Let There Be Light: Stained Glass and the Late Medieval Climate Transition

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1 Introduction

Stained glass has always played an essential role in the framework and aesthetics of Gothic architecture, from the very debut of the early style at the Basilique St. Denis to its Neo-Gothic revival in the Nineteenth century. In fact, it is difficult to conceptualize a Gothic structure without some form of ornamental glass, be it simple white grisailles with intricate leadwork or full colour windows. This choice in glass, however, not only provides an important artistic element to the building but also directly influences the amount of indoor lighting and thus affects how the of the interior structure is perceived by an observer. Additionally, in an age (such as the Medieval period) without substantial artificial lighting, besides that provided by certain lamps, candles, torches, lanterns (all often costly to maintain over long periods of time), and open doors, the amount of interior lighting available (for both functional and aesthetic purposes) is largely determined by the light that can be transmitted through windows (often referred to as daylighting). In turn, the amount of daylight that enters a building depends largely on whether the regional climate is predominately sunny or cloudy, with different regimes producing different interior lighting conditions inside Medieval churches and perhaps affecting the type of glazing that is locally preferred.

This study concerns the possibility that the evolution of stained glass design in different regions during the course of the Medieval period might be related to climate and climate change. In general, Romanesque cathedrals, due to their possession of the bulky walls needed in order to construct strong, tall vaults, were often unable to support extensive window space. Under the sunnier conditions that would have prevailed during the Medieval Warm Period (MWP), however, limited window size would not have necessarily been a problem. The invention of the Gothic style toward the end of the MWP, with its external vaulting, allowed for the dramatic
expansion of window size over the wall space. At the same time, however, most Gothic churches were decorated with low transmissivity stained glass with deep, rich, relatively dark colours, suggesting a continued dependence on sunlight for interior lighting (thus not at once revolutionizing the interior lighting conditions from that of the Romanesque period in the manner that Wachs (1964) claims). However, as the Medieval Warm Period came to a quick close and the Little Ice Age (LIA) began over the two successive centuries, windows became more symmetric on the north and south aisles and size and acreage in cathedrals continued to increase (a response to diffuse lighting conditions, according to Wachs (1964)), while at the same time stained glass became lighter coloured and more translucent, suggesting that indirect, diffuse lighting associated with cloudier conditions became the primary source of interior illumination. The eventual elimination of age-old traditional architectural features by the Late Middle Ages, including blind triforia and tribune galleries, and their replacement with windows also suggests this demand for more light (Janson 316). Despite this trend in Northern Cathedrals, southern churches adopted the new Gothic style as well but often maintained much smaller window sizes than those of the north (indeed, the bright sunshine so prevalent in the Mediterranean climate regime, according to Wachs, Street, and Sherrill, would not be able to support such expansive windows), and when stained glass was used in the south (usually over windows no larger than Early Gothic sizes), it often possessed lower transmissivities similar to Early Gothic stained glass in the north (Assisi, Siena Duomo, Florence Duomo, Santa Maria Novella). In general, it has already been noted by Moore (3) that “generally speaking, in climates where daylight is plentiful and predictably bright, architects have responded by decreasing opening sizes or using a diffusing medium in openings, (grills, and translucent or tinted
glazing),” and the smaller windows with often heavy tracery (especially in rose windows) so prevalent in the Mediterranean seem to conform to this idea.

A connection between regional averages in stained glass transmissivity and generalized climate regimes has also already been proposed by previous authors in the field of stained glass, with Charles Sherrill, an early Twentieth century stained glass historian and author of a famous series of guide books on stained glass, being the staunchest advocate of climate as the most important factor behind stained glass design. In addition, Wachs (1964) has also argued that the expansion of window sizes during the Gothic era in northern European churches acted as a climatic adaptation to generally diffuse lighting conditions (associated with extended periods of cloud cover) inherently present over Western Europe, made possible finally with the invention of Gothic. Although his hypothesis regarding larger windows associated with diffuse lighting can be generally confirmed by modern daylighting theory, in which modeling methods used to determine ideal natural interior lighting are separated into cloudy climates and sunny climates (Robbins 30-35), and this has also been discussed by Noal (123). However, Wachs failed to take into account the very low transmissivity of early Gothic windows, which did not increase interior lighting by the drastic amounts implied, and both authors did not consider the possibility that the climate regime had not remained constant during the period that they were considering. However, the climate relationship is still worth exploring, especially concerning the possibility that the choice of predominately coloured or white windows was partially influenced by changes that occurred in the climate during the High and Late Middle Ages.

In order to understand this hypothesis linking window size and transmissivity to climate change, however, it is necessary to have some knowledge of the translucency of coloured and clear glass. Fortunately, some particularly revealing preliminary quantitative work has already
When testing a panel from the Trinity Chapel in Canterbury (Early Gothic, late Twelfth and early Thirteenth century stained glass), Robert Sowers demonstrated using an illuminance meter that the amount of light passing through a piece of stained glass is largely determined by its colour (Sowers Blues 220). For example, he discovered that red glass was the most opaque, producing a brightness of only one-half footcandle. Blue was similarly dark, with a brightness of one footcandle; green, yellow, and pink followed blue, and white was the brightest glass at five footcandles (220). This corresponds well with what humans generally perceive as bright versus dark (or rich) colours, and the observed data follows the scale that many stained glass historians refer to when judging glass as particularly bright or dark. In addition, Sowers also took similar measurements in All Saints in York (provided with a largely Fifteenth century glazing program), in which he discovered a lighter ruby at 10 footcandles, a dark blue of 13 footcandles, a light blue of 50 footcandles, and an unpainted white with 200 footcandles, thus demonstrating that the brightness of the glass tended to change with time as well as location (220). One advantage to Sowers’s study is his close proximity to the glass when making these measurements (thus demonstrating the amount of light received in one direction). However, Sowers’s research is severely limiting because it only provides data for a couple of glass panes on two windows and may not reflect the average values of glass in different locations at different times (nor the combined effect of the glass), and his study also does not provide any indication of exterior illuminance (he simply estimates exterior illuminance at 200 footcandles given past experience of diffuse lighting conditions); as a consequence glazing transmittance cannot be directly evaluated from his data (Sowers Blues 220). However, it is possible to determine from Sowers’s example that the amount of daylight passing through the glass is greatly affected by colour
palette, with red and blue glass providing the least interior lighting and whites providing the most in both the Thirteenth and Fifteenth century cases.

The goal of this paper is to use qualitative arguments (in lieu of a more quantitative analysis to come later) based on palette and perceived window brightness to indicate ways in which climate change might have affected, over a period of decades, stained glass design and execution. In addition, this research also explores alternate theories to the dramatic brightening of stained glass that occurred in the course of the Thirteenth century. First, a summary of the changing climate is provided, and then an introduction to important terms and features associated with stained glass is given. Following these introductions, French, English, German, and Mediterranean glass are analyzed region-by-region to highlight important local trends and changes in palette with time to illustrate the possible stained glass-climate change connection.

2 A Brief Summary of the Climate Transition of the Middle Ages

A variety of scientific techniques have been implemented in an attempt to understand the climates of the past. Unfortunately, only a relatively primitive, indirect cloudiness proxy index has thus far been developed for comparison to stained glass sources. Link (1958) researched the number of comet reports per year between 500 B.C. and the present in China and Western Europe, with a proportionality constant developed for human skill (Lamb 409-410). The basis of the proxy index is the fact that humans cannot observe comets when conditions are cloudier, whereas they are able to do so during clear night skies. The majority of the reports from before 900 A.D. are from China, and after that date they are predominately reports from Western Europe (thus making the index more likely to represent the trends of the MWP and LIA in Europe). In general, the index, presented in Figure 1, shows a minimum in cloudiness during the
heart of the MWP, approximately bottoming out at 1100 A.D., and a sudden and sustained increase in cloudiness during the early 1200s followed by a steady high cloudiness conditions until approximately 1450 A.D, at which point the cloudiness appears to fall dramatically around 1500 before rising again quickly in the early Sixteenth century and remaining steady. The latter decrease, however, may be related more to the debatable issue of skill adjustment, with the dates around 1500 associated with the advent of telescopes and the Renaissance fascination with astronomy. The prolonged minimum in cloudiness during the MWP and maximum at the beginning of the transition does suggest that stained glass windows would have had time to adjust to different cloudiness conditions. However, one must be critical of the results, as most

Figure 1: Link (1958)'s plotted cloudiness index using comet reports, taken from Lamb (409).

comet reports from the past several thousand years are likely to have not survived. Also, it is unlikely that Link searched every archived document in Europe and China for comet reports in creating his index. Furthermore, the index does not identify what parts of Europe were most affected by the cloudiness, as the coverage area is too broad when including both China and all of Europe, whose cloudiness may not be mutually correlated). Therefore, important information could be omitted from the index. But in general the results, if taken as representative, seem to
indicate that a correlation between cloudiness and stained glass aesthetics is possible. Also, taking an art historical approach to the issue of cloudiness in Northern Europe, Lamb also found that Little Ice Age northern landscapes, such as those by Baroque era artists Ruisdael and Pieter Brueghel the Elder, indicate that summer conditions were probably often half cloudy to mostly cloudy, and winters were often cloudy, in the Netherlands and Great Britain (276).

