Medical Transplants

"Today, there are new instruments of medical diagnosis, new systems of representation. So if we want to talk about the state of the art in building envelopes, we should look to the very latest techniques of imaging the body and ask ourselves what effects they may have on the way we conceive buildings."[1]

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INTRODUCTION

Throughout recent history, both the medical and architectural professions have incrementally developed their knowledge bases as more is understood about the subject of their study; the human body or the architectural edifice. Advancements in the professions assist in, among other things, developing public trust. Both architecture and medicine are practice-based disciplines where continual pursuit of better processes and more quality results are demanded. In this pursuit there is not typically one right answer and the posture of the professional is to maintain what Le Corbusier called "a patient search." Continual development has also occurred in the processes, techniques, tools, and training of those professionals. While not necessarily always intentional, the history of these two professions has shared various exchanges throughout time. This text identifies two distinct exchanges, or "transplants," that have moved from the medical to the architectural profession with considerable resultant impacts. Transplant 1, the medical image, occurred from the Renaissance forward, while Transplant 2, problem-based learning, occurred in the mid-20th century.

TRANSPLANT 1

The Renaissance architect played a significant role in the formation of the architectural profession, as we know it today. During this period in history, the initial separation of the architect from the process of making architecture began. Master craftsman became master draftsman and the task of the architect moved from building architecture to crafting its representation. Prior to this period, the representation of architecture would most likely have been limited to a plan and/or an elevation, giving the locational and proportional specifics of the edifice while the architect addressed the process and details of its construction on-site. As the architect incrementally withdrew from the construction site, the need for communication became ever more paramount. Architects relied upon

projections of future construction as a means of instruction to builders manipulating and assembling materials on the construction site. Stan Allen writes:

> By the translation of measure and proportion across scale, architectural projections work to effect transformations of reality at a distance from the author. Projections are the architect's means to negotiate the gap between ideas and material: a series of evasions, subterfuges, and ruses through which the architect manages to transform reality by necessarily indirect means.[2]

This condition necessitated more sophisticated techniques of projection as the distance from marking to making grew. Transition from *doing it* to telling someone else *how to do it* called for an expansion of communication in ways that could imbed more information within a drawing; information of materiality, connection, and sequence. As a result, architects looked outside of the profession to expand the range of technique.

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Concurrent to the development of the architect proper, many other professions were institutionalizing themselves within this new society. The medical profession was attempting to gain public trust and better understand how to diagnose, treat, and improve the human body. This was done partly through a process of documenting the specimen with illustrations and diagrams explaining the complexity and connectivity of the interior of the body. Scientists, artists, and scholars were dissecting cadavers while drawing what they saw. These illustrations were highly detailed and, although often incorrect, served as a means to establishing the profession as experts in the treatment of sickness and injury. From this formative phase, the medical profession saw the use of the image as a means of communicating the objectivity of its subject – dehumanizing to remove the identity and personality outside of codified notational systems within the margins. Although the illustrations were masterfully crafted and rendered, the overlay of explanatory information extended these representations beyond mere visual effect to the realm of professional reliability. This progression has seen medical imagery be continually developed from the category of illustration or image (meant for looking at) to the category of instrument, where the medical images of today are essential to the diagnosis and treatment of medical conditions.

Figure 1: The Anatomy Lesson of Dr. Nicolaes Tulp, Rembrandt.

TAXONOMY OF EXCHANGE

The architectural profession has borrowed various techniques and tools from the medical profession. This has at times been blatant and other times more tangential. Architects were often highly observant of the ways in which other professions conduct their business. For the purposes of this text, Transplant 1 has been been categorically described through the following taxonomy of technique (notational systems, cross section, and layered/exploded illustrations) describing how each has assisted in the development of the profession.

NOTATIONAL SYSTEMS

Medical and architectural imagery incorporates the use of notational systems that serve to augment the pictorial content supplying information such as context, identity, dimension, and proportion. Within the medical profession, these systems might identify an adjacent organ, register the dimensional data of an abnormal growth, or identify biometric data relative to a specific system such as flow rate or pace. This information is highly useful in the documentation of sickness or disease, and its aim is clarity of communication where visuals fall short.

