

Leonardo da Vinci's Animal Anatomy

Subjects: Zoology

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Leonardo da Vinci was the personification of the ideal Renaissance man. Among his many skills, including human anatomical studies, he was also interested in animal anatomy. This comparative study focused on two species: bears and horses. Based on anatomical details (ankle and toes –*tarsus* and *digits*–), his drawings of "bear's foot" series depict the right leg and foot, instead of the previously reported left hindlimb. Besides, on the first drawing of this series there is a silhouette of a dog/wolf forearm (*antebrachium*, *carpus* and *manus*) not formerly reported. Relative to Leonardo's horse anatomical drawings, "The viscera of a horse" representing the horse trunk, and based on its blood vessel disposition, we concluded that it is more compatible with the dog anatomy than with the horse structure. Other drawings of comparative anatomy of human and horse pelvic limbs were also explored in detail regarding motion in the full paper.

Keywords: Leonardo da Vinci ; anatomical drawings ; bear ; horse ; bear pelvic limb ; dog antebrachium ; horse trunk

1. Introduction

Leonardo da Vinci was one of the most important renaissance personalities of his time, and the fifth centenary of his death will be commemorated in 2019. Being the illegitimate son of a notary, he did not continue the family saga and was educated privately. He had no formal education, thereby not conditioning his curiosity about the world around him. The erudite texts of his time were written in Latin and Greek, languages he did not master, and his access to the literature was therefore limited.

He was an artist and a scientist. As a painter, scientist, engineer and theorist, he produced thousands of drawings^[1], personifying the 'Renaissance man' skilled and versed in arts and sciences^[2].

His interest in anatomy was overwhelming, proven by the numerous sheets dedicated to his anatomical studies, with abundant notes and drawings, exemplifying Leonardo's principle that anatomic parts and organs should be represented in multiple views. Considering that dissections of human corpses outside Universities were not regarded as appropriate by the ecclesiastical authorities, he performed some dissections of animals. According to the Royal Collection Trust^[3], at the outset of Leonardo's anatomical investigations, he was unable to procure much human material. Hence, many of his dissections were therefore of animals.

Practically his entire collection of anatomical drawings was compiled in the Windsor Codex, property of Her Majesty Queen Elizabeth II. These drawings of the human body were exhibited in an unprecedented exhibition in 2012 at the Queen's Gallery, Buckingham Palace (London, UK). Although previous access to the collection was highly restricted, nowadays, the Royal Collection Trust offers the possibility of free access to these drawings in high resolution on its website, which greatly enables the observation of these masterpieces and their details.

Several works have been published based on these anatomical drawings, the most exhaustive ones are those from the collection of three volumes from Clark^{[4][5]}, compiling all the inventory information, the book from O'Malley and Saunders^[6] and its posterior editions in 1983 and 2003^{[7][8]}, and the official book of the exhibition. Clayton and Philo^[9] and another book published in 2013^[10], the two latter reviews, mainly referred to human anatomy, although they also include comments on some animal anatomy drawings. Apart from books, there are numerous scientific articles sharing the same subject: Leonardo da Vinci's anatomical drawings, mainly intended to some areas of expertise, such as those from Schultheiss et al.^[11], Jose^[12], Ganseman and Broos^[13], Pasipoularides^[2], Sterpetti^[14], Bowen et al.^[15] and West^[16], among others.

It is well known that Leonardo dissected numerous animals^[17]. As a result, many endeavors have been made to identify the animal of which the individual anatomical drawings have been made. In some cases, such identification is easy, while in others it is impossible^[17]. Leonardo da Vinci's methods of acquiring knowledge were observation and experiment, and for him, the study of anatomy became a science, combining both the study of structure and function^[12].

Reviewing the work of several authors on the description of Leonardo's animal anatomy drawings, and comparing them with the high-resolution images available on the website of the Royal Collection Trust^[3], it can be noted that some of them were not properly described elsewhere, with some inaccuracies or misunderstandings that deserve to be discussed, probably due to the fact that the consulted authors were experts in human anatomy and, therefore, had no deep understanding of animal anatomy. Hence, it is important to point out that human anatomy could be considered similar, although with some differences, to animal anatomy. For major details, all of Leonardo da Vinci's anatomical drawings can be accessed on the Royal Collection Trust website^[3].

