerve as it passes up through the posterior thigh into the gluteal area. The nerve passes through the pelvis at the greater sciatic notch and goes toward the spine. At this point, the nerve fibers disappear from view and the meridian description changes to something that is "wedged around the spine." The best correlate for this is the deep extensor muscles which flank the spine and have tendinous attachments into the lateral processes of the vertebrae. The extensor muscles continue up either side of the spine, blend into the muscles of the neck which in turn attach into the occiput. Here they meet the temporalis muscle and, as this muscle, flow under the zygomatic arch toward the eye and jaw.

Similarly, *foot shao yang* (lesser *yang*) (Table 7) starts at the ankle with the superficial fibular nerve (Figure 8). It continues along the lateral side of the leg to the head of the fibula where the nerve passes through into the back of the knee. The meridian continues from the head of the fibula as the iliotibial tract and tensor facia lata, passing along the lateral side of the leg to the iliac crest. The pathway continues with latissimus dorsi from its attachments along the iliac crest and the spinous processes of the vertebrae up to the inferior border of the scapula where it "sends out a weak branch to the shoulder." This is the tendon attaching into the humerus, forming the posterior border of the axilla (with teres major). Trapezius muscle overlaps with latissimus dorsi, similarly attaching into the spinous processes. This muscle therefore forms the next part of the meridian as it continues up the back to attach into the base of the skull at the

TABLE 10 Foot *tai yin*

Name	Test description
Foot *tai yin*	Greatest *yin* meridian of the foot—"starts at the big toe and runs along the medial surface of the leg and thigh. Connects at the ankle, knee, and thigh. It travels along the adductors of the thigh, and covers the abdomen."
Anatomical pathway	Y. This is the pathway of the long saphenous vein, commencing at the dorsal arch of the foot to travel along the medial side of the foot, pass anterior to the medial malleolus, rise along the medial aspect of the leg and thigh. Z. At the groin the saphenous vein forms an anastomosis with the femoral vein at the saphenofemoral junction. AA. There are perforating veins in the calf (Crocketts), leg (Boyd), and thigh (Dodds). From the groin, the vein connects with the epigastric vessels which form a network over the belly, and connect with the venous network of the internal thoracic vessels to drain into the subclavian. Strong similarities are also seen in the pathways of foot *yang ming*, and foot *jue yin*.

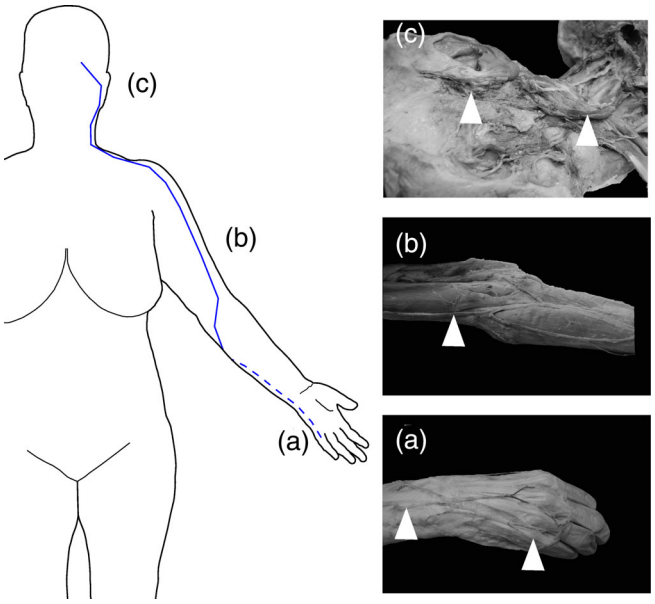

FIGURE 2 Arm *tai yang* left: schematic drawing of arm *tai yang* meridian pathway right: A—vein from little finger leading to basilic vein in the posterior forearm, B—cephalic vein in arm, and C—external jugular vein with auriculotemporal vein to anterior ear and eye

