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Revealing the Key to Success in Science...Doodling: A study on the importance of art in science

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Jessica Jennette

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Student Name (print or type): Jessica Jennette

Faculty Supervisor (print or type): Kimberly Martens

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Abstract

Title of project/ thesis: Revealing the Key to Success in Science ...*Doodling*:
A study on the importance of art in science

The hypothesis is that Art, as a learning tool and creative process, actually improves a student's basic skills in Science. When incorporated into the curriculum, art projects that are directly related to the science subject matter help students understand the material and improve their skills and thinking processes.

Research includes: historical evidence of intelligence strengthened by an art and science background, current art processes that are related to adolescent performance or development in school, published pieces concerning the connections between art and science, and studies on cognitive development in the brain that are influenced by art-science interactions. Additional interviews with professionals in the fields of Education, Psychology (Sciences) and/or Art were conducted in hopes of learning that there are advantages that using art in science may provide high school students. Issues such as budget cuts have also been addressed as circumstances that may obstruct the idea of an art-science curriculum.

Through extensive research, evidence has been compiled that suggests that art plays a significant and valid role in the high school science classroom.

"Science and art are not mutually exclusive.
Each can enhance the appreciation of the other."
-Paul Lichter

It's 10:30 in the morning and you are changing books between classes. Your thoughts sound something like, "*Only one more hour until lunch... what do I have next? Oh yeah, science.*" Picking up the stuff you need, "*Why are science books always so heavy? It's like they didn't have time to make every High School student take weight training and thought they'd make up for it by forcing us to haul fifty-pound books to class.*" You cross the threshold into the science classroom, catch sight of your last science project, a poster of the Krebs cycle, hanging on the wall next to the rest of the class's. "*Man, I did a good job on that poster; that was a fun lesson... wonder what's for lunch today.*"

Science education has often used illustration in the classroom. Flashbacks to High School Biology reveal diagrams of a rabbit's anatomy, the parts of a worm, the structure of a cell, or the layers of our skin, all depicted in a visual format. Taking this a step further, however, it may be suggested that visual art is more than just a natural ally to science education, and may, in fact, be indispensable to the scientific learning process (Burkhardt, 2001). The intent here is to explore the possibility that giving art a slightly larger role in the science classroom not only improves students' proficiency and knowledge of the subject matter, but also helps build essential skills that are applicable to science and other disciplines. Pick a science notebook I've saved from my miniature library and you'll find a decorated cover with atoms, space-age designs, or sketches of something the teacher was talking about in class, pages and pages of illustrated notes with color-coded highlighted terms, and doodles in practically every margin through out its entirety. I've always thought that people didn't fully appreciate the fine art of doodling in science class (I never found it quite as easy or useful to make visual notes in my other subjects). Advocates for doodling would hypothesize that making visual notations of the concepts presented in science class help students to better internalize the information. Now, after investigating the cause behind that belief, justification of using art to help understand science is much easier to supply. Not only is visual art a natural aid in explaining scientific concepts, but it may also affects one's thought patterns in ways that expand the degree of understanding and improve one's cognitive ability and skill levels in learning (Burkhardt, 2001). Areas that provide support for this theory and it's useful applications in the High school context include historical evidence, modern science programs that incorporate art, expert opinions on the topic, and research in brain function and development.

History provides a wealth of examples that show a strong correlation between art and science and how the two, together, are a successful recipe for achieving academic excellence in science. One classic example is Albert Einstein. As an adolescent, he attended a school that emphasized the arts and sciences in the curriculum; specifically, visualization and imagery were taught as an important part of the scientific process (Robertson, 2003). Einstein is quoted as saying, "Searching for God's design is the source of all true art and science" (Robertson, 2003). An interpretation of this statement may be that both art and science are, by nature, exploratory and observational subjects and therefore already have much in common with each other. This quote could also show how the interplay between art and science played a key role in Einstein's success as a scientist, a detail that is not often related to his genius or fame.

