

Biological Theory

Integrating Development, Evolution, and Cognition

Supplementary material for the article published in *Biological Theory*:

Revisiting Leonardo on Muscles: Intimations of Mathematical Biology and Biomechanics

by

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**10 selected anatomical drawings by Leonardo da Vinci from the Royal Collection, UK,
with commentary by Martin Kemp, and a portrait of Leonardo attributed to his pupil**

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Fig. 1



Fig 2

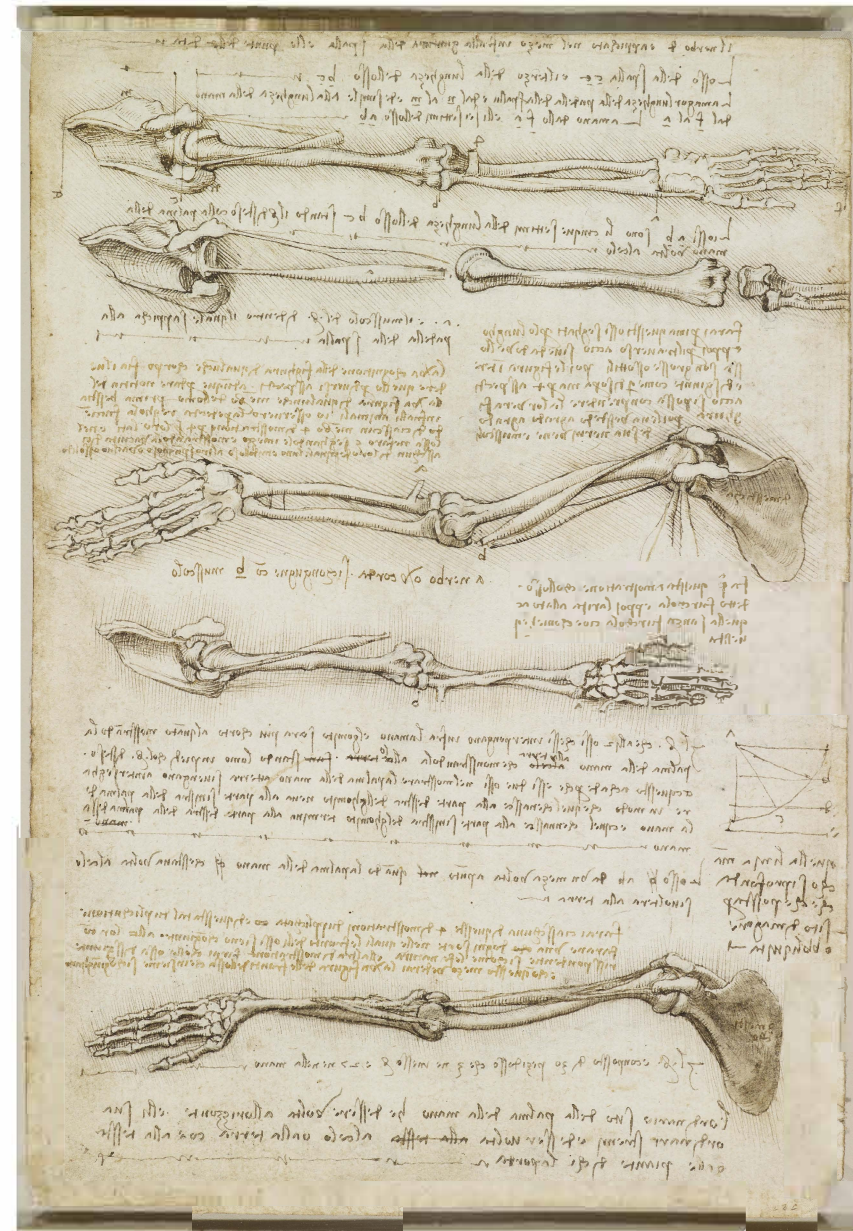


Fig.3

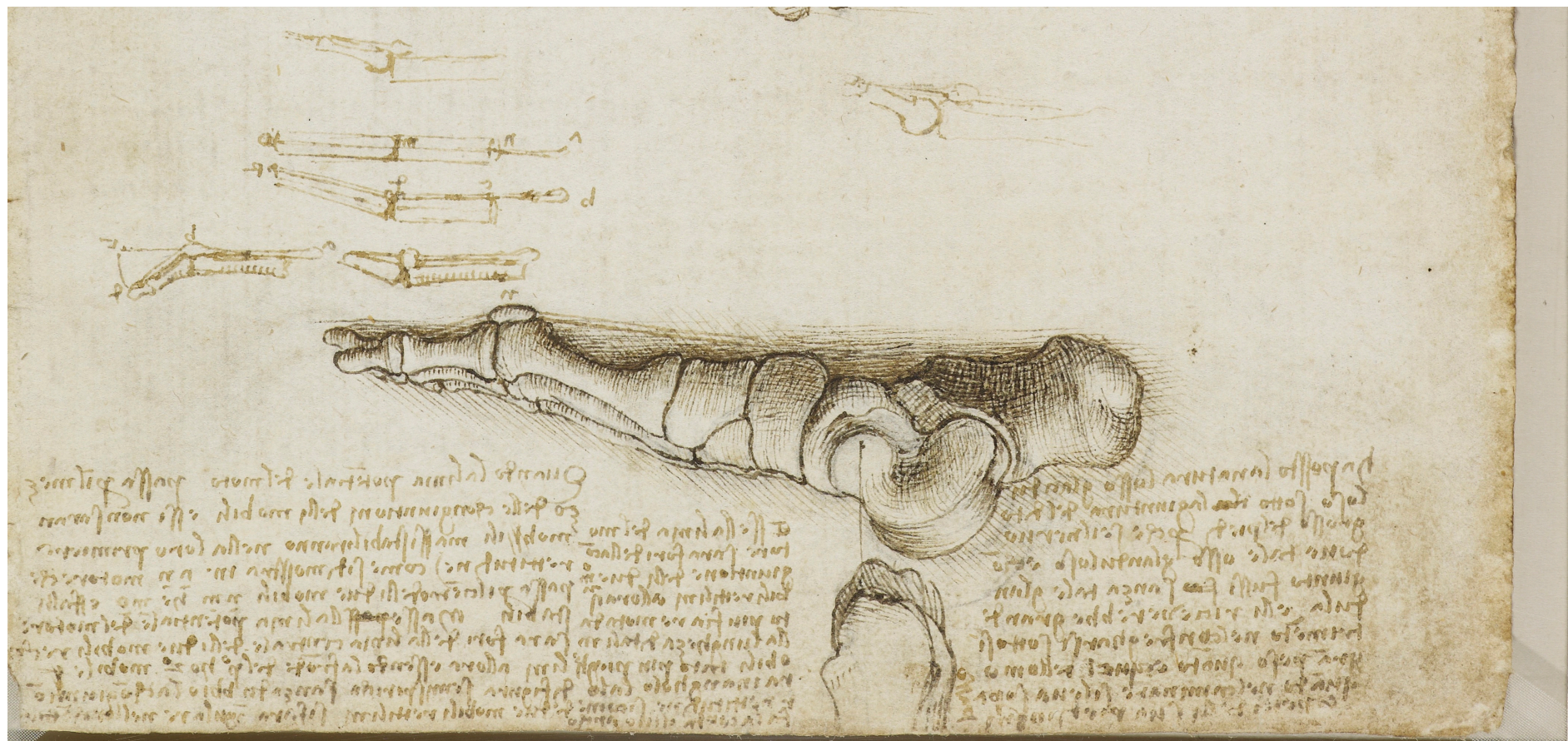


Fig 4

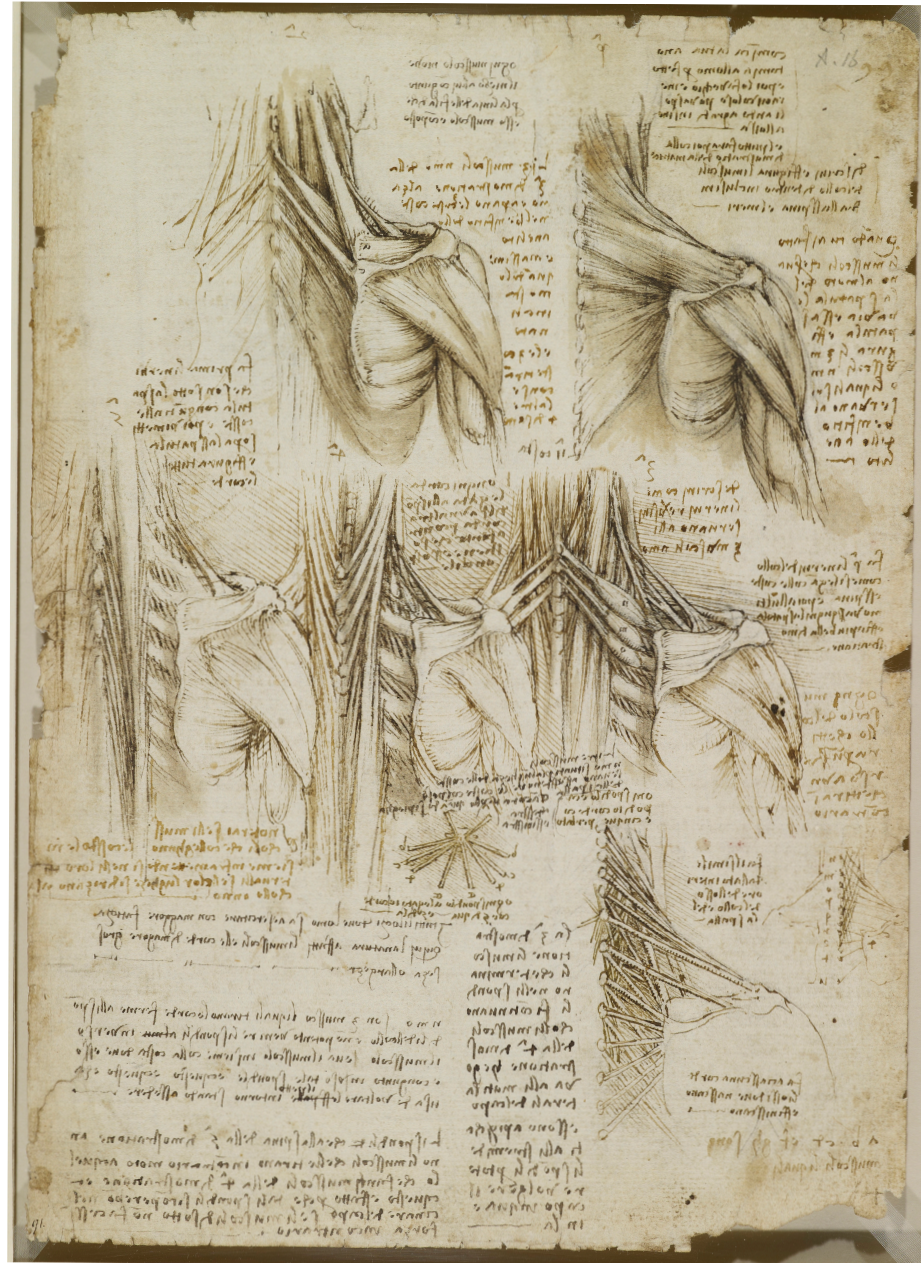
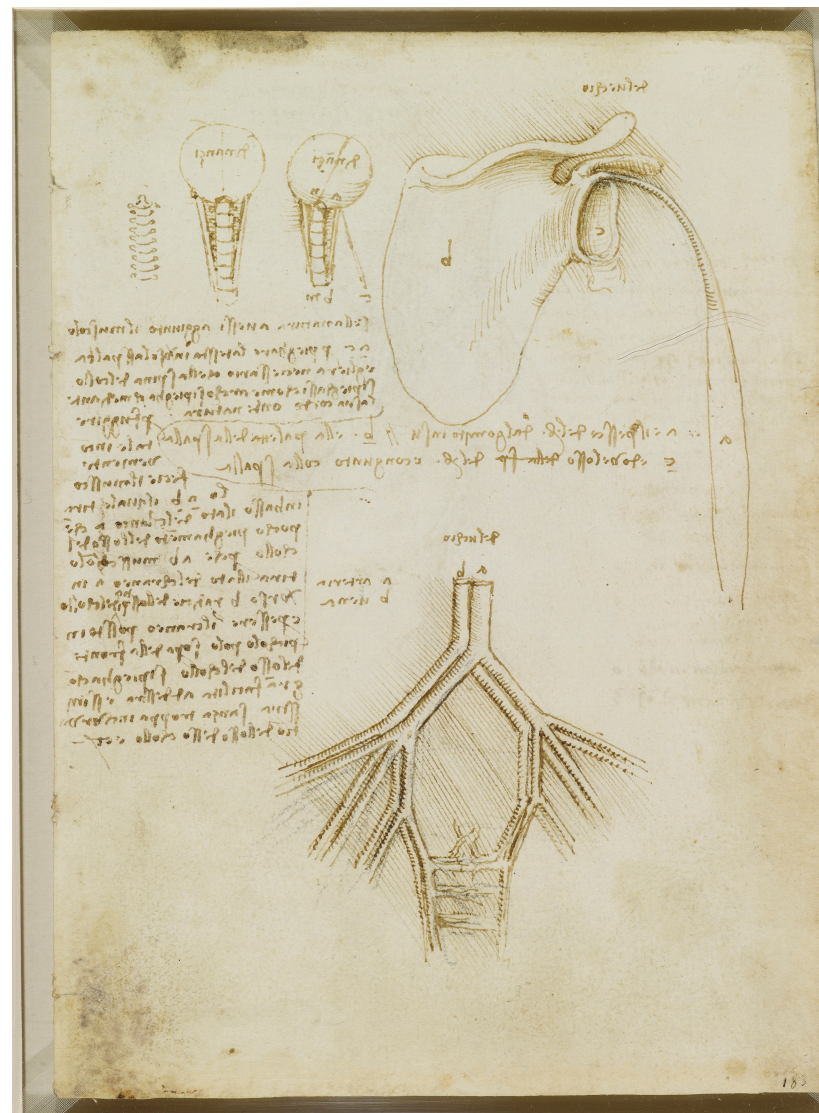