TABLE 11 Foot *jue yin*

Name	Test description
Foot *jue yin*	Hidden *yin* meridian of the foot—"it starts in the first web-space next to the big toe, goes inside the calf and joins with *tai yin* meridian, goes into the thigh and exits at the fish muscle (adductors), travels to the lower abdomen."
Anatomical pathway	BB. This is description of the arterial supply to the foot, commencing at the point where the lateral plantar artery forms an anastomosis with dorsalis pedis. The artery passes into the deep compartment of the leg with the venae comitante (see also *shao yin*) and progresses to the popliteal fossa. CC. It joins into the popliteal artery, and passes through the adductor hiatus with *tai yin* and *yang ming*. From the groin, the vein connects with the epigastric vessels which form a network over the belly, and connect with the venous network of the internal thoracic vessels to drain into the subclavian. Strong similarities are also seen in foot *yang ming*, and foot *tai yin*.

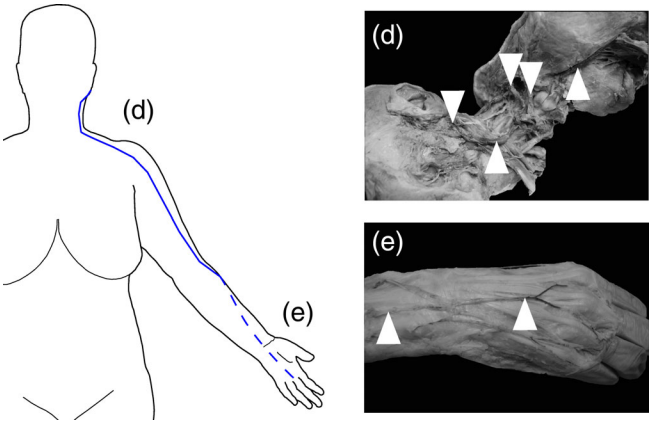

FIGURE 3 Arm *shao yang* left: schematic drawing of arm *shao yang* meridian pathway right: D—auriculotemporal vein travels from the posterior ear, flows into the external jugular, two branches pass to the top of the shoulder, the vein continues into the arm as the cephalic vein in the deltopectoral groove. E—basilic vein continues into the dorsum of the hand to the middle finger

occiput (pillow bone). From here, the pathway is the same as for *tai yang*, with muscular continuity with temporalis as it passes under the zygoma to connect with the face and corner of the eye.

Foot yang ming (Table 8) is the first meridian to discuss the "fish thigh." We interpret the fish thigh as the adductor muscles containing the adductor hiatus (Figure 9). This is a significant anatomical landmark which allows the femoral

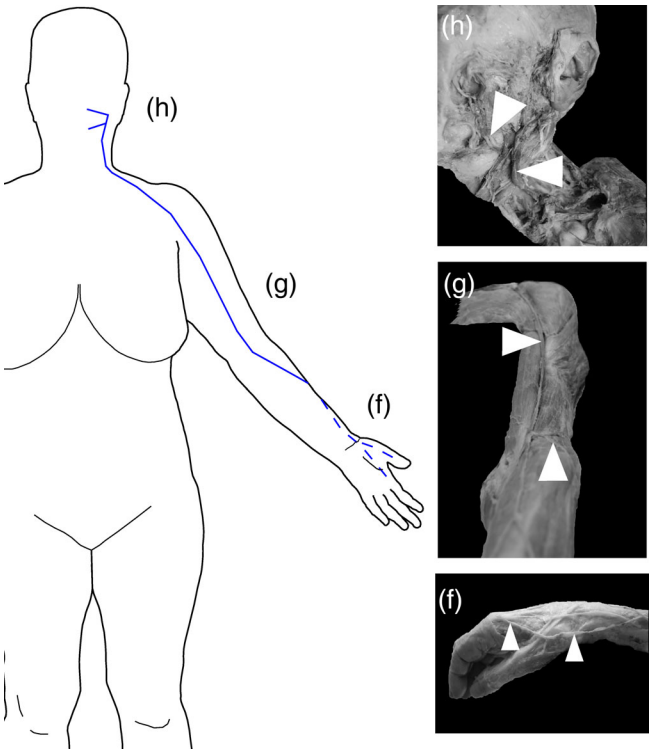

FIGURE 4 Arm *yang ming* left: schematic drawing of arm yang ming meridian pathway right: F—vein from the hand starting at the thumb and forefinger, G—median cubital vein at the elbow continues as cephalic vein, H—external jugular vein in neck becomes facial vein (and artery) to mouth

