Leonardo da Vinci's Embryological Annotations [1]

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Among his myriad scientific and artistic contributions, Leonardo da Vinci?s work in embryology [4] was groundbreaking. He observed and diagramed the previously undemonstrated position of the fetus [5] in the womb [6] with detailed accompanying annotations of his observations. Leonardo was highly paranoid of plagiarism and wrote all of his notes in mirror-like handwriting laden with his own codes, making his writing difficult to discern and delaying its impact. Although he carried out his studies in embryology [4] from 1510?1512, it was not until the 1900s that his work was popularized among the scientific community. Leonardo?s embryological annotations found in the third volume of his private notebooks represent his notable contributions to and explanations of human development and embryology [4].

Having reportedly performed only one dissection of a human fetus [5], Leonardo?s resulting conclusions were lacking in their accuracy. Leonardo believed that the fetus [5] under dissection was four months in age, but his embryological drawings were later interpreted to have depicted a fetus [5] that was actually in the sixth or seventh month of gestation [7]. Leonardo is considered to be the first to have quantitatively measured the fetus [5]. Giving his measurements in *braccios*, which is Italian for one arms length, Leonardo noted that a fully formed fetus [5] would measure half a *braccio* in length, just less than one foot. He also discovered that in relation to the body, the liver in the fetus [5] was much larger than its relative size in adulthood. He declared that the umbilical cord [8] was always the exact same length as the embryo at all stages of development, and that the child would quadruple in size after birth. Leonardo understood the relationships between changes in size and weight over time and asserted that growth and development occur faster per day inside the womb [6] than once the child is born. This realization occurred almost one hundred years before William Harvey [9] reached similar conclusions on the relationship of changes in size and weight over time.

Some of Leonardo?s conclusions on the nutritive and respiratory aspects of the developing fetus [5] also emerge from his annotations. For example, he was certain there was absolutely no respiring of the fetus [5] in the womb [6] because he believed it would drown. Leonardo also argued that the fetus [5] could not make a sound or cry because if there was no respiration there could be no voice. Assuming a widely accepted notion that was put forth by Galen [10] nearly 1000 years prior to Leonardo?s experiments, Leonardo believed that the nutrients from the mother were carried to the fetus?s liver through the mother?s menstrual blood via the umbilical cord [8]. Leonardo theorized that the umbilical cord [8] carried out the dual functions of supplying nutrients to and exporting urine from the fetus [5]. He believed that the umbilical cord [8] transported nutrients to the liver, and then passed them through a portal into the stomach where some of the nutrients were digested and the rest were converted to the fetus?s heart, which Leonardo assumed did not beat. His conclusions raised questions regarding fetal nourishment while also taking into account the existence of the fetal stomach. The existence of the fetal bile duct was unknown at the time.

Leonardo believed the umbilical cord [8] exported the fetus?s urine outside of the womb [6] because he assumed the position of the right foot blocked the urinary passage and prevented

the movement of urine there. This theory of the umbilical cord?s dual processes has a direct correlation to Leonardo?s studies in hydrology and his knowledge of back eddies in the flow of rivers, in which the water current doubles back on itself to flow in the opposite direction. This natural philosophy and observation of nature influenced his hypotheses whereby human physiology should follow similar laws. Since the fetus [5] under dissection had its feet crossed in front of the urinary passage, Leonardo reached the conclusion that the foot completely blocked any passage of waste through the urethra, and so he relied upon his knowledge of hydrology to formulate conclusions that the umbilical cord [8] would facilitate the movement of waste as well as providing nutrients.

In determining the fetus?s ensoulment [11], the point at which the human soul is believed to enter the body, Leonardo noted that the fetus [5] was not imparted with a soul at conception [12]. He also disagreed with the assessment made by Aristotle [13] that ensoulment [11] happened at around day forty of the fetus?s development. Instead, Leonardo believed that the mother and fetus [5] shared one soul until birth. Leonardo also diverged from Aristotle?s views regarding generation. While Aristotle [13] believed that the female parent contributed only unorganized matter to the embryo and that the father was responsible for providing the form or appearance of the child, Leonardo attributed an equal share in the form of the child to both parents. This belief was based on his observation of the female?s characteristics being visible in the offspring of interracial parents, which he recorded were of mixed color and from which he could only conclude that the mother had as equal a share in determining children?s appearance as the father.

Leonardo da Vinci?s descriptive methods of scientific observation are represented in his embryological annotations, which give great insight into his embryological analysis. Being lucky enough to exist in a time free from extreme religious prosecution in Europe, Leonardo?s experiments also represented curiosity that had been stifled throughout earlier times. Although it would not be until many years later that his observations would be investigated by others, Leonardo?s scientific research and analytic powers are evidence of his forward thinking and interests in the beginnings of human development.