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Gothic Architecture, Geometry, and the Aesthetics of Transcendence

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In these remarks I will discuss Gothic architecture, geometry, and what I call the aesthetics of transcendence. I'll focus mainly on the design of great buildings like Strasbourg Cathedral (Figure 1), whose spire is the tallest surviving work of the Middle Ages, a 466-foot symphony of intricately carved stone. I also want to talk about how I came to study and admire this material, starting out from a curiously backdoor approach involving the sciences. Ultimately, therefore, I will argue that Gothic architecture can be fruitfully compared to a variety of things, such as fractals, heavy metal guitar music, and dinosaurs. These are some of my very favorite things, and I think that they actually go together in some important ways.

I'm going to start off with dinosaurs because that's what I came to first. Many kids like dinosaurs, and I liked dinosaurs when I was young for all the obvious reasons: they're big, powerful, exciting, and we haven't seen their like in our living experience. Also, my father was a geologist and paleontologist, so I got this from the cradle as part of my intellectual foundation. When I was a kid, the narrative about dinosaurs was: "yes, they're big; yes little kids like them; but they failed—they died out, and they aren't around anymore." Stereotypical dinosaurs had walnut-sized brains, after all. They were really stupid and they went extinct—so dinosaurs got many thumbs down, even if little kids liked them. That was basically the state of the question on dinosaurs when I was young, but it bothered me. I thought to myself "How can Tyrannosaurs Rex be lame?" There seemed to be something wrong with the narrative—to which I'll return.

I learned from my Dad that dinosaurs were neat, but I also got an appreciation for evolution, for cladistics, for the branching tree of life, and for the way humans relate to other species and to nature. A lot of this thinking about biology and evolutionary perspectives continues to inform my work on art and architecture in powerful ways even today.**[1]** When I see simplified diagrams showing the ascent and supposed decent of man, I realize that they don't really capture the way nature works. They lack the branching, ramifying structure that you see in the tree of life. They are simply cartoons, presenting a linearized story that people have made about a much more complex reality. I'll come back to this, since we in art history often see this kind of distortion of history into linear narratives.

When I was a little kid, my TV-watching habits confirmed my geekiness and the interest in science that I was getting from my dad. For me it was all about *Star Trek*, and more specifically about the animated *Star Trek* that was broadcast in 1973. I wanted to be like Spock, the totally logical science officer, and he still ranks as one of my paramount heroes.

Another thing that happened early on is that I discovered a passion for drawing—and that is also fundamental for my research still today. Going on from *Star Trek* and *Star Wars*, for example, I made a little drawing when I was ten years old, showing the mothership from *Close Encounters of the Third Kind* (Figure 2). The range of crystalline skyscraper forms at the top of the image looks a little bit like a Gothic church. Linearity, intricacy, and complex systems of order always have turned me on, and drawing those complex systems has long been fundamental for me. I couldn't do the work that I do today, as an art historian, if I hadn't spent so many childhood hours doing stuff like this.

Science fiction also got me interested in geometry, of both the Euclidian and non-Euclidian varieties. I began to learn about things like Newtonian mechanics, and Kepler's law of equal areas being swept out in equal times by a body orbiting the gravity well. Later, I found out about the Einsteinian vision of gravity as the curvature of space-time fabric. I was really fascinated by this material, and I would pursue that interest by studying physics in both college and graduate school. But again, it's the geometrical perspective that that I gained in my studies that has gone on to inform how I think about art and architecture even today.

1980 was a big year for the history of science in some ways, and it was a big year for me personally. In the broader world, this was the year that Carl Sagan broadcast *Cosmos,* which has aged, I think, very well. It's really an extraordinary show, trying to talk about the way life on Earth relates to the cosmic perspective. It's a little pretentious, it's a little cheesy, and it has Carl Sagan talking about "billions and billions of stars"—but it's still powerful. Like my current work on Gothic architecture, it's a lot about transcendence, and about the aesthetics of transcendence. Looking at galaxies and imagining these billions and billions of stars can give you a moving emotional and aesthetic perspective. Sagan was really trying to be an apostle of transcendent rationalism, treating science almost like a religion without God—and that idea still speaks to me very powerfully. But I soon got doses of both God and the Devil.

1980 was the year that my parents took me to live in France, where we visited, among other places, the Cathedral of Reims (Figure 3). I was, frankly, blown away. It was a secular conversion experience of sorts. I realized this 800-year-old building was far more complex than anything I'd seen in *Star Trek* or *Star Wars* or anywhere. It had a kind of formal order that I really hadn't experienced anywhere else before, one that gives you a feeling of transcendence. As you walk into this building, you can sense its scale, as you see the people sitting at the bottom of its 14-story interior. The parts relate to the wholes in some very powerful ways. Even the bases of the columns come nearly up to your armpits. You thus have the sense of being a very small part of this large, divine, architectural cosmos. For this reason, the noted architectural historian Paul Frankl talked about Gothic buildings having an aesthetics based on "partiality." [2]

All sorts of questions immediately struck me when I saw Reims Cathedral: how was it built? How does it stand up? How can you put a stone ceiling on top of walls of stained glass? It's a miraculous effect... Why was it built? Was it really supposed to look like as it does? Or should it have multiple spires, as this famous reconstruction by the 19th-century French architect Viollet-le-Duc suggests? (Figure 4)[3] The building right now lacks spires. So one must ask whether they were really intended. And, if they were, why were they not built? These questions that I had as a 12-year-old eventually turned into my doctoral dissertation and my first book, which argue that multiple spires were indeed planned for Reims.[4] But, because the bishop was a jerk who was hated by most everybody in the episcopate, they wouldn't give enough money to finish the project. So the social history of art comes into this, also.

Buildings like Reims and drawings like Viollet-le-Duc's greatly inspired me, so instead of just doing drawings based on science fiction, I began in high school draw Gothic cathedrals. As I started to read up on Gothic, I saw many graphics charting the progression of Gothic in France from 1150 to 1300, and I thought, "Wait a second, I've seen this before." It's once again a simple linear narrative like the supposed ascent of man. I already knew that nature was more complex than this. I knew that there is process known as adaptive radiation, as seen with Darwin's finches on the Galapagos, where their beaks evolved to match their food. Eventually I was gratified to find that the same patterns of adaptive radiation also happen in Gothic art and architecture. There's not just one linear sequence, but a whole ramifying tree of influences. So that was neat to see.

Also, the more I read, the more I discovered there is just absolutely incredible stuff in Gothic architecture. Cologne Cathedral, for example, visually suggests transcendence by the elongation of the elements like the columns, which seem to soar heavenward without limit or constraint, but with a sense of superhuman intricacy and scale. As at Reims, there are huge windows beneath the stone vaults, which are braced on the exterior by lacy flying buttresses. All of these elements together create a god-like, superhuman effect. To take another example, the west façade of Strasbourg Cathedral presents an extraordinary rich set of designs progressing from the large scale to the small scale, with ever-increasing intricacy (Figure 5). I find it quite amazing that this was done in the 13th Century. That's just the bottom part of the façade, which goes up and up and up and up, to support the 466-foot spire completed in the 15th century. Now, I loved this; I thought it was great. But as I started to read art history I realized that not everyone loved it. In fact, this architecture was mocked and derided in the Renaissance. Giorgio Vasari, the 16th-century author widely recognized as the first modern art historian, mocked Gothic architecture for supposedly lacking every familiar form of order.