Another example of the link that exists between science and art concerns a scientist who goes by the name of Kekule. Arguably, his largest contribution to science was his discovery of the benzene ring structure. What makes his discovery remarkable is the story of how he first made the connection between the structure of benzene and a ring configuration. Kekule, while doing work, supposedly late at night, started to fall asleep and while in this stage of half-sleep, he saw the image, in his words, as "dancing atoms whirling in a ring…" (Rieser, 1972). This dream ultimately led him to the discovery of the structure of benzene, a fact that paved the way for defining the shapes and properties of molecules that are still taught today (Rieser, 1972).

The relationship between Kekule's vision and discovery is a good example of the interplay that can occur involving visual imagery and science. The book Art and Science uses A-thinking and R-thinking to support the theory that these two disciplines are complementary (1972). According to the book, A-thinking is a category of thought encompassing visions, hallucinations, dreams, etc., and R-thinking includes the critical and logical thinking processes (Rieser, 1972). So, in these terms, the dream-like and artistic thought patterns are both in the A-thinking category. The science- subconscious imagery interaction is what Kekule claimed was responsible for his discovery (Rieser, 1972). As Rieser puts it, "…an interplay of these two kinds of thinking is responsible for both scientific and artistic productions" (Rieser, 1972). From a teacher's perspective, if this interplay can be useful to seasoned scientists, it can also be beneficial to developing high school students.

A third illustration that reinforces the science-art collaboration, dating back to the fifteenth century, is found in the scientific writings of Leonardo da Vinci. Known for his artistic genius, and not so much for his affiliation in science and philosophy, Da Vinci had generated a number of scientific observations in his lifetime, recorded secretly in his journals as text and illustrations (Letter to Teachers: Exploring Leonardo, 1997). Artists are sometimes said to have a more developed sense of observation than others as far as understanding relationships goes. Given this conjecture is true, that talent included understanding functional relationships, artists would be given an advantage over others when comprehending, explaining, and inventing mechanical devices. There is evidence that the painter of the Mona Lisa had a keener sense of observation in mechanics and physics than most of the world at that time; whether this is due to his affiliation in science, art, or perhaps both is still considered speculation. Despite his numerous revelations in the science field, Da Vinci never published his studies; most of his inventions of the fifteenth and sixteenth centuries had only remained sketches (Letter to Teachers: Exploring Leonardo, 1997). These sketches were inspiration for some of the technologically advanced machinery used today. A few examples of Leonardo's secret designs that in one form or another still survive today include his 'cork-screw' flight machine, a concept that is applied to today's helicopter, an impermeable vehicle operated from the inside that has since morphed into the iron tank, and a outfit that would allow an individual to breathe underwater, which we now call a SCUBA suit.

In addition to this, Da Vinci is also known for his astonishing sketches of human anatomy (Leonardo Da Vinci: Man of Both Worlds). Musculature, skeletal structures, and illustrations of the womb and its contents are all depicted with more detail than had ever before been achieved and were discovered among his private, unpublished drawings centuries later (See figures 1-4, attached to this paper, to view Da Vinci's anatomy sketches). What is so impressive, though, is the time period in which these drawings were created (Leonardo Da Vinci: Man of Both Worlds). Da Vinci lived during the mid 15th and early 16th centuries and it was 300 or 400 years later when his inventions resurfaced and became the subject of new technology; the cutting-edge medical illustrations that were being made were found to have already been documented, not a few years or decades earlier, but hundreds of years prior to their discoveries (Leonardo Da Vinci: Man of Both Worlds)! This may imply several things. First, that Leonardo's talent in both of these disciplines could be a recipe for genius; not only did he make tremendous conceptual breakthroughs in his life (that were unappreciated by the society he lived in), but he was also centuries before his time and revered as a genius in eras long after his death. Also, Da Vinci's outstanding ability in art and ground-breaking scientific thoughts and concepts may not have been completely coincidental. It could be suggested that the artist's interests in art and science were fueled by each other, which led Da Vinci to make connections and advances in fields that had never before been made.