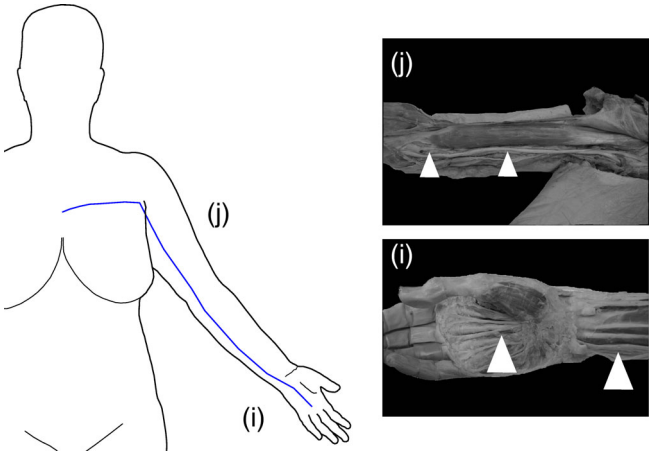

FIGURE 5 Arm *tai yin* left: schematic drawing of arm tai yin meridian pathway right: I—ulnar artery in the palm and medial forearm, J—brachial artery in the arm

artery and vein to pass around the thigh from the anterior surface into the back of the knee. The adductor hiatus is formed by a tunnel of connective tissue through which the vessels pass, protecting them from being compressed when the muscle contracts. The section of this meridian below

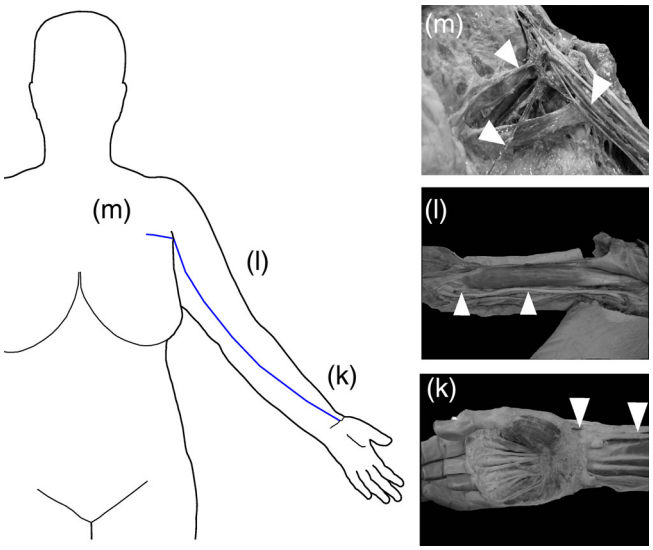

FIGURE 6 Arm *shao yin* left: schematic drawing of arm shao yin meridian pathway right: K—radial artery in wrist and forearm, L—brachial artery in arm, M—brachial artery with costobrachial branches to thorax

