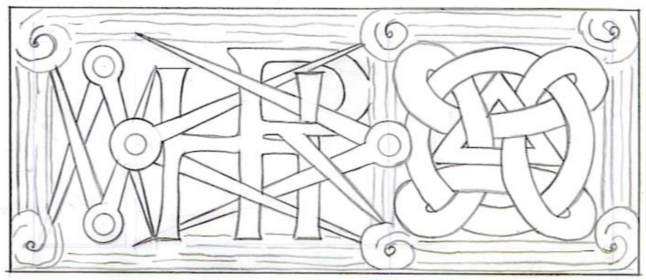
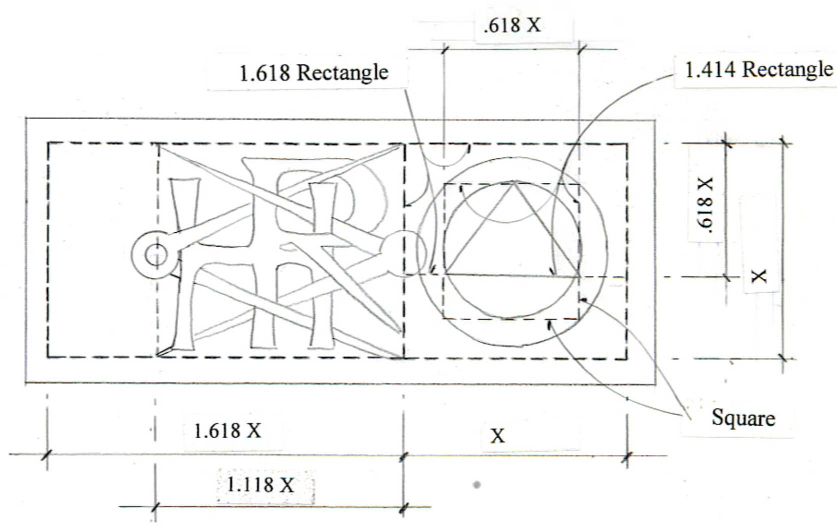




AUSTIN HALL PLAQUE

FIGURE #1

H. H. Richardson and the Golden Section Proportions in his Architecture

Richard L. Brown

In a discreet corner beside the entrance to Austin Hall (1881-1884) at Harvard University stands a small rectangular plaque carved with the initials of the building's architect, Henry Hobson Richardson. But also hidden in the design are geometric patterns that are significant clues to Richardson's design methodology (See Figure #1 and Photo #10). The plaque itself measures about one foot by two and a half feet and is placed about six feet off the ground to the left of the three entrance arches. Along with Richardson's initials there is hewn a curvilinear design interwoven with a triangle and a circle, a set of proportional scaling dividers, and crossed architectural dividers. At the outside edge of the plaque carved spirals articulate six focus points. Intriguingly, when one puts together these different elements, the plaque defines the essence of the Golden Section proportioning system and some of its basic permutations that Richardson used throughout his career. Since Richardson himself wrote so little about his architecture, it is interesting to find such a critical and revealing statement actually carved in one of his building with his own initials.

This article will examine proportions in the design of Richardson's buildings and attempt to understand the importance he placed on proportions as a tool in the design process. To do this I will give a basic explanation of the Golden Section and how Richardson revealed it in the Austin Hall plaque. Then after a brief historical view of proportions and how Richardson started to use them, I will do a detailed building analysis of proportional uses in one of Richardson's smaller buildings, the Crane Library (1880-1882). It is well suited for this purpose because of its modest size and relatively good documentation (Despite the fact that the plaque is on Austin Hall, it was too complex, large and lacking in good documentation to do a complete analysis). After the analysis of the Crane Library I will return for a brief look at Austin Hall to show how Richardson used a slightly different approach on that building.

An in-depth building analysis is critical and indeed the only way to fully understand the design process and intent of the architect. Through this analysis, one will be able to realize the importance the architect placed on the proportions of each element and their interrelationship in the building. It will be possible to see how in the use of proportions, the design of the fireplace and the windowpanes are related to the design of the front elevation. In fact everything is interconnected. Although this article will only analyze the proportional system, similar in-depth analysis could also be done for other design concepts such as tectonics, function, circulation, fenestration, and structure. These would then further enhance the understanding of the building.

There are several important ideas that will emerge from this examination. First, by using his proportions to relate the largest idea down to the smallest detail, Richardson created a unifying link throughout the structure. Secondly, although Richardson almost always used the Golden Section proportions, within the Golden Section he developed for each building its own *sequence of proportions* that give each building its own rhythm and continuity. Additionally, near the entrance of several of his buildings, Richardson provided clues as to how the proportional system would be developed. Although these clues were probably not meant for the general public, they do present a subtle challenge to understanding the buildings.

Since not all architects use proportional systems, it is important to try to understand the benefits such a system offers to those who do use them. In the most general sense, proportions are used to create a relationship between different elements of a building. Whether it is between large and small elements, adjacent objects or two different spaces, if they share a common proportional system then there is a link that helps unify them. And if everything in a building shares a common proportional system then that system creates a unifying feature that permeates the whole structure. Throughout his career Richardson used proportions in just such a manner. They helped hold his buildings together by creating a common rhythm in all the forms, objects and spaces.

PROPORTIONS COMMONLY USED BY RICHARDSON

The basis for Richardson's proportional system is rooted in four rectangular forms and an understanding of those forms is crucial. They are the square and three other forms derived from the square. They are illustrated in figure #2 and are as follows:

SQUARE - This is the simplest of all forms. It is a rectangle with al 90 degrees angles and whose sides are all equal. It can be subdivided into two other 2:1 rectangles or four squares whose sides are 1/2 the length of the original square.

GOLDEN RECTANGLE or 1.618 RECTANGLE - This is a rectangle with a long history in architecture. The ratio of its sides are 1 : 1.618 or .618 : 1. This means that it is the only rectangle that can be divided into a square and another rectangle where the remaining rectangle has the same proportions as the original rectangle, and where the remaining rectangle's long side is the same length as the short side of the original rectangle. It is geometrically (or graphically) created by starting with a square and dividing the square in half. One then takes the diagonal of one of the resulting rectangles and adds it to the short length of the other rectangle. This yields one length of a golden rectangle whose other length is the same as one side of the original square. (The terms "Golden Section" and "Golden Rectangle" are used interchangeably although a "Golden Rectangle" refers only to a rectangle and a "Golden Section" refers to any shape developed from the proportions of 1 : 1.618.)[1]

1 : 1.118 RECTANGLE - This is a favorite of Richardson's and is derived directly from the Golden Rectangle. It is formed by dividing the golden rectangle into three segments; two halves of a square and the smaller Golden Section. If one then joins one of the halves of the square (or as I will call it now a 2 : 1 rectangle) and the remaining Golden Rectangle the resulting rectangle has the ratio of 1 : 1.118 (or 1 : [1.618 - .5]). This rectangle will be referred to as a 1.118 rectangle. It should also be noted that it is one half of a 1 : 2.236 rectangle which is a square root of five rectangle. [2] Its proportions are also 1 : 1/1.118.

1 : 1.414 RECTANGLE - Although used less frequently, this rectangle is nevertheless still significant in Richardson's designs. It is the only rectangle that

when divided in half yields two rectangles of the same proportion as the original rectangle. It is geometrically created by using the side of a square and the diagonal of the same square as the two different sides of a rectangle. It will be referred to as a 1.414 rectangle.

SIGNIFICANT PROPORTIONS USE BY H. H. RICHARDSON

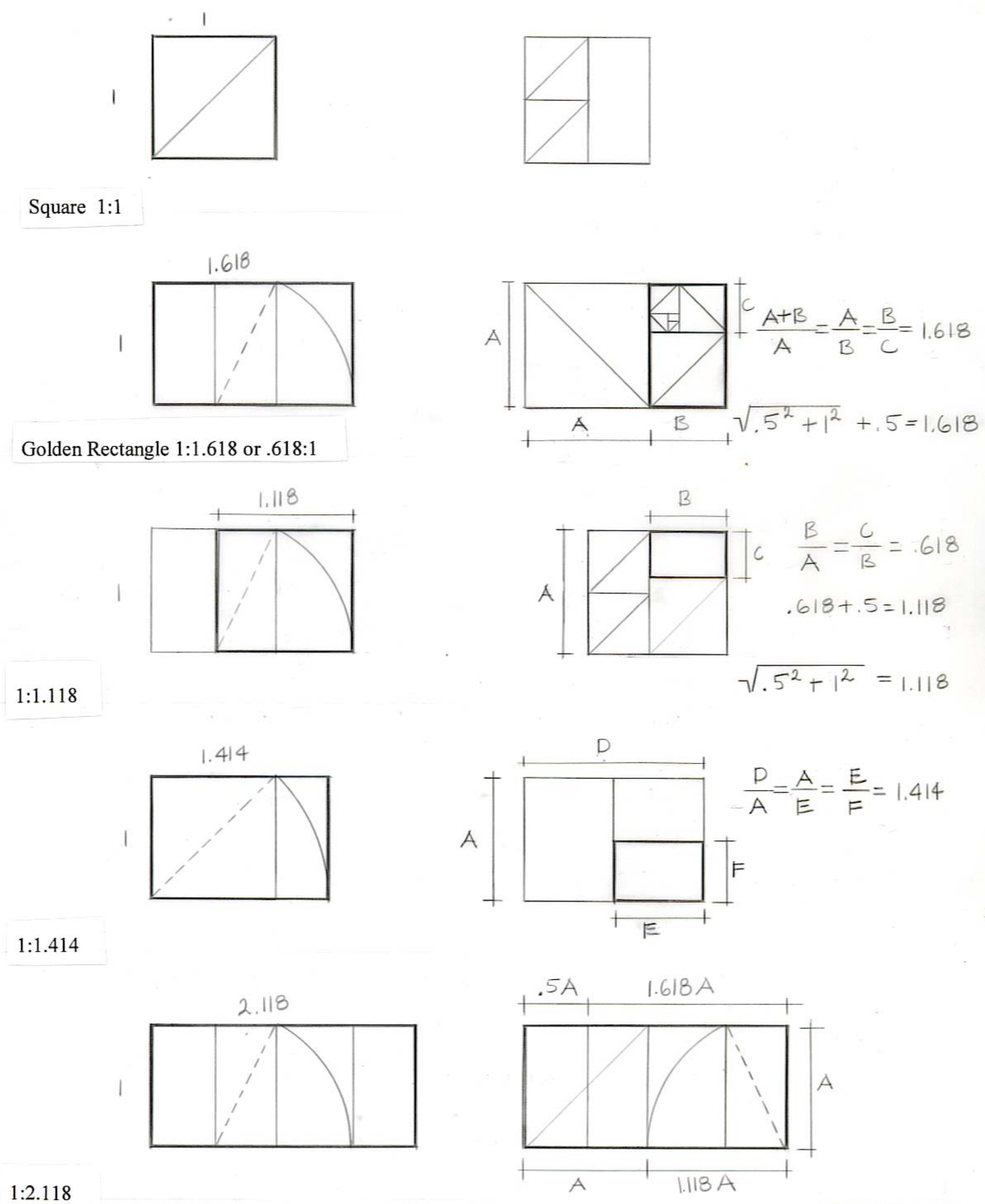


FIGURE #2

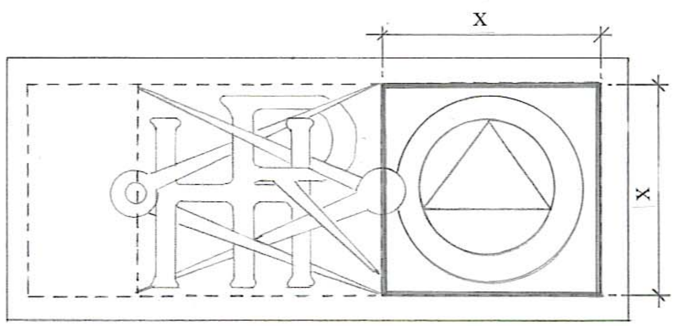
Somewhat specific to the Crane Library, however, is one additional rectangle, which is the combination of several of the previous ones. It is the 1 : 2.118 rectangle (Refer to figure #2).

1 : 2.118 RECTANGLE - This is the combination of either a golden rectangle and a 2 : 1 rectangle or a 1 : 1.118 rectangle and a square. It is also possible to look at this rectangle as two overlapping golden rectangles, where they both share the same 1 : 1.118 rectangle in the middle. It will be referred to as a 2.118 rectangle.

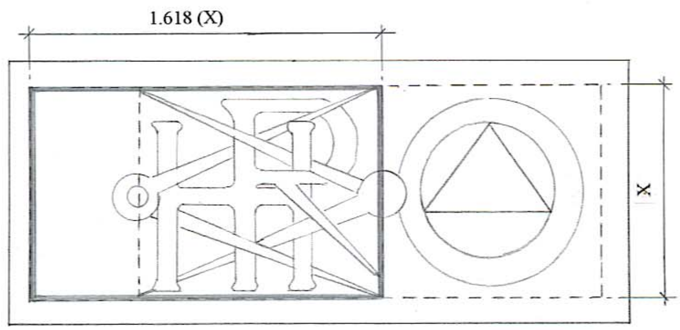
ANALYSIS OF THE AUSTIN HALL PLAQUE

It is also these same forms that Richardson had carved into the Austin Hall plaque. Looking closely at the plaque's design, it is possible to see both the simple beauty of the design and the intricacies of the proportional relationships that he uses (refer to Figure #1 and Photo #10). The square, the golden rectangle (or the 1.618 rectangle), the 1.118 rectangle, and the 1.414 rectangle are all shown in this plaque. They are then interrelated to each other and to Richardson's own monogram. As the architectural dividers are intertwined with his monogram, this gives an interesting correlation between the architect and his desire to show the proportional system (See Figure #1). A detailed analysis of the plaque is shown in Figure #3 through Figure #7. It is divided into three phases. Steps 1 - 3 look at the main focus points around the exterior of the plaque. Steps 4 - 8 look at the geometric pattern on the right side. And Steps 9 – 21 look at Richardson's monogram and its proportional design.

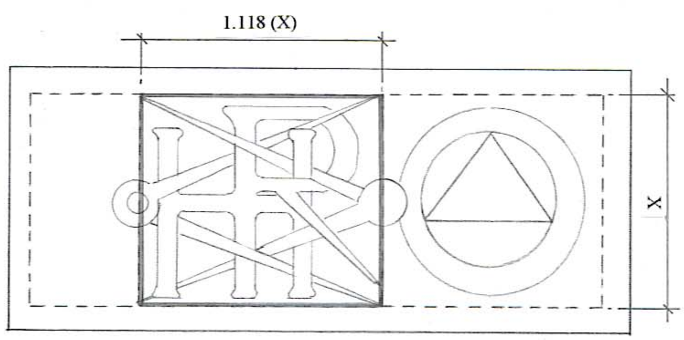
We start at the outside edge of the plaque where six focus points are articulated by the center of several spirals. The two on the right and the center two define a square. The two on the left and the center two define a Golden Rectangle. Subdividing the Golden Rectangle are architectural dividers whose points, along with the two center focal points, define a 1.118 rectangle. These first three steps define the exterior of the plaques design and show the basic proportions that Richardson will use. They are simple expressions of the Golden



1) Square "X" - We start at the outside edge of the plaque where six focus points are articulated by the center of several spirals. The two on the right and the center two define a square.

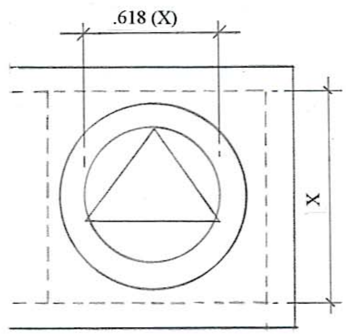


2) 1.618 rectangle - The two on the left and the center two define a Golden Rectangle.

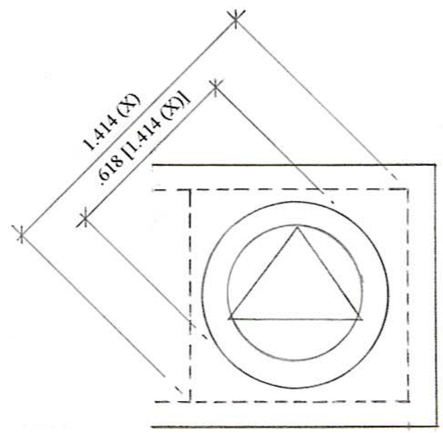


3) 1.118 rectangle - Subdividing the Golden Rectangle are architectural dividers whose points (along with the two center focal points) define a 1.118 rectangle.

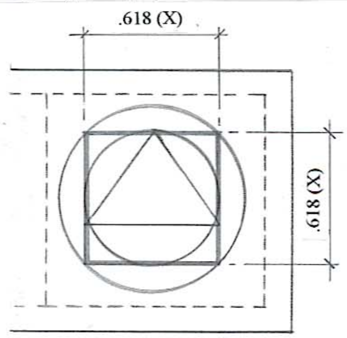
FIGURE #3



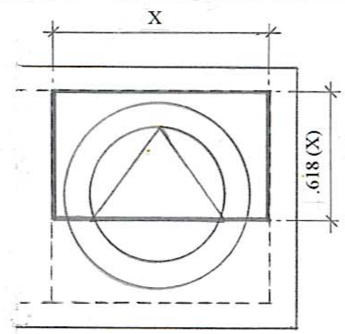
4) The inside circle's diameter is .618 x one side of the large original square.



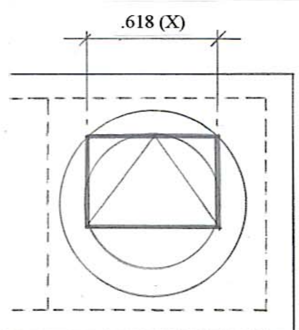
5) The outside circle's diameter is .618 x the diagonal of the large square (or .618 (1.414 [X]).



6) Square - Because these two circles are proportional to the same square's side and diagonal, by simple geometry and Pythagorean's theorem, they have a ratio to each other of 1 : 1.414. Or in other words, the same .618(X) square's sides will be tangent to the inside circle while its corners will touch the outside of the circle.

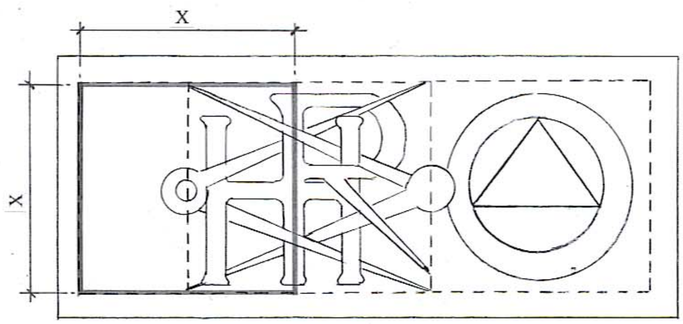


7) 1.618 rectangle - The extended line of the base of the triangle and the top portion of the original large square form a Golden Rectangle whose dimensions are X and .618X.