Some of the best climate and climate change indicators are provided by tree rings, ice cores, historical records, phenological (wine record) data, radiocarbon dating of organic material crushed by expanding glaciers, and fluctuating grain prices, and although these data occasionally provide conflicting results for small periods of time, a broader consensus is obtainable concerning the climates of various periods in history. When many of these data are combined and/or compared, a consistent MWP and LIA can be identified, with cooling during the transition from the former to the latter beginning in the late 1100s A.D. and accelerating quickly by the early and mid 1200s before reaching a temporal minimum by around 1300, seen in Figure 2 (Varekamp 593). More generally, the MWP can be distinguished in most data records, stretching from approximately 800 to 1200 A.D., but it was perhaps most pronounced during the Central Middle Ages (1000 to 1140 A.D.) (Fagan 19). This era of European history was marked by a strong westerly flow (pushing the Atlantic atmospheric pressure ridge across Europe) which, along with increased sunspots and low volcanic activity levels, likely provided mild temperatures and dry weather (Ladurie 255).
Figure 2: Average global temperature trend derived from proxy data, taken and adapted from Varekamp (593)

Figure 3: Oxygen-18 composition for yearly layers in an ice core extracted from Camp Century, Greenland, taken from Ladurie (255)

Figure 4: Carbon-14 composition in tree rings, taken from Ladurie (255)
Extraction of the Oxygen-18 compound (O-18) from ice cap layers in Greenland, which can be used to find average temperatures (high levels of O-18 indicate warmer temperatures), suggests that the period from 800 to 1200 A.D. (see Figure 3) was consistently warm in North America and Europe, with the greatest peaks in O-18 levels occurring between 950 and 1170 A.D. Correspondingly, remaining organic material near Hudson Bay indicates that between 880 and 1140 A.D. the forest limit in North America stretched several hundred miles further north than it does today (257). However, these estimations may not provide a completely adequate representation of European climates given errors and inconsistencies in the formula for ice core data and their observation location several thousand miles away from Western Europe (260).

Tree ring samples provide a more regional scale picture of climate trends; Carbon-14 (C-14) concentrations, for example, generally decrease when solar radiation is high (and are high for when clouds, rain, and particulate matter block radiation) (263). Data obtained from tree (on a global scale) seems to indicate a marked minimum in the Twelfth Century (associated with greater radiation and warmer temperatures) and an increasing trend again beginning in the early-mid Thirteenth century (associated with cooling temperatures), as seen in Figure 4.

Other archaeological and cultural studies similarly suggest a warmer climate in Europe during the Eleventh and Twelfth centuries; for example, the dominance of the Viking culture, while perhaps most closely linked to cultural, political, and military factors in Europe, might also provide important clues about the European climate of the Central Middle Ages (Fagan 62). Vikings maintained a colonial empire during the Eleventh Century, sailing across the northern seas near Iceland and Greenland while avoiding major sea ice. This, however, was not the case in the Thirteenth and Fourteenth centuries, as noted directly by an observer—Priest Ivar Baardson.
of Norway—who indicated that the old routes to the Viking colonies had become blocked with ice and were more dangerous to traverse (Ladurie 235, Fagan 49). However, increasing gales and ice over the north seas had become a significant problem as early as 1250 (Fagan 62). Because Viking boats were constructed in a manner that was relatively incapable of dealing with icepack on the waters, the fact that they were able to traverse so much of the subpolar North Atlantic Ocean in the 1000s and 1100s (as well as establish a sustained grain agriculture in parts of Iceland and Greenland that even today would not be readily supported) appears to indicate that warmer climatic conditions prevailed during this time in the northern seas from Scandinavia to Greenland to North America (Ladurie 261). The jet stream was also likely much further north than its average 56-60° latitude (N) position over Western Europe, providing more rain to central Scandinavia and parts of Scotland while keeping much of northern and central Europe in the warmer, drier high pressure of the Atlantic ridge (300). In fact, the average global temperature of the MWP was likely 1°C to 1.3°C warmer than in the following centuries (254-255).

In addition, archived records also provide important indications of the warm and dry nature of the European climate during the Central Middle Ages. For example, according to Boulainvilliers, a Seventeenth century recordkeeper, the Sarthe River in France dried up three times during the MWP (twice during the 800s and once in 1168) (256). This dry trend is also reflected in organic evidence: strata samples in German bogs indicate that peat levels were particularly low between 800 and 1200 A.D (256). In addition, Lamb (1985) reveals that peat bogs in western England showed a long period of little growth (and relatively dry conditions) between 900 and 1200 A.D, followed by a period of rapid growth between 1200 to 1250 A.D. associated with substantially wetter conditions. Also, the dry weather may have allowed for an increased likelihood of locust outbreaks, which were particularly severe in 873 and 1195 and
resulted in famine (257). Thus, the average climate in Western Europe during the Central Middle Ages appeared to be both warm and dry, dominated by the subtropical high ridge and more similar to a Mediterranean climate. The warm weather proved beneficial for wine grapes, and natural wine production extended all the way into England (whereas today the general viticulture limit is located on the northern border of Champagne in France), although even so English wine production was limited largely to monasteries (Fagan 2). Similarly, the dry, hot summers proved particularly beneficial for cereals (the predominant agricultural staple in the diet of Medieval peoples), and the population throughout Europe grew steadily during the Medieval period as more and more land came under cultivation and inefficient Medieval agricultural practices naturally maintained abundant harvests (Ladurie 258, 290). The population growth of the MWP also provided a larger nonagricultural workforce, and this fact, along with the additional wealth and stability associated with agricultural success, allowed for the construction of a proliferation of larger and more elaborate churches, the interior lighting of which is the focus of this study (Fagan 19).

However, by the Thirteenth century, the nearly Mediterranean-like climate of northern Europe during the previous two to three hundred years was coming to an end, especially in northwestern Europe, and this is also suggested by traditional climate-determining methods. By 1215, glaciers began to advance in the Alps (prior to this date glacial retreat had been observed since 750 A.D.), some growing fast enough to crush Medieval mountain villages in the subsequent centuries (Ladurie 250, 264). Ice core O-18 levels also appear to indicate a strong plummet in average temperatures beginning in the late Twelfth Century and continuing into the Thirteenth Century (with O-18 levels remaining well below that of the MWP thereafter). Unfortunately, tree ring data do not correlate directly with the ice core data, but they also
indicate an increase in C-14 levels beginning in the Thirteenth Century. Thus, temperatures appeared to be getting cooler across Europe, and the 1200s generally marks the transition from the MWP to the LIA.

After nearly one hundred years of slow climatic decline, the transition to the Little Ice Age was completed dramatically in the early Fourteenth Century in the form of rapid oscillations in the mean jet pattern and semi-permanent weather systems, known as the North Atlantic Oscillation (NAO) pattern. During this transition, the perpetually mild warm weather of the MWP (consistent positive NAO) was interrupted by colder weather and large amounts of precipitation (usually a negative NAO or transition to a negative NAO pattern)—when more precipitation shifts southward over continental Europe) (Fagan 29). The unstable jet pattern, cooler temperatures, and extensive rains led to the Great Famine, one of the most significant long-term food shortages in European history. Fields were flooded in the spring and summer of 1315, followed by colder temperatures that led to a poor harvest. The flooding rains continued through 1320 in many parts of Europe, providing for cooler temperatures (through evaporative cooling), a shortening of the growing season, and very poor conditions for cereal crops (Grove 17). An increasing number of devastating windstorms in northern Europe (Normandy and England) were also particularly harmful to agricultural production, and the freezing of the Baltic Sea during the cold winters (the first time since the turn of the millennium) limited trade and the transportation of food to some areas (18-19).

Then, following this ‘Great Deluge,’ the years from 1320 to 1324 were characterized by an extreme drought (17). This precipitation pattern was not only significantly discussed in archived records from the time but has also been demonstrated by Mary Lyons in her analysis of oak tree ring growth in Ireland (17-18). She showed that growth rates (highest in rainy
conditions) were 7-10% above normal for most years between 1315 and 1318 and were as much as 10-22% below normal in the years from 1320 to 1324 (17). These weather extremes, flooding rains (later followed by drought) accompanied by some of the coolest conditions ever seen at that time (which stretched across the winters of 1310-1330), created extreme agricultural instability that created the famine and resulted in a rapid increase in grain prices, such as can be observed in the price records in Winchester, England (Grove 17-18, Postan 103)

However, these climatically unstable conditions were not experienced by all of Europe. Northern Europe, including the British Isles, northern France, and Germany were most affected, whereas most of the Mediterranean basin escaped famine and did not experience the same climatic seesaw pattern as the north (Grove 8). Unfortunately, due to the predominantly stable and “gentle” weather pattern of the MWP, northern Europeans were unprepared to deal with the disastrous consequences of this climatic shift (16-17). To make matters worse, leftover grains that did survive through the harvest period often rotted in the wet conditions, as they were not adequately protected by storage structures built during the warm, dry weather of the centuries before (24). Several million people are believed to have died in the famine, which caused the population growth rate, which had been high in the previous centuries, to approach zero (10). Similarly, the Black Death, which wiped out an even larger proportion of Europe’s population during the mid-1300s (estimated at approximately one-third of Europe’s total population), also might have been edged on by the prevailing climatic conditions in the early stages of the LIA. In particular, a drought in western China and wet and cool (but not freezing) conditions in Europe (along with Pax Mongolia which allowed trade routes across Asia to flourish under stable political conditions) allowed the Plague to thrive in parts of Europe (Zophy 32).
The agricultural instability during parts of the LIA also likely affected pilgrimage traffic and church and cathedral construction, both of which were interrelated for localities along the major pilgrimage routes. During both the Great Famine and the Black Death, church construction slowed or ground largely to a halt in many places, and this is especially true in England (as discussed in Colin Platt’s *Architecture of Medieval Britain: A Social History*). A case study conducted by this author that surveyed all major English cathedrals (to be discussed in another work at a later date) indicated that construction projects were most frequent during the Norman era (the MWP), whereas new work on cathedrals dropped off rapidly during the early and mid 1300s and many ongoing projects were delayed or completed at much slower rates than during the Norman and Early/Decorated Gothic periods. Also, churches must have needed to respond to the wetter conditions by providing better architectural innovations that would handle larger amounts of rain and snow, and building structural changes during the climatic transition period from 1200 to 1500, perhaps reflected by changes in roofing and water drainage.