Historical examples teach us that art and science together have the potential to open minds to a new extent. Some members of today's society, however, have adapted the idea that art is a less important form of learning at the high school level, or at least, not as important as the other subjects. This contention does not just exist at the administrative level either; several states have expressed this belief through cutting funds for art programs in their schools. Stephen Kinzer of the New York Times writes about a number of states in the U.S. that have already drastically cut funds from art programs despite studies that have shown investments in art programs produce "handsome economic returns" (Kinzer, 2003). New Jersey cut it's entire $18 million dollar budget for the state's Council of the Arts and replaced it with a smaller $10 million fund to be used as support for small arts groups (Kinzer, 2003). "California cut its support for arts and cultural programs by 41 percent...[and] Massachusetts went even further, with a 62 percent cut" (Kinzer, 2003). Arizona and Missouri have proposed cutting funds for their art programs all together to help control their budget deficits (Kinzer, 2003). Officials would probably say that it is not their wish to dissolve educational art programs in their states, but it was a decision that had to be made to get the state out of debt. National advocacy groups, however, insist repeatedly that the state would do well to support the art programs that improve the quality of education for its children, and therefore its future (Kinzer, 2003).

Surely, not all adults condone such actions by the states. This ambition motivates the search for modern science programs that incorporate art in high school. A few of my research findings that display an excellent preface for art-based science curriculum were supplements for a much younger age group... hardly suitable for fourteen and eighteen-year-olds. Admittedly, when my initial searches for material yielded curricula that were only used in elementary schools (sometimes adaptable for middle school science projects) I was a little discouraged. What has yet to be proved is that the hypotheses that support science and art as a strong interdisciplinary collaboration, such as Deborah Schecter's Science Art book, could prove to be useful in a high school context as well. Schecter, in her book, explores the natural connection between these two disciplines via a series of art projects, but does so within a second to fourth grade context (Schecter, 1997).

Initially, this might imply that science and art collaborations were meant to be limited to the elementary and middle schools, but scholars such as Nancy Recchia, with a

Masters degree from the School of the Art Institute of Chicago, demonstrate the practicality and usefulness of an art-science curriculum in the high school science field (Recchia, 2000). Her thesis addresses the factors that make an interdisciplinary science unit coupled with visual art projects a plausible, successful, and complete curriculum. Examples of the Science and Art National Standards are cross-examined with the content of the lesson plan and Recchia's discussion and show that the unit activities and goals satisfy many important standards in both disciplines simultaneously, that is, without taking much time away from one of the disciplines to address the standards of the other (Recchia, 2000). Upon examination, the lesson appears to cover the state or national standards seamlessly, without awkwardness or extra effort, and this evidence supplies yet another reason to bring art into the high school science classroom.

Other professionals also think that art is very useful in the context of scientific discovery. UC Davis physics professor Gergely Zimanyi believes that similarities between the disciplines of art and science are significant and says that, "both disciplines aim to describe nature in the abstract…[and]… try to reveal previously hidden relationships. Artists and scientists both share extraordinary abilities to visualize and find patterns in abstract and complex ideas" (Morton, No date). Leonard Shlain, a San Francisco surgeon writes in his book that, "There is in the artist's vision a peculiar prescience that precedes the physicist's equations…" and that, "artists have mysteriously incorporated into their works features of a physical description of the world that science later discovers" (Morton). The example named in this article uses Einstein as support (Morton), who attended a school that used visual art in collaboration with science to teach their students (Robertson, 2003). This further reinforces the idea that art is a significant element for science in secondary education.