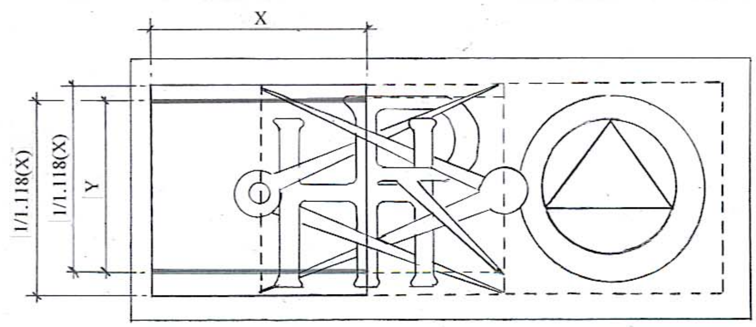


8) 1.414 rectangle - The base of the triangle has the same dimension (.618 X) as the side of the previous Golden Rectangle and also the diameter of the smaller circle. The peak of the triangle is the top of the inside circle. If one forms a rectangle by using the base of the triangle and its height, that rectangle is a 1.414 rectangle.

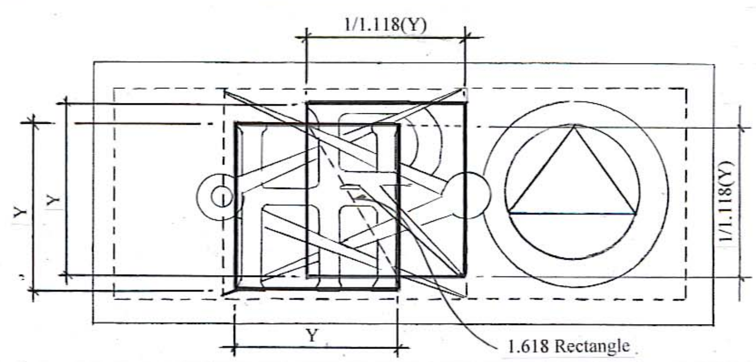
FIGURE #4



9) Square "X" – Using the two left focus points, a square is created and determines the center of the vertical portion of the "R".

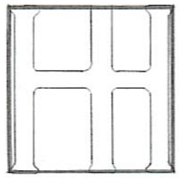


10) 1.118 Rectangle – Reduce the previous square to two horizontal 1.118 rectangles with heights of 1/1.118 X. The top and bottom edges of these 1.118 rectangles determine the top and bottom of the "R". This vertical dimension is "Y".

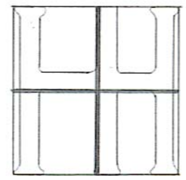


11) Square "HH", 1.118 rectangle "R" and their intersecting 1.618 rectangle – Create a 1.118 rectangle with a height of "Y", a width of "1/1.118 Y", and starting at the left edge of the original "X" square. Reduce this 1.118 rectangle to a square whose dimensions are "1/1.118 Y" by "1/1.118 Y". The top of this square aligns with the top of the "HH" square whose location is determined such that it forms a 1.618 rectangle at the intersection with the "R" rectangle. This determines the overall monogram dimensions.

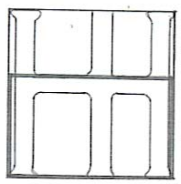
FIGURE #5



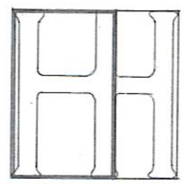
12) Square – This square previously shown by two "Y" dimensions determines the "HH".



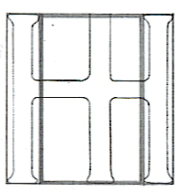
13) Subdivide - One must then notice that the "HH" is asymmetrical, but it is not arbitrary. If the square is divided in half both vertically and horizontally, those lines form the bottom of the "HH" cross-bar and the left side of the center vertical bar of the "HH".



14) 1.618 rectangle - The rest of the "HH" is created by three Golden Sections that are each derived by using a side of the square as one of the long sides of a Golden Section. The first is made by using the bottom of the square as the long side. The top of the Golden Section is then the top of the cross-bar of the "HH".

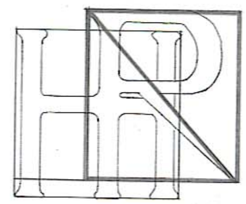


15) 1.618 rectangle - Use the left side of the square as the long side of the Golden Section which creates the right side of the center vertical bar of the "HH".

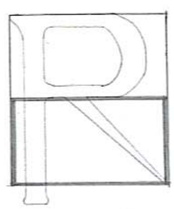


16) 1.618 rectangle - W hen placed vertically in the center of the square, the last of the three Golden Sections articulates the top inside corners of the outside vertical bars of the "HH".

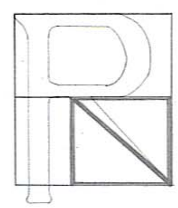
FIGURE #6



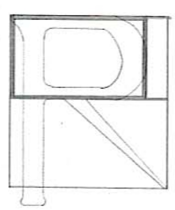
17) 1.118 rectangle – Previously shown as "Y" by "1/1.118(Y)" - Two points, the top left corner of the "R" and the bottom of its leg form a 1.118 rectangle whose diagonal is one of the lines that form the leg of the "R". This diagonal is precisely 48 degrees, the diagonal of a 1.118 rectangle.



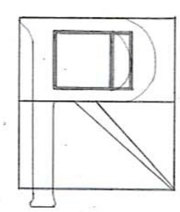
18) 1.618 rectangle - Form a Golden Section from the bottom of the 1.118 rectangle in step #17 and the top of that Golden Rectangle is the bottom of the loop of the "R".



19) 1.118 rectangle - The diagonal of the 1.118 rectangle from within the Golden Rectangle forms the other side of the leg of the "R".



20) 1.618 rectangle - Above the Golden Rectangle of Step #18 form another Golden Rectangle and that will determine the right side of the loop of the "R".



21) 1.414 rectangle - Using the short side of this Golden Rectangle as the long side of a 1.414 rectangle, place that 1.414 rectangle horizontally in the center of the previous Golden Rectangle and that determines the inside dimensions of the "R" loop. If one looks at the square inside this 1.414 rectangle that will determine the spring points of the curved line.

FIGURE #7

Section's proportions and a simple statement that says "These are the proportions that will be used".

Following these we will look at the geometric design of circles squares and triangles on the right side. Although this geometric design is clearly derived

from the Golden Section, it is more intricate. The architect is not just stating the proportions, but he
starts to show how they are interrelated, derived from one another and able to create a beautiful design. Each of these shapes can be graphically derived from one another or in other words, each shape can be created using architectural tools (dividers, compasses and straight edges) from the original square[3]. Understanding this proportional methodology of starting with one shape and developing others (smaller and larger) from it using the Golden Section is the key to understanding this plaque and Richardson's buildings as a whole. To represent the intricacies of the relationship, Richardson has a never-ending ribbon intertwined through the circle and the triangle.

Finally the monogram is more complex and even abstract in its use of the Golden Section. The proportions and methodology are there, but no longer clearly shown as lines, rectangles and other geometric shapes. There are inferred shapes and relationships that create this monogram, yet they are still formed from the Golden Section. The basis of the design is the intersection of the "R" for Richardson and the "HH" for Henry Hobson. Before getting into the actual geometric derivation of the monogram it is important to notice several things:

1) The monogram is inside the 1.118(X) rectangle (Figure #3) and very close to the center of the design.
2) The "R" is defined by a vertical 1.118 rectangle. (See 11 in Figure #5)
3) The "HH" is defined by a square. (See 11 in Figure #5)
4) Both the "R" and the "HH" have the same vertical dimension. (See 11 in Figure #5)
5) The intersection of these two shapes is a Golden Section. (See 11 in figure #5)

But unlike the design in the square on the right, the proportional features are now inferred as the end of a letter, the outside of a curve or the intersection of two lines. It is no longer just a simple geometric design, but one able to be developed with the more abstract shapes of letters.

So in a sense, Richardson takes the observer on a little instructional journey from the obvious, to the complex, to the intricate and abstract. The next step would be to see how he translates the proportions into his actual buildings which we will do later.

What is important to realize is that all the elements in this design are proportionally related to each other. Using Golden Section proportions, everything is derived from the same square. It is not simply that Richardson shows a Golden Section, but that he shows it derived from a square and related to all the other elements in the design. It is this interrelationship of one element to all the others that is crucially important.

Richardson is not just putting his initials on the corner of a building. He is showing all the basic proportional shapes that he uses, interrelating them, and showing that they are intertwined with him (his monogram) and his design process(drafting tools). It is a statement of great significance by this architect and gives great credibility to ideas to be discussed in the rest of this article.

Using these four primary proportions (1.618 rectangle, 1.118 rectangle, 1.414 rectangle, and a square) Richardson designs all his buildings. But within each building he develops a slightly different formula or *sequence of proportions* for combining and developing the proportions. It is a specific series of steps from one proportion to another, to another and so on. This sequence of proportions then gets repeated throughout the building and at all different scales creating a common rhythm for the building. This shall be investigated later in both the Crane Library and Austin Hall.

As one can guess from these brief descriptions of proportional shapes, it is difficult to verbally describe a graphic image. Hence, in trying best to describe how Richardson proportionally created, divided, and subdivided the Crane

Library I have used a combination of graphic and verbal descriptions. In most cases it is easiest to follow the graphic diagrams, because they will best illustrate the progression or flow from one proportion to the next. Typically in many of the diagrams I will use the terms "Reduce" or "Expand" from one shape to another. This simply means using one side of one shape to generate another shape that is either smaller or larger. By using a common side of each shape there is then a proportional relationship between them and whatever subsequent shapes are derived. It is this reducing or expanding step by step progression, which develops and ties the whole building together.

GOLDEN SECTION IN HISTORY

Yet as important as this analytical look at proportions is, one cannot ignore the historical context of the use of proportions in architecture. Over the past century many scholars have explored the stylistic evolution of H. H. Richardson's buildings, but little attention has been paid to his formal creative design method. In particular, this elegant proportioning has never been examined in any detail. This system, in fact, formed the backbone of his design methodology, and every architectural move and decision in his buildings fits within it. This is not to say that the proportioning system is the dominant idea of each building. It is not. Yet it is the framework within which those ideas are expressed. Richardson's architectural concept for each building was not to create a perfectly proportioned object. Rather he realized each building's total idea through a specific proportioning system, which was a unifying element that held the building together visually, artistically and functionally.

Many architects, including Richardson, have employed proportions to organize their buildings,[4] but scholars have rarely investigated the degree to which these proportions were used. Often an article or book will show a drawing with an overlay of rectangles or triangles showing how the architect used proportions to organize the building. But they seldom demonstrate in detail how a proportioning system functions throughout the building as a method of unifying different spaces, materials or scales[5]. Richardson employed his proportions throughout his career to relate the large-scale site planning to the smallest detail. It was a means to organize, visually link, and design the whole building from the smallest scale detail to the largest concept. Yet it is important to realize that it was still only a tool in the design process not the final design objective.

Clearly, of all proportional systems, Richardson's favorite was the Golden Section. This geometric system offers a wide variety of permutations and because of its expansive and reductive possibilities it is well suited to architectural composition. But one of the most fascinating things about the Golden Section is its existence in such a wide range of different fields. From the academic to the philosophical, to the scientific, the Golden Section seems to permeate almost all segments of life. To astronomers, it is in the equation for a spiral galaxy[6]. To biologists, it is the growth curve of a nautilus shell[7]. To botanists, it is the seed pattern of a sunflower, a pineapple, an apple, and a pine cone[8]. To mathematical historians, it is the answer to a little puzzle about rabbits Fibonacci proposed in his book "Liber Abaci" (the book that incidentally introduce the Hindu-Arabic numbering system we use today to the west in 1202)[9]. To best-seller readers, it is the heart of Dan Brown's book "The Da Vinci Code"[10]. To Geometricians, it is the ratio of the diagonal of a pentagon to its side[11]. To stock brokers, it is the basis for the wave principle of the stock markets fluctuations[12]. To crystallographers, it is the ratio of the terraces in aluminum-copper-iron alloys[13]. To musicians, it is in the shape of a Stradivarius violin[14]. To number theorists, it is the famous Fibonacci series and all its permutations[15]. And to mathematicians it is simply the most beautiful irrational number there is.

Understanding the breadth of the uses of the Golden Section it is then possible to realize how in 1509 Luca Pacioli was able to coin the term "Divine

Proportion" in his book *De Divina Proportione* (illustrated by Leonardo de Vinci)[16][17].

Yet returning to architecture, the Golden Section can be traced throughout history from the Great Pyramid[18](2500 BC), to Tombs of the Kings @ Thebes[19] (1400-1200BC), to the Parthenon[20] (432 BC) , to the Pantheon[21] (124 AD), to Gothic cathedrals[22] [23] (1150 AD), to Jefferson's University of Virginia Library[24](1821 AD)and eventually to modern architects like Le Corbusier[25], Frank Lloyd Wright and Venturi[26].

Yet this path is a difficult one to trace. Although someone can measure a building and say its dimensions are 10 feet by 16 feet[27], close enough to be called a Golden Rectangle, that can always be doubted unless there is a paper trail where the architect says he used these proportions or followed a treatise on architecture that recommended them. In fact there is often fierce debate whether many of the previously mentioned monuments actually use the Golden Section.

The only clear bit of written evidence for the Golden Section in antiquity is Euclid's *Elements* written in Alexandria in about 300 BC[28]. It was the defining book in mathematics for the next 2100 years and in it Euclid uses the Golden Section (or as he defined it the "mean to extreme ratio") in numerous geometric derivations[29]. But its first introduction to the west was in a translation from Arabic to Latin in 1120 A.D. (Significantly this also corresponds to the start of the great era of Gothic building where geometry was of crucial importance. Combine this with Fibonacci's introduction of the Hindu-Arabic number system to the west and suddenly western culture would be able to take huge leaps in math, science, engineering and [very importantly] navigation). Yet even with the knowledge of *Elements,* written documentation of the use of the Golden Section until the mid-nineteenth century is still very sketchy to say the least[30].

Finally in the nineteenth century architectural historians started to document the monuments of the past in detail with mathematical analyses of them (this included Egyptian through Renaissance buildings). Among them was Eugene-Emmanuel Viollet-le-Duc, the great gothic restorations architect and Professeur de l'Histoire de l'Art et Esthetique at the Ecole des Beaux-Arts (be it for however briefly a time)[31]. In both his *Dictionaire raisonne* [32]and his *Entretiens sur l'architecture* [33] he documents what he calls the "Egyptian Triangle" (an isosceles triangle whose base to height ratio is 8 : 5 – again very close to a Golden Section) numerous times in his analysis of gothic architecture. But since we generally do not even know the names of the gothic architects not to mention have drawings or other documentation of the buildings, this is only secondary evidence of it use.

During the Renaissance there probably was knowledge of the Golden Section[34], but the common proportional organization was that dictated by Vitruvious and Palladio, a simpler and more arithmetic set of formulas.

RICHARDSON AND THE GOLDEN SECTION

How Richardson derived his knowledge of the Golden Section is also not entirely clear, although when certain facts they are put together, they give persuasive evidence of his intimate knowledge of the proportion:

1) While at Harvard (1885-89) he had what anyone would call a horrible academic record[35]. In fact after four years he was ranked 89th out of 91. The only thing that saved him from claiming the basement position was the fact that he took and actually did well in all the mathematical courses offered by Harvard. And as previously mentioned, Euclidian geometry, with its knowledge of the Golden Section would have been in any basic geometry course. It should also be noted that when Richardson first applied to the Ecole de Beaux Arts one of the only two

tests that he passed was in descriptive geometry[36]. Yet it should be noted that although Richardson had a horrendous academic record, his significant interest in socializing served him very well in terms of clients and client contacts.

2) In his education at the Ecole de Beaux Arts, as Professor Richard Chafee said, "Students took proportions for granted"[37]. Although there is no evidence of the Golden Section in Beaux Arts architecture, the sense of highly organized architecture with a sense of proportion was instilled there.

3) The library that Richardson amassed during his lifetime was very varied and extensive[38]. But in regards to proportioning, authors John Ruskin and Viollet-le-Duc stood out. He collected their writings from his time in France until his death. This is despite the fact that neither of them were fans of the classical revival style favored at the Ecole de Beaux Arts. Ruskin, in both his *Stones of Venice* and *Seven Lamps of Architecture*[39], was an ardent supporter of any type of proportioning. And Viollet-le-Duc in his *Entretiens sur l'architecture* and *Dictionnaire Raisonne* went to a great extent to show and espouse the use of the "Egyptian Triangle". All of these documents were published prior to Richardson's leaving Paris, but of more significance is that Richardson continued to collect writings by each of these authors until his death. This emphasizes that Richardson: 1) knew of the Golden Section proportioning system prior to starting his practice and 2) that in continuing to collect writings by these authors he expressed some support of their philosophies.

But during his education in Paris, Richardson was taught how to organize buildings in the traditional Beaux-Arts style. This style developed each building symmetrically around a primary axis, included a defined hierarchy of spaces, and used classical details and elements throughout. As David Van Zanten has commented,

> "The manner in which the students arranged these spaces and volumes was to group them along axes, symmetrically and pyramidally. The basic solution for the composition of a monumental building on an unencumbered site was discovered almost at once: two axes embodied in two enfilades and intersecting at right angles at a major central space, the whole compressed inside a circumscribed rectangle."[40]

Although in his practice Richardson often strayed away from the rigid formal design patterns of the Ecole, he used the basic design "methods" that he learned in Paris for the rest of his life[41]. Particularly important were the ideas that all details should be subservient to and reinforce the overall concept, that the building should be developed from the plan and program, and that a proportional system should be used to organize a building.[42] Often in the Richardson archives[43] one can find the small thumbnail sketch that Richardson would produce very early on in the design process, which would clearly contain the essential building organization and show which spaces were to have critical proportions. This early development of the parti is important to the Beaux-Arts method of design. From these small sketches everything else would be developed. But it is also clear that from early on in the process, the design would be done within the framework of a proportioning system. In fact in all preliminary designs for the Crane Library the Golden Section is evident.

Having developed a strong knowledge in the Beaux-Arts system, Richardson had one advantage over his French counterparts - he would not practice in France. Although the Ecole des Beaus-Arts was perhaps the greatest architectural school in the world, the architectural system in France was so in-grown that the possibility for innovative architecture was extremely restricted.[44]

By returning to the United States Richardson freed himself of many of the Beaux-Arts constraints and was able absorb other architectural influences including the Norman Romanesque, the French and Italian Gothic, the picturesque English and the residential Japanese.[45] He became the master of the eclectic (It should be noted that Richardson was one of the first significant architects to collect and maintain a significant photographic library of architecture). Using his French design methods, he was able to integrate these many other images and concepts into a coherent style that he could call his own.

CRANE LIBRARY OVERVIEW

The Crane Memorial Library is a prime example of Richardson's Romanesque style (Photo #1 & #2). A building which Henry-Russell Hitchcock has called "the greatest library Richardson ever built,"[46] it is perfect for demonstrating his use of proportions in one of his mature buildings. It is small and relatively simple so it will serve well as an example. The library was designed in memory of Thomas Crane who had made a small fortune through his Manhattan stone yard that dealt with Quincy Granite. His son, Albert Crane, offered the town of Quincy the funds to build the library and in April 1880 commissioned Richardson as the architect. It was completed in 1882. Of the five libraries that Richardson designed, it is one of the smallest, but it is also one of the most elegant. Although completely asymmetrical, its composition is both vibrant and unified, while at the same time fitting into his rigorous mathematical proportioning system.