What they liked the Renaissance was an architecture based on human forms and human proportions. A column, for example, should have a certain height, stipulated by modules, so as to match the proportions of a young woman for the Ionic or Corinthian orders, or those of a young man for the Doric order. This is a very human-based architecture, quite opposed to the more abstract, transcendent, and immaterial architecture of Gothic. In the decades around 1500 Gothic was eclipsed by this new fashion. Many buildings of the Renaissance are interesting and impressive in their fashion, but they don't actually rock me in the way that Gothic buildings do.

Heavy metal music also rocks me. I got into it about the same time I got into Gothic architecture, and actually—believe it or not—for a lot of the same reasons. Now this idea probably seems ridiculous on its face: we are talking about the medieval versus the modern, the respectable versus the crass, and architecture versus music. But there's a statement often attributed to Goethe saying that "Architecture is frozen music," or as my advisor used to say, "Music is melted architecture." So we can, actually make this comparison. And I want to argue that it's really not so very ridiculous.[5]

Metal is crass, but it's not everyday crass. It's about transcendence. Just think about all the names of the bands that I grew up with: Judas Priest, Black Sabbath, Blue Öyster Cult. They all have what UCLA musicologist Robert Walser has called "the auratic power of blasphemy."[6] They want to get you out of the everyday and into the world of heaven and hell, just as much as the cathedrals did in the Middle Ages. And furthermore, they're doing it through some of the same formal means. For instance, I said about Cologne that the columns seem to stretch upwards without constraint. That would be criticized in the Renaissance, because a column is supposed to have a certain fixed height. It would be seen as disproportion, or distortion. Distortion, of course, is also fundamental to the aesthetics and affect of heavy metal, as one can clearly hear in the guitar solos of artists like Judas Priest's K.K. Downing.[7]

Metal and Gothic architecture are accomplishing some of the same psychological and formal effects through similar means—crazy as that may sound. Now, I can go further, to say that this question is not just about distortion, but about virtuosity, as well. There are a lot of people who don't like heavy metal, but almost everybody can admit that heavy metal guitarists can play really fast. And there are a lot of people who don't like Gothic, but almost all of them can admit that Gothic cathedrals are really complicated. So, virtuosity, showing what you do with a certain set of technical means, is a common feature of both the heavy metal guitar solo and Strasbourg Cathedral's spire, for example. As a high-school student, I thus began to get a sense of déjà vu all over again: heavy metal gets criticized, Gothic architecture gets criticized, dinosaurs get criticized. All of these things have grandiose exteriors, and all are produced by walnut-sized brains. I had the feeling that everything I loved was being dismissed as stupid.

But, the critique of dinosaurs as stupid and unfit is deeply flawed. In 1980, the same year I went to Reims, and the same year *Cosmos* came out, the father-and-son team of Luis and Walter Alvarez at Berkeley found that dinosaurs were wiped out by a giant asteroid impact. They found high levels of iridium dust in the so-called K-T boundary at the end of the Cretaceous. The dinosaurs weren't lame; the dinosaurs got hit by a natural disaster. It wasn't their fault, so we don't have to be judgmental about dinosaurs. When I was a kid, before 1980, dinosaurs were misunderstood, and their fate was projected back onto them. I think that the same thing can go for metal and for Gothic architecture. I will leave the defense of heavy metal to my favorite book of cultural criticism, Robert Walser's *Running With The Devil*; it's a brilliant book, managing to be both erudite and convincing about the aesthetics of metal. My mandate, meanwhile, is to discuss Gothic and its geometrical order, which can best be appreciated in light of some other recent developments.

One other thing that happened around 1980 is that computer modeling took a big step forward, with the discovery of the mathematical objects called fractals. Over the past three decades, therefore, as new techniques have emerged for the study of complex systems, there has been an increasing recognition that not all order is simple. Fractals are mathematical objects whose construction is based on a simple recipe that runs over and over recursively. This is the way that a lot of computer graphics people in the movie industry make CGI imagery; they use recursive recipes to generate objects and textures. Such things look chaotic, and they are associated with a branch of mathematics called chaos theory, but they are actually growing in terms of well-defined rules. This is especially clear in the most famous fractal of all, the so-called Mandelbrot Set.**[8]** It's essentially the map of a set of points in a mathematical plane that stays in the same region when the generating recipe is run *ad infinitum*. It turns out the boundary of that set is infinitely complex, so it has a lot of texture and detail like a Gothic cathedral does. And each of these little subunits resembles the whole. This is what mathematicians call self-similarity.

Self-similarity can also be seen in simpler examples. Imagine taking a cube whose surfaces are subdivided into 3 x 3 grids like a Rubik's cube, and subtracting away everything except the eight sub-cubes in its corners. If you do the same thing to sub-cubes on and on and on *ad infinitum*, you eventually get a kind of cubist Swiss cheese that's called Cantor Dust, which has a total volume of zero. In another simple example, the Koch Snowflake, you just take an equilateral triangle and append three smaller triangles to get a Star of David. You do the same thing to each of the little pieces and so on and so on, in a process that can go on infinitely, in principle (**Figure 6**). One thing that's neat about that is that it has a finite area but it a theoretically infinite perimeter if you keep going. It also exemplifies the principle of self-similarity; each little sub-snowflake is like a miniature copy of the whole. That is the same aesthetic principle that you see at work on the façade of Strasbourg.

Now, it's not only Gothic architecture that has this sort of quasi-fractal self-similarity. You can see it in Islamic architecture, as in the amazing vaults from the Alhambra in Spain. It's a powerful principle of formal generation in nature, which you can see in sunflowers, and in pinecones.**[9]** This makes sense because it's a kind of growth principle that goes through steps. It thus relates to the mathematical series called Fibonacci's Series, in which each term is the sum of the two preceding. The series thus begins 1, 1, 2, 3, 5, 8, and so forth. If you take these numbers as the side lengths of adjacent squares, they can be arranged into a spiral pattern like that of a chambered nautilus shell (Figure 7). As the rectangular framing figure grows, the ratio of its longer side to its shorter side goes: 1/1=1, 2/1=2, 3/2=1.5, 5/3=1.666, 8/5=1.6, and so on, eventually converging to a value of around 1.618. This special ratio, known as the Golden Section, harmonically relates the whole to the part in accord with the equation whole/part=part/(whole-part). Writing this as x/1=1/(x-1), or x^2-x-1=0, we can solve for x=(1+√5)/2=1.618… using the quadratic formula.