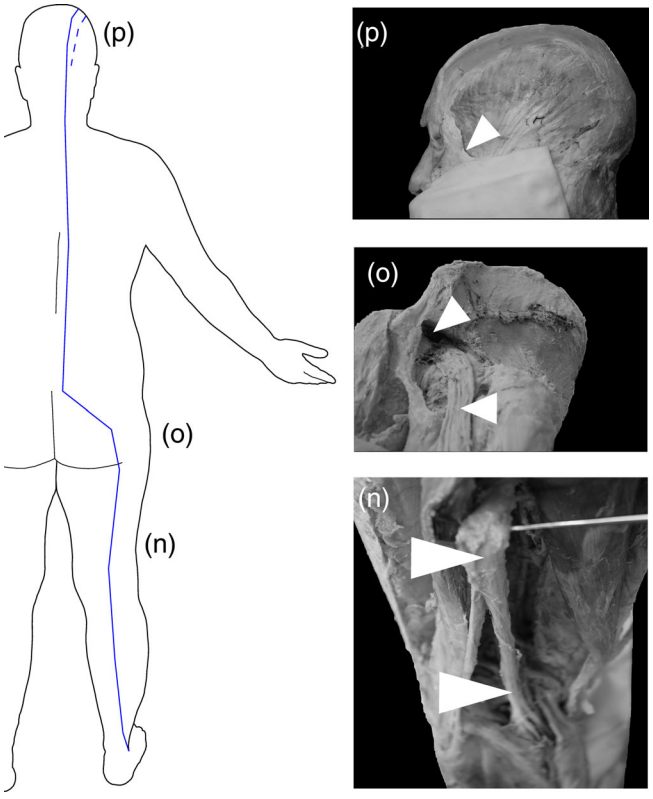

FIGURE 7 Foot *tai yang* left: schematic drawing of foot tai yang meridian pathway right: N—sciatic nerve in popliteal fossa and posterior thigh, O—sciatic nerve passing through greater sciatic notch, P—temporalis muscle passing under the zygomatic arch

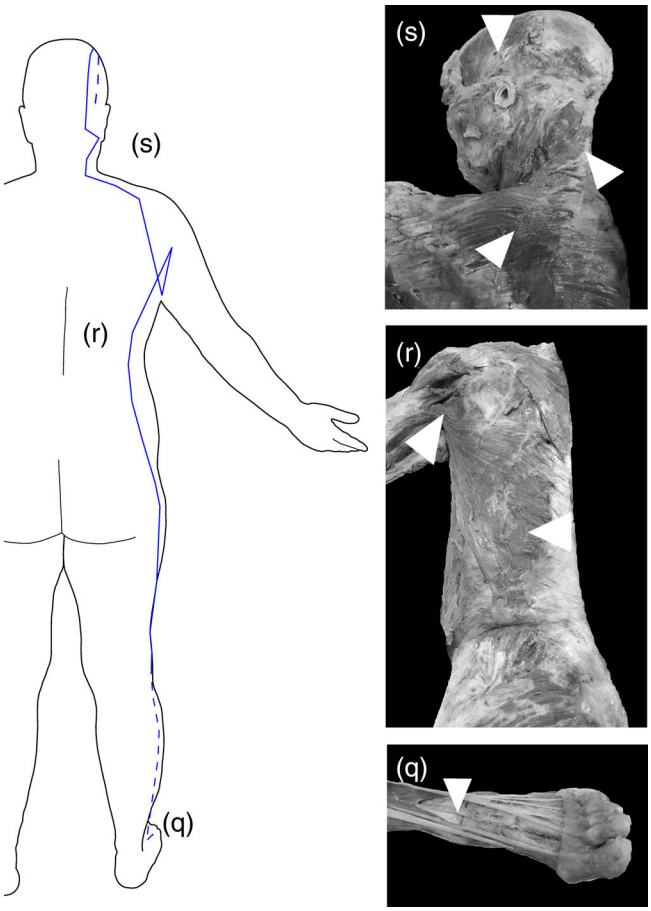

FIGURE 8 Foot *shao yang* left: schematic drawing of foot *shao yang* meridian pathway right: Q—superficial fibular nerve at ankle, R—latissimus dorsi muscle with insertion to humerus, S—trapezius muscle over the scapula to the occiput, and temporalis muscle

the knee is the anterior tibial artery. In the thigh, it is the femoral vessels, travelling upward to the point where they cross the pelvic brim. There is then a network of blood vessels that cover the surface of the belly and thorax; epigastric in the abdomen and internal thoracic in the thorax, which eventually resolve into the subclavian. To our way of viewing anatomy, this system then drains into the heart. However, following the Chinese priority of describing superficial pathways already seen in the *yang* arm meridians, the vascular pathway continues up the external jugular to the face. Here it encircles the mouth, passes along the nose to the inner canthus of the eye and, via the auriculotemporal vein, travels past the ear.