The Crane Library was designed at the height of Richardson's unfortunately short career (1866-1886). Just prior to this date, several significant buildings had been completed which had helped establish Richardson's reputation. Trinity Church in Boston was finished three years earlier in 1877 and the William Watts Sherman house in 1876. Two libraries of similar scale, the Winn Memorial Public Library, Woburn, Massachusetts (1876-1879) and the Oliver Ames Free Library in North Easton, Massachusetts (1877-1879) had also recently been completed. At Harvard, the stately Sever Hall was in the last phases of construction as was the New York Capitol Building, in Albany. In the middle of construction were the Oakes Ames Memorial Town Hall and the Trinity Church Rectory.

With this list of major buildings Richardson had clearly established himself as one of the most prominent American architects of that era. Strangely, it seems that relatively few projects were actually "in design" at the time the Crane Library commission came to the office. Only the Ames Gate Lodge in North Easton, some minor Parks Commission projects in Boston and possibly preliminary work for the Albany City Hall competition were actively being worked on.[47] It is perhaps fortuitous that the commission came at that particular time. Although it was a relatively small building, Richardson would have been able to give it considerable attention, making it the best of the library genre that Richardson had developed.[48]

The organization of Crane Library is straightforward. The plan (refer to figure #17) is designed as a simple rectangle with three primary spaces, a stack wing, an entrance hall and a reading room. The interior is a two-story high open space (Photo #5) except for the north and south sides of the stack area that are two levels of single-story book storage alcoves. A fireplace dominates the east end, as does a large window on the west end. On the exterior, Richardson chose a light gray North Easton granite and dark Longmeadow brownstone for trim around windows and at several significant bands.[49] The original building had two parapetted gables at either end and two minor cross gables on the north and south sides of the entry hall (A 1908 addition by W. M. Aikens extended the original gable on the north side making it a "T" shaped building). A circular stair tower at the edge of the entry gable adds a vertical element to the elevation as well as a means to get to the second floor book storage alcoves and the third floor meeting room. The defining character of the building is the massiveness of its exterior stone, contrasted with the thinness of the roof and the softness of the wooden interior.

The windows and openings can be divided into several types that Richardson used according to the interior function and the exterior compositional effect. First is the large entry arch (Photo #3), located just off center of the minor cross gable. As an arch that defines the exterior vestibule, it is able to emphasize the thick stone character of the exterior wall. Then there are similar large windows at the end of the stack area and beside the reading room (at the east end of the southern elevation). They let in the necessary light for reading and are used as large compositional elements. Opposed to these large semi-circular and rectilinear elements is a long narrow band of windows just under the roof line of the second story level of the stack room. It lets in southern light for the stack area and creates a horizontal balance to the entry, tower and square window of the reading room.

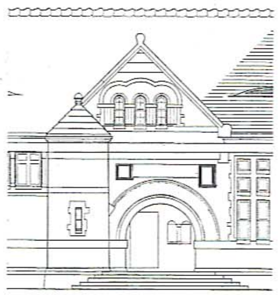
Smaller windows and details are also used to reinforce the larger compositional, functional and architectural ideas. Such is the case with the ingenious eyebrow windows that serve no function except to show the significant tectonic difference between the apparently paper-thin roof and the massive stone walls. Similarly, the stone banding is often used to indicate floor levels and ties the building together as regulating lines in the proportioning system.

All these seemingly disparate architectural elements are unified through the proportioning system that was used both to give an organization to the building and to interrelate the large and small scale elements in it. The rhythm and character of a building can be seen in both the elevation, which one sees from afar, and the details, which can be intimately touched. This is one of the most important concepts of this study: that the proportioning system unifies the whole building not just in a same scale "room to room" relationship, but in a large-scale to small-scale relationship. In other words, the process that designs the plan is the same process that designs the doorknob, and that process is framed and united through the proportioning system.

RICHARDSON'S CLUES

To someone first visiting the Crane Library, the impression is of a strong massive and simple building. And this is just the impression that Richardson was after. Using his Ecole des Beaus-Arts training, his design process would have started with the plan and then moved to three dimensions. But on closer examination a subtle degree of complexity is apparent. Most of the elements are asymmetrical, some are over scaled and some are put together in unusual combinations. In fact on the south entrance elevation many of these abnormalities are actually very subtle clues to help explain the specific mathematical puzzle of this building. These details are similar to the stone plaque on Austin Hall and they also reveal the same significant proportions. Indeed, around the entrance to Austin Hall there are many other clues that will be briefly examined later.

So even though Richardson started his design process with the plan, examining the proportional system will be more easily understood starting where he ended, in the details. In the Crane Library most of these clues are around the cave-like semicircular entrance, the trim details and the library's signage.

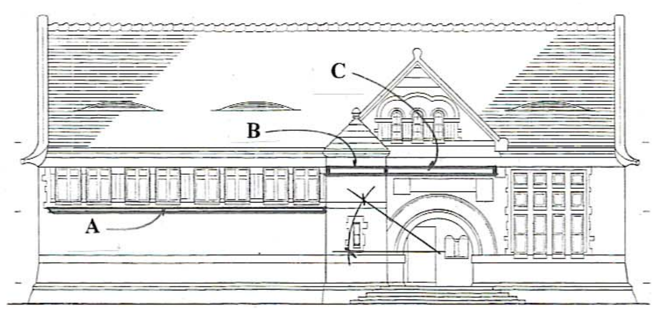


1) Crane crest and Town of Quincy plaque

2) 1.118 Rectangle

3) 1.618 Golden Rectangle

4) 1.414 Rectangle



5) 35 degree angle and trim details

FIGURE #8

Above the entrance is a large brown stone that is inscribed "ANNO DOMINI MDCCCLXXXI". On either side of this stone are plaques. The one on the left is the crest of the Crane family, and the one on the right is the seal of the town of Quincy. This area serves an important symbolic function announcing the donor and community as important parties in the building. The third partner, Richardson, the architect, embedded his own series of symbols as well. In the combination of stone plaques is encoded the proportions used for the Crane Library. It represents a sign that explains, "This building is based on the following proportioning rectangles." It can be read as follows (Refer to figure #8 and Photo #3). The five following descriptions correspond to the five sketches in figure #8[50]:

1) The Crane family crest on the left is a 1.118 rectangle. The Town of Quincy plaque on the right is a 1.414 rectangle
2) There is a 1.118 rectangle formed by the top left corner point of the Crane plaque, the top right corner of the Town of Quincy plaque, and the first floor trim line.
3) There is a 1.618 rectangle formed by the top of the center plaque with the dedication date and the first floor trim line.
4) There is a 1.414 rectangle formed by the bottom of the date plaque and the first floor trim line.
5) The angle formed by a horizontal line through the center of the arch and the point where the arch trim stops short of the tower is 35 degrees, which is the same as a diagonal of a 1.414 rectangle. One should remember the triangle and circle in the Austin Hall plaque and their relation to a 1.414 rectangle.

Besides the clues showing what types of proportions are being used, Richardson also gives several clues showing key dimensions which will be used to generate the interior spaces of the building. At first glance they appear to be extraneous pieces of trim, but on closer examination one realizes that they are quite intentional. Their ornamentation is unique and they have very defined starting points and ending points that determine specific dimensions. Since the building has almost no exterior ornamentation, one must look at the few places ornamentation is used and realize there is a special reason for its placement.

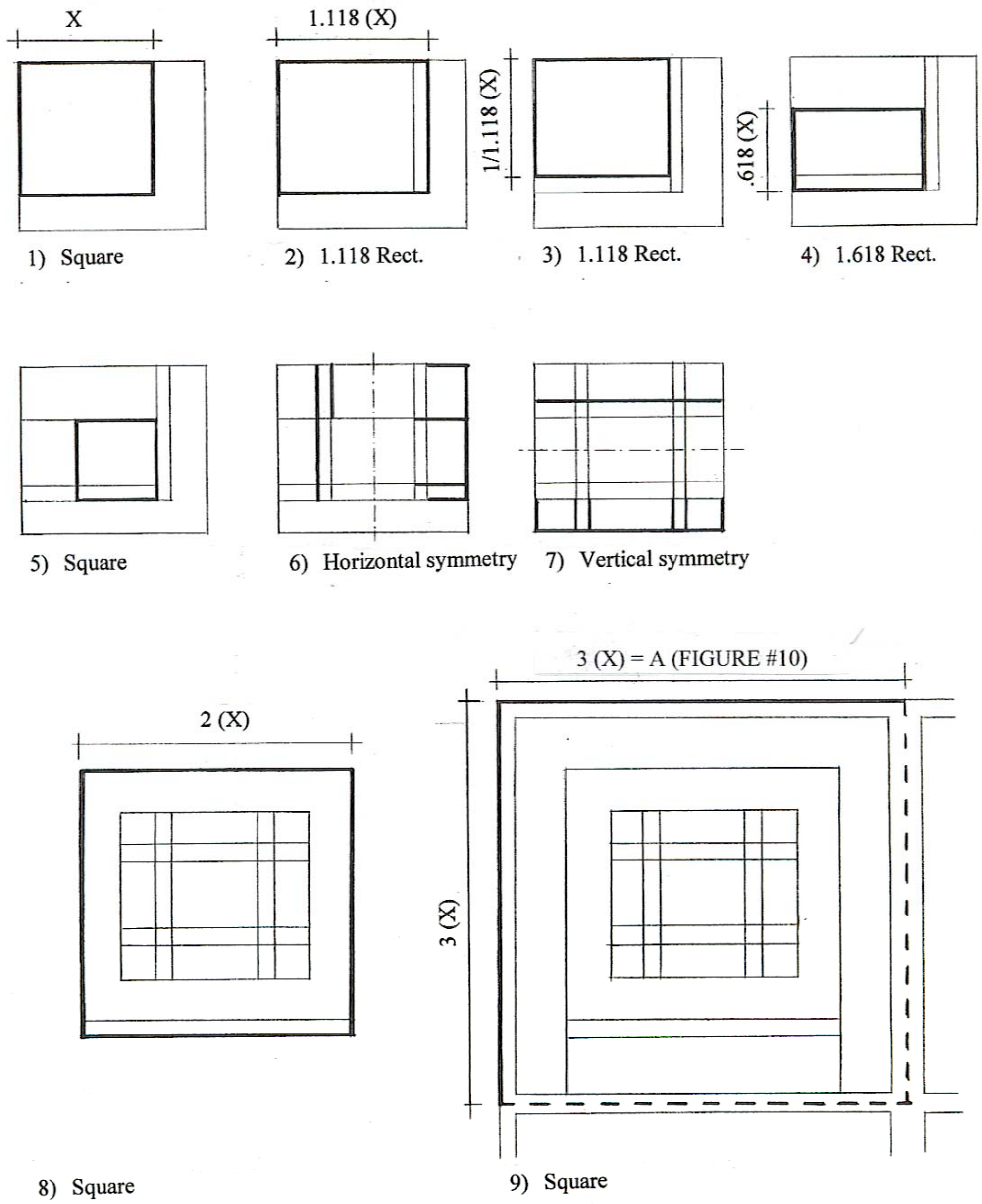
Three of the most significant are the following (refer to the fifth diagram in figure #8, the floor plans in figure #18 & #19, and photo #3):

A) Just below the long band of windows on the left side of the building is a piece of trim, "A," that extends a little more than the whole length of those windows. This represents the interior length of the stack area and the interior length of the entry/reading room area. As I will show later, this is also the long side of a 1.118 rectangle which when reduced to other proportions define all the spaces in each side of the interior of the building.
B) Just below the roof line of the tower is a piece of trim, "B," that wraps around the tower in a diameter that is equal to the depth of the smallest area in the stack room (9'-0").
C) Continuing from that trim on the tower is a slightly different trim, "C," that continues across the middle of the entrance gable. This represents the distance of the short side of a golden rectangle that generates the entrance hall.

What soon becomes apparent is that every gesture and line is integral in Richardson's defining the form of the building. Whether it is a clue to the inside dimensions of the building, a band that represents the floor level, or a band that articulates the proportional system, nothing is arbitrary and everything has its place.

WINDOW DETAIL AS REPRESENTATIVE OF THE WHOLE

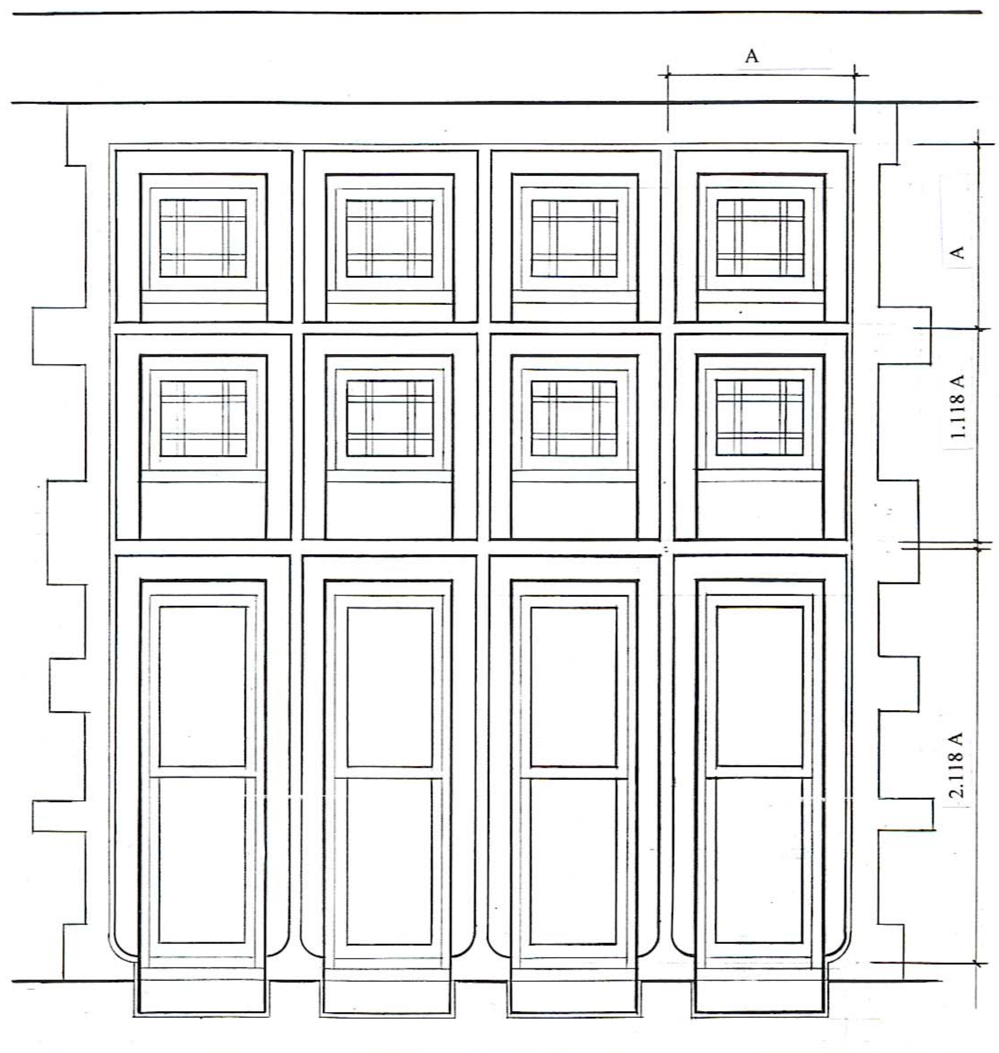
Although Richardson did reveal the proportions (Golden Section Proportions and 1.414 rectangles) and key dimensions in the clues around the entrance, he did not show the *sequence of proportions* that he would use to put all of these elements together. By using the term *sequence of proportions* I am referring to a specific series of progressions from one proportion to another that the architect uses repeatedly throughout the building. It is this set progressions which when repeated many times throughout the building help establish a



DETAIL DEVELOPMENT OF A TYPICAL WINDOW AT THE SOUTH SIDE OF THE READING ROOM AND WEST SIDE OF THE STACK AREA

FIGURE #9

EXTERIOR ELEVATION OF THE WINDOWS ON THE SOUTH SIDE OF THE READING ROOM (SIMILAR TO THE WEST END OF THE STACK AREA)



Steps 10) and 11)

FIGURE #10

continuity and sense of rhythm in the building. At the Crane Library in particular, the sequence of proportions that forms the foundation for the proportional system is a four-part progression. It starts with a square, expands that square to a 1.118 rectangle, reduces that same square to a 1.118 rectangle and reduces the square to a 1.618 Golden Rectangle (See steps 1-4 in Figure #9). Off of this basic progression, many variations are developed to formulate the design for the elevations, the plans, the windows, the fireplace, the interior elevations and even the furniture. To understand this (and the building as a whole) more completely, the simplest place to start is at one of Crane Library's smallest details, the lead pattern of a window in one of the large groupings of windows. It is small and simple, but most significantly the window's development uses the sequence of proportions. The window is a representative of the overall system which then expands into the proportional system of the whole building. Thus studying the window will also demonstrate how its sequence of proportions can relate to the sequence of proportions of other parts of the building.

The window to be investigated occurs in two locations (it might have had other locations, but subsequent renovations have covered up significant parts of the north and east elevations). One is in the large group of windows at the end of the stack room on the west elevation (figure #11) and the other is on the similar group of windows off the reading room on the southern or entrance elevation (figure #14). Each group of windows is divided into vertical segments (six in the west elevation group of windows and four in the south elevation group of windows) that are then divided vertically into one large window on the bottom and two smaller windows on the top. These two smaller top windows are the starting point for this study. They have the same leaded glass and are set in the same sized wood frame. Their difference is the shape of the stone frame that surrounds the glass and wood portion of the window (Refer to photo #3 & #4).

The glass area of the top windows is divided into many individual panes that are joined by lead joints. These lead joints form a geometric pattern. The proportions of this pattern (which are the ones to be investigated) are derived in a progressive manner starting with a square. It is this sequence of proportions that should be noted (specifically steps 1-4 in figure #9 and the use of the 2.118 rectangle in figure #10 where dimension "A" expands from the top window to "2.118 A" in the bottom window).

Because the Golden Section is so flexible, Richardson was able to develop one sequence of proportional steps for one building and a totally different sequence of proportional steps for other buildings (Later I will briefly examine Austin Hall in this respect). In a sense it is very similar to a musical composition where one theme or rhythm is established and then elaborated upon to create a whole movement. The derivation for the window is as follows (Refer to figure #9. The numbered steps in all of the following derivations correspond to the number of the diagram in the drawing).

1) Start with a square.
2) Use the left side of the square as the short side of a 1.118 rectangle to expand to a larger rectangle.
3) Use the top side of the square as the long side of a 1.118 rectangle to reduce to a smaller rectangle.
4) Use the bottom of the square as the long side of a golden rectangle to reduce to a smaller rectangle.
5) Create the square within the golden rectangle.
6) Create a horizontally symmetrical pattern around the center of the whole window.
7) Create a vertically symmetrical pattern around the center of the whole window.