If this isn't enough to substantiate the real-life applications that this concept has in modern high schools, the support of an ivy-league school program might be able to. Project Zero, a research study, managed by Harvard's Graduate School of Education, considers "the development of new approaches to help individuals, groups, and institutions learn to the best of their capacities" (Project Zero at the Harvard Graduate School of Education, 2003). An investigation conducted within this program relates the science and art intelligences as a means to develop an appealing and interactive classroom environment within secondary and college education (Project Zero at the Harvard Graduate School of Education, 2003). The introduction on the Project Zero web page summarizes the intent of the ongoing investigation:

> "Project Zero's mission is to understand and enhance learning, thinking, and creativity in the arts, as well as humanistic and scientific disciplines, at the individual and institutional levels (2003)."

The "Theory of Multiple Intelligences" is an important principle for Project Zero (Gardner, 1989). The model divides intelligence, a concept that has been previously defined as a general ability (a single trait), into several independent skills, specifically: verbal, mathematical, spatial, bodily-kinesthetic, musical, interpersonal, intrapersonal, and naturalist skills. Having this belief in the roots of the project makes the facilitators in the program sensitive to the intelligence of each individual student. Also, this theory may lead to the conclusion that those adolescents who do not have very strong mathematical and naturalist skills (intelligences commonly applied in the sciences) or who do not have highly developed spatial skills (the intelligence associated with art) are given an opportunity to strengthen their intelligences that have room for improvement within the context of an interdisciplinary science class. This model implies that if a student's skills are improved within one area, their overall intelligence is increased (Santrock, 2003) due to both new knowledge in a specific area and the interactions between the different genres of intelligence.

It would be safe to claim that the goal of teachers is to strengthen the weak skills of students- that the objective of a school is to increase the knowledge and thinking skills of its adolescents to higher levels. New studies on the development of the adolescent mind reveal that connections in the brain, say between the creative and the logical parts of the mind, are being made and pruned as a result of the cognitive activity that occurs between the ages of three and fifteen, approximately (Santrock, 2003). The fact that this statement was referenced by Dr. Lee Shumow, a Northern Illinois University Professor, Ph.D. in Educational Psychology, makes a larger impression on me and further convinces me that art-science curricula have a place in the school system (Shumow, 2004). Fifteen is the age of an average Sophomore in high school. Freshman and Sophomores are, therefore, in a position to receive long-term benefits from an art-science class where a wide variety of connections in the brain are being cultivated during this critical time in adolescent development. Science classes that emphasize science-art connections for Juniors and Seniors, or those that are older than fifteen, are still giving students the opportunity to learn from the contexts of their stronger intelligence, thereby providing equal advantages to adolescents with different strengths (Shumow, 2004).

The ideal student, if there is such a thing, in addition to having cultivated very useful connections in his or her brain, might also be described as "well-rounded" or "whole-brained." When looking to understand the relationship between art and science more fully, studying the brain proves to be insightful. The right and left hemispheres of the brain are known to house different functions and cognitive abilities. For example, the mathematical/logical portion of the brain is located in the left hemisphere where the synthesizing abilities and creativity is located in the right hemisphere (Funderstanding-Right Brain v. Left Brain, 2001). Both areas are able to 'communicate' with each other across the corpus callosum. In a similar fashion, the general type of thinking required in science classes are assumed to be in the deducing, mathematical portion of the brain or in the left hemisphere, whereas the general type of thinking in art is thought to occur in the visual interpretation region or in the right hemisphere. When simplifying the functions of the two hemispheres of the brain, it is said the right half is home to creativity and the left half is responsible for logic (Funderstanding-Right Brain v. Left Brain, 2001). Naturally, at times, science requires some creative thinking just as art requires some logic.

One particular High School art teacher, Maja Shoemaker, with a Masters degree in Curriculum and Instruction, was interviewed for this study, and believes that Art and Science are natural compliments, a credence supported by Project Zero (Gardner, 1989). Her convictions are such that she has developed her own theory on the subject.