4.3.2 | *Yin*

The *yin* vessels of the leg deal with the medial/deep aspects of the leg, and the blood vessels that are found there. *Foot shao yin* (lesser *yin*) (Table 9) is described as originating in the calf (Figure 10), going along the inside of the leg to the thigh, to the belly and along the inside of the spine to the liver, gallbladder and kidneys. This we identify as the veins that travel with the posterior tibial artery in the deep compartment of the leg. The deep veins drain into the popliteal vein, which passes through the adductor hiatus to become the femoral vein. From here, it passes over the pelvic brim to go deeply into the pelvis as first the external, then the common iliac vein. These then drain into the vena cava which passes along the right side of the spine to seemingly disappear into the liver. The renal veins also connect to the kidneys and are a part of the pathway described. The rest of the meridian from the heart up to the face is referred to in passing here as "and wraps around the tongue." The internal jugular veins from the heart to the face are very prominent, and disappear from view in the neck behind the jaw where they go through the jugular foramen into the skull, seeming to pass behind the tongue.

Foot tai yin (greater *yin*) (Table 10) describes the pathway of the long saphenous vein (Figure 11), starting as it drains the venous arch of the foot and runs along the medial side of the leg and thigh before connecting to the femoral vein, which passes along the inside of the thigh. The description says something equivalent to "and connects" at several points, and there are several consistent, large perforating veins in the leg and thigh to which this probably refers (Crockett's, Boyd's and Dodd's perforators and the saphenofemoral junction). From the femoral vein at the top of the thigh the structure described branches to go to the epigastric veins. From here, the *Mawangdui* description of *foot tai yin* is very similar to that for *foot yang ming* as the blood courses over the abdomen.

The similarity in the paths of *foot tai yin* and *foot yang ming* meridians begs the question "why is a yin (deep) meridian mapped principally onto a superficial vein, and a yang (superficial) meridian mapped onto deeper structures?"

In this context, the best explanation we find is that the superficial (greater saphenous) vein is "*tai*" *yin*, that is, greater *yin*. It is located on the median (*yin*) aspect of the leg, and describes the greatest and most superficial of the blood vessels found there. The superficial vein connects directly from the surface with the deeper *shao yin* (lesser *yin*) vessel. Blood is considered to be an inherently *yin* substance, so these two vessels for the more superficial (greater) and deeper (lesser) blood vessels on the *yin* (medial) surface of the lower limb.

The *yang* of *foot yang ming* refers to its location on the anterolateral aspect of the leg, and later, on the surface of the abdomen. It is the anastomosis between the greater saphenous vein and the femoral vein that connects these two meridians explaining the similarity from there onward,

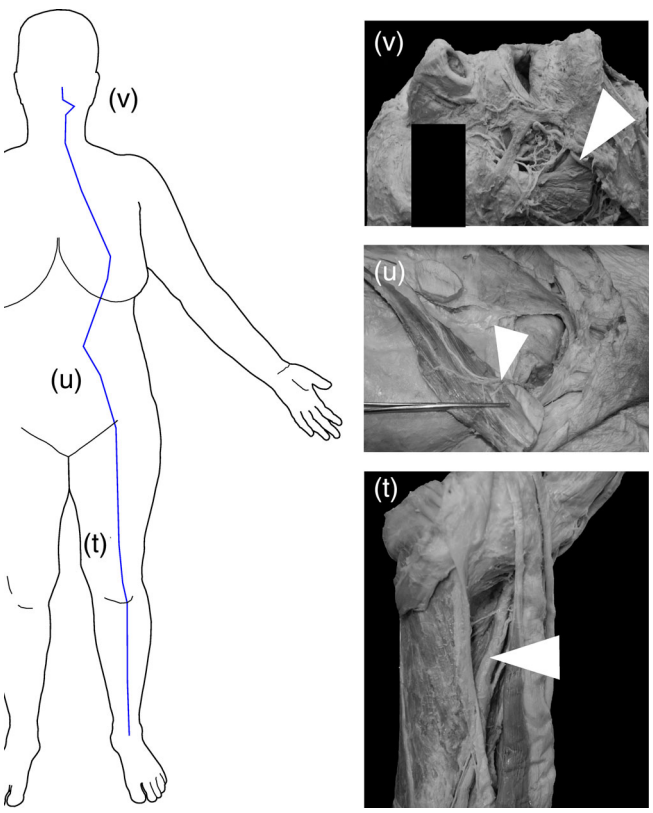

FIGURE 9 Foot *yang ming* left: schematic drawing of foot *yang ming* meridian pathway right: T—femoral artery in the adductor hiatus, U—epigastric vessels rising from the pubis to pass into the abdomen, V—facial artery passing over the angle of the jaw to the mouth and nose