In general, the conditions of the LIA, although not providing as severe weather fluctuations as during the Great Famine, extended into the Renaissance and beyond, not ending until the Modern Warm Era began in the Nineteenth century. Both the C-14 and O-18 tendencies demonstrate this cooler trend extending through the modern period. In particular, average C-14 values shows two important minima in temperatures and a maximum in precipitation—Spörer minimum of the Sixteenth century and the Maunder Minimum of the late Seventeenth century. These two epochs, as well as the LIA in general, were characterized by colder, wetter conditions over northern Europe, accompanied by a lack of sunspot (solar) activity and auroral reports (which were both extensively documented by Early Modern scientists) (Parker 272-275).
Temperatures are estimated to have been 1°C cooler than average, and winters might have been several degrees Celsius below the current mean, depending on the location (Ladurie 244). In addition, the jet stream position likely shifted to an average position 1° latitude to the south (56-60°N) of its current mean position of 57-60°N (300). This would cause the jet to shift closer to continental Europe, with oscillations in the jet stream more likely to reach further south over Europe than in the preceding MWP. Thus, it makes sense that northern and central Europe would be the regions where the most architectural changes related to climate transition would occur. The evolution of lighting design in the north (contrasted with changes or a lack of change in the south) are the focus of this study.

3 General Characteristics and Trends for Medieval Stained Glass

3.1 Glass Production and Colouring

Glass from the Medieval period contains several basic components still used in transparent glass manufacture today. While Medieval stained glass is often poorly imitated in modern times, and certain craft secrets of Medieval glass creation and design continue to confound experts in the field (Cowen 43-44), the general process is relatively well known through prominent primary sources provided by Theophilius and Eraclius during the Early Gothic era and Anthony of Pisa and Cennino Cennini during the late Fourteenth century (Richard Marks 28). First, a silica was melted down to form a translucent glassy material, and this silica was readily available to many Medieval artisans as some form of sand (Raguin 36). In fact, Chartres was particularly noted for the fine quality of its glass-making sand (Arnold 9). The silica, when heated to extremely high temperatures, forms a strong, permanent network of translucent (vitreous) material rather than recrystalizing (Arnold 13). However, Medieval
technologies were too primitive to heat sand to the levels necessary to break the original silica bonds, and thus the melting point had to be reduced by the introduction of an alkali metal (soda or potash) (Arnold 13), which serves to destabilize the silica bonds and induce melting. The subsequent addition of a network stabilizer, often derived in Medieval glass from lime or alkaline earth metals (Raguin 37, Arnold 13). Although soda produces a more secure glass than potash, the latter ingredient was most widely used, being readily available to Medieval glassmakers from the burnt ashes of beech trees (mixed in a pot, from where the word potash derives its name) (Arnold 13). Because the beech trees themselves contain iron and manganese elements, different combinations of potash and sand could provide different colourations (Arnold 13, Raguin 36).

However, in order to provide the range of deep blues, reds, and greens used in early stained glass, a metal oxide was often added to the glass; cobalt was applied for blue (readily available from Bohemian sources), copper for red, and manganese and iron oxide for greens and yellows (Marks 28, Arnold 14). Until the advent of silver staining, discussed below, all individual glass panels possessed the same colour throughout and were often called pot metal glass, a name which connotes the thick and richly coloured glass of the Twelfth and Thirteenth centuries. These tones often interacted with impurities present in Romanesque and Early/High Gothic glass to give it, on closer inspection, a streaky quality (more prominent in the twelfth and thirteenth centuries than in later periods, and especially visible in Twelfth and Thirteenth century reds) that provides Early and High Gothic glass with its richness and visual sparkle (Raguin 38).

No color additives were needed in white glass (thus affecting cost, as discussed below); however, because of the impurities present in the glass it remained a tainted milky white colour until apparent improvements in glass making methods were made in the Fourteenth century (Richard
Marks 28). This fact is further illustrated in an example provided by Robert Sowers, who assessed an Early Gothic white glass brightness of 5 footcandles in Canterbury Cathedral (the most transmissive of any stained glass colour of that time) and All Saints in York (a Late Gothic, northern English construction) yielded a brightness of 200 footcandles (nearly transparent) (Sowers Blues 220). Eventually, with the advent of transparent glass during the Renaissance, the psychological relationship between the inside and outside world was revolutionized, and windows were designed to view the outside world (rather than be looked at). Further, the popularity of Mediterranean Renaissance Classicism and Baroque architecture eventually mandated a return in much of Northern Europe to relatively smaller windows or less window acreage (compared to the High to Late Gothic giants) provided with clear (or mostly clear) glass (Drake 76, Perrot 8).

3.2 The Evolution of Glass Colouring: Silver Stained and Flashed Glass

One of the most important innovations in the evolution of stained glass was the development of silver stain, a technique known (perhaps first) to the Egyptians, discovered through Islamic influences in Spain, discussed by King Alfonso X of Castille in his book El Lapidario near the end of the Thirteenth Century, and promulgated by French elites (Grodecki and Brisac 177). In reality, despite Alfonso’s apparent rediscovery, the technique was actually known in Europe since Carolingian times and perhaps earlier (Lillich Studies 43). The process involves the staining of white glass through the application of silver oxide during the melting phase. The silver oxide diffuses deep into the glass in the applied areas and can be used to produce various shades of a highly transmissive yellow or orange, the most common application, although occasionally blue glass was stained yellow to produce a light green (Raguin 47, Arnold 181). Impurities were also often removed after the process to provide a clearer glass (47). One of
the primary advantages of this technique centres around the fact that silver oxide can be unequally applied to produce multiple shades of yellow on a single glass panel. For example, a white or light yellow face could be combined with golden hair on a single glass pane, whereas in previous methods two different pieces of glass would have had to be used for the same results. The applications and advantages of silver staining were thus wide-ranging, and this technique was used extensively in windows, particularly in France, England, and Germany by the second quarter of the Fourteenth century (Grodecki and Brisac 177). In general, silver stained panels yield a high transparency and thus high transmissivity (Richard Marks 38), and this characteristic of silver-stained-glass fit well within the broader lightening of colour tones and/or whitening of glass (depending on the region) seen in Northern Europe in the decades before its introduction.

In addition to silver staining, flash or abrasion glass also became more popular in the Fourteenth and Fifteenth centuries. The technique of flashing had been developed since the beginning of the use of red; the copper added to the glass made it so dark as to be opaque, and only thin films of red (usually only a few millimeters thick) applied to white glass could be used in order to produce the characteristic ruby reds of Early Gothic stained glass (Cowen 43, Raguin 38). Certain shades of blue were also produced in this way, although the process remained restricted until the Late Medieval and Renaissance periods, at which time a variety of colours were flashed on white and sometimes two colours were flashed together (Arnold 9). This flashing of colours during the Late Medieval Period on an increasingly transparent white maintained a tradition of high transmissivity windows while also using a wide variety of colours and colour combinations. Also, one of the most attractive advantages of using flashed glass during the Late Medieval Period centred around its ability to provide a greater range of pictorial effects, as during this era drawing and composition began to dominate stained glass, and the
glass medium became increasingly like that of a painting. In particular, the thin film of colour fused onto a panel could be easily scratched out (hence the name ‘abrasion glass’), revealing varying tones of the white or coloured glass underneath and thus providing the effects of lightening and shadow. The flash glass remained popular well into the Renaissance, although another glass decoration technique—the use of coloured enamels painted onto the glass to provide detailing and pictorial effects—vied with flashing for supremacy. Like flashed glass, varying the amount of enamels applied (to predominately white glass) also provided a high transparency and brightness, especially when compared to Thirteenth century glass.

3.3 The Role of Enamels and their Influence on Corrosive Weathering

Enamels have also been used throughout the history of stained glass to provide the outlines or essential features on figures and details and thus play a vital role in glass painting. They also serve, as Arnold (21) indicates, to provide limitations on the colour of stained glass and alter its overall transmissivity. In general, Early and High Gothic stained glass, especially in France, maintained deep red and blue backgrounds (which dominate the overall colouration of the windows) encompassing historiographical scenes or figures which are themselves lighter in tone to contrast with and stand out against the darker background, on which the dark brown or black enamels can be distinguished and easily read. The early Medieval enamels tend to be applied extraordinarily thickly on the low transmissity glass (Carmona 5939), with a strong emphasis on figure outline, thus further limiting light transmission. Because stained glass windows during much of the Twelfth century possessed a mosaic quality, in which dozens of glass fragments (if not over one hundred) could be used to compose a small scene, the lead cames, or thin strips of lead, encompassing each glass fragment and the varying colours of the fragments themselves provide the most basic outlines, and the enamels bestow smaller details,
such as folds in drapery or individual strands of hair. When larger glass panels were used (often for large figural scenes in the clerestory and also in late Thirteenth Century and later figural glass), the enamels started playing a more important role in providing these figural details (but were also further spread apart across large panes).