In the Middle Ages the quadratic formula was unknown. But you can arrive at the Golden Section without it, just by just taking a square, dividing it into a half, and swinging the diagonal out of that half square. So that begins to connect to something that a draftsman can plausibly do as he is drawing a cathedral. If we really want to understand in detail how Gothic cathedrals were made—and I do—then it helps to look at original medieval documents like the pinnacle design booklets that were published in the 15th century by a builder named Mathes Roriczer.**[10]** He describes a design process that has a quasi-fractal order. He says that you start with a square, rotating a square within it, then rotating another square within that, and untwisting it. You go through this series of recursive steps to make the base. Then you stack these modules up into the third dimension this is a process that Germans call "*Auszug*," pulling the form from the two-dimensional plane into three-dimensional space. Roriczer is trying to tell us how Gothic designers worked, but his writings are inadequate to the task: they are short, and they are tedious to read, combining the worst features of math books and cook books. Also, he deals only with pinnacles, which don't display all the complexity of full buildings.

So, attempting to generalize from work like Roriczer's, I began to look at some examples of real buildings and associated drawings showing how the design process may have unfolded.**[11]** One interesting case involves the west façade of the Cathedral of Laon, in France, from around 1200. Each of its towers starts out square, and then it gets its corners beveled off so that it turns into an octagon. It has sub-parts that are rotated squares that have their corners beveled, so that they turn into octagons. The parts thus echo the shape of the whole, in accord with the previously noted principle of self-similarity. We have, for this building, some surviving drawings, from the portfolio of an itinerant draftsman named Villard de Honnecourt.**[12]** In the plan drawing, there is a square with an octagonal geometry inside, which you can get to by rotating squares in more or less the same way recommended by Roriczer. Extensions of this system are clearly meant to give the buttress depths, despite the imprecision of Villard's drawing.

Villard also provides an elevation of the Laon tower. At first it doesn't appear to have a lot of geometrical order. In fact, it looks quasi-perspectival because you see foreshortening from below. Villard really exaggerated the scale of the sculpted oxen on the tower, and he also inserted a mysterious hand that doesn't exist in the building. So what's going on here? Well, the drawing fits into a perfect double square. The eyes of the oxen are halfway up the second square, and the hand is aligned there, so there is some kind of geometrical signal. How does this work on the building? It turns out the real tower actually fits into a double square, as well, if you measure to the buttress faces, and if you start with the same molding Villard does. Furthermore, the oxen really do stand on platforms that are halfway up that second square. So, even though the tower doesn't really look like Villard's, his sketch captures some important elements of its geometrical character. I'm inclined to think that he talked to somebody in the Laon Cathedral workshop who told him, the towers are a double square, the oxen are three quarters of the way up, and then he produced this sketch by combining this information with his visual impressions. The key point, though, is that in both the drawings and the real building, the plan and the elevation interlock with a kind of 2D-plus-2D sliding system of geometry. This was already happening at Laon around 1200, and it would continue throughout the Gothic era.

Let's move on to consider a more impressive example, Plan B for Strasbourg Cathedral.**[13]** The drawing itself is about 10 feet tall, and it's one of the most important drawings of the Middle Ages because it opens the way to the amazing façade mentioned earlier (Figure 5). One curious thing about this drawing is that the bottom is really carefully drawn in red, while the top is more cursorily drawn in black. The distinction between the two zones can be seen in modern redrawings like Figure 8, which show the full scheme at right and the presumably original lower portions at left. When I was writing my first book about spires, I needed to figure this out the chronological relationship between these parts of the drawing. Were they conceived together? To attack this problem, I began by examining the geometry of the area where the upper and lower portions meet. Lo and behold, there is a compass prick in the middle of a square framed by the pinnacles. If I rotate that square I get the width of the tower, which is an interesting result in itself. Furthermore, there's an octagon implied by the rotated squares, and its footprint matches the footprint of the spire. The pinnacles come from the old part of the drawing, and the spire comes from the new part, but geometrically they interlock. It is significant, moreover, that if I scribe a circle around that octagon I find that the framing lines are the axes of the main buttresses, which go all the way down into the old part of the drawing. This relationship between an octagon and its circle gives a certain ratio, of .924, which is the cosine of the 22.5-degree angle that one sees between the equator of an octagon and the rays to its corners. This ratio has not previously received a lot of attention in studies of Gothic architecture. Instead, attention has focused on the .707 ratio, or cosine of 45 degrees, which relates the side length of a square to the diameter of a circle circumscribed about it (Figure 9). But the principle of relating polygons to their circumscribing circles is the same in both cases, and many such constructions were used by Gothic builders, with the shape of the polygon depending upon the context.

In Strasbourg Plan B, both squares and octagons figure into the geometrical system. One can see this by examining the upper portion of the drawing. The top of the spire is missing, since the parchment has been trimmed off, but its location can be found by simple extrapolation. It was meant to fall exactly two big square units above a prominent compass prick in an otherwise unarticulated zone of the tower shaft. The compass prick sits at the bottom of a star octagon that sits above the big octagon framed by the pinnacles. The large and small octagons thus interact dialogically through the principle of self-similarity mentioned earlier. This system can be extended across the whole of the drawing, whose coherent geometrical armature interlocks beautifully from top to bottom (Figure 10). So what that tells me, ultimately, is that the whole thing probably was planned in the 13th century as one piece, even if its actual production was divided into the two phases differentiated by their ink color.

For another example, we can consider the Cathedral of Prague, in the modern-day Czech Republic. We have the blueprints, basically, for the flying buttresses of the choir, which were designed by a famous architect named Peter Parler. As in Villard's drawings, we have a series of sculptures as geometrical markers. Three small carved grotesques are meant to sit on the diagonal of a big octagon that controls the proportions of the whole composition. The drawing doesn't show how wide the main nave is, but if you take a modern ground plan of the building, it shows us the main vessel is twice as wide as each side aisle. This means that the entire church elevation has the proportions of a single great octagon. That's how they planned it, and that's actually how they built it, too. I would never have noticed that fact about the real building had the draftsman not put the little grotesques on that telltale diagonal line. So, this example reveals something important about the power of drawings to convey information.

Peter Parler's son Wenzel went on from Prague to Vienna, where he and his assistants worked on the local cathedral of St. Stephen. Here again we have the drawings for the ground plan and the elevation of a great tower. In this instance there are several telltale dots spaced along the axes of the tower, so that the axes are exactly three quarters of the way to the outer dots. That's evidence of a kind of arithmetical thinking. But there are other dimensions in the drawing that can only be gotten by geometrical construction. The margins of the parchment, for example, can be found by circumscribing a circle around an octagon defined by the buttress axes. The pinnacle shapes, moreover, can be found by connecting diagonals across this octagonal frame. One can thus work down from the overall shape to define even the minute details, in accord with a kind of quasi-fractal recursive process.