Regarding Leonardo's anatomical drawings, apart from human anatomy, he also depicted some animal species such as dogs, bears, pigs, horses, oxen and monkeys. The main aim of this comparative study on anatomy was focused only on two species: bears and horses.

According to Forlani-Tempesti^[1], da Vinci mentioned bears in his notes for his anatomical treatise: "I will discourse of the hands of each animal to show in what they vary; as in the bear which has the ligatures of the toes joined above the instep", and again: "Here is to be depicted the foot of the bear or ape or other animals to show how they vary from the foot of man or, say, the feet of certain birds" ^[1]. Bears are also the protagonists of other drawings of da Vinci: A bear walking (Robert Lehman Collection) and three other studies of a bear's (or a wolf's or dog's) paws (1490–1495) and head (Colville Collection)^[1]. However, those images of paws cannot be from a bear, simply because bears have a *manus* (hand) with five *digits* (fingers) with their *distal phalanxes* (claws) in contact with the floor. In contrast, a dog and wolf *manus* only have four *digits* ending in *unguicula* (claws) in contact to the ground, plus the *digit I* (dewclaw) medially placed at the level of the metacarpal bones.

2. Flaws of the Anatomy of the Bear's Pes (Foot) and the Hidden Antebrachium (Forearm) and Manus from a Dog/Wolf

The set of drawings that made us realize that some inaccuracies were made in terms of their description was that of the bear's foot (Royal Collection Inventory Number—RCIN 912372-5). Regarding RCIN 912372 ([Figure 1](#)), the first reference to it was stated by Professor William Wright in 1919^[18], in a section entitled 'Leonardo as an Anatomist', published by the Burlington Magazine to commemorate the Quartercentenary of Leonardo da Vinci^[18] as 'one of the finest of Leonardo's anatomical drawings, the hind foot of a plantigrade carnivorous animal—probably a bear, a view supported by the fact that in one of the manuscripts, a reference is made to a bear's foot'.