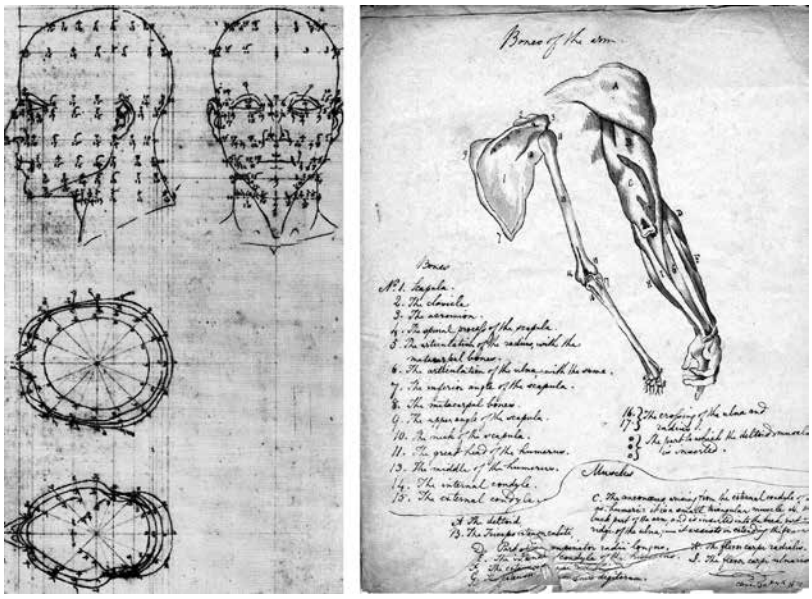

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Figure 2: Notation system of skull, Piero della Francesca (left) ; anatomical illustration of human arm, Leonardo da Vinci (right).

Within the architectural profession, notational systems perform similarly in their desire to communicate information and do so with a high level of clarity. A primary difference of use between the professions is the potential to communicate and direct procedural instructions outside of the image. The medical image is typically reflective conveying information that 'is' (ex. bone, tumor, break, blockage, etc.), while the architectural image, while having reflective capabilities as well, is often projective conveying information that 'could be'. Stan Allen cites philosopher Nelson Goodman and his theory of an allographic system defining it as one "capable of being reproduced at a distance from the author by means of notation."[3] He uses the example of the musical score as one that, with its system of notation, can be replicated outside of the original with a great level of accuracy. The ability to communicate a material and formal condition in architecture, and its potential to be replicated regardless of place and time, is a significant subtext to the charge of architectural representation.

The use of an allographic system is also important as it relates translation and authorship. The architectural image is authored and thus, highly subjective. In

its conception and development, decisions have been made with regards to a diverse set of parameters where value is assessed; orientation, media, view, etc. While most images are subjective, the lack of authorship (and even less, the desire for that authorship) tasks the medical image with communicating the facts of its subject without bias or preference. Authorship exists via the image's interpretation by the medical professional where they offer a professional analysis and opinion of the information communicated (which is closely related to transplant 2 in this text). In this condition, the medical image serves as a communication device between the body (as compared to the edifice) and the professional (as compared to the architect).

CROSS SECTION

The word section, rooted within the medical term dissection, has significant history with both the medical and architectural professions. Artists and illustrators used the cross section as a technique to document the arrangement and sequencing of animal and human bodies as scientists began to better analyze their physiology. Several illustrations from the Renaissance period on to modern day show parts of the human body cleanly sliced in a lateral or transverse means illuminating the arrangement of internal systems kept private by the skin. The cross section provides referential information of body's associative qualities in regards to its internal 'construction' and made visible those systems that "passed unnoticed in the real world because they were out of sight."[4] It is important to note that this period also saw significant development in the cross sectional illustration as the church released its hold on the ability for the medical professional to dissect the human body. Prior to this, inferences were made from dissections of animals and then translated onto the human body. This most often resulted in highly inaccurate illustrations of human anatomy.