Such complex Gothic geometries appeal to me, but they were largely rejected in the Renaissance, in favor of simpler schemes, many of which were based on the proportions of the human figure.**[14]** That approach, which implicitly placed mankind at the center of the universe, appealed to humanist intellectuals, and it flattered the vanity of power-hungry rulers. The Renaissance is often considered progressive, but in many respects its architecture was more conservative than that of the Gothic tradition. For over a century these two modes coexisted side by side, but with different associations. In a famous manuscript diptych by the 15th-century French artist Jean Fouquet, it's telling that the virgin is suckling the Christ child in a Gothic portal, while the earthly patron of the work, Etienne Chevalier, sits on the opposite page in a classicizing frame inspired by Italian Renaissance design. Here, therefore, the Renaissance vocabulary was associated with the mundane and the worldly, and the Gothic was associated with the sacred. You might think that this would mean Gothic was more prestigious, but the tenor of the age was changing.

The Renaissance appeal to the human had a tremendous impact on the climate of art production. In a sense, this was like the impact of the asteroid that killed off the dinosaurs, by causing a dramatic change in the climate. In the early sixteenth century, the Gothic design tradition was still going strong, as one can see from considering the spire of St. Mary's church in Antwerp, completed in 1520 as the tallest structure in the region. In those years, Antwerp was a powerful, thriving, independent city-state, and the spire served as a civic monument and symbol of local pride. The Gothic era in general was marked by the dominance of local communities and towns, with wealthy burgers putting their money together to make great civic monuments. But that kind of intersection between the religious and civic was challenged in the 16th century by the rise of centralized monarchies, run by kings and emperors who resided in neo-classical palaces. Philip II of Spain, for example, was busy building the Escorial palace complex outside of Madrid in the same years that his forces were invading the Low Countries and ravaging cities like Antwerp. The complex and geometrically abstract architecture of the Gothic tradition was thus displaced by the classical architecture of the totalitarian nation state, which gratified the ego of the ruler through the human-based proportions of its neo-Roman articulation.

In terms of proportion, too, Renaissance architecture marks a departure from Gothic traditions, with arithmetical thinking displacing the more geometrical approach seen in the Gothic era. In the mid-20th century the art historian Rudolph Wittkower popularized the idea that Renaissance proportions are based on numbers that go together like the tones of music.**[15]** This idea has contributed greatly to the intellectual cachet of Renaissance design. With the turn to simple numerical ratios, though, Renaissance designers lost touch with a more dynamic geometrical design mode that allowed medieval builders to create effects of superhuman transcendence. The soaring lines and quasi-fractal detailing of Gothic could not be readily replicated in a Renaissance manner.

More complicated geometries started to come back into fashion in the seventeenth century. The chapel housing the Shroud of Turin, for example, is an amazing structure designed by Guarino Guarini, which has been carefully studied by my colleague John Scott.**[16]** From the interior, especially, the architecture appears to fragment into tiny pieces. If you look up at the dome, it's like looking into a kaleidoscope or like looking into a telescope into the heavens. This seemingly infinite subdivision, not coincidentally, was achieved in the seventeenth century, when Galileo was looking into the heavens for his pioneering work on astronomy, and when Leibniz and Newton were developing the calculus based on infinite subdivision of intervals.

The stylistic history of the next century is too complex for me to explore here, but I should note that this kind of transcendent aesthetics did continue to have a place at the table through the nineteenth century. So, for example, the great parish church in Ulm, Germany, was finally completed in the 1890, in substantial accord with the original fifteenth-century plans. There was still a taste for such transcendent architecture, and the builders of the day were able to finish the job that their Gothic ancestors had begun. Any visitor who climbs the tower today experiences a powerful sense of transcendence. You walk up through a series of stairway turrets, and then you can look back at the rest of the church from a height about halfway up the main tower. Then you go up some more, climbing an amazing staircase that runs straight up the axis of the spire cone. The lacy openwork walls come in closer and closer, and eventually you pop through into a little bud at the top. When you look down, the town looks like a tiny model. This is an amazing perspective to have, even today, and in the fifteenth century, when they were planning this structure, it would have been quite God-like.

In terms of the aesthetics of transcendence, the modern world can do some things other than just finish the job the Gothic builders started. For example, it can transmute the Gothic vocabulary into the streamlined architecture of Art Deco, seen in skyscrapers like the Empire State Building and the Chrysler Building, both completed around 1930. Just this past year builders in Dubai completed the tallest work of architecture yet, the Burj Khalifa, a skyscraper over half a mile high. It was designed by an architect named Adrian Smith, who, sadly, is not the same Adrian Smith who plays lead guitar for Iron Maiden. That would have been too perfect a demonstration of my thesis about heavy metal and architecture… Workers in other media have also engaged with the aesthetics of transcendence. Abstract Expressionist painters like Jackson Pollock have long been discussed in this connection, and these days, computer technology is getting so common that people are starting to employ fractals in architecture. A designer named Michael Hansmeyer, for example, has recently begun to develop plans for infinitely detailed columns.[17]

From my point of view, Gothic architecture still embodies a uniquely powerful vision of the aesthetics of transcendence. Virtuosity, complexity, and formal distortion appeal to me in Gothic architecture, much as they do in heavy metal music. I see the demise of Gothic architecture as the result of a sudden and drastic change in cultural climate, an interpretation that draws on my interest in evolutionary biology and the history of life. Since I know that evolution involves far more than simple linear progression, I believe that Darwinian evolutionary thinking can provide a powerful framework for considering cultural changes over time in all of their ramifying complexity. More broadly, I believe passionately in the importance of dialog between the sciences and the humanities. I therefore hope that these comments, and the whole UNI symposium from which they derive, will help to foster interest in that cross-disciplinary conversation.

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[1] See Robert Bork, "Art, Science, and Evolution," in Elizabeth Mansfield, ed., *Making Art History: A Changing Discipline and Its Institutions* (New York, 2007), 187-201.
[2] Paul Frankl, *Gothic Architecture* (Princeton, 1962), pp. 10-14.
[3] E.E. Viollet-le-Duc, fig. 18 from "Cathédrale," in *Dictionnaire raisonné de l'architecture Française du XIe au XVIe siècle* (Paris: 1856).
[4] Robert Bork, *Great Spires* (Cologne, 2003), pp. 87-95.
[5] See Robert Bork, "Stairways to Heaven: Gothic architecture, heavy Metal, and the Aesthetics of Transcendence," *Medieval Academy News* 157 (spring 2007): 11.
[6] Robert Walser, *Running with the Devil: Power, Gender, and Madness in Heavy Metal Music* (Hanover, 1990), p. 2.
[7] An especially good example begins at the 3:33 mark in the live version of "The Sinner," from *Unleashed in the East*; see **http://www.youtube.com/watch?v=fKpsDdmv6OA**
[8] Benoit Mandelbrot, *Fractals: Form, Chance and Dimension* (San Francisco, 1977).
[9] See, for instance, Matila Ghyka, *The Geometry of Art and Life* (New York, 1946).
[10] Lon Shelby, *Gothic Design Techniques: the fifteenth-century design booklets of Mathes Roriczer and Hanns Schmuttermayer* (Carbondale, 1977).
[11] All of the Gothic case studies mentioned in this essay are covered more completely in Robert Bork, *The Geometry of Creation: Architectural Drawing and the Dynamics of Gothic Design* (Farnham, 2011).