Enamels also supply the fine detailing of white grisaille windows, characterized by predominantly white glass often decorated with thin, intricate foliated designs (Lillich Band 30). The combined effect of early grisaille windows, containing both the detailing enamel and white glass, is often characterized as a light, translucent milkly greenish or grayish tint, although later Thirteenth and Fourteenth Century grisailles had a much clearer appearance and were often heavily mixed with small bosses of colour (Grodecki and Brisac 154). By the Late Gothic and Renaissance periods, enamels played an increasingly important role in the decoration of the figures, as the art of stained glass had evolved to imitate the effects of painting and drawing (especially by the Fifteenth century in Northern Europe and well before in Italy), and important (non-glazier) artists such as Dürer provided extensively naturalistic and detailed designs for stained glass windows (Raguin 146). At this time enamels were applied liberally to enhance detail, placed on both sides of the glass, and were applied using thinner lines and coats than in earlier glass (partially due to greater application of linseed oil and partially for the aesthetic effect on translucence) (Carmona 5939, 5944). The application of colour enamels was developed to its full extent in the Renaissance stained glass of Switzerland and was a popular medium across Europe at the close of the Medieval Period into the Baroque age (Drake 80).

Enamels also provide remarkable protection against the corrosive effects of rain and snow, as has been shown recently by Carmona et al. in analyzing stained glass samples from various eras in León Cathedral. The corrosion of stained glass is generally caused by high
humidity, precipitation, and pollutants (the process is dominated by water or water vapour and pollutants only play a secondary role enhancing the effect by increasing the acidity of the exchange) (Carmona 5939, Raguin 52). Water vapour and precipitation promotes the attraction of alkalis to the panel surface (silanol groups of Si bonded to OH), which in turn leads to an ion exchange between the water and alkaline glass, weakening the network and allowing the further leaching of the vitreous network’s stabilizing alkaline earth metals (Carmona 5939). The result is the formation of insoluble salts and ions on the glass surface which can enhance this process, eventually resulting in the formation of craters or pits in the glass (5939). However, heavy precipitation can also play a positive role, removing leached alkalis before they become more concentrated on the glass surface (Raguin 52). In such a case, drier Mediterranean climates with more convective precipitation may be more favourable to base glasses than in northern Europe, where lighter overrunning precipitation and humid conditions prevail year-round, especially in England. Thus, a detailed study of the weathering effects on stained glass, if they can be properly dated, may provide important indications of past humidity and precipitation patterns. Indeed, the weathering of stained glass in northern cathedrals such as York remains a particularly important conservation concern.

While an exploration of stained glass corrosion and climatic conditions remains an interesting prospect that should be investigated, the purpose of this study is not to establish glass degradation as a climate proxy but to provide ways in which aesthetics and stained glass design may have been indirectly influenced by the climate changes. Such a connection could have led to the improvement of glass making and enamel techniques in later centuries. Carmona et al. established that the thicker Medieval glass in León, dating from the last decades of the Thirteenth century, suffered from more weathering and damage than the thin, translucent Renaissance glass
produced later (Carmona 5940, Arnold 223). Several reasons may account for the better state of the Renaissance glass: higher melting temperatures were used (less potassium oxide was used to lower the melting temperatures, which provided less overall leaching), it was produced at a later date, and, perhaps most importantly, it was protected from corrosion by the extensive enamel applied to both sides of the glass (whereas Medieval glass only possessed enamels on the inside) (Carmona 5940-5944). In particular, the intentional application of enamels on the exterior surfaces of the glass, while undoubtedly related to aesthetic design (Carmona 5944), might reflect the improvement of the glass making technique to adapt to the wetter conditions of the LIA.

The need for more weather resistant stained glass is especially pronounced in Northern Europe, where greater rainfall rates result in much faster deterioration than stained glass in the Mediterranean. The fact that enamelwork was heavily developed during the Renaissance and used primarily in the north may not be a coincidence (Garcia Vallès et al., 1997, 2003). The effects of corrosion of earlier Medieval glass were readily apparent to glaziers, sometimes even several decades after their completion, and cathedral fabrics often stipulated funds for maintenance work on the glass. In addition, northern glaziers maintaining old glass may have also noticed the protective effects afforded by enamelwork (Richard Marks 39). Earlier improvements between Romanesque and Early Gothic glass, however, are not seen, perhaps demonstrating an ignorance of the protective properties of enamels or also possibly because of the relatively less corrosion during the drier climates of the MWP in parts of northern Europe. Applying Carmona et al.’s findings to northern glass, the use of coloured enamels as a primary glass colouration and decoration method established not only a means of intricately detailed drawing and naturalistic aesthetic expression (a late gothic and Renaissance ideal in Western
Art) but also provided a high transmissivity (for ideal lighting conditions given many days with cloud cover and diffuse lighting) and additive protection of the glass from high humidity and precipitation that was becoming increasingly prevalent during the LIA.

### 3.4 Lead Cames and Ironwork

Lead cames, or the thin lead strips holding individual pieces of glass together in a composition, also act as essential elements of stained glass design. Lead is highly malleable and thus particularly adequate for encompassing irregularly-shaped pieces of glass, and lead strips also require little maintenance and can hold glass panels in place for centuries without being replaced (Raguin 50-51). The cames themselves are attached to the glass through the application of a putty around pane edges, which provides additional stability. While relatively thin, the lead came and putty combinations provide strong, dark lines within the windows, which were exploited in early Thirteenth century mosaic glass to provide the majority of figural outlines (with thick enamel glazing only used for details within the small glass fragments, such as drapery folds, facial features, and hair). However, during the Late Medieval and Renaissance periods, where large scale, multi-light narrative compositions were applied to windows (first in France and Germany in the Fifteenth Centuries and later with Flemish influence in England in the Sixteenth century), the lead cames increasingly interfered with the large-scale composition and were reduced as much as possible. However, lead caming could never be avoided, and stained glass historians such as Arnold have noted that glaziers were increasingly at war with the lead lines in toward the end of the Medieval period. Thus, aesthetic desires and tastes often dictated the role of lead cames, with Early Gothic glaziers using them to their utmost advantage and later artisans working to eliminate them.
Another important factor in the use of lead cames were the cost; extensive leading such as that used in Thirteenth century mosaic stained glass was relatively expensive (Drake 40-45). Lead came outlines, applied with a putty along seal joints associated with the glass, also reduce the translucency of windows, an important feature of mosaic glass when many lead cames are placed within a window (Carmona 5937). Thus, the more sparing use of lead cames in Romanesque glass and later in Fourteenth century through Renaissance glass may have had strategic value as far as allowing increased light transmission.

Lead cames generally serve to attach pieces of glass together, but they can easily give way to the pressure of light winds, and thus additional support in the form of iron bars are necessary (Raguin 52). The way in which these support bars are arranged can in turn be used to estimate the period of the glass that they enclose (Arnold 7). In general, Romanesque glass was positioned between square iron bars in most instances; windows of the first half of the Thirteenth century, however, possessed curved bars that were fit to the outlines of individual medallions or geometric designs. But later in the Thirteenth century the square bar was used again (perhaps due to changing iconography and orientation of individual lancets into narrow lights separated by thin mullions).

4 French Medieval Stained Glass: A Bold Evolution from Early to Late Gothic

A study of Gothic stained glass invariably begins with France, and in particular the Île-de-France region where the formal language of Gothic architecture was first holistically conceptualized and promulgated. Along with the revolution in architecture occurring in the Twelfth Century, stained glass and its role within the cathedral fabric was also transformed with the transition from Romanesque to Gothic. In late Romanesque architecture (even in an age of
increasing agricultural prosperity and regional stability in northern France), the use of stained glass was often more sporadic, dedicated only to a few windows, whereas others were likely kept clear, filled with a translucent medium (such as parchment), or provided with shutters (Cowen 41, Moore 9). Often only the larger Romanesque windows within a church made use of stained glass, such as the great west windows of Notre-Dame-le-Grand in Poitiers or Notre Dame in Le Mans. In order to maintain the structural integrity of high-vaulted Romanesque churches with limited external buttressing and thick walls, windows were often kept relatively small, although in certain locations, such as in Norman architecture (Eleventh and early Twelfth century) and German Late Romanesque (Thirteenth Century) window apertures were much larger in size than those maintained further south (Moore 9). In addition, when Romanesque windows possessed stained glass, they often contained deep colours, such as in the mid-Twelfth century lancets in the west front of Chartres Cathedral (Raguin 30).