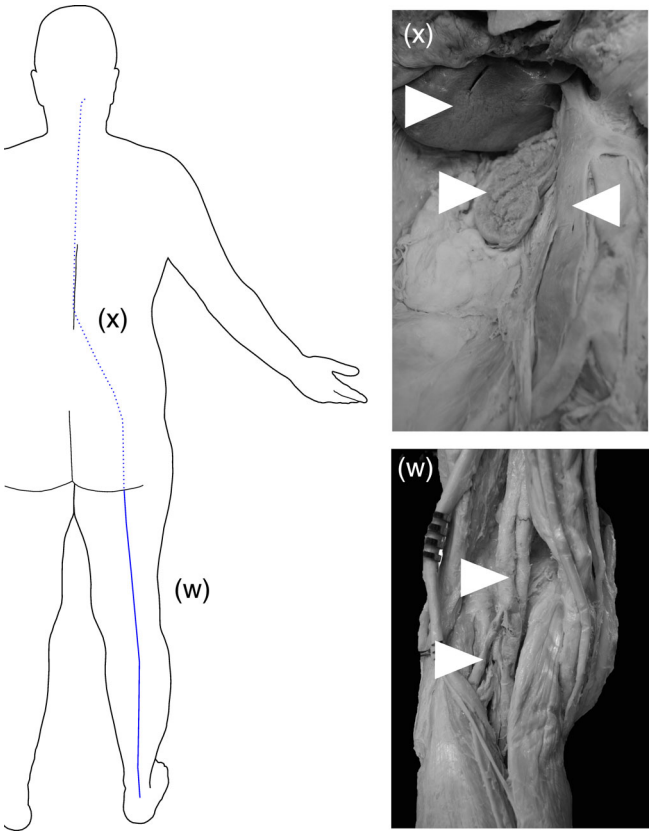

FIGURE 10 Foot *shao yin* left: schematic drawing of foot *shao yin* meridian pathway right: W—venae comitante of the leg joining the femoral artery in the popliteal fossa, X—inferior vena cava flowing to the liver with the renal vein and kidney (dissected to show renal medullas) on the left

however their individual descriptions below the groin contain a large degree of internal logic, following the general principles of *yin*/medial, *yang*/lateral.

Foot jue yin (hidden *yin*) (Table 11) is the final foot meridian. This pathway is clearly that of the arterial supply to the leg and foot (Figure 12). There is an anastomosis between dorsalis pedis on the dorsum of the foot and the lateral plantar artery in the first webspace, which we have shown elsewhere is considered significant in later texts (Shaw, 2014). We therefore consider that this anastomosis is the "connection with the big toe of the foot that follows the foot instep." The lateral plantar artery passes under the foot, comes around, and runs between the medial malleolus and the Achilles tendon on the medial side, where it becomes the posterior tibial artery and the posterior tibial pulse can be felt. The artery (and the entire posterior neurovascular bundle) passes up along the inside of the calf into the "hidden" deep compartment of the leg. From here, it travels to the back of the knee and follows the same pathway that has already been described through the "fish thigh" to the lower abdomen together with *foot tai yin*.

5 | DISCUSSION

In the text above (and the Supplementary Information), we have shown how the text of the *Mawangdui* medical manuscripts maps onto the structures visible in a human cadaver. We propose, based on the close alignment we find between body and text, that the pathways the *Mawangdui* describes are not esoteric. Instead, they represent the earliest surviving anatomical atlas, designed to provide a concise description of the human body for students and practitioners of medicine in ancient China.