Fig.5



Fig.6



[illegible]

Fig.8

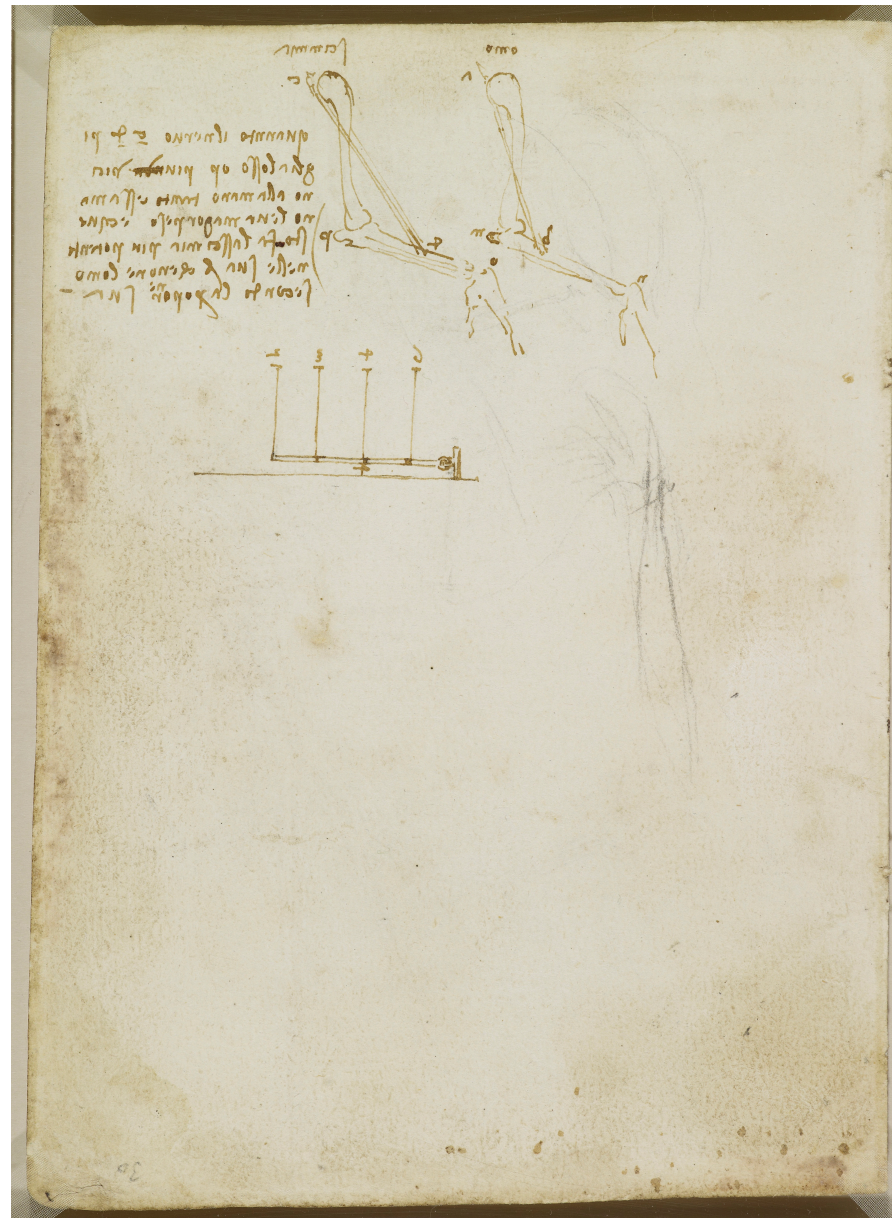


Fig9

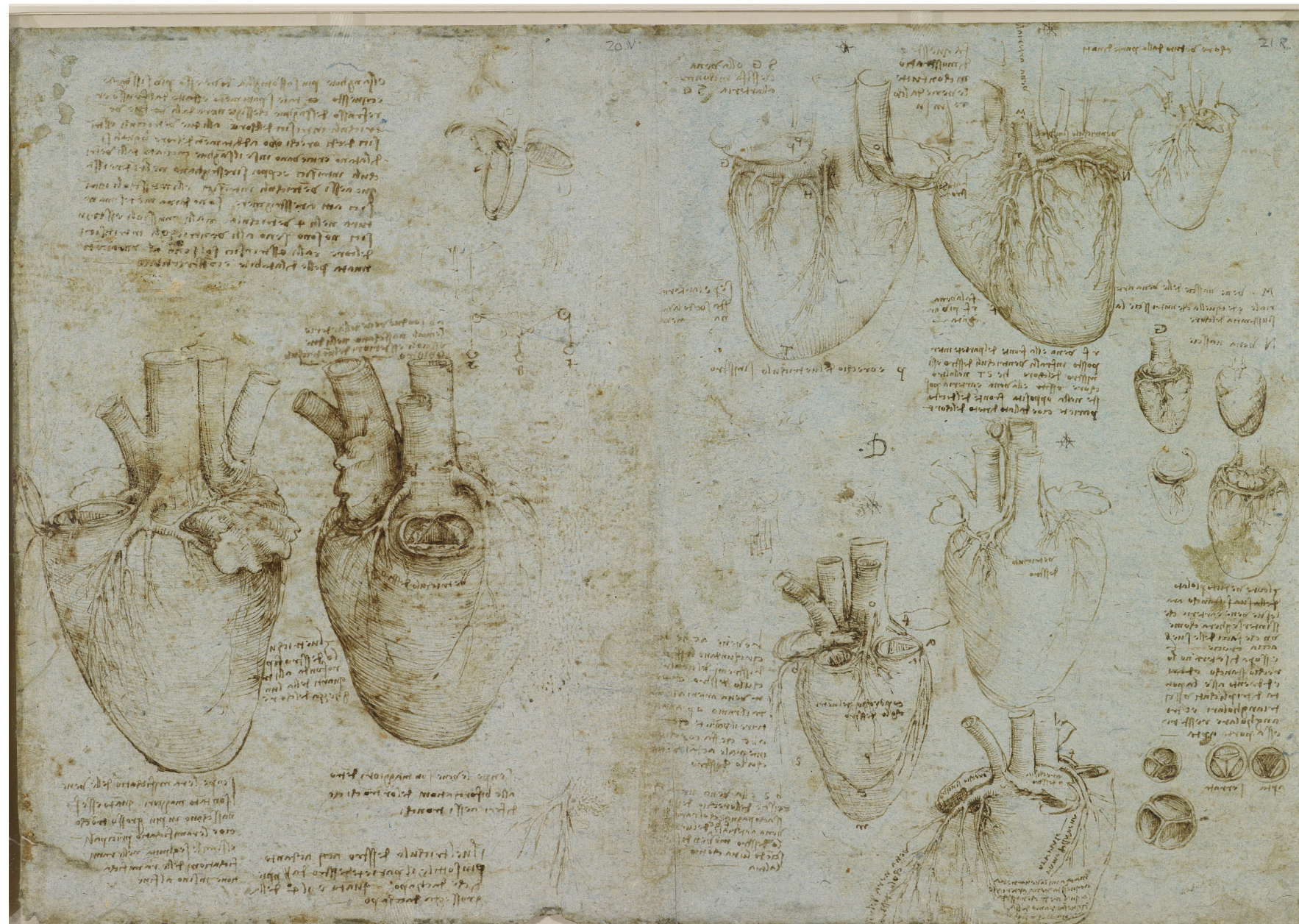


Fig.10

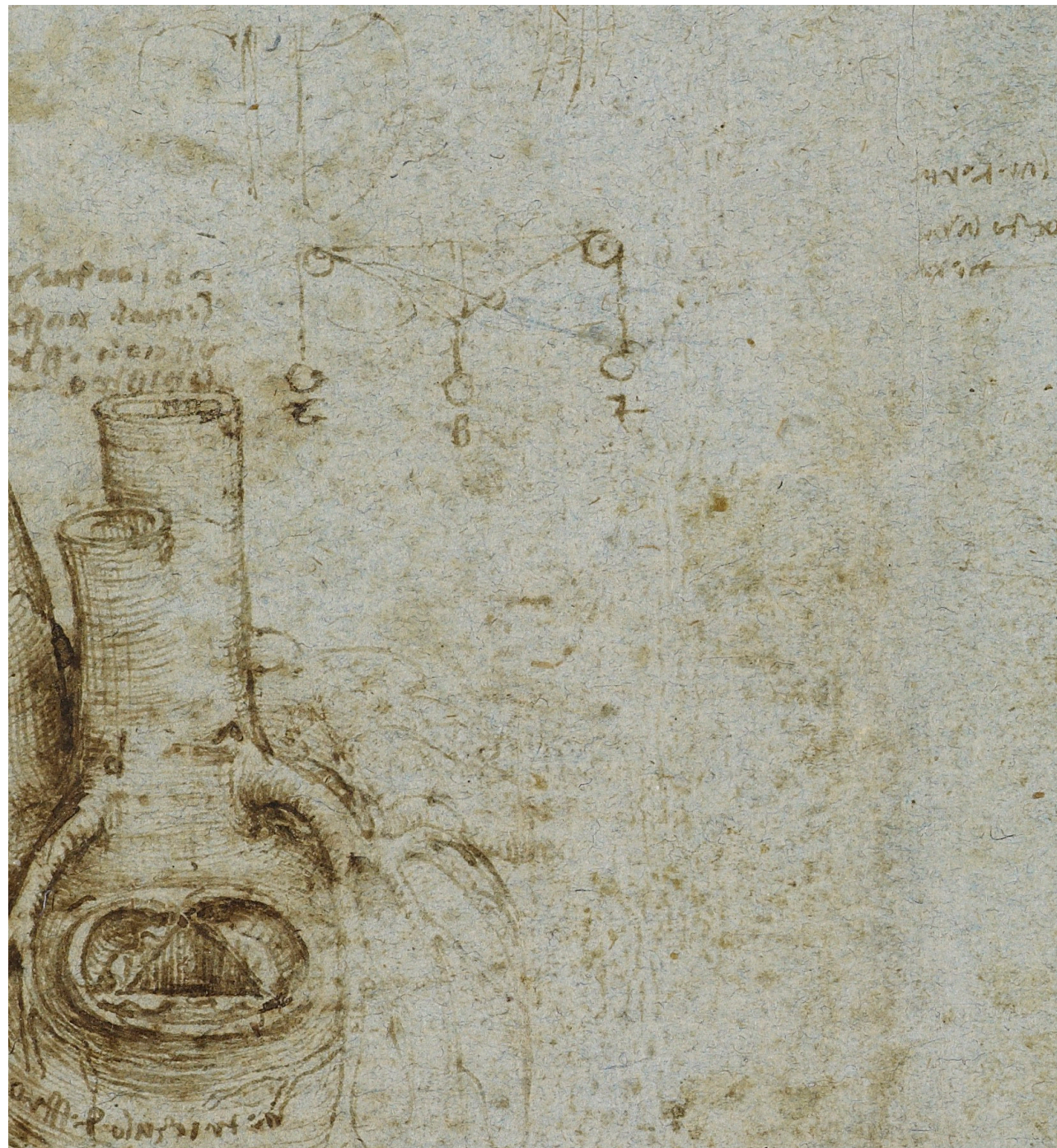


Fig.11

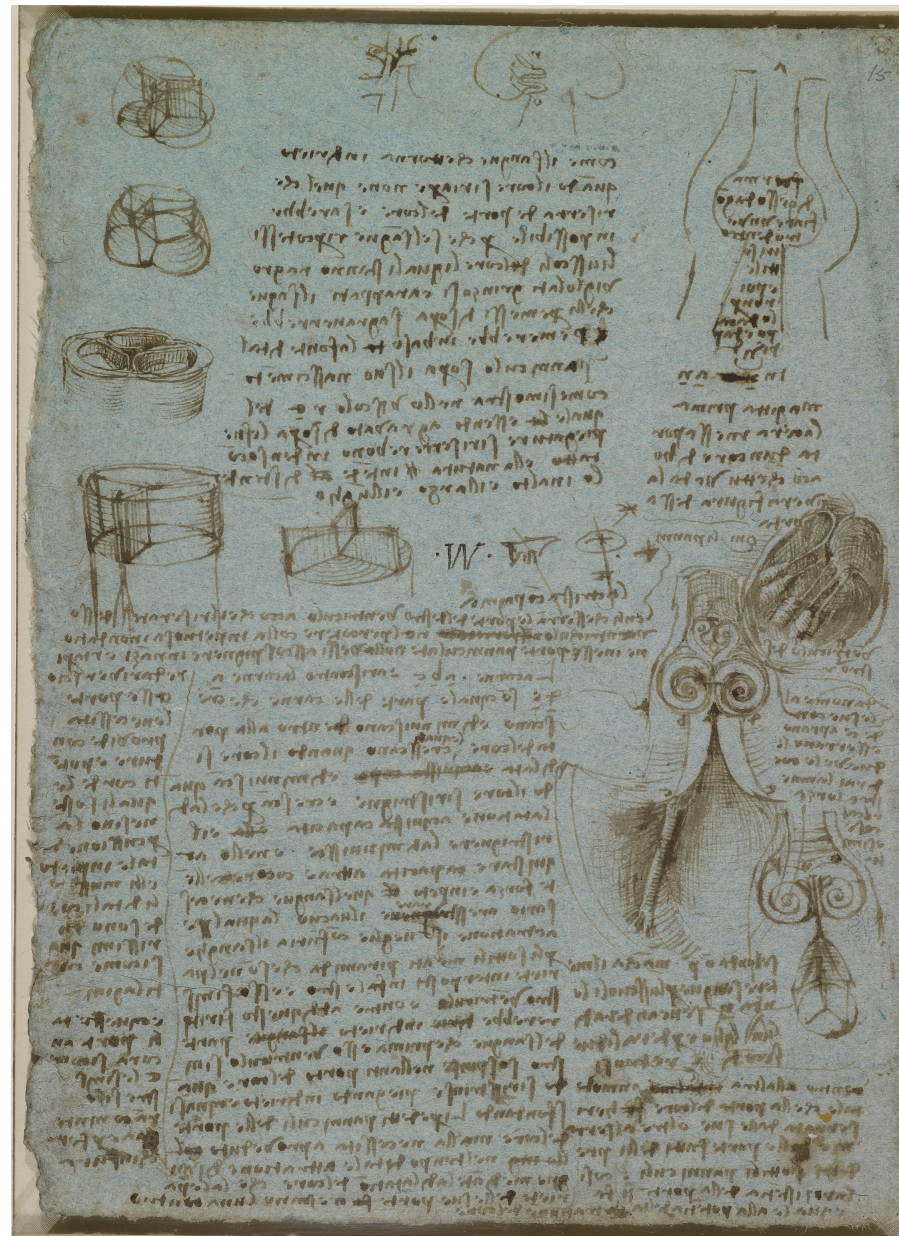


Figure Captions

Fig. 1 Portrait of Leonardo, attributed to his pupil Francesco Melzi, in red chalk on paper, ca. 1515-1518. (RCIN 912726)

Fig. 2 Bones of the arm with schematic indications of muscles.

The notes describe how the supination and pronation of the arm are driven by the biceps. Leonardo stresses that drawings should be made from multiple viewpoints to give “true knowledge of the shape of any form.” A small and obscure geometrical demonstration in the right margin shows how the reorientation of the bones in the forearm from straight to oblique effectively makes the forearm shorter. (RCIN 919000v / RL 19000v / K&P 135v)

Fig. 3 Detail of a page devoted to the bones of the foot and muscles of the shoulder.