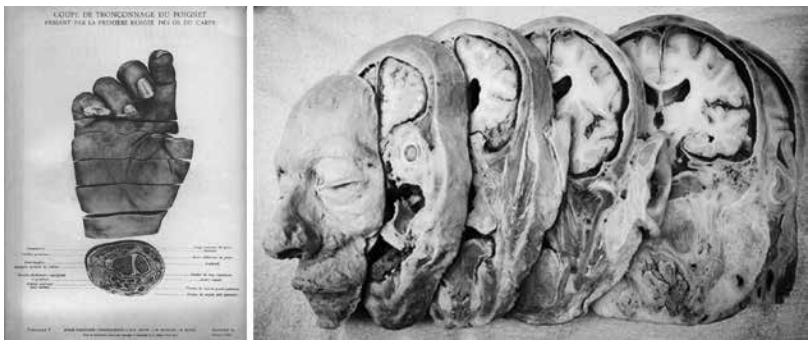

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Figure 3: Cut section through human head and hand.

Architects were also investigating the 'body' of architecture through its dissection. We see, through the section, further evidence of this exchange between the medical and architectural professions in drawings like da Vinci's section through a human skull.

> Leonardo da Vinci, in depicting a human skull in strikingly effective drawings of the late 1480's and 1490's, approached the problem architecturally, as if the skull were a dome, showing its vertical section and interior, and a horizontal section in perspective which constitutes a plan. Curiously, a technical advance in architectural representation was made by Leonardo in the discipline of human anatomy, but it is not surprising, considering that, at the same time, as we saw, a related advance – the raising of an elevation from a plan – was made by Piero della Francesca in examining exactly the same object, the disembodied human head.[5]

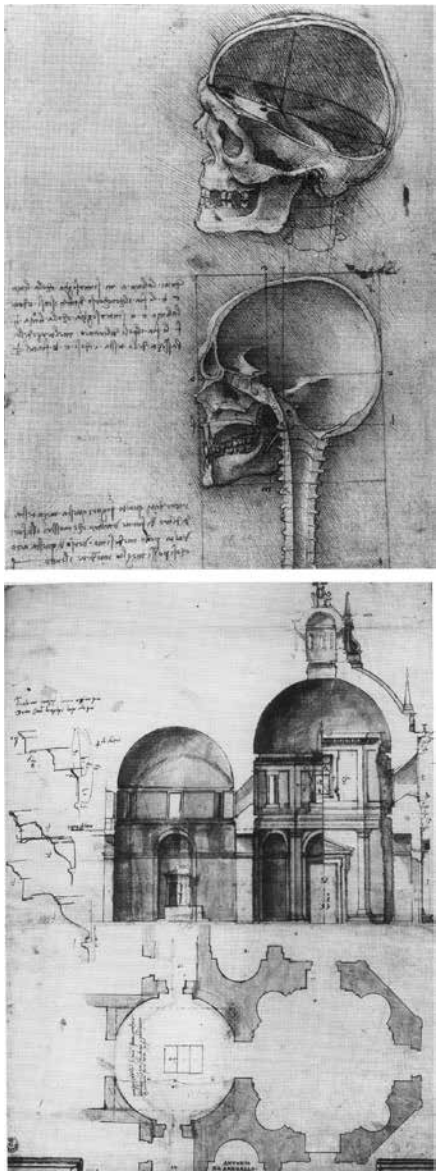

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Figure 4: Section through human skull, Leonardo da Vinci (top); Cathedral section, Antonio de Sangallo the Younger (bottom).

The convention of section allowed da Vinci and others to propose philosophical assertions like the connection of the brain to the spine in comparing it to the actual evidence as showcased through the illustrated dissection and documentation. A good example of this is shown through a vertical section of the head drawn by da Vinci showing the spine as a cavity connecting to the pelvic region alluding to the delivery of the soul from the head to the reproductive organs. This made evident a conflict between science and philosophy.[6]

An exchange of the opposite direction occurred during the Enlightenment Period where doctors were strategic in their use of the cross section to compare anatomical drawings of animals to sections of the middle class dwellings. This analogy served to compare the internal systems of domestic drainage, ventilation, and illumination with that of the body in order to provoke change in the construction practices of the modern dwelling unit. Houses and bodies were represented in the Victorian popular press in cross section to show the complex networks of overlapping "systems." This type of drawing emphasized the flow and interplay of air, water, waste, and other substances through the structure.[7]