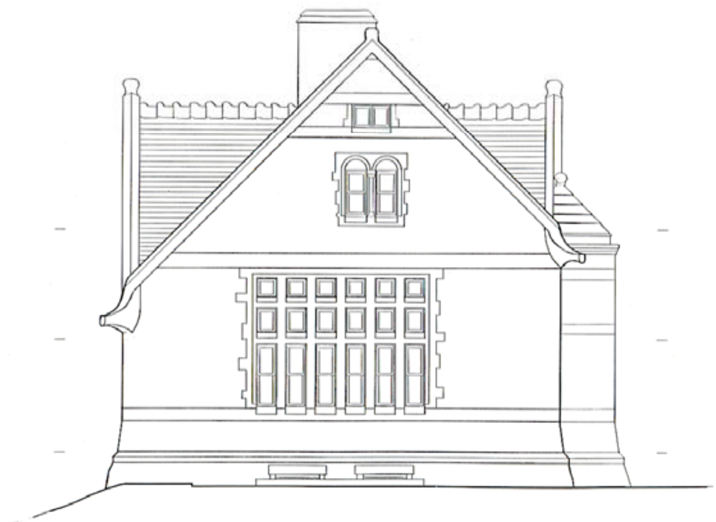
This geometric pattern in the panes of glass is only the first key Richardson gives us to the secrets of these windows. As previously noted, these lead patterns are in the top two windows of a series of three that make up a vertical segment of the total window (refer to figure #9 & #10). Continuing on:

8) Each of these small windows is then contained in a wooden square frame, whose side is twice the size of a side from the original square from step #1.
9) The top small window is then framed in a larger square stone frame ("A" in figure #10 and photograph #3), whose side is three times the size of a side from the original square from step #1.
10) The bottom small window is framed in a 1.118 rectangular stone frame (Refer to figure #10).
11) Added together they form the size of the bottom large window, which has a ratio of 2.118.

So within this window development, Richardson has revealed the sequence of proportions that will be the foundation for the rest of the building and the variation he will use to create the front elevation. Specifically, steps 1-4 and 9-11 are the important ones, but in more general terms, the idea of starting with a square and developing it further with the use of the 1.118 rectangle and the 1.618 Golden Rectangle is consistent throughout the building. This sequence of proportions can be compared later to a different sequence of proportions in Austin Hall, also using the Golden Section.

WEST ELEVATION

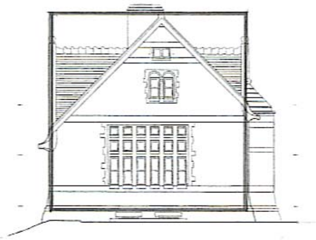
It is now worth showing how these small window details are related to the overall building. On the west elevation (figure #11) the large group of windows is made of six of these same vertical segments. The gable is asymmetrical, with the peak of the gable being slightly closer to the front than the rear. This also means that the front roof is shorter than the rear roof. The group of windows is located so that the center line of the whole elevation is between the two center vertical segments of the group and the vertical line from the peak of the gable is between the fourth and fifth vertical segments. Thus the windows can be seen as having two relationships to the elevation as a whole. One being the same sequence of proportions (as will soon be shown) and the



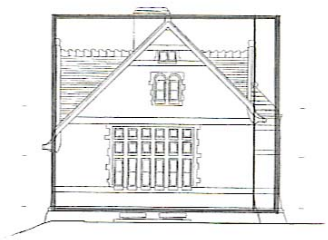
WEST ELEVATION

FIGURE #11

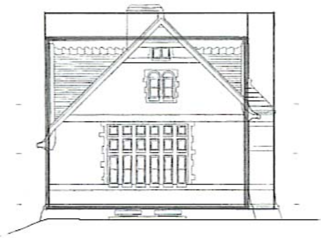
other being that the grouping of the windows directly relates to the center of the elevation and the peak of the roof. The start of the geometric construction of the side elevation uses the same initial sequence of proportions that the leaded window development used. In Richardson's somewhat dizzying progression of mathematical shapes and sequences, the progression is shown in figure # 12 & #13 (Refer also to Photo #4). The process starts with a square formed by the two sides of the elevation, the base and the peak of the gable. From there Richardson used the same sequence of proportions as in the leaded windows to locate the key elements of the elevation. Then using more of the Golden Section proportions and other variations of the sequence of proportions he further subdivides the forms and locates other features. This is important to realize because it demonstrates the proportional relationship Richardson consistently creates between all the architectural elements, large and small.



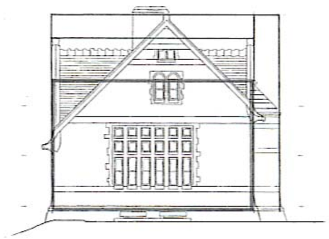
1) Square
Determines outside of elevation



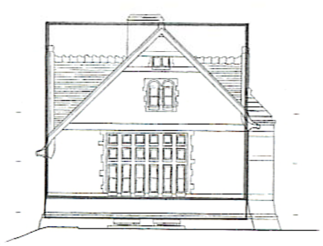
2) Expand step #1 sq. to 1.118 rect.
Determines outside line of tower



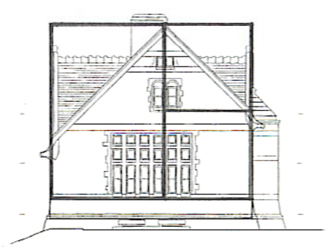
3) Reduce step #1 sq. to 1.118 rect.
Determines peak of cross gable



4) Reduce step #1 sq. to 1.618 rect.
Determines top of tower

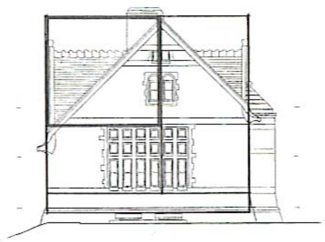


5) Reduce step #1 sq. to 1.118 rect.
Determines dark band beneath windows

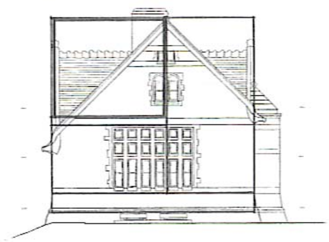


6) Reduce step #5 1.118 rect. to 2 squares and a 1.618 rect.
Determines peak of gable

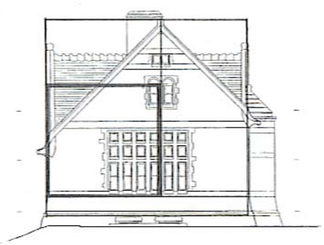
FIGURE #12



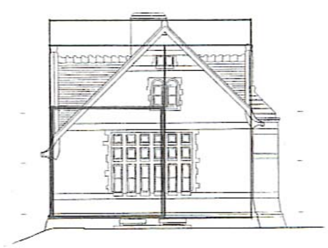
7) Reduce step #6 1.618 rect. to a square. Diagonal of this square and the top square from step # 6 determine the roof slope (45 degrees)



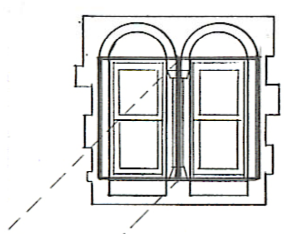
8) Reduce step #7 sq. to a 1.118 rect. Determines the top of the dark band just above the large windows



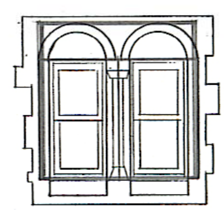
9) Reduce step #6 1.618 rectangle to a square. Top right corner creates the starting point for the generation of the two smaller windows



10) Reduce step #3 rectangle to a 1.618 rectangle and further to a square. The top right corner of the square is the other starting point for the generation of the two smaller windows



11) Using the line between the two starting just mentioned, (The ends of the two dashed lines) create two 1.618 rectangles. These two rectangles determine the rectilinear portion of the windows



12) Using the bottom line of these two 1.618 rectangles create a square. This determines the overall outline of the windows as emphasized by Richardson's detailing

FIGURE #13

For example, the locations of the smaller double arched windows above the large windows is shown in diagrams #9 & #10 of Figure #13. Then the derivation of their shape is shown in diagrams #11 and #12. This shows the clear link between the details of the windows and the overall proportional scheme for the elevation as a whole. Again it is the use of both the square and the Golden Rectangle that develop the location and the form. (Additionally the top small attic window is simply 1.414 rectangle located above the band that represents the ceiling of the third floor)

This elevation and its unusual profile are similar to several other Richardson buildings, most notably the Ames Free Library and the entrance gable of the William Watts Sherman house (actually the roof pitch of the entrance gable on the Watts Sherman house is 41.81 degrees, the diagonal of a 1.118 rectangle as opposed to 45 degrees that is the roof pitch of the Crane Library, but the asymmetrical effect and the use of the square in relation to the 1.118 rectangle is the same). Some scholars, including Jeffrey Karl Ochsner and Thomas Hubka have referred to this profile as a "saltbox" shape, derived from an interest in the colonial revival.[51] This may be true, but what is also evident is that the specific design of each building and its resolution of the details are very dependent on Richardson's geometries and the geometric progressions. The shape, although derived geometrically, is also directly related to the functions in each of the buildings and how each building relates to its environment. In this respect the Crane Library's saltbox shape is more than just a colonial revival form, it benefits the building by allowing more light into the reading spaces by having higher windows on the southern side, helping to give a greater emphasis to the entrance side by making it taller and giving the whole building a sense of motion as though it is growing out of the earth. This is in addition to the fact that the shape is generated geometrically as well as being a historical reference. The colonial revivalist image of the saltbox shape must therefore be considered as only one of the many factors, along with geometry and function, which lead to the use of this asymmetrical shape in these buildings.

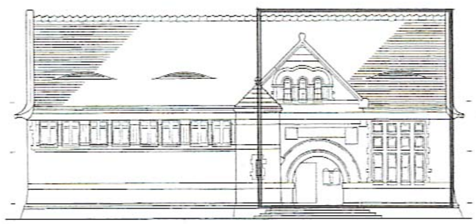
SOUTH ELEVATION

FIGURE #14 .

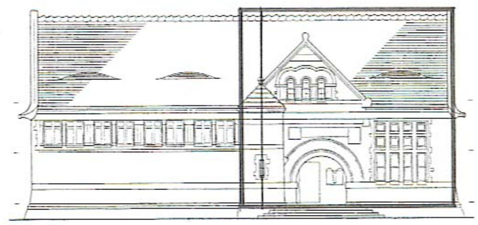
THE FRONT OR SOUTH ELEVATION

Once the west elevation is understood, we can see that Richardson crafted the front or south elevation (figure #14) in a similar fashion. The same-sized starting square and the same first four proportional steps as on the west side are again used on the front. The derivation of the proportions of the front elevation are shown in Figures #15 & #16 (see also Photo #2).

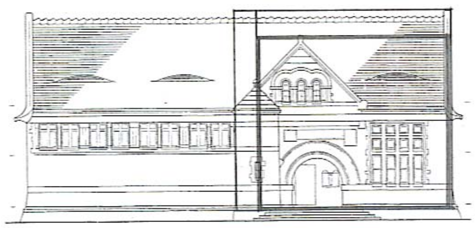
Notice that after the first four steps various other manipulations of the Golden Rectangle are use to locate elements of the elevation. Finally, the whole elevation is developed by expanding the original square to a 2.118 rectangle, just as had been done in the small windows in figure #9 and #10.



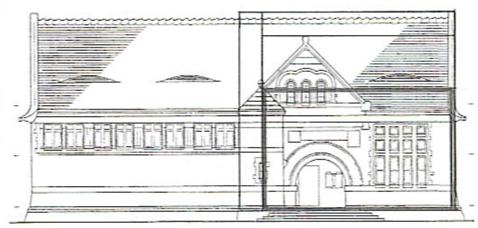
1) Square
Determines center of tower



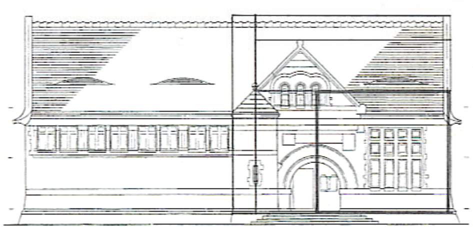
2) Expand step #1 sq. to 1.118 rect.
Determines left side of tower



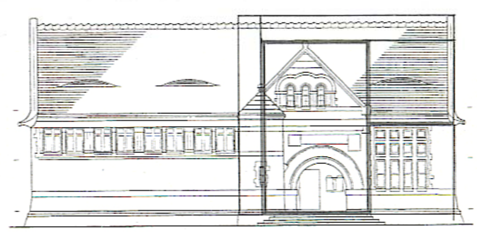
3) Reduce step #1 sq. to 1.118 rect.
Determines peak of gable



4) Reduce step #1 sq. to 1.618 rect.
Determines top of tower roof

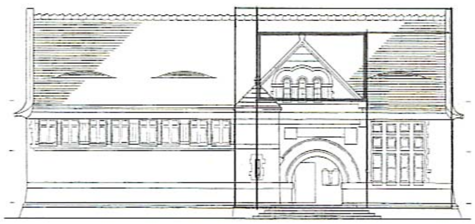


5) Reduce step #4 rect. to 1.118 rect.
Determines centerline of entry
and third floor windows

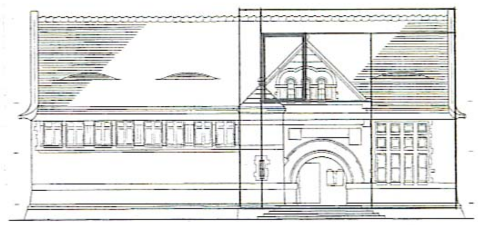


6) Reduce step #3 rect. to 1.618 rect.
and two squares
Determines side of entry gable and
band above windows

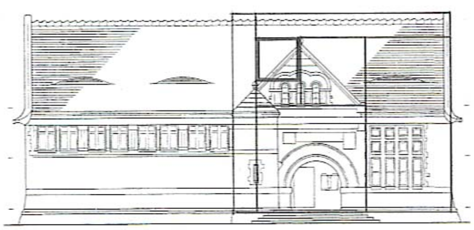
FIGURE #15



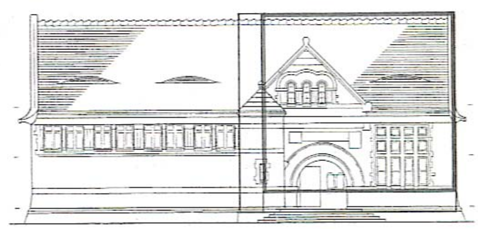
7) Reduce step #6 rect. to 1.618 rect.
Determines corner of roof line



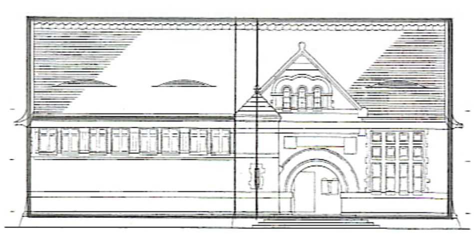
8) Reduce step #7 rect. to 1.618 rect.
Determines peak of entry gable



9) Reduce step #8 rect. to square
Determines peak of tower ornament



10) Reduce step #1 sq. to 1.118 rect.
Determines dark band beneath windows

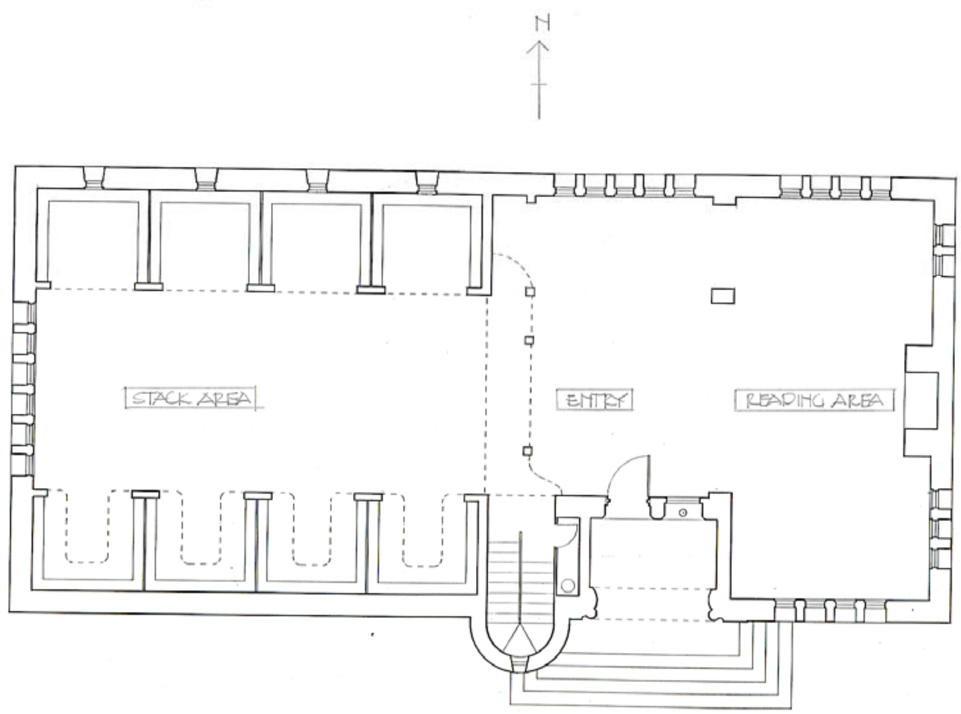


11) Expand step #2 rect. to 2.118 rect.
Determines whole elevation and centerline of sq. determines roofline

FIGURE #16

THE INTERIOR PLAN

Strangely enough, the outside forms and inside spaces do not align. Although the outside and the inside are each divided into three sections, these sections just miss corresponding to each other. The only relations are the dimensional clues pictured on the outside of the building (diagram #5 in figure #8) and the tripartite visual concept that the elevation projects (the entry, a large room on the left with the band of windows and a different type of large room on the right being the reading area). The fact is that the entry gable does not align with the interior entry space even though one would think that it should. This difference is also evident in the proportional system, in that the interior is developed in a slightly different fashion than the exterior. As the exterior is developed from the outside dimensions of the walls, the interior is developed



FIRST FLOOR PLAN

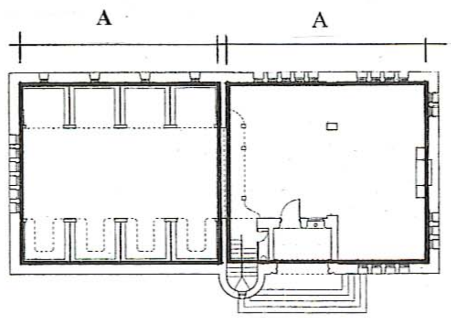
FIGURE #17

from the inside dimensions, which are several feet less than the outside. (For architects throughout history, wall thicknesses have complicated proportional systems. Often column lines or centerlines of walls are used to develop proportions, but in the Crane Library Richardson uses the interior and exterior faces of the walls, thus creating two different sets of dimensions and proportions)

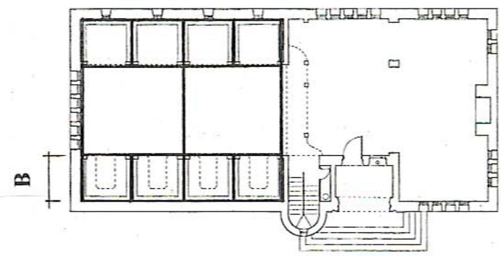
The development of the interior proportioning system can be divided into two segments; the stack area and the entry/reading room (refer to Figures #17, #18 & #19). Both of these are 1.118 rectangles, but they are developed in different ways from each other. As previously mentioned, the stack area starts from the dimension of an exterior piece of trim under the long strip of windows ("A" in figure #8). This represents the long side of the 1.118 rectangle, which defines the whole stack area. Two 1.118 rectangles, half the size of the original define the two story space in the center and eight rectangles, one quarter the size of the original represent the storage alcoves. This progression is shown in diagram #2 of Figure #18.