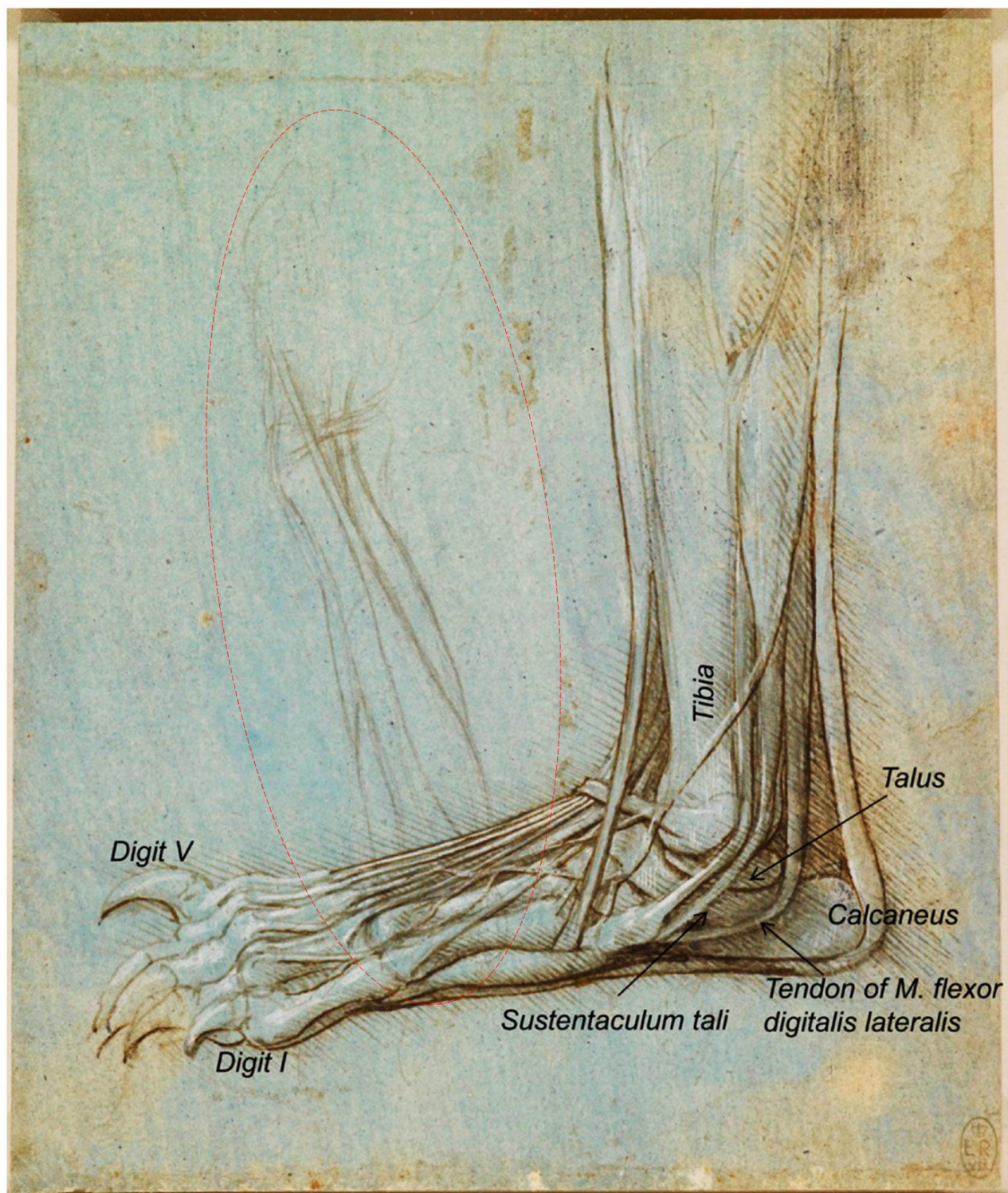


Figure 1. Bear's foot series—Number 1. Bear distal right pelvic limb/pes, medial aspect. A bear's foot c.1488–1490. Modified from www.rct.uk/collection/912372 (Royal Collection Trust^[2]). This image is credited as Royal Collection Trust/© Her Majesty Queen Elizabeth II 2020.

This drawing shows with some accuracy the bones, muscles and tendons of a bear's lower leg and foot, with the big toe, claw raised, away from the viewer". The bear, as a plantigrade animal, walks like humans, with the whole plantar face of the *pes* (the sole with the heel) touching the ground. However, in contrast to humans, the shortest *digit* (toe) is not the fifth one (the lateral one), but the medial one, that is the first *digit* ^{[19][20]}. Hence, to the best of our knowledge, we support that the bear's foot depicted by Leonardo corresponds to the right hind limb instead of the left one, as previously reported by O'Malley and Saunders ^[6] and Clayton and Philo^[9] as well as at its description at the Royal Collection Trust website^[2], maybe in resemblance to humans. In addition, the *calcaneus* bone of the *tarsus* is always in a lateral position to the *talus*, and the medial projection of the *calcaneus* bone to support the *talus* is quite visible, the so-called *sustentaculum tali*, with a groove to the tendon of the muscle *flexor digitalis lateralis* ^[21]. Figure 1 also shows, on the left-centre, a preliminary sketch of some muscles that continues under the depicted bear's foot. If observed upside-down, and once analyzed all the details, it seems to represent the forearm (*antebrachium*) and hand (*manus*) of a dog/wolf.