[12] Carl Barnes, *The Portfolio of Villard de Honnecourt: A New Critical Edition and Color Facsimile* (Farnham, 2009).
[13] For a more complete but readily available version of this discussion, see Robert Bork, "Plan B and the Geometry of Façade Design at Strasbourg Cathedral, 1250-1350," *Journal of the Society of Architectural Historians*, 64 (December 2005): 442-73.
[14] For more complete discussion of these themes, see Bork, *The Geometry of Creation*, and Robert Bork, "Ars Sine Historia Nihil Est? How the 'Story Deficit' Helped to Doom Gothic Architecture," in Achim Timmermann and Zoë Opacic, eds, *Architecture, Liturgy, and Identity* (Turnhout, 2010), 323-34.
[15] Rudolph Wittkower, *Architectural Principles in the Age of Humanism* (London, 1949).
[16] John Beldon Scott, *Architecture for the Shroud: Relic and Ritual in Turin* (Chicago, 2003).
[17] See **www.michael-hansmeyer.com**.

Appendix – List of Figures

Figure 1: : Strasbourg Cathedral, spire (photo by Robert Bork).

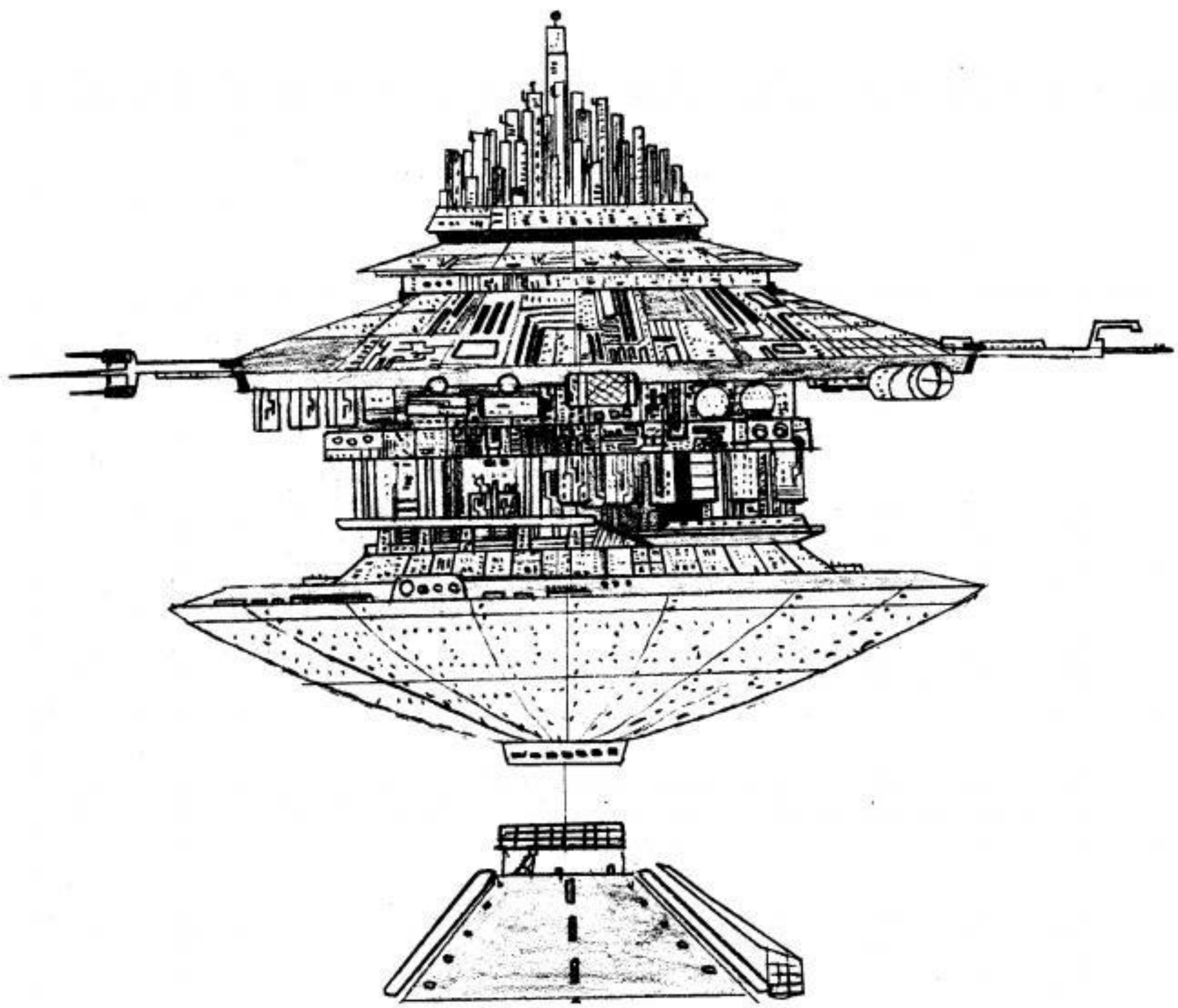

Figure 2: Drawing of mothership, from *Close Encounters of the Third Kind* (drawing by Robert Bork).