Here, I paraphrase her conjectures. Patterns of thought that occur when creating a piece of art, particularly when doing so from observation (drawing a still-life, for example), evokes similar cognitive functions as those that occur in science class. During the drawing process in an art classroom, a student must first creatively interpret what he or she sees, and then make choices as to how to portray it in a two-dimensional format. The student must next determine if the spatial interpretation they've just made make sense, a tangent where brain activity leaves the artistic hemisphere and crosses the corpus callosum into the logical, left area of the brain. The artist's thoughts slide back over to the right hemisphere to make further interpretations and the process continues sliding back and forth from the right half of the brain to the left, thereby creating a "fluidity of thought." This process may stimulate the mind to access parts of the brain across the corpus callosum more readily (Shoemaker, 2004).

Conveniently, the thought patterns that are most useful in scientific learning and reasoning require the same fluidity of thought. In a science classroom, during a lesson where new information was being presented to the students, each adolescent would (ideally) consider the scientific concept and memorize the content, which are both left brain functions, and evaluate whether the information makes sense to them by comparing the new concepts with their prior knowledge, a task that may require some creative comparison. Other students are more visual learners and attempt to picture the scientific concept in order to make sense of it. Osmosis, for example, when being considered by a visual learner for the first time may be rationalized by picturing a cell and visualizing what would happen to the cell when the solute concentration is greater inside the cell than outside the cell and visa versa. This type of thought accesses the visual-spatial, or right hemisphere of the brain. Using art to display knowledge of a scientific concept would be very helpful to students that learn by employing a visualization system. Therefore, a curriculum that incorporates both left and right-brained functions addresses the needs of students that learn in different ways. A science and art program may also provide an opportunity for students to exercise "fluidity of thought" so that students are shown how to view a new concept in a different way, particularly when the concept does not make sense initially.

To be fair, many students are able learn scientific concepts easily enough and have little need of spatial reasoning to fully understand new material. On the other hand, many students do benefit from pictorial representations of science-related ideas, and therefore value visual aids, whether produced by the teacher or by the students, themselves.

A primary concern of science classes is the degree to which the students comprehend the material. Dr. Keith Millis, of the Psychology department at NIU with a Ph.D. in Cognitive psychology, describes three levels at which human beings record knowledge (using the process of reading a science text book as a "dumbed-down" example to accommodate a Biological Sciences major): the superficial level where information like appearance, font type, bold words, and paragraph size are absorbed; the contextual level, where the student may understand the basic ideas of the chapter, and the inference level, where a student fully grasps the meaning in the chapter and is able to compare the knowledge to personal observations or experience (Millis, 2004). Dr. Millis agrees that most science teachers believe that the contextual level is an appropriate level of comprehension for high school students to achieve (2004). Is it impractical to hold students to the highest standard of comprehension? I don't believe so; this goal is reachable and some teachers may choose to use alternative strategies to achieve this deeper comprehension. Students that are asked to take scientific concepts from its familiar encoding and place it in another, from the text book into sculpture for example, are re-introduced to the concepts in new, and often more interesting ways (Millis, 2004). Alternative perspectives is one of the most efficient ways of reaching the inferential platform of understanding (Millis, 2004).

So, within the practical contexts of the teacher, which is the better situation?... to incorporate art projects regularly within the class, strengthen the visual learners, and risk being redundant for the students who do not profit from visual reinforcement, or to maintain a more "acceptable" atmosphere, specifically, running a classroom with no 'extra fluff,' living up to society's expectations for a high school science course, and risk a lower level of comprehension in the visual learner portion of the class. Personally, I would dub the first situation "taking a risk" and the second "playing it safe." There can be no criticism of teachers who choose to play it safe, but there is something to be said for those who choose option one over option two.