However, the Romanesque palette, while predominately coloured, did not maintain the dark, impenetrable blues and reds that prevail in the stained glass of the early Thirteenth century. Twelfth-Century Belles-Verrières often dedicated substantial window space to lighter aqua blues and whites, used both in figures (drapery) and backgrounds, such as in the Ascension/ Crucifixion window of Poitiers and the Ascension window in Le Mans. Similarly, the lighter blues (sky blue and aqua) and paler skin tones of the Notre-Dame de la Belle Verrière window in Chartres (which directly contrasts with its darker Thirteenth century surroundings) also suggests a distinctly lighter colour tradition in Romanesque glass, as do the generally bright tones of the West Window at Le Mans. Similar examples of brighter Romanesque stained glass can be seen in Germany and Switzerland; examples are provided by the predominantly white, green, and yellow Old Testament Prophets of Augsburg Cathedral (mid Eleventh century), the oldest fully-
intact stained glass windows in Europe, the Virgin and Child window from la Chapelle St-Jacques de Flums, the Virgin and Child window from La Trinité at Vendome, and the Mary Magdalene window from the Church of Weistenfeld (Corinthe) (Raguin 59, Groedecki 185). These predominantly Romanesque-style stained glass windows are noticeably different than the richer early Thirteenth century Gothic French glass. Even Louis Grodecki and Catherine Brisac (61) note in a discussion of Twelfth century Romanesque glazing that “the colours are relatively light in the best preserved areas [of Romanesque windows] but rather dark in areas of restoration.” Another distinguishing feature of French Romanesque stained glass are the larger panes of glass used, much bigger than commonly seen in the mosaic glass of the Thirteenth century (as seen at Poitiers and Le Mans west window and Chartres’s Notre Dame de la Belle Verriere) (Sherrill Austria 19, Sherrill Spain 19). Compositions were also often kept simple, with ornamentation minimized and figures predominating, and alternating coloured backgrounds also served to separate figures in many cases (Arnold 27). However, in Gothic churches with extensive window space, stained glass in the late Eleventh century became fundamentally mosaic in character, with small fragments of glass assembled into large mosaic-like compositions using lead cames. Essential ornamental detail beyond simple figural compositions is also characteristic of Thirteenth century glass, in which each fragment of glass represents a figure or setting element.

With interior lighting being a primary concern for glaziers, the lighter coloured, large-paned, sporadic character of French Romanesque glass seems like a reasonable adaptation to the architectural style that hosts it. One potential reason for the relatively sparing use of stained glass in the Romanesque framework is the fact that coloured stained glass significantly limits incoming light, and with the smaller windows required by the limitations of Romanesque
buttressing, more windows needed to be kept open for adequate lighting (and in many cases for the direct illumination of wall murals by prevailing sunlight). Furthermore, as far as we know glass as the predominate filler of window apertures was just entering its prime during the Romanesque period. In addition, when stained glass was prevalently used in Romanesque churches, it required larger panes (with fewer lead cames) and sometimes lighter colours (more whites in the background or perhaps surrounding scenes) to maximize lighting efficiency in Romanesque interiors. In addition, full colour windows appeared to be more common in interiors with relatively large windows compared to other Romanesque churches, such as in the case of the great west window at Le Mans, which provides an abundance of light to the nave, as would have the clerestory windows if glazed initially with another more translucent material or adjustable shutters (nonexistent today).

4.1 Abbé Suger’s Revolution at St. Denis: The New Style and the Transformation of Glass

However, the advent of the Gothic style revolutionized not only window size and coverage but also the role of stained glass within the broader framework of interior design. This change in mindset concerning the place of stained glass in architecture is perhaps best evident from an examination of Abbé Suger’s renovated choir ambulatory at the Basilique St. Denis outside of Paris, still largely intact today; it is the first unified expression of the then-called New Style. Suger himself describes the windows of his choir as filled with “painted and sapphire glass” (Panofsky 77); he commissioned a largely full-colour program in the hemicycle’s aisle windows with little evidence of the widespread use of grisailles (Lillich Armor 70). Unlike in a Romanesque interior, where sometimes only a few large, crucial windows were dedicated to stained glass, in St. Denis an extensive program of coloured glass was applied to virtually every window. In addition, these windows make prevalent use of darker blues and reds, with fewer
pale aquas and whites, and the panes of glass themselves are much smaller than the more classical Romanesque-style glass in Poitiers and other regions, reflecting the evolution to coloured mosaic glass. Also unlike the Romanesque and Romanesque-style glass at Le Mans and Poitiers, the St. Denis windows contain more setting details, including animals, trees, the sea, and even architecture (Raguin 66). The full colour windows themselves also had strikingly little white glass in them, with almost every small mosaic fragment possessing some colour (often pronounced reds and blues for the background, and lighter colours for medallion figures to provide contrast). To balance the prevalence of deep coloured glass are two griffin windows, nearly grisaille in character with a milky grey appearance, that frame the ambulatory’s entrance and exit region. Stained glass design in churches adopting and evolving St-Denis’s Gothic architectural design also tended to follow the style of this incredibly influential basilica in its stained glass tradition as well, adopting the smaller mosaic glass and a deep colour palette, with the occasional lighter coloured window mixed in. The New Style had greatly influenced both dignitaries and church officials alike, some of whom, such as the bishop of Chartres, transferred the new architectural language to their churches. Other important ideas in stained glass may have also been generated at St. Denis; for example, the famous Tree of Jesse design, also seen nearly contemporaneously at Chartres (west front), became popular in stained glass designs throughout Europe well into the Renaissance period (Raguin 111).

The post-St. Denis changes in both the palette and the approach to stained glass are marked. For the first time in Medieval architectural history, windows began to cover a large fraction of the wall space, and the evolution of glass within this space is likely a direct reflection of these changes (Groedecki and Brisac 10). In the Romanesque period stained glass had been an attractive mode of decoration; however, its practical use was limited by the small size of many of
the windows. Once window apertures had opened up, suddenly more light was available and extensive full colour programs seemed plausible. In the case of St. Denis, the size of the new Gothic windows of the choir must have been striking when set against the likely small-windowed Early Medieval nave. More extensive than most windows previously seen in architecture and glittering with colour, Suger alludes to the new lighting aesthetic in his consecration dedication of the new chevet: “the church shines with its middle part brightened. For bright is that which is brightly coupled with the bright, and bright is the noble edifice which is pervaded by the new light” (Panofsky 22). The Abbé Suger also provides more philosophical allusions to the golden door, stained glass and other decorations of his newly-consecrated basilica by noting, “Bright is the noble work; but, being nobly bright the work. Should brighten the minds so that they may travel, through the true lights, to the True Light where Christ is the true door” (23). In his use of words such as the “new light” and also “True light” to allude to Christ, the new decorative aesthetic, including the windows, clearly had important theological and philosophical dimensions, and one in which the Dionysian tradition of the unknown god seems to take second place to interior brilliance and the light of Christ. Even with the new windows filled with rich colours, Suger suggests that his new decoration expresses the brightness of God. Clearly, the large, full-colour windows play a vital role in the decoration, and Suger would not, perhaps could not, leave them blank or covered with a translucent parchment like many Romanesque windows.

Suger’s St. Denis reveals that since the very beginning of Gothic architecture, stained glass has played a vital role as both an aesthetic element and a modifier of light (Raguin 60). In fact, stained glass historian Virginia Raguin goes so far as to say that “Gothic developed with stained glass as a necessary construction element” (Raguin 84). In particular, the expansion of window sizes in the Gothic style lifted constraints that had previously applied to the employment
of stained glass. Now churches and cathedrals with the adequate revenue sources could execute extensive programs of predominately full-colour windows and still provide adequate interior lighting. However, as Virginia Raguin indicates, the large windows of Gothic architecture did not seem well-suited to plain white glass, and no important gothic church or cathedral was complete without the addition of some form of stained glass. Romanesque architecture, on the other hand, could clearly operate without the inclusion of stained glass, as the numerous surviving early and high Romanesque churches in France, Germany, Spain and Italy attest.

The very choice to use full-colour windows within many Early and High Gothic stained glass programs, such as the aisle windows of St. Denis and the later aisle and clerestory windows of Chartres, also attests to a general satisfaction with the lighting provided by rich Early Gothic and early High Gothic glass. Indeed, as discussed earlier, Abbé Suger even emphasizes their brightness. This contrasts with the conceptions provided by some modern stained glass historians, who, in comparing the early full-colour tradition to later glass, often refer to it using the exact opposite term, ‘dark’, and attribute the deep colours and darkness of Early and High Gothic glass to a Dionysian tradition of a dark and unknown God. However, Abbé Suger clearly contradicts this notion; to him and the early Gothic viewer, the coloured stained glass within the large Early Gothic windows was bright and did provide an abundance of light. Similarly, Pierre de Roissy, Chancellor of the Chapter of Chartres, wrote in 1200 that “les fenêtres vitrées qui sont dans l’église et par lesquelles…se transmit la clarité du soleil, signifient les Saintes Écritures, qui repoussent de nous le mal, tout en nous illuminant” (Grodecki 14). The language here, similar to that of Abbé Suger, emphasizes the brightness and radiant, didactic power of the windows, especially when transmitting the sun’s light into the church. Given a sunnier climate in northern Europe during the MWP (Abbé Suger and Pierre de Roissy occupied the heart of this climatic
epoch), it seems plausible that church officials and parishioners during the Early and High Gothic architectural eras would have been satisfied with the light provided by full colour windows. Emerging from the smaller windowed interiors of the Romanesque era, they may have indeed provided an important lighting improvement. On the other hand, Arnold (122) describes the interior of colourful Chartres on a cloudy day as “difficult to read,” although this was clearly not the intention of the chancellor Pierre de Roissy.