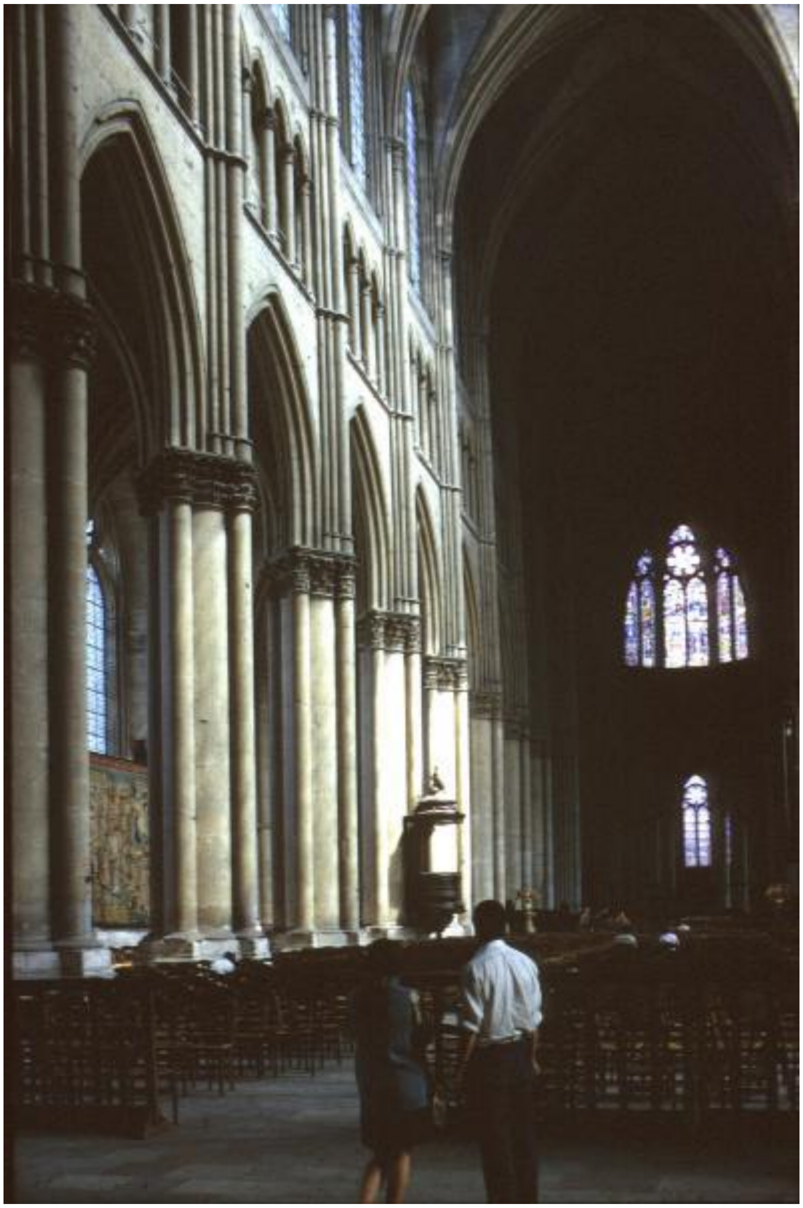

Figure 3: Reims Cathedral, interior (photo by Charles D. Cuttler).

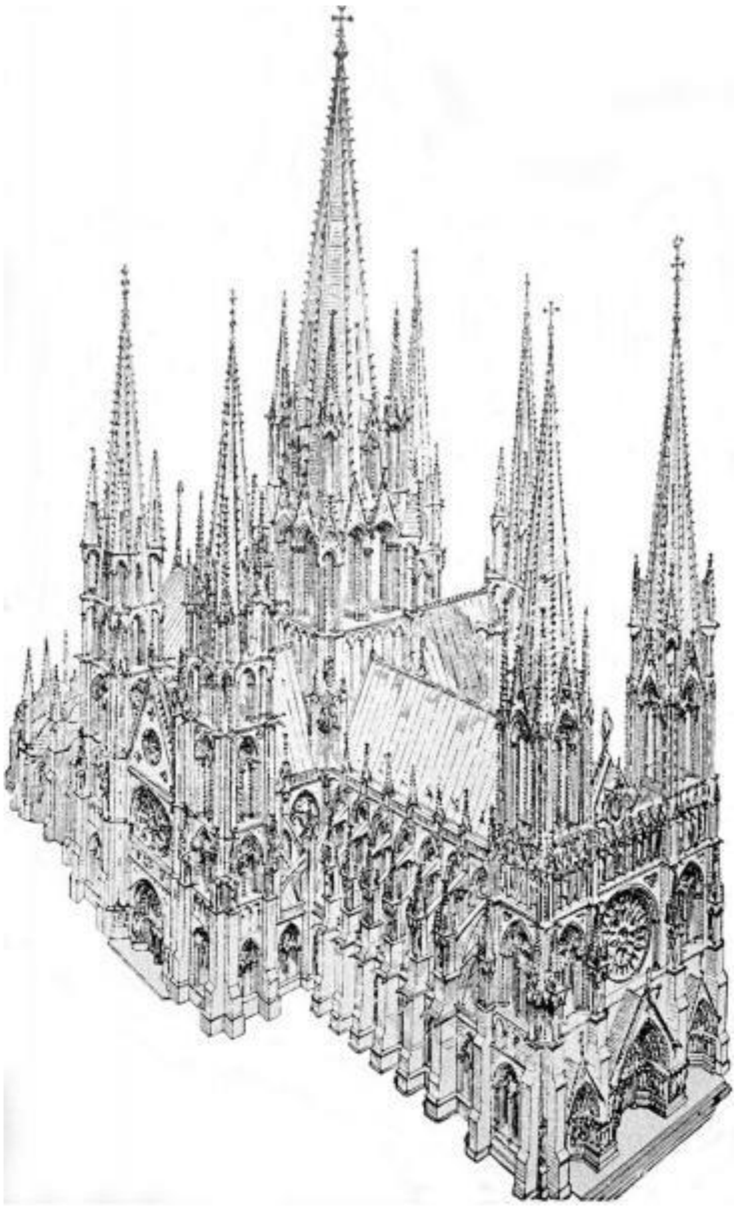

Figure 4: Reims Cathedral, hypothetical vision of exterior (drawing by E.E. Viollet-le-Duc).

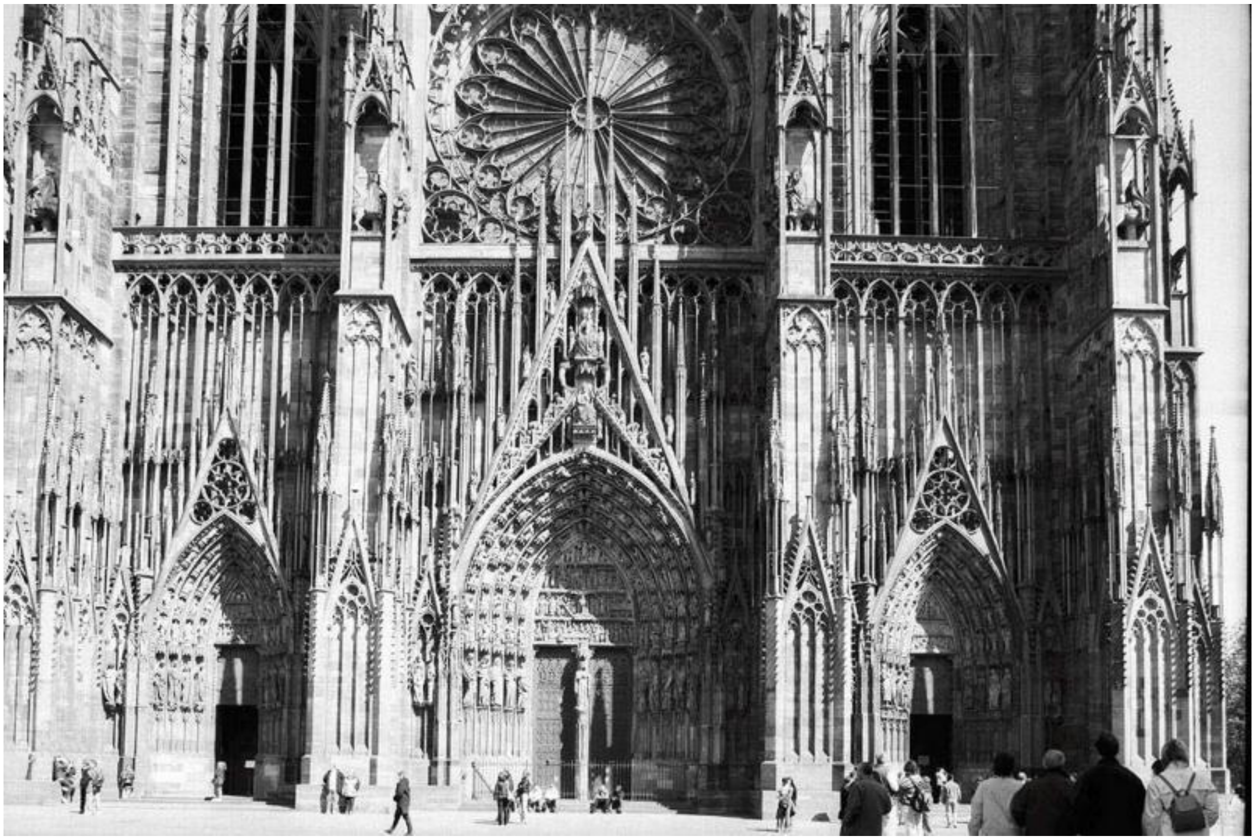

Figure 5: Strasbourg Cathedral, lower façade (photo by Charlotte Stanford).