The argument that the visual arts could help adolescents learn to understand scientific concepts is only the surface issue of this thesis. What's really interesting is the thought that drawing, using artistic visual aids, creating models, and similar projects actually improve a student's skills in science comprehension. One such skill is interpreting observation. To use an example mentioned before in this paper, still-life drawing or a slow and evaluative study requires a high level of observational skills… *the eyes are half way up the head, the bottom of the nose is half way between the eyes and the chin, and the bottom of the lower lip… is half way between the nose and the chin* (Shoemaker, 2004). Realizing the difference between this kind of art and drawing a smiley face, an icon used since childhood and now replaced with a new, more sophisticated method, is a skill that is applicable in science (Shoemaker, 2004). The majority of biological research and learning is based on observation; where the organs of a fetal pig are located, how two deciduous trees are similar to and different from each other, how organisms survive in the deep abyssal zones of the ocean… practically all the discoveries adolescents make in science come from observation and are therefore strengthened by observational art experiences.

Another useful science skill, likely reinforced by art, is applying logic and reasoning to a situation.

Visual imagery, a trait more often paired with art can also be indispensable to the scientist. Falling back on the ultimate example, Albert Einstein, we see that visual imagery is not merely used in creating art. When considering Newtonian physics of the speed of light, Einstein digested the visual imagery designed to make the theory understandable, very much like today's scientific similes (Robinson, 2003). After considering the model and the relationships between the interacting parts, Einstein rejected the assumption of Newtonian Physics and concluded that the speed of light is always constant, independent of the speed of the viewer (Robinson, 2003). Ian Robinson uses this and several other examples to predict: "better imagery, more creativity," and creativity, as we can see, is also an important commodity in scientific reasoning (2003). Image generation is also an efficient way of storing information in the long-term memory (Denis, Logie, Cornoldi, De Vega, Engelkamp, 2000). As stated in the book Imagery, Language, and Visuo-Spatial Thinking, "…it is well known that mental imagery can offer critical support to a variety of thinking processes, including spatial reasoning, problem solving using analogical representations, or mental discovery of novel or emergent properties" (Denis, et al., 2000). Within the high school science milieu, memorization and reasoning are at the roots of academic success in class; applying skills, like image generation, that are nurtured by art experiences aid students in understanding and study (Denis, et al., 2000).

As demonstrated, science and art have a strong relationship and present a good case for being an outstanding interdisciplinary experience; historically, the two disciplines have served hand-in-hand together for a time that exceeds centuries. Evidence supports the similarities of cognitive patterns within the brain itself, creating a connection that may lead to increased comprehension in science in so many possible ways that we can not fathom the full extent of understanding (i.e. Einstein, Da Vinci). Research shows that modern programs that use science and art in the curriculum can and have been successful (i.e. Recchia's lesson plan and Harvard's Project Zero). And yet, despite the strong evidence that supports the interdisciplinary education, one outstanding difference has developed, specifically, that science remains a required and highly respected area of study, whereas the arts are struggling to keep its place in the curriculum. It has been suggested that schools sometimes compare the success of art as a discipline by how much it contributes to the "more important" subjects (Gardner and Perkins, 2000). For reasons unknown, hesitation to attempt to recombine two convincingly complementary disciplines continues.

Experienced educators, among others, say that if you're not a part of the solution, you're part of the problem. Involving a multifaceted, contemplative discipline in the high school science arena may prove to be just the change needed to bring a little profoundness back into secondary education and the lives of the students that complete it. Ours is a society that is fast becoming a place where independent thought and the pursuit of deeper understanding are no longer as highly valued, and the greatest defense in this situation may be those doodles in the margins of science notebooks.