This use of the section and exposure of the systems contained within the body of architecture enacted several other developments, which also were attributed to the ways in which the body works. The appropriation of medical knowledge into architecture through the trades is also evidenced through E. Gregson Banner's description of his house drainage system stating "it was superior because it was based on the human body. The trap, inlet pipe, and cowl had breathing power like the lungs, and the major benefit of the system was "continuous extraction."[8]

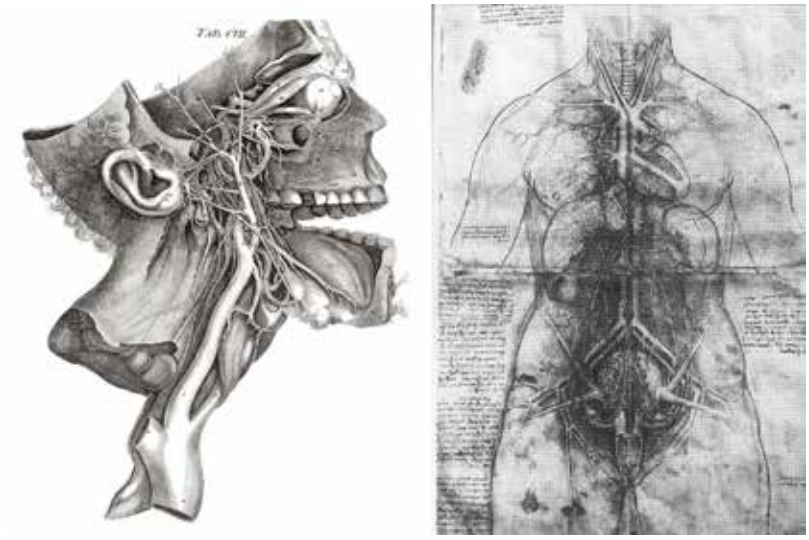
The use of several sections through a specimen in sequential progression has also seen significant use in the medical field. Primarily employed through a series of plates documenting the ways in which the combined systems are arranged and altered within the body, this technique is currently seen used in radiography procedures such as magnetic resonance imaging (MRI) and computerized axial tomography (CAT) scans where the technology captures a series of images. Within the architectural profession, many examples including Morphosis and Foreign Office Architects (FOA) have used this technique of multiple sequential sectional drawings to explain spatial and formal sequencing in architectural form. This tool is most often used by architects interested in the sequential manipulation of form to create a spatial narrative. Farshid Moussavi of FOA, in her book The Function of Form, discusses a transversal system as one in which a system's "base unit is not geometrically fixed, it is versatile and can vary as it repeats, or even mutate, when hybridized with other base units."[9] The documentation of this situation through multiple sections, possibly animated, has been the most effective measurable drawing technique to communicate this dynamic condition.

2.3. LAYERED AND EXPLODED ILLUSTRATIONS

The layered or exploded illustration allows the viewer better comprehension of the arrangement of the body with regards to the larger whole. This type primarily developed out of need to communicate the complexity and overlap of multiple components, systems, or connections within one 'body.' The layered illustration often focused in on a specific region where the technique was used while the balance of the body remained intact. Generally, This type of image used either of two techniques—layering or spatial separation.

The layered drawing progressively peeled away layers of the subject until the destination was arrived at—such as an internal organ or skeletal structure.

Tissue, muscle, fat, and bone would be peeled back or rendered semi transparent to communicate the placement and location within the intact body that serves as context. This technique is still used extensively in anatomy texts studied by medical professions today. As well, the layered illustration has developed noninvasive techniques, including the x-ray, where the body stays intact and the area of focus is highlighted through imaging techniques or the use of contrast dyes.



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The exploded technique communicates relative locational information of the subject of study through dimensional separation of the parts and clarifies layering as though suggesting its eventual rejoining. This style of drawing is most often connected with the documentation of machinery, but also exists in the medical and scientific community. The medical profession has used it to discuss relational connections within the body as a way to clarify its systems. The removal of the subject of study, for example the digestive system, suggests highly invasive methods, or the projection of the subject outside of the body.