3. Anatomy of the Horse Trunk that Turned into a Dog's Trunk

Later on, according to Clayton and Philo^[10] “Writing in the mid-sixteenth century, the biographer Giorgio Vasari stated that Leonardo compiled a treatise on the anatomy of the horse. One drawing of the viscera of a large quadruped, probably a horse, does survive from this period, suggesting that Leonardo conducted full dissections to investigate the internal anatomy of the beast. But Vasari also stated that the treatise on the horse was lost when Milan was invaded by French forces in 1499. Ludovico Sforza was overthrown, and soon afterwards, Leonardo left the city and returned to Florence”^[10]. This text refers to the drawing RCIN 919097-recto, entitled ‘The viscera of a horse’ (1490–1492; [Figure 2](#)), and described at the Royal Collection Trust^[2] as: “an anterior view of the arteries, veins and the genito-urinary system of an animal, probably a horse,” implying that Leonardo did not name this drawing. The drawing represents the ventral aspect of the trunk of an animal (supposedly, a horse) with the lungs and the *canalis alimentarius* (esophagus, stomach and intestines) removed. The large vessels depicted at the centre, all the figure down, represent the *aorta* (on the right of the figure) and the *vena cava caudalis* (on the left of the image). The way they ramify helps us to discard the idea that this drawing represents a human being. In humans, the *aorta* ends up dividing into two branches: *Aa. iliaca commune* (*dextra* and *sinistra*). In contrast, in animals, the end of the *aorta abdominalis* (at the level of the pelvic limbs) produces two branches (*external iliac arteries*—*dextra* and *sinistra*), well depicted, and subsequently continues and produces two more (*internal iliac arteries*), well represented in the drawing, ending as the *arteria sacral median*, not depicted. Regarding the veins, the *vena cava caudalis* is formed by the confluence of two *Vv. Iliaca commune*—*dextra* and *sinistra*, each one resulting from the junction of the *V. iliaca externa* and the *V. iliaca interna*, following a similar pattern both in humans and domestic mammals.

A

D. 7.

Two trunks at the arcus aortae
Truncus brachiocephalicus
A. subclavia sinistra (a)

V. Cava cranealis

Hepar

V. cava caudalis

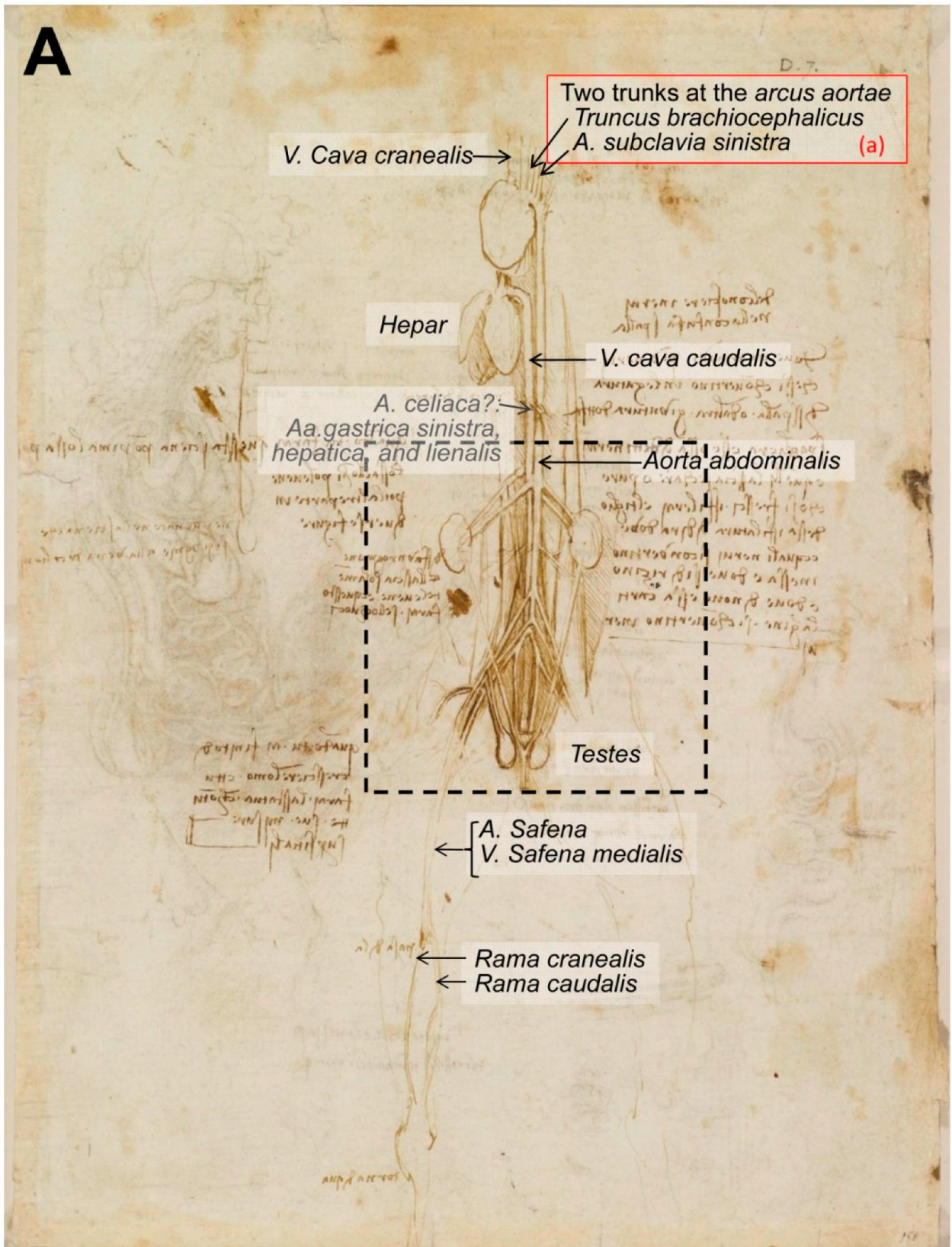
A. celiaca?
Aa. gastrica sinistra,
hepatica, and lienalis