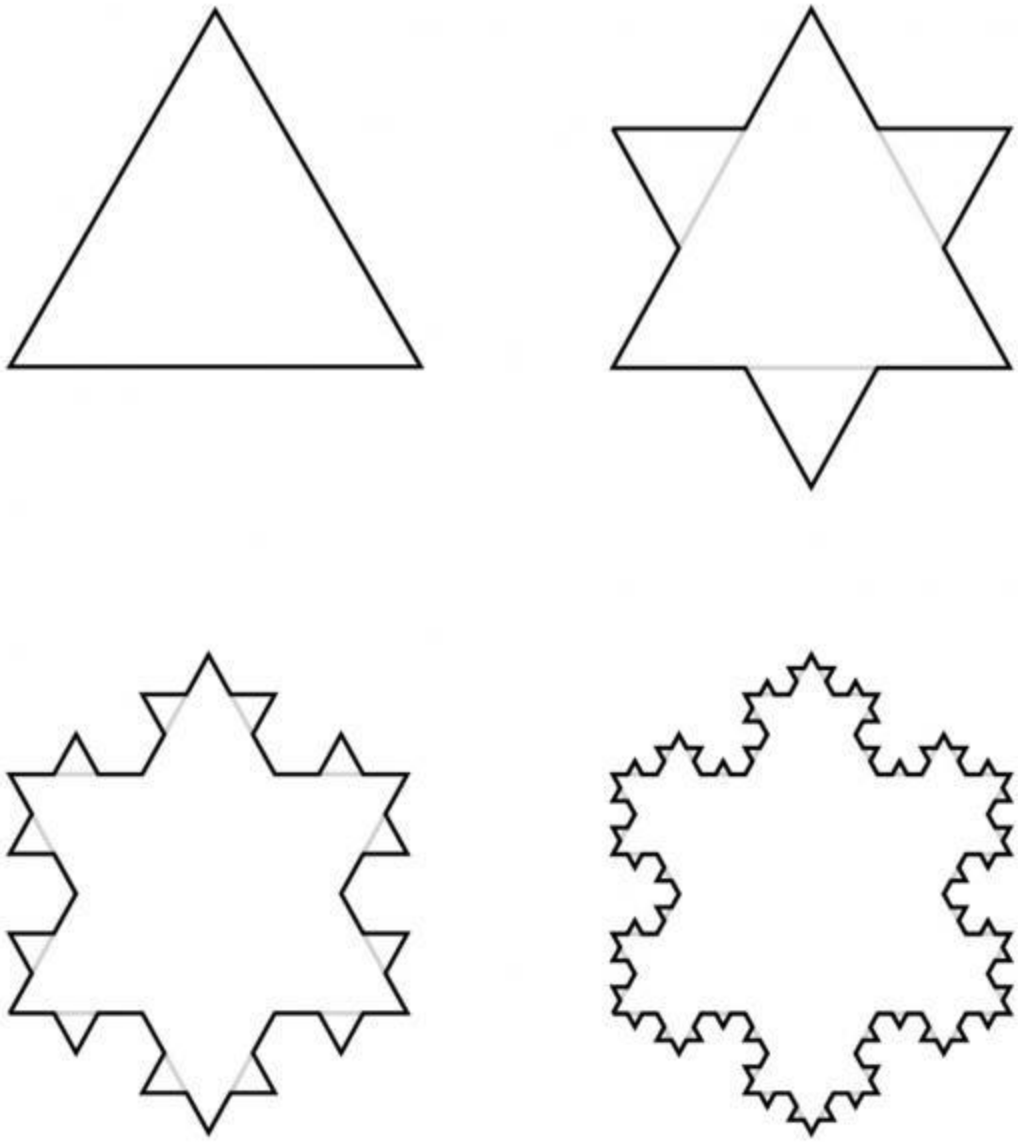

Figure 6: Koch Snowflake (graphic from Wikimedia Commons).

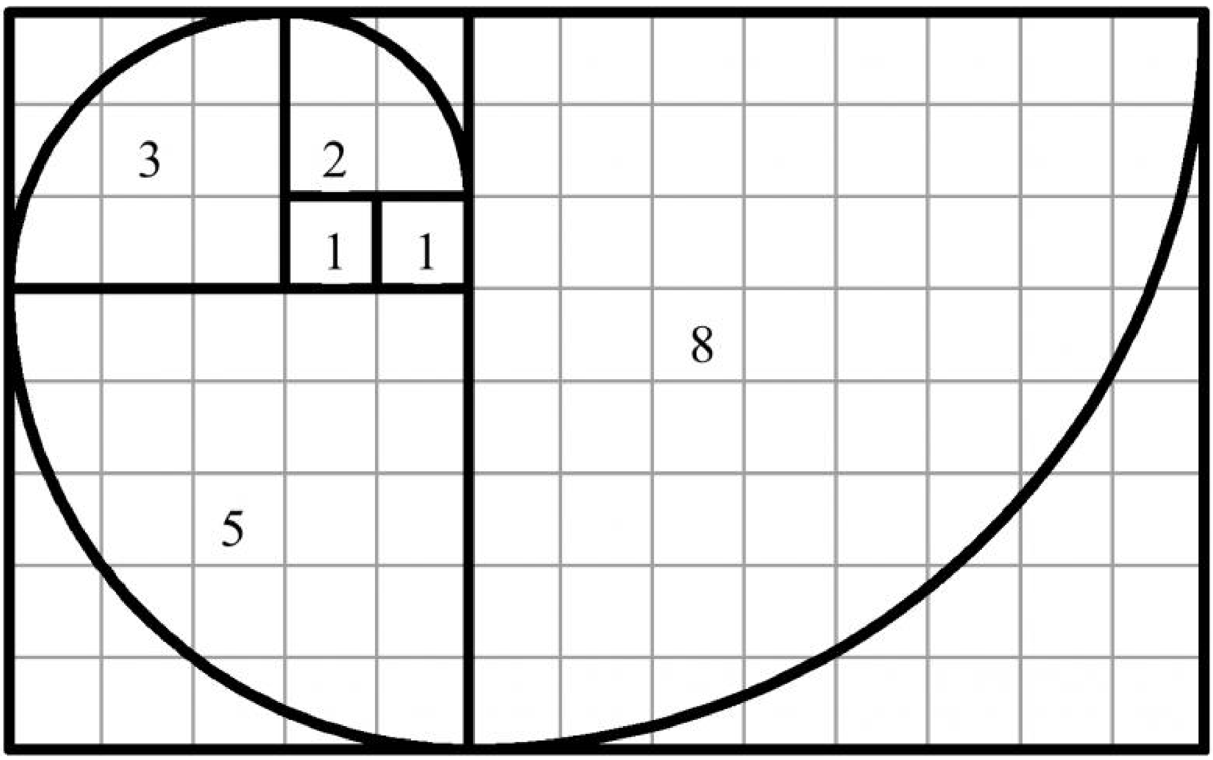

Figure 7: Fibonacci spiral (graphic by Robert Bork)