However, despite the darkness of full colour interiors on cloudy days, the fact that the majority of windows in French cathedrals were provided with coloured glass as opposed to plain glass (or grisailles) in the early Gothic and high Gothic eras (contrary to the practice of many contemporary English cathedrals), much more than after 1260, suggests that church officials were satisfied with the lighting provided when using a large amount of colour, at least early in the development of stained glass. In any case, whether or not the sunnier conditions of the MWP indirectly influenced adherence to the full-colour tradition, it can be relatively easily demonstrated, as Arnold indicates, that rich, dark stained glass provides the best interior illumination and window legibility on sunny days as opposed to cloudy days.

4.2 The Early to Mid Thirteenth Century and the Evolution of the Full Colour Tradition

The full colour tradition remained strong in France through the Thirteenth century, eventually, as Grodecki and Brisac (10) indicate, culminating in the very rich, dark, saturated colours and stronger tones of the Court Style of Sainte Chapelle and the rich windows of Le Mans, Tours, and Clermont Ferrand in the 1240s and 1250s. In the mosaic glass of the early Thirteenth century, deep reds and blues dominate the glass background, with green, yellow, and fleshy pink-brown used more sparingly to provide contrast and relief (Arnold 103).
By far, some of the best-preserved French glass from the early Thirteenth century can be found at Chartres and Bourges, two cathedrals that developed very different ideas concerning Gothic architectural design and possessed separate glazing workshops (or ateliers) but maintained a similar outlook on the extensive use of full-colour windows (at least for windows installed in the first quarter of the Thirteenth century) (Robert Marks 40-45, Grodecki and Brisac 80). Both cathedrals also dedicated vast amounts of wall space to windows. For example, almost a continuous wall of glass dominates the long choir clerestory of Chartres, including the seven coloured windows highlighting the life of the Virgin (although unlike Rayonnant windows each individual light is separated by a relatively thick trumeau, as opposed to a thin mullion) (Arnold 97). Bourges, one of the southernmost of the great Gothic cathedrals, does not adopt the same towering lancets in its choir as seen in Chartres, but it has three tiers (clerestory, triforium, and aisle levels) of the standard early-High Gothic double lancet windows which provide substantial interior illumination (although perhaps less than the tall lancets of Chartres).

However, both cathedrals were erected on different time scales. The present cathedral of Notre-Dame-de-Chartres, rebuilt with zeal following a fire (in 1194) with a substantial amount of bourgeois, aristocratic, and royal patronage, was largely constructed and glazed at the end of the Twelfth century and in the first quarter of the Thirteenth century (Grodecki and Brisac 57). St. Étienne in Bourges, on the other hand, was built over a much longer time frame, with the choir constructed in the early Thirteenth century and the nave not completed until much later (the mid 1200s). The windows of the Bourges nave were later glazed with mixed colour and grisailles (with only the choir maintaining a design and glass style true to the first half of the Thirteenth century) (Robert Marks 45, Grodecki and Brisac 128).
Among all of the French cathedrals that commissioned stained glass in the first half of the Thirteenth century, Notre-Dame-de-Chartres had the good fortune to be entirely glazed in a relatively short period of time and maintain most of its glass from that era, perhaps representing the best surviving example of the full colour tradition (Groedecki and Brisac 64). Because the windows’ rich colours provide them with a low transmissivity, observers such as Arnold (writing nearly one hundred years ago) have noted that it is necessary to “get used to the gloom and attuned to the pitch of the colour” upon entering the cathedral (Arnold 91). Today, with the substantial buildup of corrosive materials on the clerestory windows of Chartres, this is especially the case, although fortunately the clerestory panes are in the process of being cleaned and may yield a somewhat brighter interior afterward.

In general, beyond the Life of the Virgin series in the hemicycle clerestory, the Life and Ancestry of Christ on the west front, the Christ of the Apocalypse in the south transept, and Human Ancestry of Christ in the north transept, unlike Canterbury and Bourges the iconographical program of Chartres does not appear to be coherent and unified but likely determined by a large number of patrons (Arnold 96, Groedecki and Brisac 65, 81). Medallion windows, typical of the full-colour mosaic glass of the Thirteenth century, were largely applied to the aisle lights, and colossal figures were placed in the clerestory in order to provide maximum legibility (as medallion windows would hardly prove to be an effective aesthetic device or method of visual theological instruction if placed in the upper clerestory). In some cases, two side-by-side figures were made to fit a large lancet in Chartres, such as in the Saint Cosmas and St. Damian window as well as other windows located in the north and south transepts, and in the Life of the Virgin windows figures were stacked on top of each other within the tall lancets (Groedecki and Brisac 57). These conventions were later adopted in churches such
as St. Pierre in Chartres and the Cathedral of St. Gatien in Tours when adapting to the new style of window that had developed by the late High Gothic and Rayonnant periods (discussed below). The arrangement of medallion windows in ambulatory aisles and single figures placed in clerestory lancets is also seen at Bourges and other churches, with Bourges providing a particularly legible medallion windows that are near to the observer at the ground level (such as in St. Denis and contrary to Chartres) and larger figural scenes. The mid-levels of cathedrals, on the other hand, could be provided with medium-sized figures or sometimes with medallion-like scenes. For example, in Chartres there is not a triforium-level glazing scheme, but the Twelfth Century glass of the west front, elevated somewhat above the aisle level, was given a medallion framework (whereas triforium window glazing in Bourges and later in Tours encompassed relatively large figures). However, the eventual reduction and elimination of the triforium, the expansion of clerestory windows closer to ground level, and the division of these windows into thinner lancets (readily apparent in early examples such as Sainte Chapelle) required a revolution in the traditional arrangement of medallions and colossal figures by the mid-thirteenth century, contemporary with another revolution in preferred glass transmissivity (also discussed below).

Clerestory figures in Chartres were also framed by individual canopies, typical elements seen in stained glass in Canterbury as well as other contemporary cathedrals. Trefoil arches were the most common type of canopy in Chartres, occasionally portrayed with a small Romanesque-style dome if two side-by-side arches coexisted in the same window. Sometimes a single half-circle Romanesque arch or single Gothic pointed arch was also used, such as in the Saint Dionysius and Jean Clement du Mez window (Grodecki and Brisac 76). Small, thin canopies were also used to frame some of the medallion scenes (often red in colour), clearly prominent in the Legend of St. Cheron window (75). In general, canopies provided clerestory figures and
medallion figural scenes with a connection to their surrounding architecture, providing a visual link between the material church and the subjects presented in the stained glass (Arnold 136). Its importance as a stylistic element also grew as Gothic architecture evolved from High to Rayonnant and Late Gothic in French, English, and German churches. The canopy in these early, full colour windows in Chartres, while usually containing some white outlining, frequently possessed an abundance of rich colours (such as the reds seen in Chartres). They were also often understated, barely noticeable features of the background, contrary to late Thirteenth century and Fourteenth century glass, in which canopies began to take over the windows and were primarily given over to bright white and yellow colours. This evolution of the role of the canopy has been claimed by some to be related to climate; for example, stained glass historian Charles Sherrill suggested that the canopy design in Fourteenth century northern European glass served as an element for admitting more light in northern European churches as required by the cloudier climate (Sherrill, Spain and Flanders, 24). However, Chartres clearly does not conform to Sherrill’s generalization concerning the role of the canopy, suggesting its construction during a time when the presence of lighter tones and white space in windows due to a supposed concern for a cloudy climate did not appear to be a primary concern to glaziers and overseeing church officials. Indeed, the very astronomical alignment of Chartres with the sun’s rays on the summer solstice seems to suggest very indirectly that sunlight was a key concern in the construction of the cathedral of Chartres on a more philosophical level (Straeken 3).

The rose windows of Chartres also deserve mention as prominent light transmitters within the core of the cathedral. In his well-known book on rose windows, Painton Cowen claims that the roses of many French cathedrals, and particularly those of Chartres, were coloured strategically, with “gentler colouring” used in the northern rose, where typical blue and
reds are more common, and brighter “stronger” colours (white, orange, and yellow) used in the southern rose to provide greater transmittance of sunlight into the Cathedral from direct solar radiation (Cowen 44). While Chartres’s southern rose is not directly facing south (the cathedral is actually nearly aligned to the axis of the summer solstice sunrise), it does receive substantially more direct radiation than its northwest-facing north rose (Strachan and Perceval, 2). If Painton Cowen’s observations on colour preference in north versus south-facing roses is to be assumed correct, then it might be argued that glaziers were primarily concerned with the amount of illumination from sunlight rather than diffuse illumination. However, it is also probable that the iconographical choice of the Apocalypse for many southern roses such as at Chartres influenced the colour palette of southern windows as well.