Aorta abdominalis

Testes

[A. Safena
V. Safena medialis]

Rama cranealis
Rama caudalis



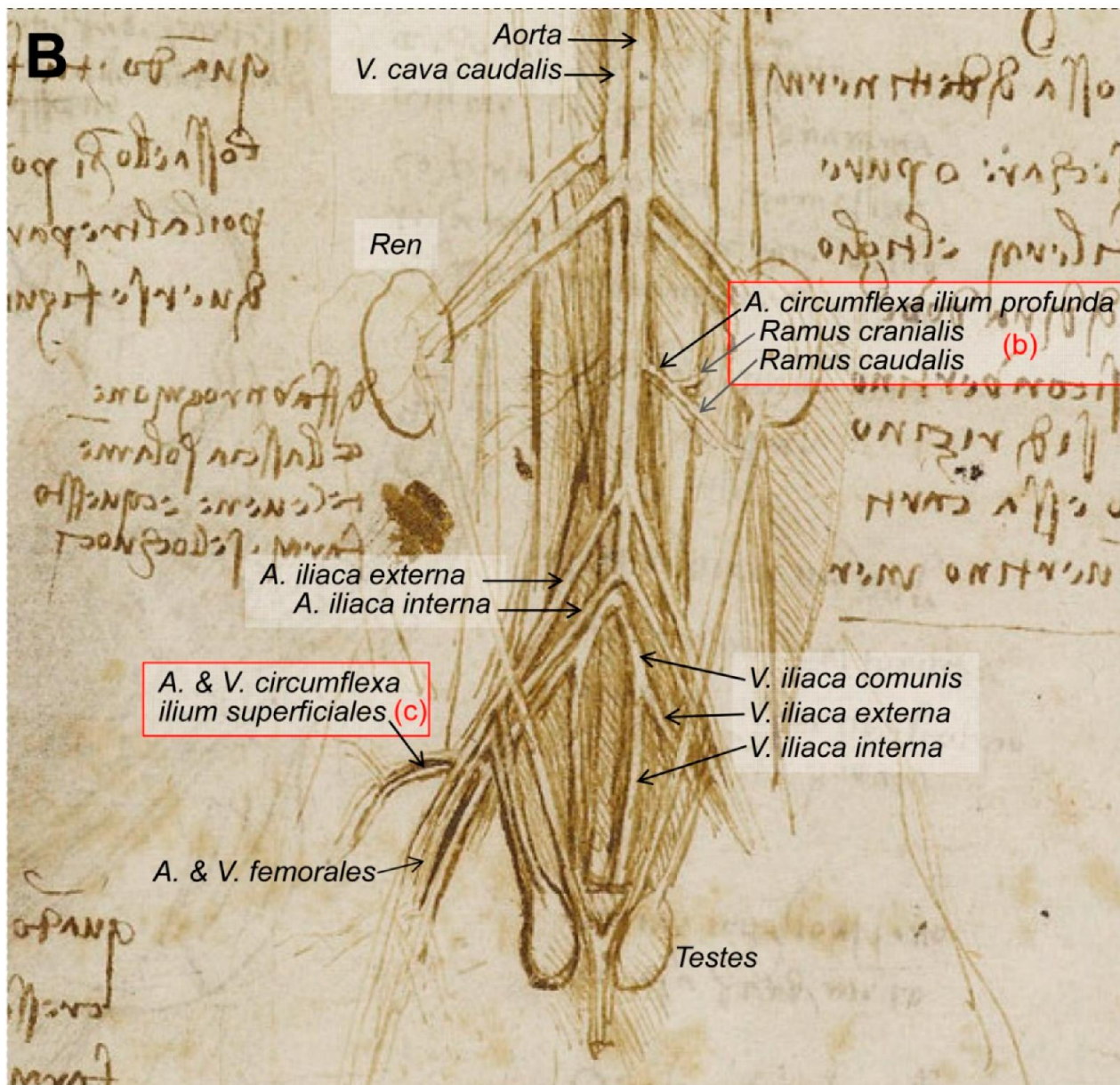


Figure 2. The viscera of a horse? (A) Whole drawing representing the ventral aspect of the trunk of an animal with the *canalis alimentarius* and lungs removed. (B) Inset at higher magnification depicting the lumbar and pelvic regions. The viscera of a horse c.1490–1492. Modified from www.rct.uk/collection/919097 recto (Royal Collection Trust^[3]). This image is credited as Royal Collection Trust/© Her Majesty Queen Elizabeth II 2020.

Regarding the blood vessels, the drawing (Figure 2) provides three key points: (a) The first huge vessel (on the left of the image), reaching the heart, could be the *Vena cava cranealis*, and the other curved vessel going down is the *aorta* and its *arcus aortae*, with two big arteries leaving the aortic arch and some smaller ones (2–3) once the arch finishes and continues to the descendent aorta (*aorta descendens*). Large domestic mammals (horses—Eq, and ruminants—Ru) only have one artery deriving from the aortic arch, the *truncus brachiocephalicus*, which is then divided into a *truncus bicaroticus* (could be absent in carnivores—dogs and cats) and two *Aa. subclaviae*. In contrast, carnivores and pigs (Su) have two arteries leaving the *arcus aortae*: The *truncus brachiocephalicus* first and secondly the *A. subclavia sinistra*. (b) On the other hand, at the kidney level, there are two arteries perfectly outlined in the drawing stemming from the *aorta*: The *A. circumflexa ilium profunda* (*dextra* and *sinistra*), exclusive to carnivores^[21] and dividing into the *rami craniales* and *caudales*. In contrast, the *Aa. circumflexa ilium profunda* derives from the *A. iliaca externa* in Su, Ru and Eq^[21], similar to humans^[22], not stemming directly from the *aorta*. (c) The *arteria* and *vena circumflexa ilium superficiales*, the first branches of the *A. femoralis* and *V. femoralis*, respectively, are exclusive to carnivores^[21]. They leave their main vessels cranially oriented, at the medial and proximal part of the thigh. These vessels (a–c) in this drawing are the main clue to determine the species. Consequently, the horse representation/provenance of this drawing could be discarded. However, the horse is the unique domestic species in which the *aorta* does not end caudally as an *arteria sacral median*, which is not represented in the illustration.

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