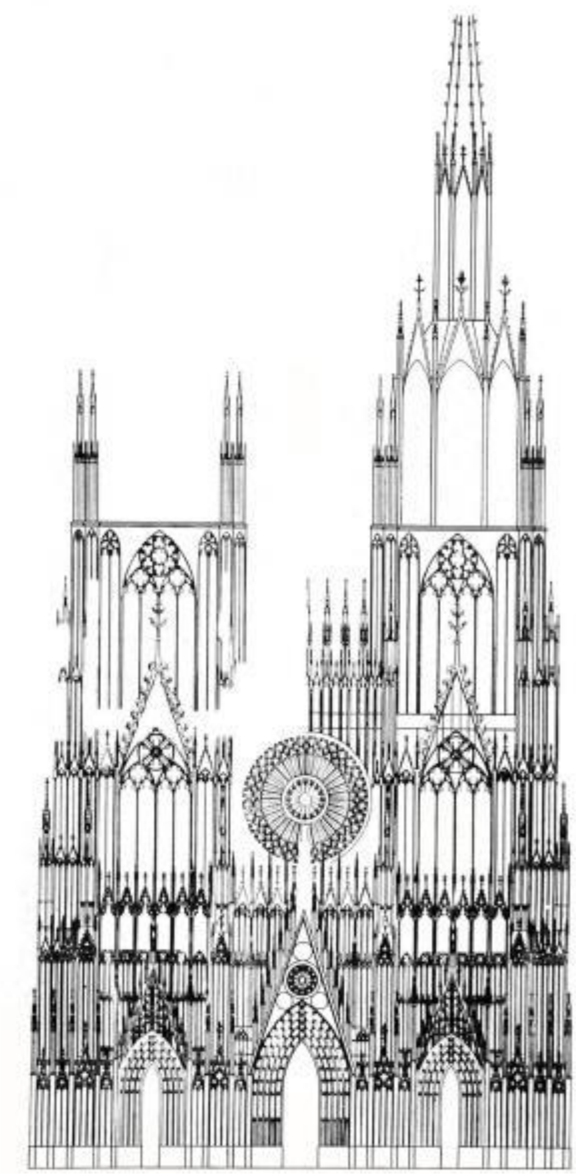

Figure 8: Strasbourg, Plan B, redrawn to show contrast between original portions and full scheme (graphic by Robert Bork).

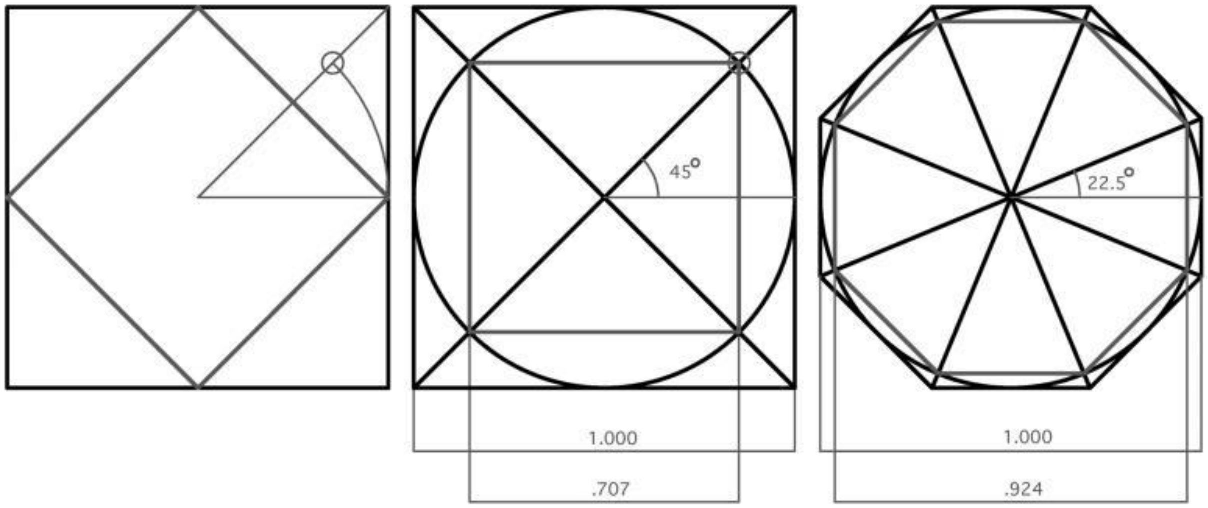

Figure 9: Square-based and octagon based geometries (graphic by Robert Bork).

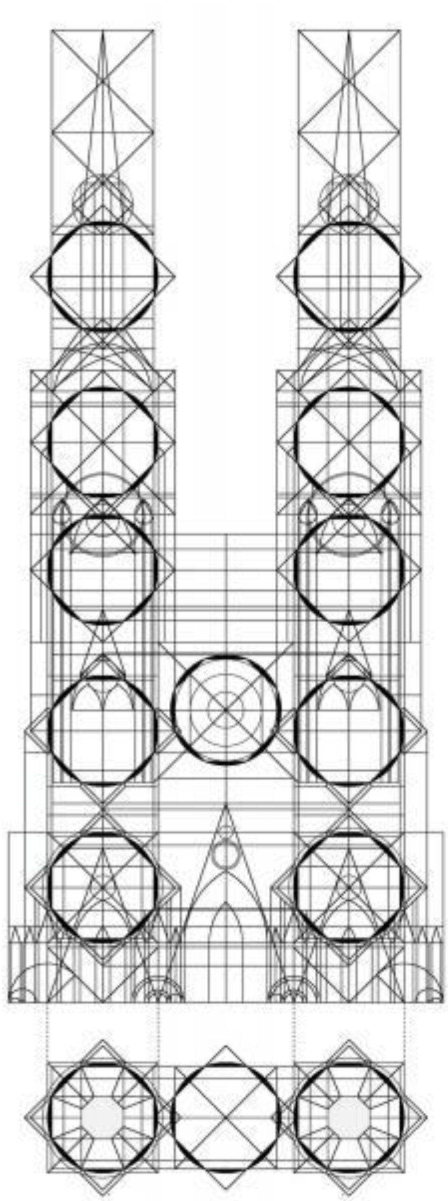

Figure 10: Strasbourg, Plan B, overall geometrical armature (graphic by Robert Bork).