In the late Twelfth and early Thirteenth centuries, outside of the wide-ranging influence of Chartres and the more localized school of Bourges, the centres of stained glass production in France were located at Reims, Soissons, Laon, and St. Quentin (Groedelcki and Brisac 35-54). Unfortunately, the full programs of these cathedrals have been significantly damaged over the centuries (35-54). Today, Laon Cathedral retains a flat eastern chevet containing a rose window and three broad lancets with richly-coloured, blue and red-dominated glazing from the first quarter of the Thirteenth century (36). St. Gervais and St-Protais in Soissons, although heavily restored, possesses an upper choir window donated by Phillip Augustus, probably dating from 1210 to 1215, and a surviving Tree of Jesse (40). All windows suggest the importance of the full colour tradition in these churches. In addition, the Collegiate Church of St. Quentin, perhaps influenced architecturally by Beauvais, possesses full-colour windows with what Grodecki and Brisac (45) describe as “cool tones” in comparison with the relative abundance of reds in Chartres and Bourges. The Castle Chapel in Baye, Champagne also maintains primarily original
glass from the early thirteenth century, typical in its dominance of reds and blues (46), and nearby Troyes Cathedral also contains many full colour windows from 1215-1230 as well as earlier, richly coloured windows from the Romanesque era, although they were poorly restored in the Nineteenth century. In Troyes, however, some of the colouration of Romanesque stained glass design in nearby German lands may be seen, with the more abundant use of strong green and yellow tones, seemingly opposed to prevalent red-and-blue Chartrain style (50). Similarly, Sens, which maintained a close relationship with the cathedral of Canterbury and may have exchanged glaziers (as is suggested by pictorial and compositional continuities between windows in Canterbury and Sens), possesses windows that Grodecki and Brisac date to the early Thirteenth century (86). Lyons in southern France also contains seven aisle-level windows in the choir ambulatory with smaller lancets and a mix of Byzantine and Northern French pictorial styles (90).

The full colour tradition also remained strong in the second quarter of the Thirteenth century, a time in which the Rayonnant Gothic architectural style (as defined and characterized by Grodecki and Brisac) was being developed. Beauvais’s ambulatory was completed in 1235-1240, and the full-colour windows of the Lady Chapel survived the collapse of Beauvais’s vaults and remain in the cathedral today (114). Nearby Amiens Cathedral, however, maintains one of the most interesting examples of the full colour tradition, as it is considered, as Grodecki and Brisac indicate, “an advanced masterpiece of Rayonnant architecture with a pierced triforium and numerous narrow lights in the upper bays” (116) Architecturally speaking, Amiens contains some of the luxuriant stonework detailing of later French cathedrals, with the beginnings of elaborate tracery and foliate design. It also maintains some of the tallest vaults of any French Gothic cathedral, second only to Beauvais, as well as extensive window space, with virtually the
entire clerestory and much of the triforium and aisle windows covered in glass. At the aisle-level in the ambulatory and Lady Chapel, extensive windows with tall narrow lancets cover the wall space in such a fashion that Grodecki and Brisac suggest that they may have acted as a model for the construction of the glass cage of the Haute Chapelle of Sainte Chapelle in Paris. Also according to Grodecki and Brisac (116), these windows fell within the full-colour tradition, although through a series of disasters and intentional destruction (including such extreme measures as canon fire) almost all of the original glass has disappeared, although fortunately some stained glass believed to have been lost in a fire was rediscovered toward the end of the Twentieth century. Grodecki and Brisac suggest that the iconographical program of Amiens must have been extensive, with “cycles both from Genesis and from the lives of the Saints” (116).

Beyond the full-colour radiating chapels of the choir, a few authentic panels of glass are present in other parts of the cathedral, most notably the Lives of St. Edmund and Edward the Confessor in the north transept (116). However, despite the evidence of the predominance of full-colour windows, Amiens may have well been an example of a summer-and-winter style program in the clerestory (a method of decoration discussed below), with alternating light-toned grisailles interspersed among darker stained glass windows, as is evidenced by one thirteenth century grisaille window surviving in Amiens noted by a nineteenth century observer (Pater 116-117). The nave, which was the first part of the building completed (finished 1215-1220 and in a more traditional High Gothic style than the Rayonnant choir (Grodecki and Brisac 116) and also the first glazed, probably conformed more to the type of stained glass decoration seen at contemporary Chartres, although unfortunately there is virtually no trace of this glass remaining in the cathedral (116). Thus, Amiens provides an example of the full colour tradition used in a cathedral that also retained elaborate interior architectural forms and tracery.
Meanwhile, to the west of Paris in Champagne the glazing programs of the large and influential church of Reims were conceived in the 1230s and carried out into the early 1240s, with many full-colour windows surviving to this day, especially in the choir clerestory and in the north transept (117). In these windows, like many of the Paris-Chartrain variety, the stained glass is dominated by blues and reds, especially those in the north nave and choir clerestories, but like in Troyes greens and yellows are also particularly prominent. The greater usage of these two brighter colours is generally typical of the Champagne region in particular and even more prevalent in neighbouring Alsace, which followed German trends in palette and colouration (117). Other important stained glass programs with full-colour windows were carried out in Châlons-sur-Marne, Orbais, Lyons, and Lausanne during the same time period. Coutances (1230-1240) and Rouen (of similar date) in Normandy also executed glazing programs with rich colours dominated by red and blue (111-112). The prevalence of coloured windows in these churches is a testament to the continuing popularity of low transmissivity, strongly-coloured windows in France, even after the climate had started to cool at the end of the Twelfth century. The reduced translucency of windows at Amiens (Murray and Addis 50) and later at Le Mans (discussed below) is particularly telling, as they demonstrate the possibilities of using full colour windows even within the framework of elaborate architectural designs present within cathedrals. Many stained glass historians, using what is known as the ‘formalist argument’ to the dramatic transition from dark to light-coloured glass in the mid to late 1200s, attribute the lightening of stained glass to the need to provide more interior lighting to highlight delicate, sculpted designs within the architecture (Grodecki and Brisac, Morgan 39). However, the Rayonnant choirs of the cathedrals of Amiens and Le Mans provide important counterexamples suggesting that both full-colour windows and elaborate architectural forms can peacefully coexist.
4.3 Early to Mid Thirteenth Century Grisailles: Providing a Lighter Interior in High Gothic France

Despite the prominence of the full-colour tradition in the early Thirteenth century, many cathedrals also began adopting grisaille windows, which had been used prevalently in Cistercian institutions since an edict by St. Bernard in 1134 banning coloured windows in buildings constructed by the monastic order (Raguin 75, Zakin 17). The Cistercians developed a particularly stark type of pure white grisaille, using slightly larger panes of mosaic-like glass and arranging them using lead cames, without a lot of crosshatching (background grey marks covering the grisaille) or similar additive decoration (Arnold 116). This type of glass, often into organic and/or geometric forms, is often referred to as ‘blankglazing’ (Lillich Studies, 401; Zakin 17-20). The windows of Cistercian institutions with this traditional form of grisaille were also sometimes smaller than in early Gothic churches, such as the grisailles at Obzaine within Romanesque-style windows, or about the size of other Early Gothic windows, such as at Pontigny (Zakin 18). The best examples of Cistercian grisailles come from drawings and surviving examples from churches in Bonlieu, Obzaine, La Bénisson-Dieu, Pontigny, and Beaulieu; their stylistic development are discussed extensively by Zakin (1974).

Stained glass historian Robert Sowers suggests that the harsh lighting provided by the clear grisaille windows of Cistercian institutions was suitable to the religious asceticism of the order, a so-called “negative aesthetic” contrasting with the more diffuse, subdued lighting inside contemporary cathedrals with coloured glass (Sowers Stained 17, 25). However, the fact that the windows of great Cistercian abbey churches, such as in Pontigny (built in the second half of the Twelfth century and early Thirteenth century), occupy much less of the total wall space than in other contemporary churches (such as the choir of St. Denis and Chartres) may suggest that the Cistercians were interested in moderating the amount of interior light (rather than making it
harsher) by using only moderately-sized single lancets with white glass over less wall space. In particular, the aesthetics of grisaille glass in an early Gothic Cistercian interior may in its essence be closely related to lighting design in Romanesque churches, where fewer clear windows provide the maximum amount of interior lighting. Also as in Romanesque churches, strong lighting contrasts in some parts of the church are inevitable (especially in areas directly adjacent to isolated windows), a sacrifice for ensuring enough lighting in the church as a whole (in particular the nave and choir). However, the window architecture of Pontigny minimizes this effect in the clerestory by using the greater freedom of window placement and coverage allowed by external flying buttresses to place a multitude of moderately-sized gothic lancets side-by-side. This close proximity of windows to each other (each of approximately the same size) provides less contrast between light and dark to the eye looking up toward the choir (using glare concepts discussed by Robbins, p. 237). Because of its combination of Gothic style with Romanesque aesthetic, the architecture of Abbey of Pontigny has been coined ‘Burgundian half-Gothic’ (Ousby 101). In Burgundy in particular, Cistercian architecture would have been heavily influenced by famous Romanesque Cistercian constructions surrounding the home institution at Citeaux, such as Fontenay Abbey. However, other Cistercian churches, such as La Bennison-Dieu (although this church is on a much smaller scale than the Pontigny Abbey), also possess relatively small windows.

While grisaille glass developed at the same time as full-colour windows, they were generally not as popular in glazing programs outside of Cistercian institutions (Grodecki and Brisac 153). Arnold (34) notes that in the ‘First Style’ (a term he applies to stained glass from the late Twelfth Century and first half of the Thirteenth century) “the amount of colour used in proportion to white glass is considerably greater than in succeeding periods.” However, with the
exception of Chartres, many cathedrals in Thirteenth century France did develop grisailles alongside full-colour windows (Arnold attributes the increasing use of grisailles in non-Cistercian Cathedrals largely as a Thirteenth century development) (Grodecki and Brisac 153, Arnold 117, 122). Grisaille glass was used in the churches of Saint-Martin-aux-Bois, St-Jean-aux Bois (1220-1230), St. Jean at Sens (1240) (smaller churches), and Châlons Cathedral (around 1250, a date straddling the transition to a more widespread acceptance of grisailles) (Grodecki and Brisac 153). Other examples of grisaille glass from the first half of the thirteenth century can be found at Essômes, Troyes, Orbais, Sens, and Reims (153).