In keeping with the philosophical and social structures in which they were created, these pathways do not describe the body the way we would today. Instead of being viewed as a series of systems linked by functional relationships, the *Mawangdui* meridians divide the body into *yin* and *yang*, and within that, into greater and lesser and sometimes other categories (*jue* or "hidden," and *ming* or "bright"). In many cases, the difference in perspective and priorities leads to clear distinctions between how we would interpret structures today and how they were understood in ancient China. As just one example,

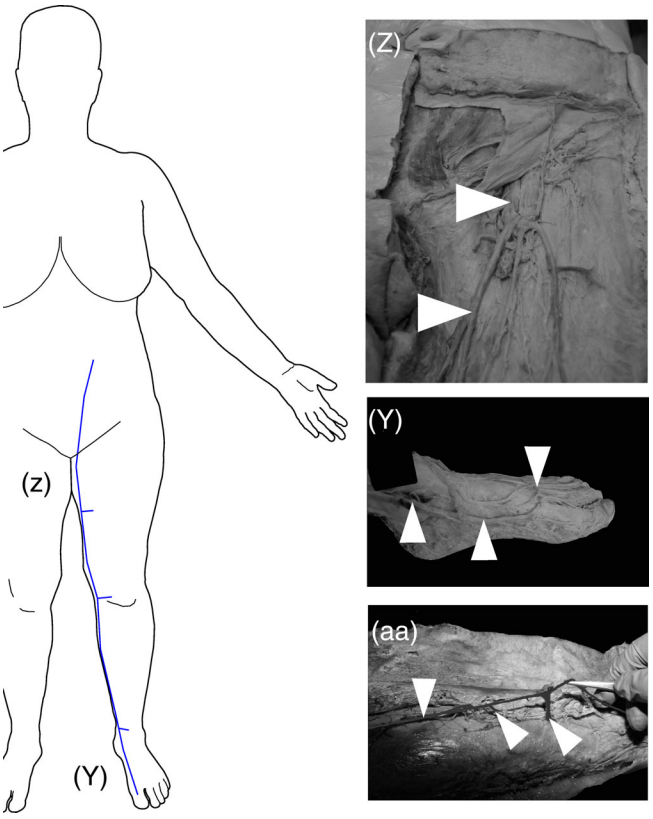

FIGURE 11 Foot *tai yin* left: schematic drawing of foot *tai yin* meridian pathwayright: Y—dorsal venous arch of the foot leading to long saphenous vein, Z—saphenofemoral junction, AA—perforating veins in posterior calf

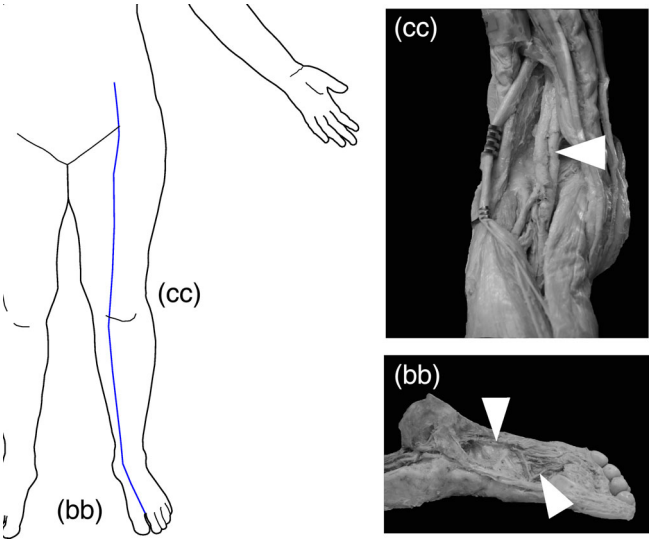

FIGURE 12 Foot *jue yin* left: schematic drawing of foot *jue yin* meridian pathwayright: BB—lateral plantar artery and branch forming anastomosis in the first web space, CC—popliteal artery

for the writers of the *Mawangdui* a pathway could transition from one "type" of structure to another provided it remained *yin* or *yang* as appropriate, while for a modern anatomist, linking (say) vein and muscle or fascial tract and artery as part of the same structure would be incomprehensible.