The architectural profession has elevated the ability of this type to communicate both arrangement and sequencing. While the medical illustration uses exploded drawings to dissect and analyze the already conjoined body, the architectural drawing is often done before construction and offers instructions for completing its assembly. It incorporates Nelson Goodman's allographic system of communication as previously discussed where composition or assembly can occur at a distance from the author.

Developed and used almost exclusively in the medical profession, x-ray technology allows for noninvasive imaging of the interior of the human body. This technique uses electromagnetic radiation to penetrate the body being absorbed in varying degrees based on density of material – bone versus tissue density for example. This varying level of attenuation results in degrees of contrast producing an image that can show the structure and skin of the body. The appeal of this image is the simultaneous availability of the structural components (bones) existing with ghosted envelope of the body (skin). The Computer Axial Tomography (CAT) scan uses x-ray technology though a series of sequential x-ray slices of the body. In her article titled "Skinless Architecture", Beatriz Colomina discussed how early 20th century modern architects, such as Mies van der Rohe and Le Corbusier, as well as contemporary architects, including OMA and FOA, were

Figure 5: Layered anatomical illustration of human head (left); Anatomy of torso and pelvis, Leonardo da Vinci (right).

inspired by medical imagery and allowed it to influence their design process. She elaborates on modern architects' fascination with the x-ray stating:

> X-ray technology and modern architecture were born around the same time and evolved in parallel. […] While the X-ray exposed the inside of the body to the public eye, the modern building unveiled its interior, subjecting what was previously private to public scrutiny.[10]

Magnetic Resonance Imaging (MRI) utilizes magnetic fields which activate cellular structures that are then detectable through the imager. This image can give incredible amounts of information about the internal structures of the body and be adjusted to detect fluids, active dyes, and various other systems. These contrast mediums can increase the legibility of a specific target increasing the potential of the image to assist in diagnosis. While at first this technique may seem quite similar to the x-ray, the MRI extends the imaging potential to capture additional data over time such as flow and systems exchange.

TRANSPLANT 2

> "I believe that education, therefore, is a process of living and not a preparation for future living."[11]
>
> *- John Dewey*

> ***practice:*** -noun 1. repeated exercise in or performance of an activity or skill so as to acquire or maintain proficiency in it.

Traditional educational theory positions the student as an empty vessel ready to be "filled up" with the knowledge provided by the instructor. Over time, this philosophy has not proved to be effective in developing life-long learning strategies, or high content retention rates in the mind of the learner. These methods also suggest that the student brings very little to the learning environment, and all content or positions are provided instead of being formulated. John Dewey's quote more closely aligns with a Constructivist viewpoint suggesting the active engagement of the learner in the acquisition of knowledge. The Constructivist philosophy of learning is experiential, adaptive learning integrating new knowledge with existing knowledge to construct new relationships and revise existing cognitive structures.

Practice-based professions such as medicine and architecture require the professional to work from experience, construct knowledge, and respond with informed professional judgement when faced with a new challenge or problem. This ability is developed in the educational environment of these professions establishing an emergent mindset. Transplant 2, problem-based learning (PBL), originated in medical schools of the mid 20th century and has been instrumental in this effort.

> In PBL, learners are presented with a problem in order to activate their prior knowledge. This prior knowledge is then built upon further as the learners collaborate in small groups to construct a theory or proposed mental model to explain the problem in terms of its underlying causal structure. As learners continue to study related resources, their initial mental model is further modified and refined.[12]

Two theories with regards to the PBL mechanism include "activation-elaboration hypothesis" and the more recent "situational interest hypothesis."

The activation-elaboration hypothesis suggests that the problem provided to the student will activate previous knowledge acquired by the student. This activation combined with the challenge put forth in the problem statement creates elaboration of that knowledge through "self explanation, discussion with peers, practicing, [and] responding to questions."[13] Activation-elaboration theory builds on a Socratic method fostering life-long learning traits essential to the professional entering a practice-based discipline.

The situational interest hypothesis suggests "problems or puzzles create a desire in students to find out more about the topic, which leads to increased concentration, focused attention, and a willingness to learn."[14] This can lead to general curiosity in the student when they become aware of a knowledge gap between what they know, and a problem which does not fit with their current view or understanding. This awareness challenges the student to generate new knowledge structures that can assist in making sense of the condition and offer solutions to address a problem within its context.