The entry/reading room half of the building is also derived from a 1.118 rectangle of the same size as in the stack area (also using the "A" dimension in figure #8) and its development is shown in diagram #3 and #4 of Figure #18. From its 1.118 rectangle it is reduced to a 1.618 rectangle (the entry) and a 2:1 rectangle (the reading area). The reading area is then further reduced to help define the fireplace and space on either side it.

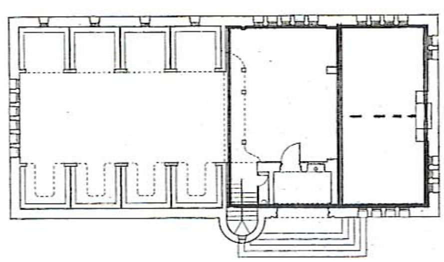
The inside entry area of the building is generated in a slightly different way. It includes posts, originally designed to support a second floor bridge that was to connect the north side to the south side stair tower (The bridge and all second floor space are shown as dotted lines on the first floor plan). In the final construction, this bridge was never built and a small circular stair was installed in the most northwest storage alcove. A wooden screen and the circulation desk were instead installed at this same location[52]. The derivation of the interior entry space is shown in Figure #19.



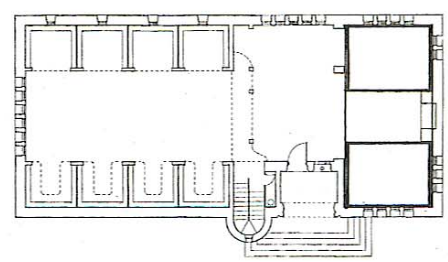
1) Two 1.118 rectangles whose length is equal to length of trim "A" in Figure #4



2) Subdivide stack area rect. into two large 1.118 rectangles and eight smaller 1.118 rectangles. Determines two story open area and book storage area.



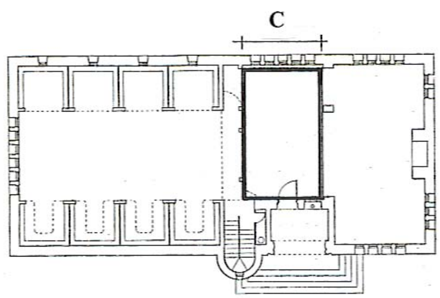
3) Subdivide step #1 eastern rect. into a 1.618 (Golden) rect. and a double square rectangle. Determines the reading area and the entry area. Centerline of the double square rect. determines the fireplace centerline.



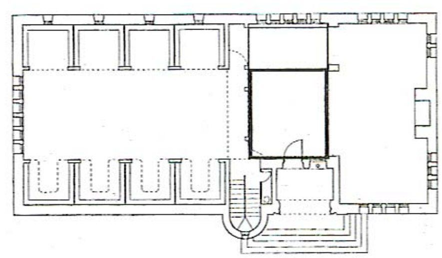
4) Create two 1.414 rectangles within the double square rect. Determines the edges of the fireplace.

PROPORTIONAL DEVELOPMENT OF FLOOR PLAN

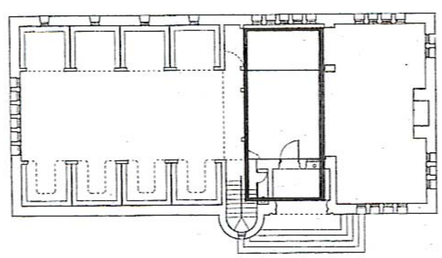
FIGURE #18



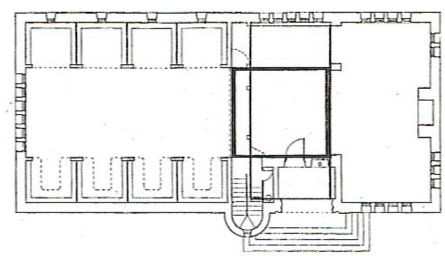
1) 1.618 rect. whose short side is equal to length of trim "C" in Figure #4.



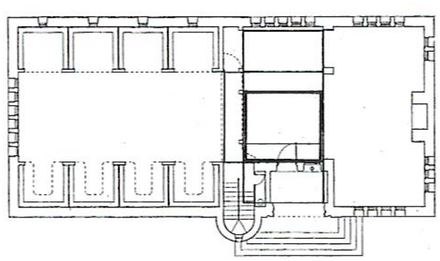
2) Reduce step #1 rect. to a 1.118 rect. Determines bridge col. and corresponds to two story opening of stack area.



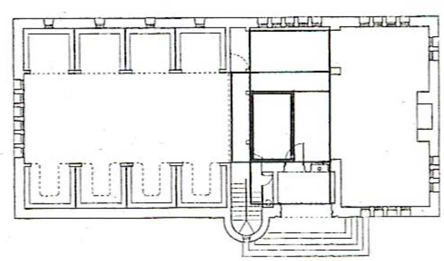
3) Expand step #1 rect. to a 2.118 rect. Determines the inside of entry arch and is another use of the 2.118 rect.



4) Expand the step #2 rect. to another 1.118 rect. in other direction. Determines the width of entry with the bridge and stairtower. This is equal in size and aligns with two-story 1.118 rect. in stack area.



5) Reduce step #2 rect. to a 1.118 rect. in the opposite direction. Determines the other columns for the bridge.



6) Reduce step #5 rect. to a 1.618 rectangle. Determines the centerline of the entry door.

FIGURE #19

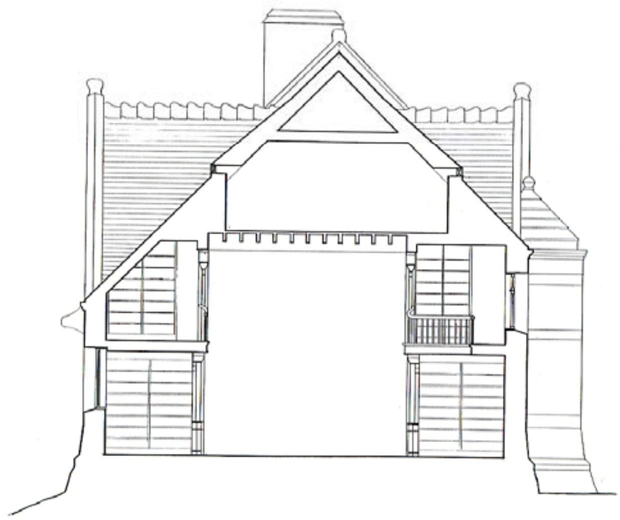
It starts with a 1.618 rectangle whose short side is equal the length of trim "C" in figure #8 and then continues by using various permutations of the Golden Section to locate most of the interior entry elements.

The definition of all of the interior spaces is then architecturally reinforced by the large groups of windows or other significant objects such as the fireplace. For example the two-story stack area is lit by the large group of windows centered on its west end. Likewise the reading area is defined by the axis of the fireplace and the cross axis of the windows on the north and south sides. Even the entry space originally had a group of five windows on its central axis (Now replaced by an addition).

THE BUILDING SECTION

In conjunction with the plan one must also look at the section to understand how Richardson realized this proportioning system in three dimensions. The section to be investigated is through the stack area, cut north to south and looking east (Refer to figures #20, #21 & #22). Again the proportioning starts with a square and expands to a 1.118 rectangle. See the complete progression in figure #21. What is interesting is that the large two-story stack area is developed as two 1.118 rectangles in plan and the same 1.118 rectangle in section. Flanked on either side of this dramatic space are the storage alcoves, which are each square in section (except for the north second floor ones which are cut by the roofline). In many of the archive plans this space was terminated on the east side by the second story bridge. Whether or not the building benefits by having the dramatic two-story space go the whole length of the building is debatable.

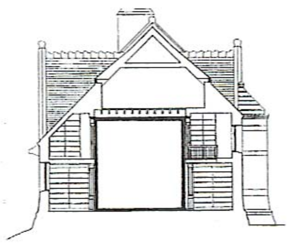
Through this section it is also possible to determine the geometric origins of the famous eyebrow windows (shown in the elevation, figure #14 and the section, figure #20 and #22). If one actually goes into the attic, it is remarkable how small they are and what little light they let in. Even in the middle of the building next to the eyebrow windows, the light is stronger from the end gable



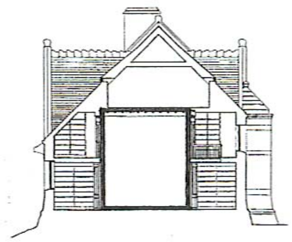
BUILDING SECTION THRU STACK AREA LOOKING EAST

FIGURE #20

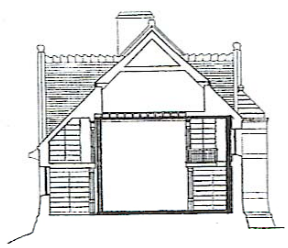
windows than from the eyebrow windows. One realizes that the purpose of these windows is not so much to let light in, as it is to reveal the thinness of the tile roof in contrast to the massiveness of the stone walls (Revealed by the parapetted gables and the entrance arch). This starts to venture into the tectonic quality of Richardson's architecture, which is a whole different and equally interesting issue. (In the Crane Library the primary materials are North Easton Granite for the walls, Longmeadow Brownstone for the trim, lead pane glass for the windows, red tile for the roof and North Carolina pine for the entire interior. By relating, contrasting and revealing these materials throughout the building, Richardson exacts from each material its own special quality.) Returning to the eyebrow windows, they are located by a 1.118 rectangle that is derived from the 1.618 rectangle as shown in figure #22. The arch of the windows is then



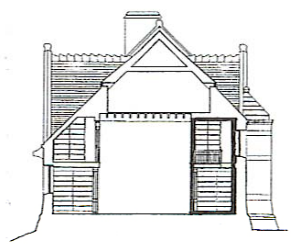
1) Square
Determines the bottom of the beam and the edge of the two-story space.



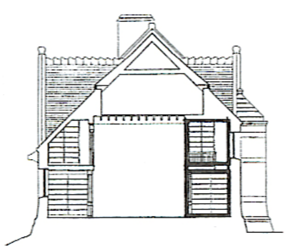
2) Expand step #1 sq. to a 1.118 rect.
Determines the ceiling. This is the same sized rect. as in the plan in diagram #2, Figure 18



3) 1.414 Rectangle
Determines the outside walls and the ceiling of the storage alcoves.

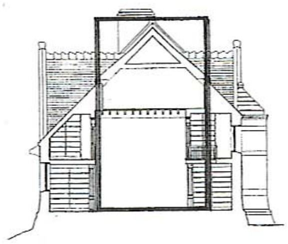


4) 2.118 Rectangle
Determines the two-story storage alcoves.

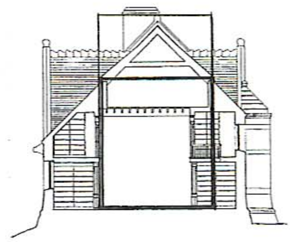


5) Reduce the 2.118 rect. to a square and a 1.118 rect. Further reduce the 1.118 rect. to a square.
Determines the height of each alcove.

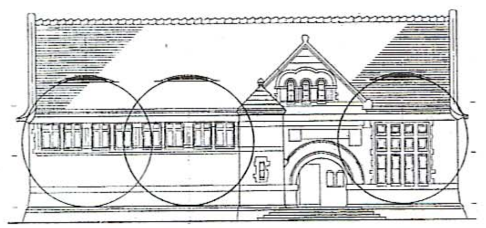
FIGURE #21



1) 1.618 rectangle from floor to top of roof peak.



2) Reduce the 1.618 rect. to a 1.118 rect. Determine the eyebrow window location and aligns with the storage alcove wall on the north side.



3) Circle - using the height to the eyebrow window from the floor level as the diameter. Determines the arch of the eyebrow window.

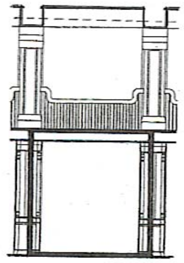
FIGURE #22

generated from the diameter of a circle that is equal to the height of the windows above the first floor level.

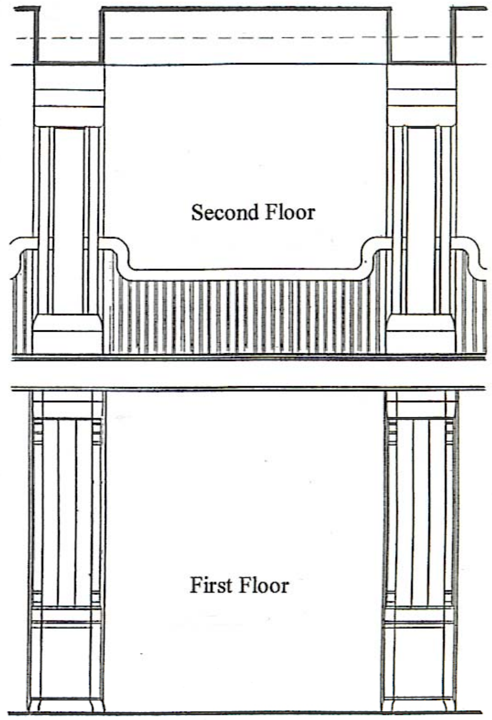
THE INTERIOR ELEVATIONS

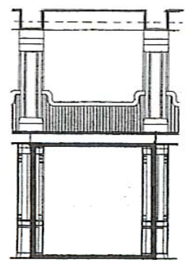
Analyzing the stack area, it is also important to look at the interior elevations of the two story alcoves, because, as one would suspect, these are also designed to fit into the proportioning system. Each side of the stack area is divided into four equal segments corresponding to each of the alcoves. Between each of the open areas of the alcoves is a partition wall about two feet wide that the book shelves are attached to. Since the alcoves are all identical, it is possible to look at one and understand the concept for all of them (Refer to figures #23 & #24 and Photo #7.). As with most of the architectural elements in this library, the derivation starts with the square and evolves through the 1.118 rectangle. Integral in this analysis is also the three dimensional quality of the storage alcove. If one compares the elevation derivations with those of the plan and section, it is possible to see many common features. For example, because the section of the alcove is a square, this means that the 1.118 rectangle in the elevation (diagram #2 of figure #23) is the same as the 1.118 plan of each alcove (diagram #2 on figure #18).

One of the interesting things about using a proportional system such as the Golden Rectangle is that there are many more relationships than merely the obvious ones. As one follows a derivation down from the largest elements to the smallest (or the other way around), it is possible to find many intermediate relationships that, although they might not have been originally intended, are associated simply as a result of the system.



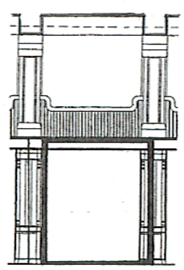
1) Square.
Determines floor to floor height and centerline of columns.



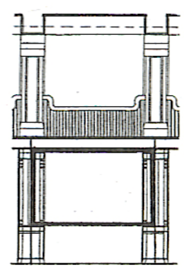


2) Reduce step #1 sq. to 1.118 rect.
Determines the first fl. ceiling.

INTERIOR ELEVATION OF ONE TWO-STORY STORAGE ALCOVE

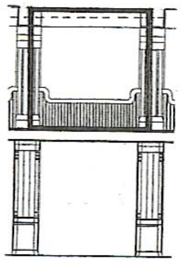


3) Reduce step #1 sq. to a 1.118 rect. in the other direction. Determines the inside of the storage alcove walls.

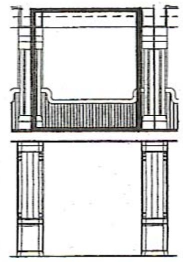


4) 1.618 rect. inside step #2 rect. Determines the chair rail height.

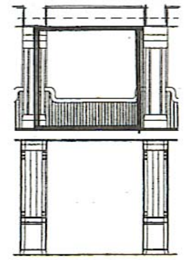
FIGURE #23



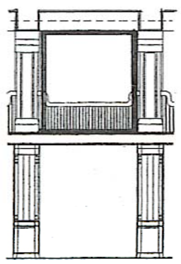
1) Square. Determines the floor to ceiling height and is the same sq. as in the first floor.



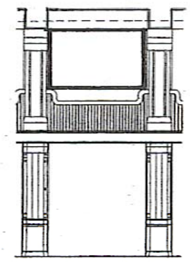
2) Reduce step #1 sq. to a 1.118 rect. Determines the inside of the storage alcove walls.



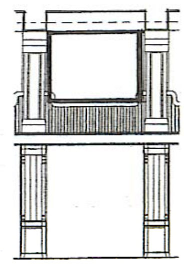
3) Reduce step #2 rect. to a 1.118 rect. Determines the ceiling beam height.



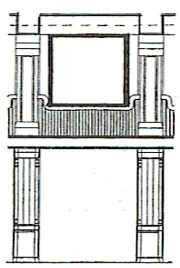
4) Reduce step #3 rect. to a square. Determines the total second floor opening.



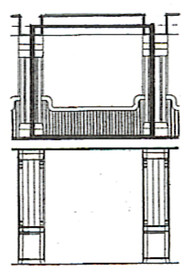
5) Reduce step #4 sq. to a 1.618 rect. Determines the height of the top segment of the guard rail.



6) Reduce step #4 sq. to a 1.118 rect. Determines the height of the bottom segment of the guard rail.



7) Reduce step #6 sq. to a 1.414 rect. and center it. Determines the downturn line of the guard rail.



8) Reduce step #1 sq. to a 1.118 rect. Determines cross beams and aligns with top of fireplace.

FIGURE #24

THE FIREPLACE

Perhaps the most significant single element in the interior is the fireplace. It dominates the end of not only the reading room, but the whole interior space.