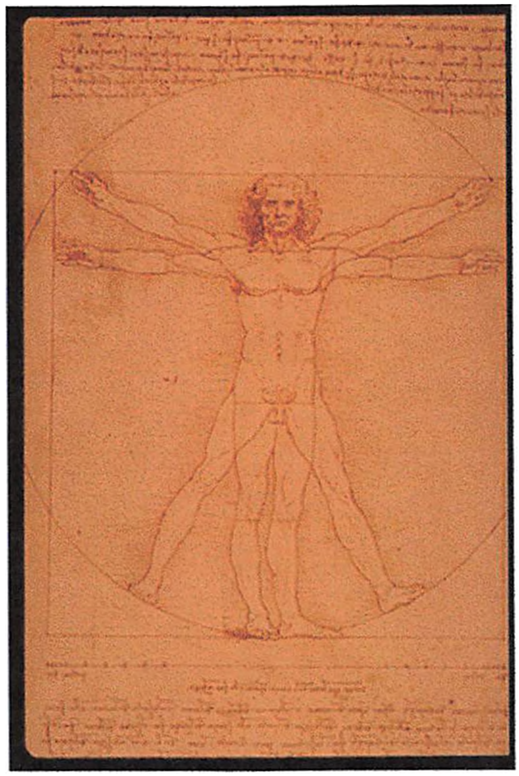

Figure 1. Da Vinci's canon

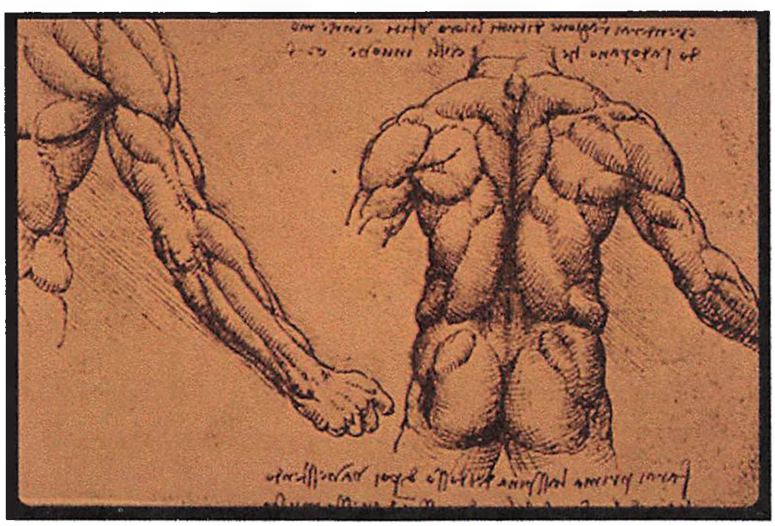

Figure 2. Da Vinci's dorsal musculature

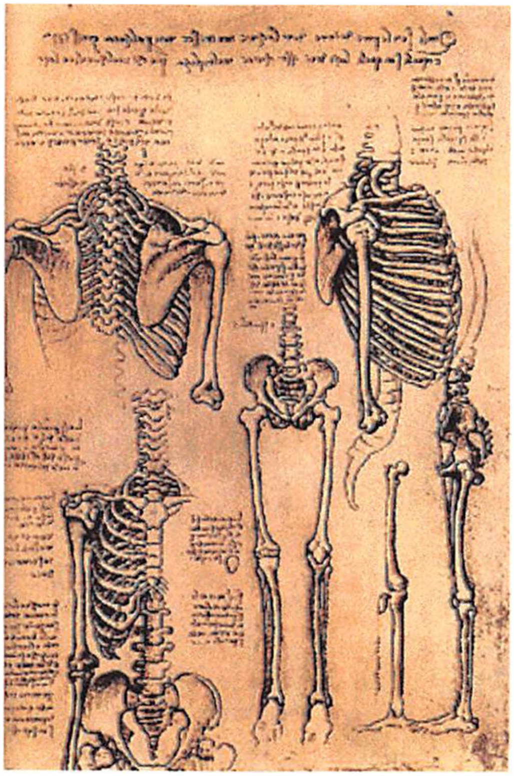

Figure 3. Da Vinci's skeleton

Figure 4. Da Vinci's womb anatomy

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