The history of problem-based learning dates back to the mid 1960's and reportedly began at McMaster University in Canada.[15] To that point, medical education consisted of students memorizing vast volumes of information. The rate at which this information was being updated and expanded made it nearly impossible for the medical student to be current, comprehensive, or mentally able to retain the information. This necessitated a new pedagogy, one that would address the medical professional's ability to be informed and capable of working in real-time situations where informed decisions could be constructed. PBL was seen as a solution to this condition and a way to more quickly respond to the rapid pace of the profession.

The current studio format on which architectural education is modeled is problem-based learning. Architects in training are given a problem that looks, to varying degrees, like that which a professional architect might be presented with. Architectural educators use techniques such as hard and soft scaffolding to continually progress the student closer and closer to the scenarios that they will face post graduation. PBL encourages self-learning and establishes a mindset in the graduate that embraces techniques of reframing design contexts and problems, a skill which is paramount for the profession.

Problem-based learning, in conjunction with the use of precedents, assists the design student in using abductive reasoning in the solving of a design problem. Abductive reasoning allows the process of decision making to move forward based on the best possible answer in light of the situations at hand. For example, a medical diagnosis proposes the most likely condition which would explain the given set of symptoms observed. The architect uses abductive reasoning and precedent in the development of a design solution which best responds to a given condition. Although the exact scenario might not have been observed before, similar circumstances allow the designer to make a creative leap which responds in the most appropriate way.

Horst Rittel and Melvin Webber put forth the term "wicked problems" to describe a problem which contains a trait of indeterminacy—one in which the answer can only be arrived at through abductive reasoning.[16] The process for addressing wicked problem is an "argumentative process in the course of which an image of the problem and of the solution emerges gradually among the participants, as a product of incessant judgment, subjected to critical argument."[17] The

design problems which designers face today, and even more the problems which are in the foreseeable future, require a professional who has been trained not only to find answers to a question, but also to be able to formulate those questions.

CONCLUSION

The relationship between the medical and architectural professions has a long history of exchange. Beatriz Colomina's assertion suggests that the trajectory of the architectural profession might often be foreshadowed in the medical techniques is not far from the truth. While the connections and exchanges might not always be explicit or intentional, history has shown that the exchange has served to push each of the professions to new levels. The ability to remain current in a discipline with emerging information, tools, techniques, and technology is critical. As new techniques emerge in each, the ability to appropriate them into the other will ever be a temptation, and it will be encouraged.

ENDNOTES

1. Beatriz Colomina, Skinless Architecture. (Weimar: Wissenschaftliche Zeitschrift der Bauhaus-Universität Weimar, 2003), 124.
2. Stan Allen, *Practice: Architecture, Technique and Representation* (London: Gordon and Breach, 2000), 2.
3. Ibid, 33.
4. Annmarie Adams, *Architecture in the Family Way.* (Montreal: McGill-Queen's University Press, 1996) 65.
5. James Ackerman, *Origins, Imitation, Conventions.* (Cambridge, MA: The MIT Press, 2002) 58.
6. Ibid, 151.
7. Adams, 64-65.
8. Adams, 69.
9. Farshid Moussavi, *The Function of Form* (New York: Actar and Harvard Graduate School of Design, 2009), 28-29.
10. Colomina, 123.
11. John Dewey, "My Pedagogic Creed" *The School Journal, Volume LIV, Number 3* (1897), 77-80.
12. Henk G Schmidt, Jerome I Rotgans, Elaine HJ Yew. "The process of problem-based learning: what works and why." *Medical Education* 45 (8): 793.
13. Ibid, 793.
14. Ibid, 794.
15. Harry Hilen, Albert Scherpbier, and Wynand Wijnen. "History of Problem Based Learning in Medical Education." *Lessons From Problem-based Learning.* (New York: Oxford Scholarship Online, 2010) 6.
16. Horst WJ Rittel, Melvin M Webber. "Dilemmas in a General Theory of Planning." Policy Sciences 4 (Amsterdam: Elsevier Scientific Publishing Company, 1973).
17. Ibid, 162.