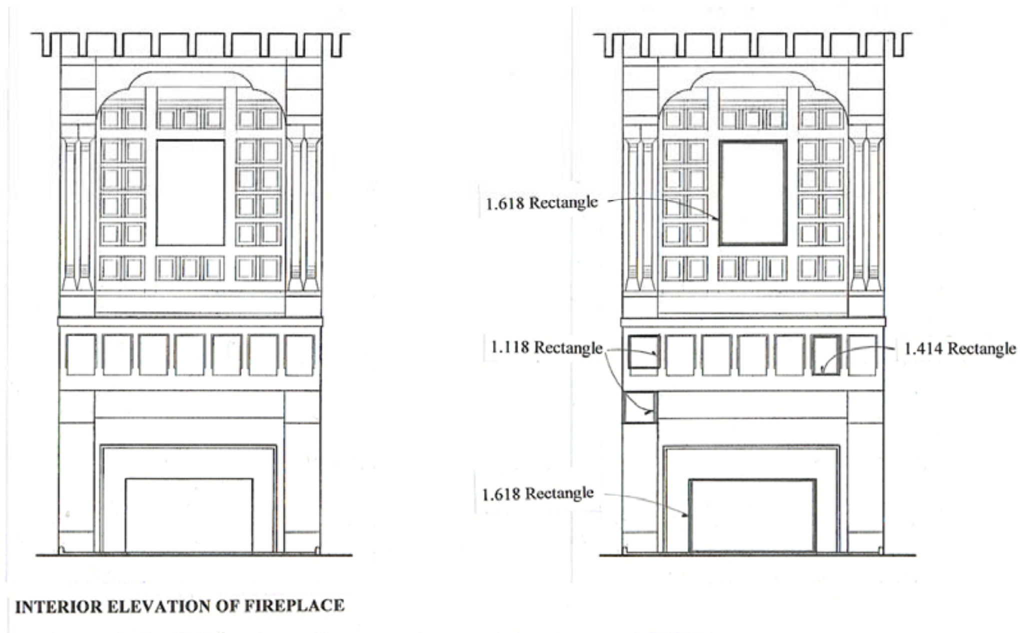
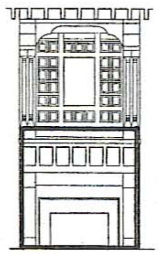


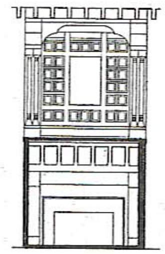
FIGURE #25

Since the bridge between the two second-floor stack areas was (fortunately for the fireplace) not built, the fireplace can be clearly seen from the whole interior space. It is a massive element that is the width of one of the storage alcoves and goes from the floor to the ceiling with a similar proportional development as a two story section of a storage alcove (Refer to figures #25, #26 and #27 and Photo #6).

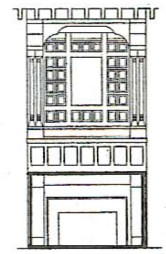
The scheme for the fireplace is two squares on top of each other (of the same dimensions as the storage alcoves). As usual, the proportional development in both cases starts with the square and evolves through a series of proportions closely related to the sequence of proportions mentioned earlier. In the bottom square of the fireplace, the focus is the firebox while in the top portion the design orients around a 1.618 rectangle that was originally to hold a bronze portrait of Thomas Crane by August Saint-Gaudens. The dividing line between the upper



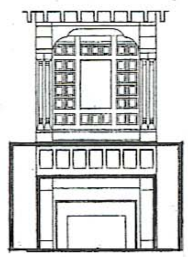
1) Square. Top of square aligns with floor of second floor storage alcove and width equals one bay.



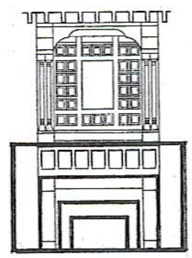
2) Reduce step #1 sq. to a 1.118 rectangle. Determines the top of the mantel, which aligns with the ceiling of the first floor storage alcove.



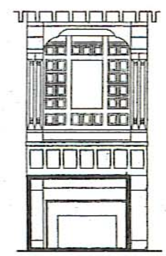
3) Reduce step #1 sq. to 1.618 rect. Determines the top of molding band.



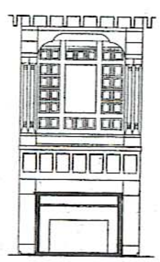
4) Expand step #2 rect. to a 1.618 rect.



5) Create a 1.618 rect. that is smaller than the step #3 rect. by the same ratio the step #3 rect. is smaller than the step #4 rect. Repeat the process to determine the firebox.



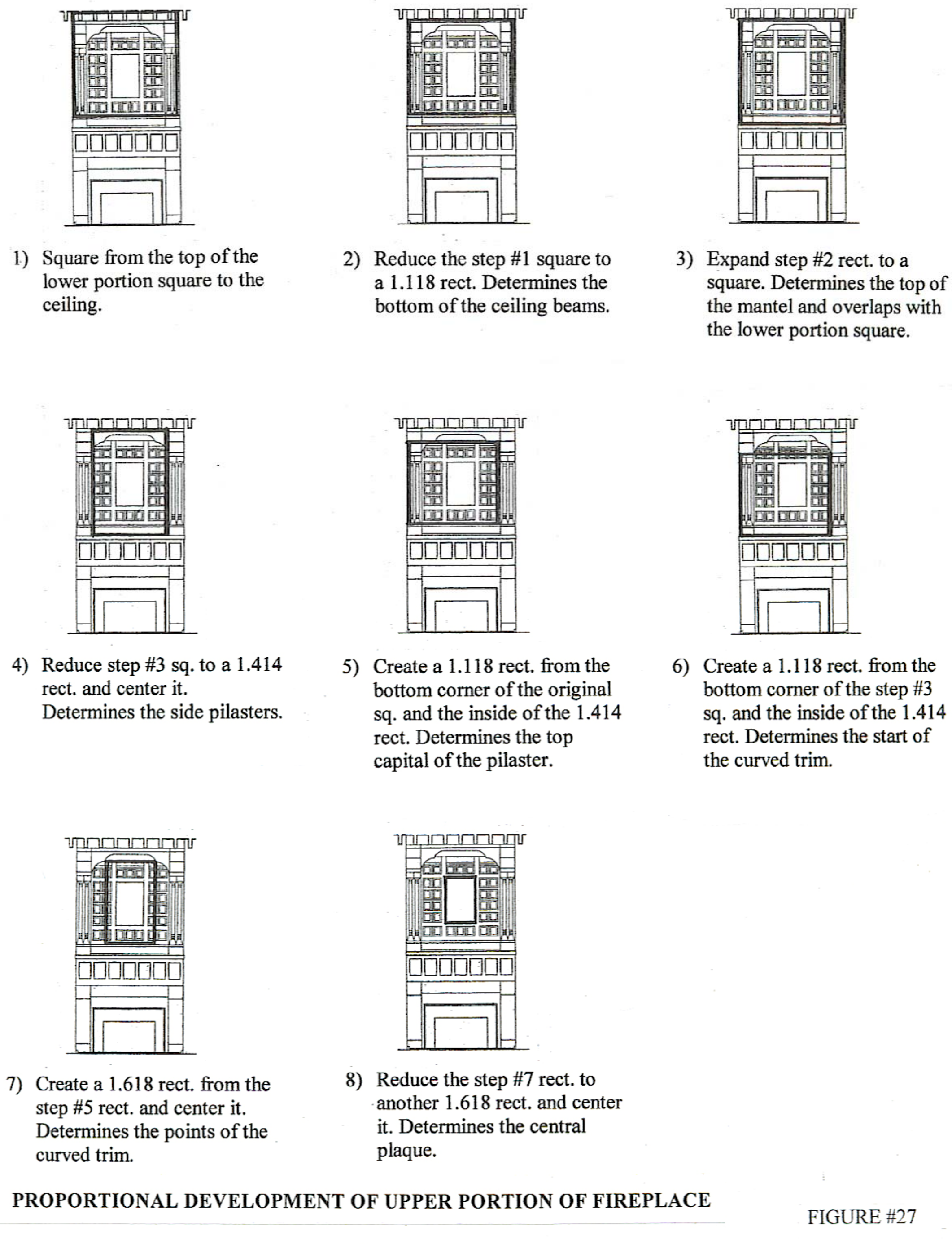
6) Reduce the step #3 rect. to a 1.414 rect. (both directions) Determines the side pilasters.



7) Create a 1.414 rect. within the pilasters. Determines the bottom of the molding band.

PROPORTIONAL DEVELOPMENT OF LOWER PORTION OF FIREPLACE

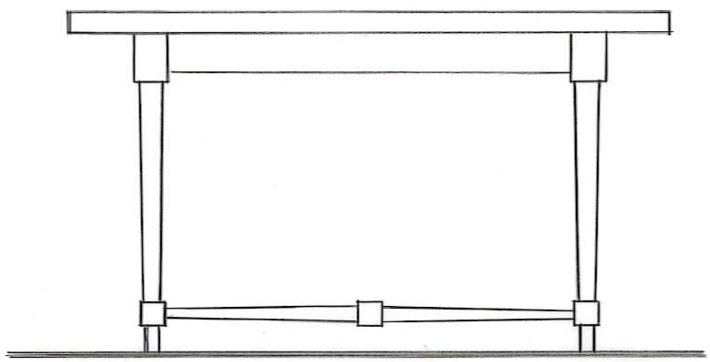
FIGURE #26



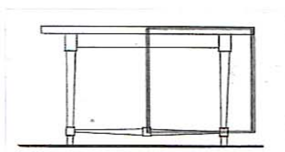
PROPORTIONAL DEVELOPMENT OF UPPER PORTION OF FIREPLACE

FIGURE #27

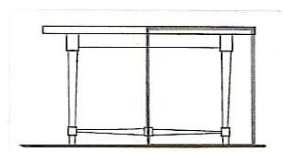
and the lower portions of the fireplace is the mantel, which corresponds to the ceiling of the first floor of the storage alcove. Clearly, from the number of alignments and proportions that are similar to the storage alcoves, these two designs were meant to relate to each other. Additionally, there are several rectangular features that are significant proportional shapes. These are shown on the second drawing in figure #25.



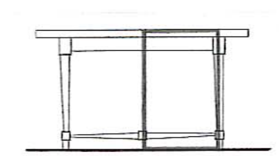
END ELEVATION OF LIBRARY TABLE



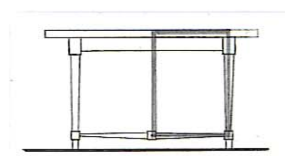
1) Square



2) 1.118 Rectangle



3) 1.618 Rectangle



4) 1.414 Rectangle. It should be noted that numerically a 1.414 rect. cannot be derived from the previous rectangles, but graphically it is very close.

FIGURE #28

FURNITURE

Thus far, this investigation has started at the smallest element, the pattern of the leading in the window, expanded to the whole elevation, and then returned to the intimate scale of the fireplace. Yet there is one more detail that should be investigated. That is the furniture. Richardson was fortunate to be able to design not only the whole building, but most of the furniture in it. Some of the principal pieces that still remain are the large library tables that were once located in the two story space of the stack area. As a short study of the end elevation of the tables reveals, they are also developed in a proportional manner. The four steps are shown in figure #28. They start with the square and then include the 1.118 rectangle, the 1.618 rectangle and the 1.414 rectangle. In a superficial look at the overall building, the table might seem unimportant, but since this study is examining the total process of the proportional development, the table becomes much more significant. It reinforces the idea that the use of proportions was considered a constant in the design methodology, even in such secondary features as furniture.

AUSTIN HALL AND OTHER BUILDING

After examining one building in detail, the obvious question is: to what degree did Richardson use proportioning systems in the rest of his buildings? Was Crane Library a unique situation, did he use it in all of his buildings or was it something that he used only occasionally? Preliminary research shows that he used it all the time. Certainly a proportional system is used in all his railroad stations and churches. In addition, a number of other buildings I have investigated were developed that way, including the Ames Gate Lodge, the Glessner House, the Allegheny County Courthouse,[53] the Billings Memorial

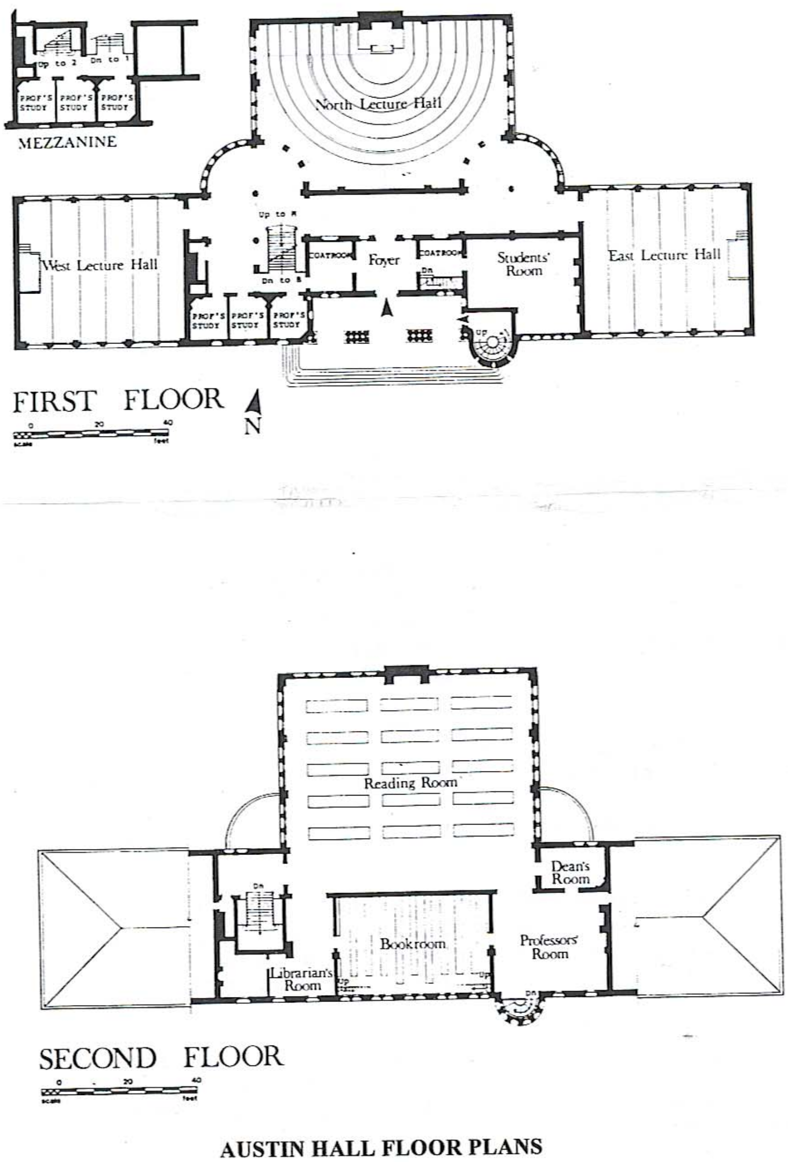


FIGURE #29

Library, the Stoughton House, the Robert Treat Paine House, Sever Hall, the Ames Monument in Wyoming, the Ames Free Library [54], the Winn Memorial Public Library, the Browne House, and of course Austin Hall.[55]

In fact, beyond the stone plaque, Austin Hall is one of the most interesting examples of his use of proportions[56]. Not only are the spaces and elevations compelling proportional challenges, but the whole entrance is one giant (and humorous) billboard showing how he intends to create the building mathematically. It is offered as sign or challenge to examine the building as a mathematical problem or puzzle. If one looks closely at the entrance to Austin Hall, it is again possible to see many clues that Richardson is offering to explain his building. This is similar to the signage on the front of the Crane Library, but in a much more complex form. Below are listed several of the clues, that must be included with the previously mentioned stone plaque (refer to photographs #8, #9, & #10).

1) A decorative pilaster just above the stone plaque on the left side of the entrance has a band across it that divides it into golden section proportions. If one takes the dimension from the top of the pilaster to the top of the band as the base dimension "A", the dimension to the bottom of the band is 1.118 x A and the dimension to the bottom of the pilaster is 1.618 x A. Both being proportions of the Golden Section.
2) The dentils in the two outside arches of the entry (Photo #9) only go part of the way around the curve so that they create a protractor showing the angle of 22.4 degrees. This is the angle formed when one places three golden rectangles lengthwise next to each other and draws a line from the mid-point of the lower line of the middle rectangle to the upper outside corner of the outside golden rectangle. Coincidentally the front portion of Austin Hall is made of three golden rectangles and if one extends the line from the last dental through the center of each arch they intersect at the ground in the middle of the center archway. That is then the center point of the bottom of the middle golden rectangle of the three that form the front of Austin Hall.
3) The numerous columns in the entry are all not fluted except for two (Photo #9). The dimension between these two fluted columns is the key dimension for starting the proportional derivation of the whole building. It is the length of the short side of one of the three front golden rectangles.
4) Although the frieze of the building (the original Harvard Law School building) is carved with great legal words of wisdom ("And thou shalt teach them the way wherein they must walk and the work that they must do"), the characters carved in stone around the entrance area might lead one to believe

> that Richardson had a less than favorable opinion of the profession that was being taught inside - two headed eagles facing in opposite directions, animals chasing their own tails, two dragons tied together by one collar, snakes strangling people and miniature carved faces whose expressions would not be complimentary to anyone.

Once again Richardson has given the clues to the building on the outside, but it is only when looking at the whole plan (figure #29) that one can start to see the sequence of proportions that were developed for the whole building. In a simple analysis (Figure #30) one can see that the proportional development of the building starts with an array of 1.414 rectangles that are reduced to 1.618 rectangles (diagrams #1 and #2 in Figure #30). From here there is a sequence of proportions based on a progression from golden rectangles to 1.118 rectangles that allows significant spaces to all be 1.118 rectangles. Those rooms are then proportionally related to one another by the same ratio. In other words even though the East and West Lecture Halls, the Reading Room, the Students' Room, and the Professors' Room are all 1.118 rectangles, they are all different sizes. But the size of the Students' room is proportionally related in size to the Lecture Rooms in the same way that the Lecture Rooms are related to the Reading Room. This proportional and geometric hierarchy is derived from the sequence of proportions that govern the building. It can also be viewed as a series of golden rectangles that increase geometrically by a ratio of 1.118 : 1.618. In looking at the diagram #3 in figure #30 the ratios become the following:

A = B
B x 1.618/1.118 = C
C = D
D x 1.618/1.118 = E
E = F
F x 1.618/1.118 = G
G = H

This pattern can of course be mirrored on the other side of the building. The room defined by the final H - H/1.118 rectangle is the upstairs large Reading

PROPORTIONAL DEVELOPMENT OF AUSTIN HALL

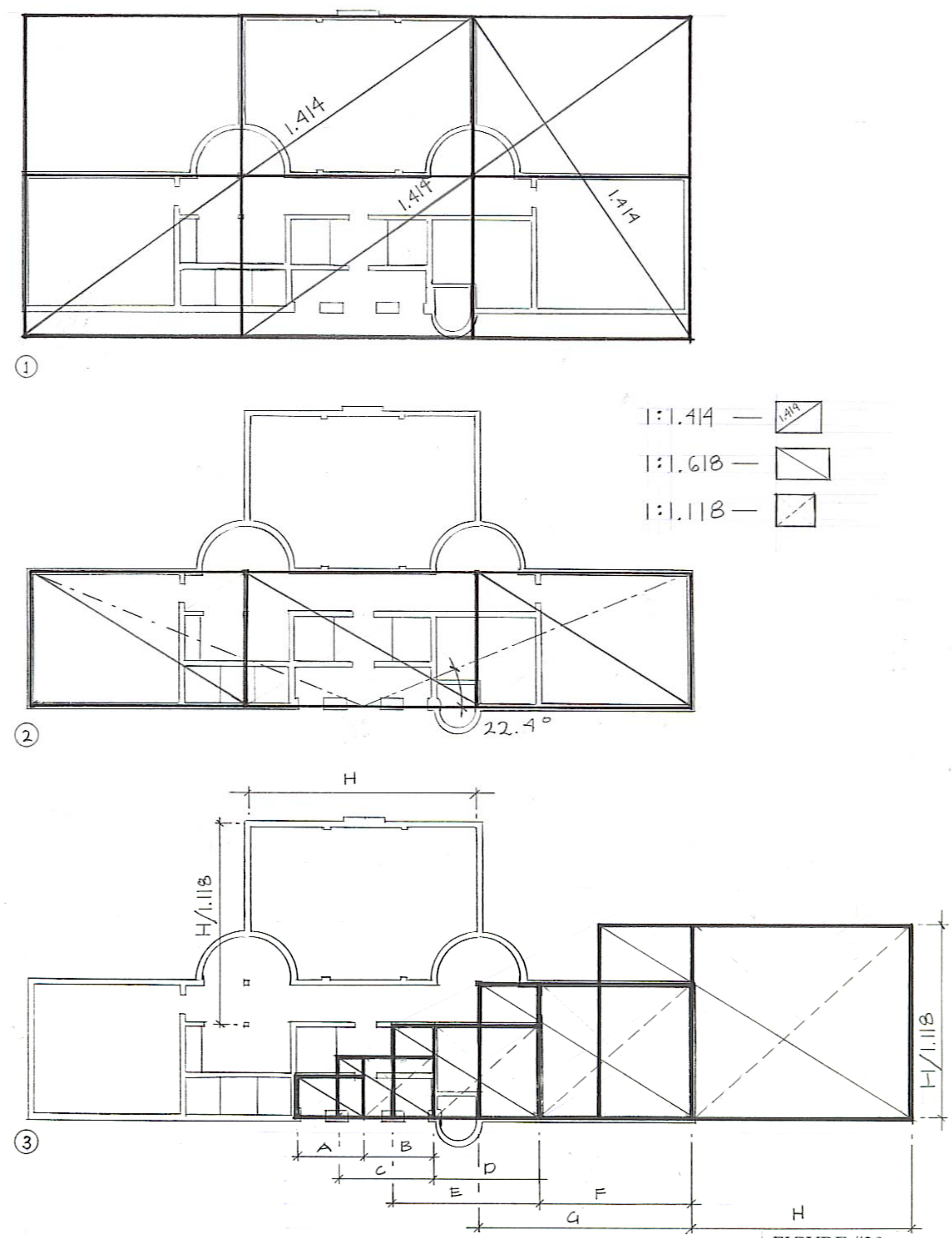


FIGURE #30

Room. For the overall building, the proportioning starts with diagrams #1 & #2, but it is diagram #3 that shows the real beauty of the sequence of proportions in Austin Hall.