The *yin*/*yang* distinction seems to be the primary component of the *Mawangdui* divisions. Modern medicine has a systematic means of naming bodily structures which was codified in the Nomina Anatomica (Subcommittees of the International Anatomical Nomenclature Committee, 1989), but prior to this there was much more variation in Western naming conventions too. A modern anatomist reading Galen, Herophilus or Erasistratus would need a new paradigmatic lens, albeit perhaps a more familiar one, just as one does for reading the *Mawangdui*. Nevertheless, we can clearly see specific pieces of anatomy reflected in the *Mawangdui* manuscripts, and this greatly strengthens our interpretation of these texts as anatomical atlases. The multiple connections in *foot tai yin* are clearly the perforating veins, which are consistently present but sufficiently well-hidden and specialized that many major anatomical atlases (Abrahams, Marks, & Hutchings, 2003; Drake, Vogl, & Mitchell, 2010) we use today do not give their names. Likewise, the descriptions of the branch of the latissimus dorsi to the humerus, or of *arm shao yang* running in the deltopectoral groove, are too closely aligned to anatomical reality to plausibly reflect the work of physicians who have never seen the dissected human body.

That said, there remain places in the *Mawangdui* where multiple interpretations are possible for a single pathway. The process of identifying the most likely anatomical structures to fit the texts was often confusing, and the subject of considerable debate between the authors. The meridians described in *Mawangdui* are in some cases very similar to the modern acupuncture meridian pathways (e.g., *yang ming*), but in other cases they are distinct from their modern counterparts (e.g., the arm vessels named tooth, shoulder and ear). Knowledge of the modern meridian pathways therefore sometimes aided the process of identification, but also created an unconscious bias of expectation of similarity and congruence. In order to maintain objectivity, we avoided giving the meridians their commonly used and more familiar names which are associated with organs, for example, bladder, kidney, stomach etc. Instead, we only referred to them by their Chinese name, as we have in this article. New translations or interpretations may yet change our understanding, and we welcome the prospect of future developments. We propose that the multiple texts in the *Mawangdui* compendium, and remaining discrepancies between them, most likely reflect the fact that the authors were engaged in ongoing conversation about the body and its function. This would further suggest that there was a progression in efforts to map the body that was supported by the Han Imperial Court, as scientists would require access to executed criminals to do this work.

We have already highlighted the many ways in which the *Mawangdui* manuscripts appear similar in form to the more familiar texts by contemporary ancient Greek anatomists. Disagreement between authors in print, the existence of multiple versions of a text, wholesale copying, extensive commentary, and distinctive world-views all appear in both, and support our drawing analogies between them. Interpreting these features as indicating the existence of ongoing scientific discussion and debate, in a social context where bodies were rare commodities and socio-political support was required to make anatomy respectable, would make sense of the fact that both seem to reflect similar working contexts. The *Mawangdui* manuscripts later became subsumed into the *Neijing*, which also describes acupuncture points. We have argued elsewhere that these also have anatomical correlates (Shaw & McLennan, 2016) and reflect an intimate knowledge of the interior of the human body.

To conclude, in this article, we have demonstrated that the 300–200 BCE *Mawangdui* medical texts represent the oldest surviving anatomical atlas in the world, predating Galen by about a thousand years. Reading these texts as anatomy rather than esoterica allows us exciting new insights into the history of acupuncture and medicine, as well as access to a view of science and the world that has been largely hidden since they were sealed away. This new knowledge will also have a major impact on the design of scientific research investigating the mechanisms for acupuncture by demonstrating that acupuncture was originally an anatomical science.

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AUTHOR CONTRIBUTIONS

Vivien Shaw: Original idea, conception and design of the work, Data curation- data collection, formal analysis and interpretation, project administration, Writing- original draft, review and editing, Final approval of the version to be published. **Rui Diogo:** Validation; writing-review and editing. **Isabelle Winder:** Data curation; formal analysis; investigation; project administration; writing-original draft; writing-review and editing.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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