Analysis of the mechanics of the foot, including the role of the sesamoid (“glandular”) bone in reducing internal friction under the ball of the foot. The small diagrams of the toes and the “glandular” bone show that “when the line of the power of motion passes through the center of the junction of moveable things, they will not be mobile but will be stabilized along their straight axis.”

The foot drawings were inverted when the texts were later added. (RCIN 919000r / RL 19000r / K&P 135r)

Fig. 4 Demonstrations of muscles of the neck, shoulders and upper spine, at progressively deeper levels, with two “cord diagrams.”

The drawings and added texts were undertaken over a period of time and develop away from naturalism. The chief concern is to demonstrate the antagonistic “cords” operating on the spine: “every tendon [*corda*] fastened to a vertebra has another tendon acting via the spur that sustains the vertebra. Every muscle of the neck that pulls in one direction has another that pulls in the contrary direction.” (RCIN 919015r / 9RL 19015r / K&P 149r)

Fig. 5 Mechanical analyses of the muscles attached to the ribs, spine and neck, with a diagram of a ship’s mast.

Leonardo added a note at the top that says, “one treats of man following the instrumental method and not vice versa.” The two major topics are how the ribs move in respiration and how the heavy head is held upright and can move. The smallest of the diagrams demonstrate by reference to the mast of a boat that “those ropes more readily prevent the collapse of the mast [*albero*] to which they are joined at their end that converge on their junction with the mast at equal angles.” (RCIN 919015v / RL 19015v / K&P 149v)

Fig. 6 Demonstrations of the mechanics of the neck with the bending of the upper spine, the scapula, the muscle of the biceps, and pelvic vessels.

This page, twice labeled “on the old man,” is earlier than the preceding illustrations, and is his earliest mechanical analysis of the spine and head. In this case, Leonardo states that the system is not like the bending of a bow by its bowstring because of the small fulcrum at the base of the cranium and the limited flexion of each of the cervical vertebrae. (RCIN 919049r / RL 19049r / K&P 58r)

Fig. 7 Demonstration of the mechanics of the jaws and the types of teeth.

This, in the series of skull drawings from 1489, is the earliest of Leonardo’s mechanical analyses of the body. He describes how each tooth performs in accordance with its location on the levers of the upper and lower jaws. (RCIN 919041 / RL 19041r / K&P 68v)

Fig. 8 Comparison of the attachment of the biceps in a monkey and a man, plus a mechanical analysis.

The drawing on the left is labeled “monkey,” on the right “man.” (RCIN 919026v / RL 19026r / K&P 112r)

Fig. 9 A large double sheet, folded once. Studies of the exterior of the heart of an ox, showing the major vessels truncated, the tricuspid valves, and the blood supply to the heart muscles.

Having earlier neglected the auricles, Leonardo now crucially states that “the blood is made more subtle where it is more beaten, and this percussion is made by the flux and reflux of the blood generated from the integral ventricles of the heart into the two external ventricles, called auricles... and then they contract returning the blood to the integral ventricle.” The auricles serve to cushion the “percussion” in a way comparable to bales of wool that are used to reduce the impact of bombardments on naval boats. The drawing of the exterior of the heart at the top left of the right-hand page illustrates the vessel *M*, that “arises from the atrial vessel, and it nourishes the substance of the heart.” (RCIN 919073v / RL 19074v-19073v / K&P 166vA)

Fig. 10 Detail of Fig. 9, showing the diagram of two pulleys and three weights.

Fig. 11 Studies of the geometry of the tricuspid valve and vortices in the neck of the aorta, and the papillary muscles, with a scheme to make a glass model. The geometrical structures involve the “principles” that were shared by all natural designs. (RCIN 919082r / RL 19082r / K&P 171r)

Caption References

RCIN and RL numbers are, respectively, the current and former systems of inventory numbering (recto and verso noted) used for the drawings in the Royal Collection at Windsor Castle.

K&P: Keele K, Pedretti C (1979–1980) *Leonardo da Vinci: corpus of the anatomical studies in the collection of Her Majesty the Queen at Windsor Castle*, in two text volumes with a box of facsimiles. Harcourt Brace Jovanovich, New York.