Thus one is able to see that Austin Hall, like the Crane Library, is developed by its own but different sequence of proportions. Obviously many more relationships exist but this short analysis serves to reinforce the concept of sequence of proportions.

CONCLUSION

Although not every detail of the Crane Library has been investigated, enough have been studied to realize that Richardson used the proportional system in every aspect of the design of this building. But as all architects know, designing a building is not just the creation of one man, but the collaboration of a whole office. As James O'Gorman describes,[57] Richardson generally did preliminary sketches, letting his assistants develop the ideas into finished drawings. He would then continue to give them criticism throughout the design and construction process. This would mean that it must have been an assumed practice in the office for all the buildings to be developed through a proportional system. This would also help explain why there is so little reference to proportions in any of the surviving documents of Richardson's office. It would have been considered simply as a natural design tool. The buildings would be laid out in a proportional manner, just as floor joists would have been calculated to support a floor or columns would be sized to hold up a roof. The proportion system did not need to be shown in the presentation drawings and it was not necessary for the working drawings. It was a method used only in the design process to create harmonious spaces and to unite the forms architecturally. But it was only part of the process, not the final product.

To understand Richardson, his architecture, and his design methodology, analysis must be recognized as an essential tool. Although Richardson never wrote about his proportional system, he did carve clues of it into his buildings.

Using these seeds of knowledge and an in-depth analysis, this investigation has shown that Richardson developed a sequence of proportions for each building and used it at all levels of his designs. All the different elements, whether representing the whole scheme or a small detail, are tied together by the proportions. Although this investigation has looked extensively at the proportional system, one must be remember that it was only the framework in which Richardson to expresses his other architectural ideas. It created a unifying language that was able to hold together Richardson's more significant concepts such as function, materials, ornamentation and historical image. Even though it was an important method for tying together disparate elements in a building, the proportioning itself was not a principal architectural idea of the building. It was only a tool.

Yet as a tool in the design methodology, its importance cannot be overlooked. Returning to the plague on Austin Hall, it is remembered that Richardson framed his own initials in an intricate and beautiful design based on this proportional system.

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[1] It should be noted that the Golden Section ratio of 1.618 is also the ultimate ratio of any two successive integers of the Fibonacci series. This series is defined as a sequence of integers starting with zero and one which are formed according to the law that each term is the sum of the two preceding terms. For example: 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233…. is a Fibonacci series and thus 34 divided by 21 equals 1.61905 and 233 divided by 144 equals 1.618056. Also note that 144 divided by 233 equals .618026. As the numbers get higher the proportion gets closer to the true Golden Section Proportion. In addition if one starts with <u>any</u> two numbers and develops a series by the same rule of adding the two previous integers to get the next, eventually the numbers will approach the Golden Section ratio. Leonardo Fibonacci (1170-1250) published his *Liber Abaci* (the book of the Abacus) in 1202 in which he introduced to the west the Hindu-Arabic system of numeration to replace the Roman numeral system. Included in this work which would have been a basic for any mathematician after this significant publication, is a small problem about the propagation of rabbits which developed into what is now referred to as the Fibonacci series. It should also be noted that for many mathematicians the more important ratio for the Golden Section occurs in a pentagon and pentagram where the ratio of the sides of a pentagon to its diagonal is the irrational number 1.6180339887…. or a Golden Section. When the diagonals are added to a pentagon they create a smaller pentagon in the center which is proportional to the larger pentagon, so this is also a means of proportional reduction.

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[2] The importance of the square root of five is that one numerical calculation for the Golden Section is the square root of five plus one, all divided by two.
[3] Using drafting tools it is possible to progress from one of these shapes to the next, but there is one discrepancy. The triangle graphically looks like it is formed from the original square and is a 1.414 rectangle but numerically it doesn't work out. The triangle appears to be formed from the peak of the inner circle, the base of the Golden Rectangle in step #7 and the bottom of the triangle whose dimension equals to the side of the Golden Rectangle in step #7. This would form a triangle whose shape as shown in figure #8 is extraordinarily close to that of a 1.414 rectangle, in fact within 1%. But unfortunately using numerical calculations they do not match. This could be Richardson's attempt to graphically show a close relationship between 1 : 1.414 rectangle formed by the triangle and the Golden Section. Graphically it works and certainly in a 120 year old stone carving it works, but unfortunately the numbers just miss.
[4]Roger H. Clark and Michael Pause, *Precedents in Architecture* (New York: Van Nostrand Reinhold, 1985), 96-103. They note a golden section in the plan of Trinity Church and the Glessner house.
[5] Scholars who have discussed proportions and mathematics in Richardson's architecture include George Hersey, Anne Jensen Adams, and Margaret Floyd. Professor Hersey examines the importance of Richardson's education at the Ecole des Beaux-Arts especially as it relates to the proportions and organization of his buildings. George L. Hersey, "Architecture and Geometry; An Incomplete handbook for Non-Mathematicians" syllabus for History of Art 198b, Spring 1996, Yale University. Anne Jensen Adams does a short analysis of Trinity Church's proportional foundations (and the preliminary elevations for the church). Anne Jensen Adams, "The Birth of a Style: Henry Hobson Richardson and the Competition Drawings for Trinity Church," *The Art Bulletin* LXII number 3 (1980): 420. Margaret Floyd writes that Professor John Coolidge "and his students over the years has confirmed Richardson's reliance on modular design systems." Margaret Floyd, *Henry Hobson Richardson:: A Genius for Architecture,* (New York: The Monacelli Press, 1998), 24.
[6] Mario Livio, *The Golden Ratio: The Story of Phi, The World's Most Astonishing Number (*New York: Broadway Books, 2002) p.121-123. This is without a doubt the most informative, thorough and unbiased book on the Golden Section available. Mr. Livio gives a comprehensive overview of the history of the Golden Section, emphasizes its great importance, but is not afraid to cast doubt on the many times in history where the use of the Golden Section could be justifiably questioned.
[7] Theodore Andrea Cook, *The Curves of Life* (New York: Dover Publications, 1979) p. 449-450.
[8] Cook, *The Curves of Life,* p. 417-420.
[9] Livio, *The Golden Ratio: The Story of Phi, The World's Most Astonishing Number, p. 96-98.*
[10] Dan Brown, *The DaVinci Code* (New York: Doubleday, 2003) p. 93-97. Although the whole book is a reference to the Golden Section it is these pages that give the best description of it.
[11] Garth E. Runion, *The Golden Section* (Parsippany, NJ. Dale Seymour Publications) p. 11-16 & 33-42.
[12] Livio, *The Golden Ratio: The Story of Phi. The World's Most Astonishing Number,* p. 223-226.
[13] Livio, *The Golden Ratio: The Story of Phi. The World's Most Astonishing Number,* p. 208.
[14] Livio, *The Golden Ratio: The Story of Phi. The World's Most Astonishing Number,* p. 184.
[15] Livio, *The Golden Ratio: The Story of Phi. The World's Most Astonishing Number,* p. 96-109 and for Fractals 212-222.
[16] H. E. Huntley, *The Divine Proportion: A Study in Mathematical Beauty,* (New York: Dover Publications, 1970) p. 25.
[17] In addition to the term "Golden Section" this ratio has also been referred to as: the Golden Ratio, the Golden Rectangle, The Golden Triangle, the Fibonacci Series, Phi (pronounced *fee*), o, the Harmonic Division of a Line, the Mean to Extreme Ratio, the Egyptian Triangle, the Modular, and the Divine Proportion.

[18] Livio, *The Golden Ratio: The Story of Phi. The World's Most Astonishing Number,* p. 51-61. See Figure #31. The Golden Section appears in the Great Pyramid in the triangle formed by the height of the pyramid from the top straight down, the line from the top of the pyramid to the middle of one of its base sides, and the line from the middle of that base side to the center of the square of the base. This triangle has a ratio of its sides equal to 1 : 1.618 : the square root of 1.618. The Great Pyramid also has the interesting mathematical fact that its base perimeter is equal to the diameter of a circle whose radius is the height of the pyramid. Although Livio doubts this as evidence that the Egyptians knew of the Golden Section, many sources believe it as incontrovertible evidence.
[19] John Pennethorne, *The Geometry and Optics of Ancient Architecture* (London and Edinburgh:Williams and Norgate, 1878) p.16 . This magnificent large folio was in Richardson's library, but since its publishing postdates when Richardson was in France, I have not included it in some of the references where Richardson might have learned the Golden Section. Although this book does show this one example of the Golden Section, it is not its primary emphasis. It is a detailed study of proportions that shows the Parthenon derived from two squares (under the portico) and it goes to great extents to show how one of the main influences in Greek design was the perspective view of the buildings.
[20] Francis D. K. Ching, *Architecture: Form, Space, and Order*, (New York: John Wiley & Sons, 1996) p. 288-289. See Figure #31. Interestingly two variations are shown, both using the Golden Section to develop the front façade, but each using slightly different starting dimensions. It seems a more compelling argument for the Golden Section could be made using the plan, where the overall dimensions are a square root of five rectangle, the cella is a golden Section and the location of the Statue of Athens in the cella is directly on the square subdivision of that Golden Section. It should also be noted that Eugene Emmanuel Violet-le-Duc (*Discourses on Architecture* (James R. Osgood & Co. 1875) p.417) overlaid what he called the "Egyptian triangle", whose ratio was 5 : 8, on the façade.
[21] Ching, *Architecture: Form, Space, and Order,* p. 290. See Figure #32.
[22]Otto Von Simpson, *The Gothic Cathedral: Origins of Gothic Architecture and the Medieval concept of Order,* (Princeton, Princeton University Press. 1956) p. 34, 208-214 & 230.
[23] Eugene Emmanuel Viollet-le-Duc, *Discourses on Architecture,* Translated with an introduction by Henry Van Brunt, (Boston: James R. Osgood and Company, 1875) p. 425-433. See Figure #32. Viollet-le-Duc uses a slightly different approach to proportion analysis. He starts with an isosceles triangle that has a height to width ration of 5:8 (essentially a Golden Ratio) and then is able to horizontally divide the sides into smaller triangles of the same proportion. He calls this the *Egyptian Triangle* because he claims that it is proportionally the exact cross-section of the Great Pyramid. Interestingly he also places the triangle on the elevation of the Parthenon in the same manner many other analysts place the Golden Rectangle.
[24] Looking at Jefferson's Elevation of the library there are several shapes and proportions that should be notices. See Figure #33:

- The circle formed by the dome and the ground level
- The square developed with the same sides as the diameter of the circle.
- The equilateral triangle formed by the top of the dome and the top of the building platform.
- The Golden Sections of the portico shown by the diagonals "a" and "b" and the golden Section shown by the diagonal "c".
- Where the roof line of the portico and the large square intersect is ½ the height of the square.
- The height rectangle "c" equals width of rectangle "a" and the diagonal of rectangle "a" is the width of rectangle "b".

[25] Le Corbusier, *Modular* (Boston: Birkhauer, 2000). See Figure #33.
[26] Clark & Pause, *Precedents in Architecture,* p. 121, 131. See Figure #34.

[27] From personal experience as an architect, I can say that although we may want to design in a proportional system based on 1 : 1.618, carpenters, masons and especially foundation contractors work in modules of feet (preferably 4'-0") or meters. Trying to get a foundation laid to 10'-0" x 16'- 2 5/32" is just not worth the cost. It fairly quickly becomes 10'-0" x 16'-0". On the other hand if one finds a columnar/grid system of 10 x 6 columns (as in Kahn's *Yale Center for British Art where it could be argued that many Fibonacci series exist*) it is likewise difficult to argue for a Golden Section unless the architect is quoted as saying he used a Fibonacci series.
[28] Livio, *The Golden Ratio: The Story of Phi. The World's Most Astonishing Number*, p. 75-77.
[29] Euclid, *Euclid's Elements* (Santa Fe, Green Lion Press, 2003) translation by Thomas L. Heath, Dana Densmore, editor, p. 47, 123, 152, 449-457.
[30] For the period just prior to the end of the nineteenth century the historian Matila Ghyka argues that Golden Section was essentially forgotten. And only with the studies of the Parthenon by Adolph Zeising in the 1850s and later studies by Jay Hambidge and Ernst Moessel (both in the 1920s) did these proportions start to be reused. This study casts doubt on that assumption. Matila Ghyka, *The Geometry of Art and Life* (New York: Dover Publications, 1977). p. 124 see:

Adolf Zeising, *Der Goldne Schnitt, nach dem nachgelassenen Manuscript des Verfassers* (Halle: Leopoldinische Akademie,1884)

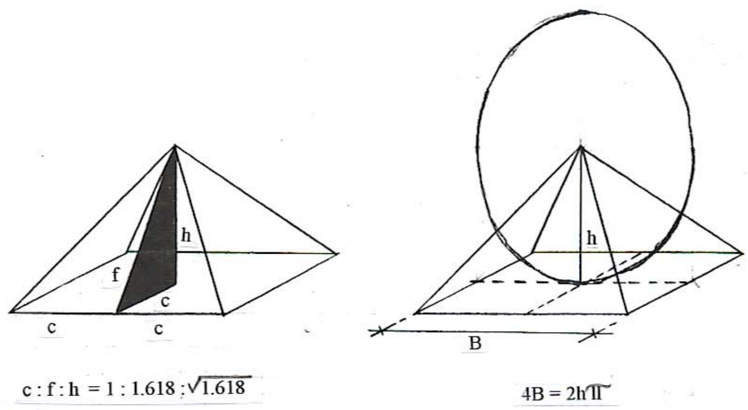
Jay Hambidge, *Dynamic Symmetry,* (Boston: Mooshorn, c. 1919)

Ernst Moessel, *Die Proportion in Antike und Mittelalter* (Munich: C. H. Beck, 1926-31)

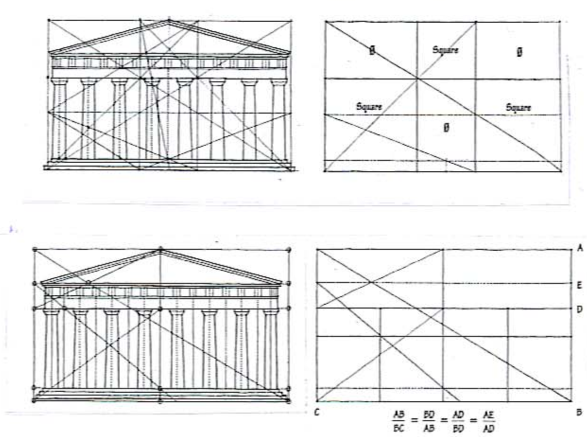
For many architects Ghyka's books were an inspiration to use the Golden Rectangles as a tool for design (In particular, Le Corbusier mentions Ghyka in Modular I & II as a significant influence.), but unfortunately Ghyka tended to see the Golden Section in many things that were not realistic, verifiable or possible, hence losing a degree of credibility.
[31] Richard Chafee, "The Teaching of Architecture at the Ecole des Beaux-Arts," *The Architecture of the Ecole des Beaux-Arts* (New York: The Museum of Modern Art, 1977), p.97-103. In a reorganizing of the Ecole des Beaux-Arts in November 1863, Viollet-le-Duc was given a significant professorship, but after major protests by the students he resigned in March of 1864.
[32] Eugene Emmanuel Viollet-le-Duc, *Dictionnaire raisonne de l'architecture francaisedu XI au XVI sielcle* (Brussels: P. Madaga, 1979) releves et observations par Philippe Boudon et Philippe Deshayes, p.220-225.
[33] Viollet-le-Duc, *Discourses on architecture*, p.413-471. In addition to the "Egyptian Triangle" an equilateral triangle is also of great importance, especially how they are both derived from a circle.
[34] Peter Murray, *The Architecture of the Italian Renaissance (*New York: SchockenBooks, 1963) p.80-81. Palazzo della Cancelleria is shown to have clearly used the Golden Rectangle. In addition the second and third formulas Palladio gives for the heights of rooms are direct copies from Euclid's *Elements:* Proposition #14 of Book #2 and Proposition #43 of Book #1. It so happens that Proposition #11 of Book #2 is the proposition that gives the definition of how to create a "mean to extreme ratio". Since it was important to learn Euclid's propositions in order, it is unlikely that Palladio knew Proposition #14 of Book #2 with out having gone through Proposition #11.
[35] The Harvard University Archives have the academic records and course catalogues for past students. All eight math courses were taught by J.M. Peirce including Geometry, Analytic Geometry, Curves and Functions, and Analytic Mechanics.
[36] Richard Chafee, "Richardson's Record at the Ecole des Beaux-Arts," *Journal of the Society of Architectural Historians XLIV* (1985) p.186
[37] Discussion with Richard Chafee on Jan. 20, 2005
[38] Richardson's library is currently at Harvard University where it is being restored. There exist three different inventories of the library from which information for this article was obtained. In addition, many of the books listed in Richardson's library are available in English translations and from other more easily accessible sources. Although it is not possible to be certain when Richardson bought the books, looking at the date of publication, language, and publisher it is

possible to make reasonable guesses which books Richardson bought in France as a student.
[39] John Ruskin, *The Seven Lamps of Architecture* (New York: Dover Publications, Inc. 1989) p.124-130, Plate XII.
[40]David Van Zanten, "Architectural Composition at the Ecole des Beaux-Arts from Charles Percier to Charles Garnier," *The Architecture of the Ecole des Beaux-Arts* (New York: The Museum of Modern Art, 1977), 118.
[41]In his mature period of design (after Trinity Church) it could be argued that he used the French planning and organization in his more formal buildings and the picturesque or more asymmetrical in the less formal buildings. Thus his houses were always asymmetrical and rambling compositions while his churches and high government buildings were always formal, symmetrical and highly organized. The Libraries and Academic buildings were somewhere in between, often fairly symmetrical with one asymmetrical element such as the tower in Austin Hall.
[42]James F. O'Gorman, *Living Architecture: A Biography of H. H. Richardson* (New York: Simon and Schuster Editions, 1997), 67.
[43]The remains of the drawings from Richardson's office are located in Houghton Library at Harvard University. Although at first glance it is voluminous, it is a mixture of some complete sets of working drawings, some presentation drawings, some perspectives, some preliminary sketches and some building details. So although it might be termed "voluminous" it can certainly not be called "complete".
[44] Chafee, "The Teaching of Architecture at the Ecole des Beaux-Arts," *The Architecture of the Ecole des Beaux-Arts* p. 88. Also, in several telephone conversations Mr. Chafee was very helpful in pointing out several important sources and information.
[45]Henderson Floyd, *Henry Hobson Richardson a Genius for Architecture*, p. 14, 191.
[46]Henry-Russell Hitchcock, *The Architecture of H. H. Richardson and his Times* (New York: The Museum of Modern Art, 1936. Republished, Cambridge: MIT Press, 1989), 138, 139, 151.
[47]Jeffrey Karl Ochsner, *H. H. Richardson Complete Architectural Works* (Cambridge: MIT Press, 1983), 226.
[48]Kenneth A, Breisch, *Henry Hobson Richardson and the Small Public Library in America a Study in Typology* (Cambridge: The MIT Press, 1997)
[49]Ochsner, H. *H. Richardson Complete Architectural Works,* p. 227.
[50] All drawings of the Crane Library are compilations of measured drawings that the Crane Library had from a set drawn in 1939 (often inaccurate), drawings from the Richardson Archives in the Houghton Library at Harvard University and extensive measurements taken on the site.
[51]Jeffrey Karl Ochsner and Thomas C. Hubka, "H. H. Richardson: The Design of the William Watts Sherman House," *Journal of the Society of Architectural Historians* LI (1992): 139.
[52]Ochsner, *H. H. Richardson Complete Architectural Works* p. 228, 231 and drawings from the Houghton Library, Harvard University.
[53] Clark and Pause, *Precedents in Architecture* p. 96-103.
[54]Breisch, *Henry Hobson Richardson and the Small Public Library in America a Study in Typology*, p. 185-187. This interesting book examines in detail the typology of the small public library in the U.S. in the late nineteenth century. Breisch does a short proportional analysis of the Ames Memorial Library, but does not mention its use of the golden rectangle.
[55]During an advanced studio I taught at Roger Williams University students analyzed Austin Hall, Sever Hall, the Ames Memorial Library, the Old Colony Railroad Station at North Easton, the Ames Gatehouse, and the Robert Treat Paine house and found the use of Golden Section proportions in all of them. Austin Hall was originally the building that I intended to study but due to its complexity and the lack of available drawings, I chose a simpler building that I could measure and about which more documents were available.

[56]See James F. O'Gorman, *H. H. Richardson and His Office - Selected Drawings* (Boston: David R. Godine, 1974).

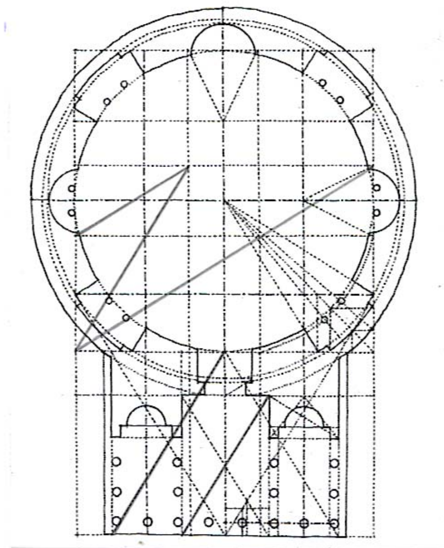


Great Pyramid Proportions

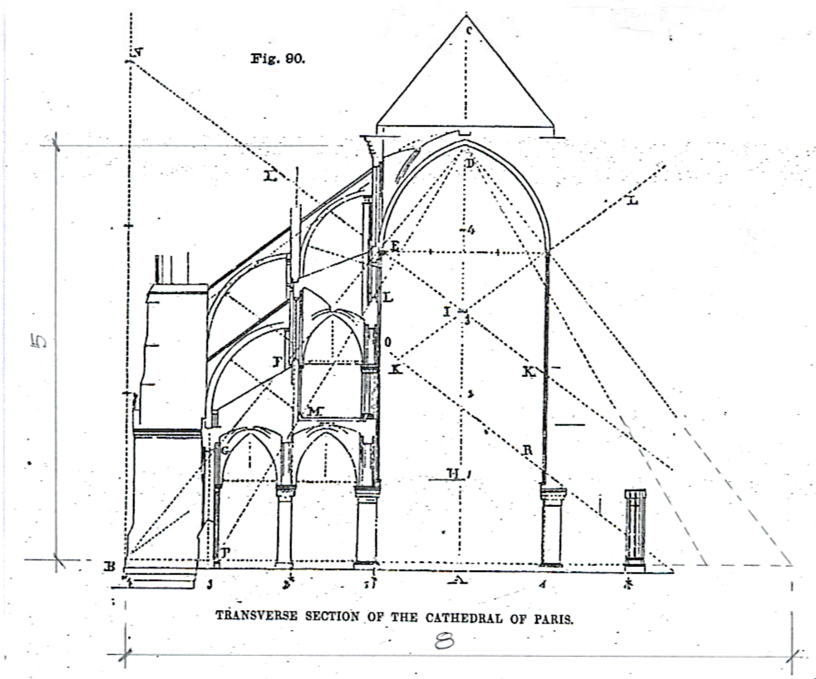


Parthenon – Two variations of the use of the 1.618 rectangle

FIGURE #31

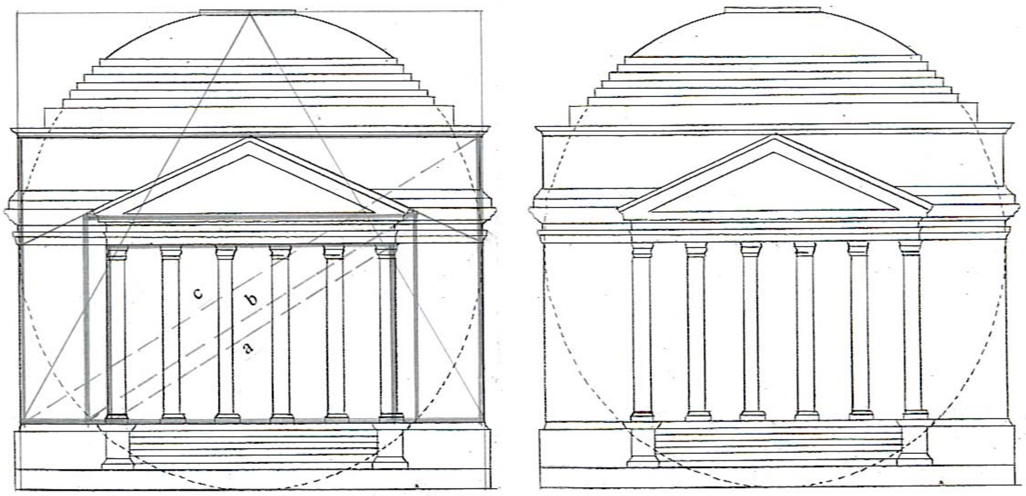


The Pantheon - Plan (Diagonals represent 1.618 rectangles)

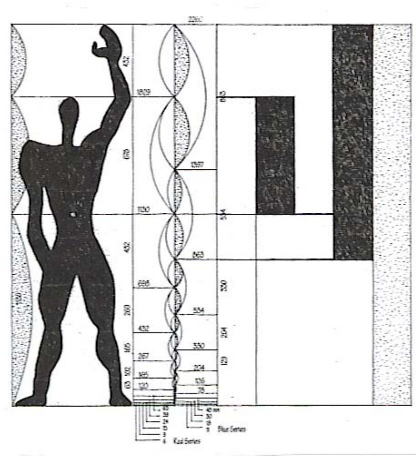


The Cathedral of Paris - Viollet-Le-Duc's diagram for the use of the equilateral triangle and the Egyptian triangle in a section of the nave. The Egyptian triangle has a base to height ratio of 8 : 5.

FIGURE #32

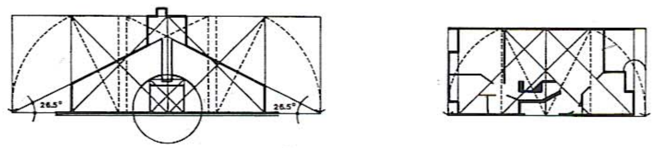


Jefferson's UVA Library – The triangle is equilateral and the diagonals show the 1.618 rectangles. The diagonal of rectangle "a" equals the long side of rectangle "b" and the long side of rectangle "a" equals the short side of rectangle "c".

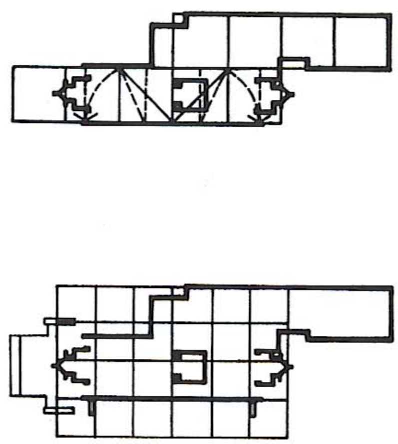


Le Corbusier's Modular

FIGURE #33



Venturi's Mother's house – Plan and elevation



F. L. Wright's Robie house plan

FIGURE #34

PHOTO #1

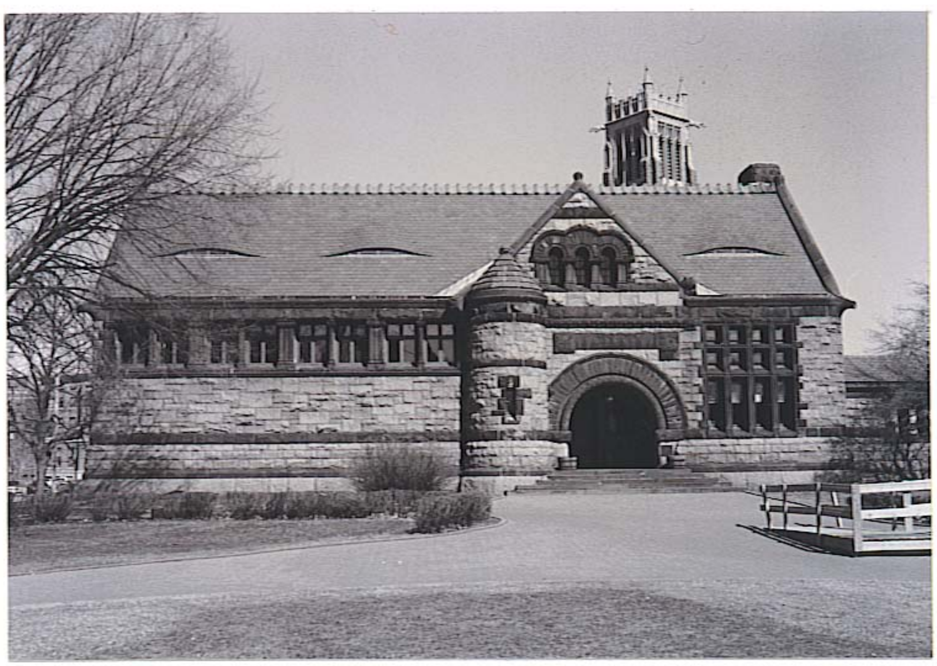


PHOTO #2

PHOTO #3

PHOTO #4

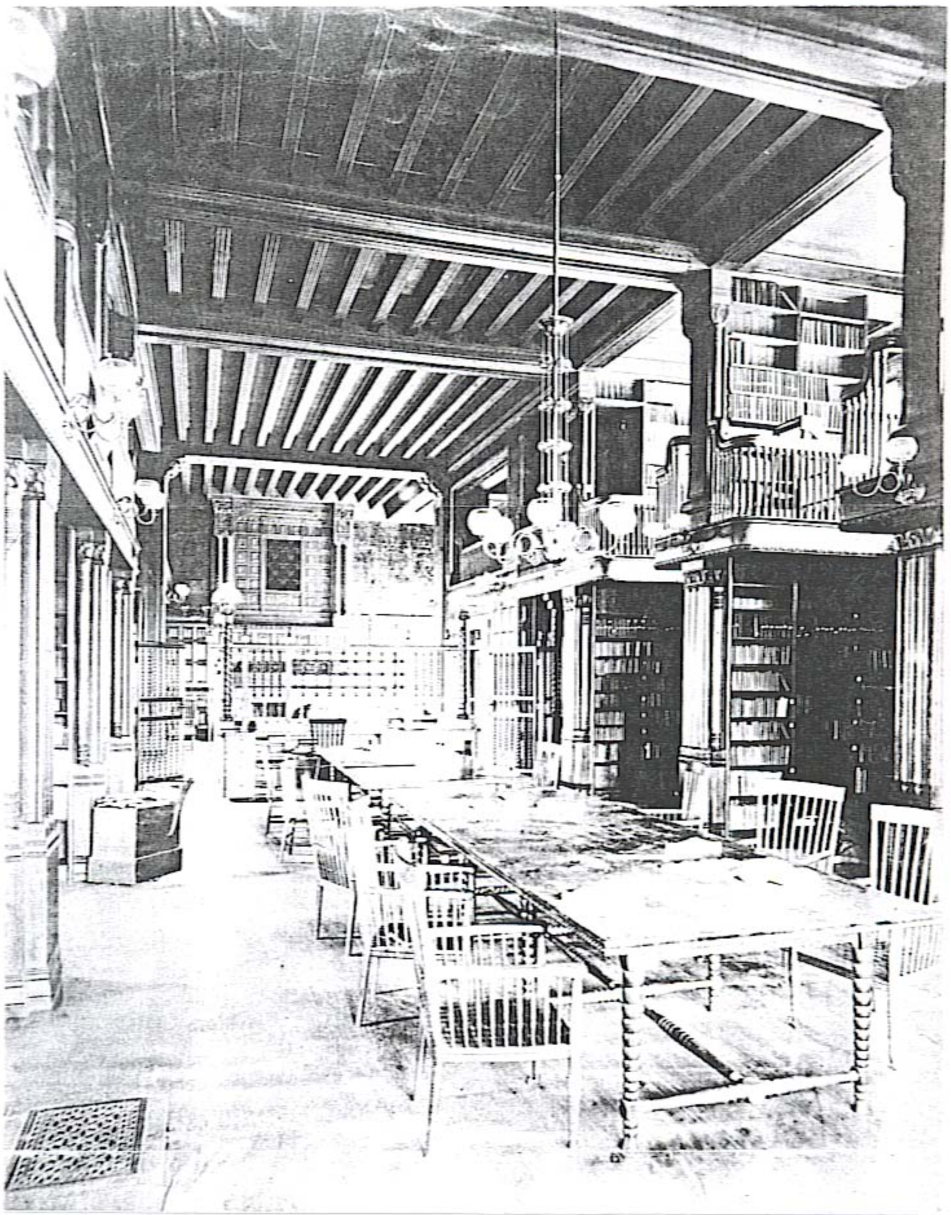


PHOTO #5

PHOTO #6

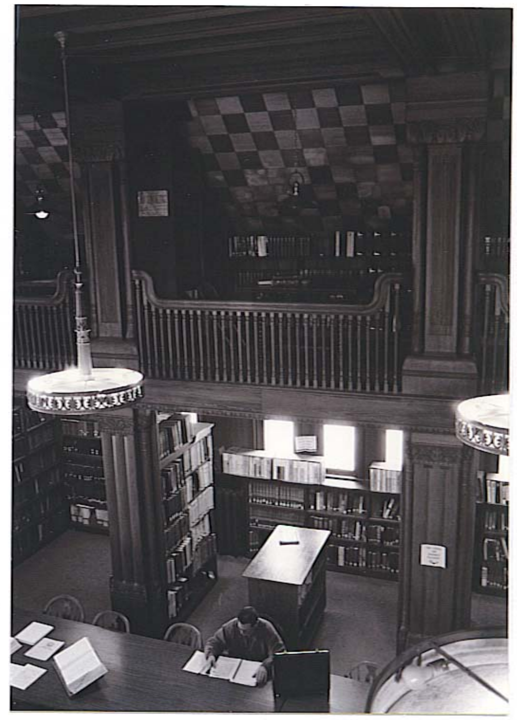


PHOTO #7

PHOTO #8

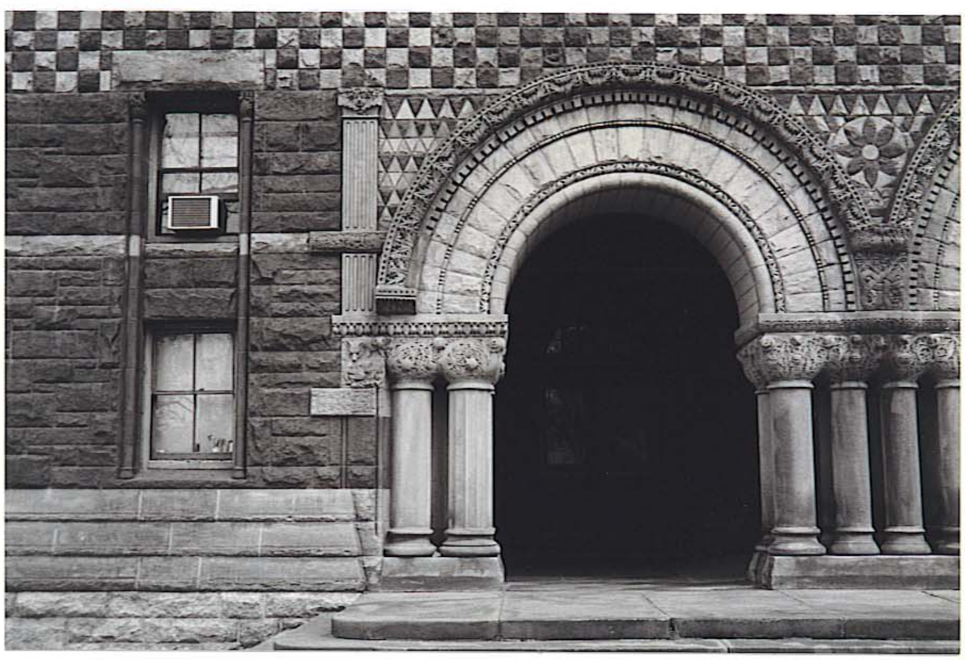


PHOTO #9

PHOTO #10