Unlike the earlier plain white grisailles of Cistercian churches, however, the more decorated grisailles that were developed around 1200 (and continued to be used through the late Thirteenth century) often possessed thick crosshatching, known in French as *cages à mouches*, behind the background of the essential floral or geometric patterns (153). This decoration increased the contrast between the pattern and the background, highlighting the design but reduced the overall window transmissivity of the glass (153). According to Robert Sowers, the *cages à mouches* serves to subdue and break up harsh light (Sowers Stained 17), and as a result adequate for sunny conditions but also still more transmissive than coloured glass when provided with cloudy conditions. In addition, early grisailles such as those of the thirteenth century were also not very transparent, especially compared to later glass, and they often producing a grayish-green or yellow hue (Lillich 2002, 33; Drake 19). However unpure, though, early Medieval white glass (and grisaille windows in general) had the highest transmissivity of any other contemporary glass type, with red and blue colours being the most opaque (Sowers Blues 220). In addition, white glass was also the most economical choice, in some cases half the cost of coloured glass
(the staining agent for which sometimes had to be imported through long-distance trade) (Richard Marks 48).

Therefore, increased interior lighting and economy seem to have justified the greater use of grisailles in many cathedrals even starting as early as the first half of the Thirteenth century (Arnold 116). Grodecki and Brisac (153) suggest that some very tall cathedrals, such as Beauvais, may have adopted grisailles due to the extreme height of the upper vaults and reduced legibility from such heights, although height does not seem to have inhibited the creation colossal coloured figures in the clerestory of Le Mans or the inclusion of smaller medallion-type scenes in the central clerestory choir window at Cologne. Morgan (39), in an account on the grisailles of Lincoln Cathedral, argues that Chartres Cathedral, in virtually eliminating grisailles altogether from its glazing program, is an outlier rather than a standard example of French cathedral glazing during the early Thirteenth century. Also, another important factor in analyzing surviving stained glass is that grisailles have often been neglected over the ages (as coloured windows are more valuable and have greater religious meaning and didactic power), are more vulnerable than coloured windows, and often become so corroded that they were eventually taken down before the modern era (Grodecki and Brisac 153). Therefore, coloured windows may be more likely to survive to today.

Meridith Lillich coined the term “summer-and-winter” to describe stained glass programs (largely those executed in the first half of the Thirteenth century) that developed schemes of alternating grisaille and full-colour windows (Lillich Armor 8). The clerestory of Sens (after reconstruction following 1230) and the Lady Chapel of St-Germain-des-Pres in Paris (1245) were glazed in this manner (8). One variant of summer-and-winter style glazing is visible in the cathedral of Auxerre (second quarter of the Thirteenth century), which possesses a
predominantly coloured series of aisle-level windows but maintains clerestory lights containing coloured figures surrounded on both sides by unusually wide grisaille borders (Grodecki 124). This arrangement provides a unique strategy for mixing colour and grisaille, with predominately full-colour windows located at the aisle level for instructive purposes but also increasing overall interior lighting provided by placing mixed grisaille-colour windows in the clerestory well above eye-level. According to Lillich (extrapolating from rudimentary evidence provided by historical drawings), this same style of clerestory window glazing, with colossal figures framed by grisaille panels, was also likely applied to the clerestory glazing (dating from 1220s to 1230s) in the cathedral of Notre-Dame-de-Paris (Lillich, Armor 8, 322). However, these windows, as well as the earlier full-colour windows provided by the Abbé Suger for the glazing of the Parisian cathedral, have long since been lost (Caviness 267).

Another important distinction between Chartres and other cathedrals is the zeal associated with the cathedral’s reconstruction (as an important pilgrimage church) along with royal, aristocratic, and bourgeois patronage, partly attributable to the miraculous survival of the Virgin’s Veil relic, that allowed for substantial opulence in the cathedral’s glass and sculpted decoration. In cases where church or cathedral fabrics were more constrained, the use of grisaille glass within window glazing programs may have been more due to economic reality rather than a desire for more light. For example, the nave of Bourges cathedral was constructed slowly between 1220 and 1255, and financial difficulties in the 1260s (although perhaps planning for the grisaille decoration began even before 1260), might have mandated that the nave be provided with grisailles around that time for economic reasons, what some have called an ‘austerity program’ (Lillich Studies, 82-83). Therefore, Chartres may be a better indicator of the ideal of its era (what can be accomplished when few barriers are present), and a deliberate change in
transmissivity not associated with economic constraints is the actual interest of this study. Similarly, the extensive full-colour windows of Sainte Chapelle, the king’s personal chapel also with a large fabric budget and completed, like Chartres, in a short period of time, may also reflect the ideal of its time (1240s), although the personal tastes of King St. Louis may have been a factor as well. Additionally, white glass may have been more-readily preferred in smaller churches (non-cathedrals) with correspondingly smaller budgets than their larger counterparts, and for similar reasons the stained glass transmissivity of rural or minor churches is largely left unaddressed in this study due to the issue of economy becoming too important of a factor in glass design and palette.

In general, the surviving examples of Chartres and Ste. Chapelle, as well as the overall greater prevalence of full-colour windows with narrative cycles in the first half of the Thirteenth century (and their virtual elimination by the Fourteenth century with the introduction of large amounts of grisaille in stained glass design) suggests that an abrupt change in interior lighting design occurred after first half of the Thirteenth century. Lillich believes this transformation to be important enough that she described it as “a new world was dawning” (Lillich Armor 8). Even with the vulnerability of grisailles and various summer-and-winter programs executed by the early-mid 1200s taken into account, the second half of the Thirteenth century still witnessed the most dramatic increase in the use of grisailles. And this shift in interior design, with the Rayonnant choirs of Amiens and Le Mans in mind, does not seem to be warranted solely by economic concerns necessitated by an increase in window acreage (as after the collapse of Beauvais, cathedrals no longer strove toward greater and greater heights, and the glass cage had already been realized in Ste Chapelle and Troyes) or the need to illuminate architectural designs.
4.4 The Colour Saturation between 1240 and 1260: Ste. Chapelle, St-Germain-des-Pres, Le Mans, and Tours

Before the full transition to grisaille-dominated windows in northern France (occurring around 1255-1260), the full-colour tradition experienced one last wave of popularity, and the glazing programs from this time are often referred to as the Court Style in stained glass (Grodecki and Brisac 10, 20). The stained glass of this period, as Grodecki and Brisac prescribe it, reached a level of colour richness and saturation not achieved even at Chartres, with palettes becoming notably “darker” (10, 20). The primary monuments to the last stand of the full-colour tradition are the churches of St-Germain-des-Pres and St. Chapelle in Paris and the cathedral of Le Mans in western France, the latter two providing the strongest evidence against the formalist argument concerning the need for high transmissivity grisailles to illuminate intricate architectural forms. St. Chapelle (1242-1248) in itself was a complex monument, with walls made of nothing but richly-coloured stained glass (Arnold 113). Despite some destruction and removal of panels, predominately in the Basse Chapelle and on the north side of the Haute Chapelle, the southern windows today are still relatively undisturbed (Grodecki and Brisac 102).

This narrow, tall chapel is considered by many to be a crowning achievement of the Rayonnant, with buttresses reduced from view and window space maximized to the fullest extent possible. Sculptures, paintings, and rich carvings also once decorated the interior, and the chapel held relics obtained by King St. Louis that had cost much more than the building itself and its coloured glazing (Hayward Church 167). Therefore, daylighting needed to be sufficient in order to illuminate the art and relics inside this important monument. Even with saturated glass, the veritable size of the windows of Sainte Chapelle accounts for much of this light. However, during cloudy conditions the interior can be relatively dark, and today the church’s artificial lighting system is activated during periods of overcast sky. At the time, however, the colour-
scheme of the glass must have been considered sufficient to illuminate the architectural detailing, sculptures, paintings, and relics that were important elements of the church itself, and this lighting was perhaps best done given sunny conditions. The chapel itself inspired a number of royal dignitaries and other visitors to the French state, some of whom went back to their homeland to commission similar glazed structures (although in many cases with local stained glass styles, as will be seen in the case of Westminster Abbey in England) (Grodecki and Brisac 188).

However, despite Sainte Chapelle’s perceived ability to provide adequate lighting conditions, the glazing in this tall church fails another requirement of stained glass windows: a legible iconography. The windows themselves were given the same form as aisle-level medallion windows; however, the lights extend high to the clerestory (albeit lower to the observer than most major church and cathedral clerestories do to the nature of the chapel), and the chapel itself (unlike the spacious cathedral of Amiens) is relatively narrow, making the medallions placed in the upper part of the windows more difficult to make out from the ground. The Sainte Chapelle windows raise an important issue that was specifically addressed through experimentation at Tours Cathedral and St Pierre in Chartres soon after the construction of Sainte Chapelle; stained glass programs had to adjust to large windows divided into narrow lancets that sometimes extended the whole length of the clerestory and sometimes to lower levels (Lillich, Band 27). In the case of Sainte Chapelle, it must have been difficult to aesthetically justify having a continuous wall of colour with small medallions in the lower half of the lancets and barely-visible colossal figures adjacent to the ceiling. While the organization of window iconography was being transformed, however, the legibility of windows suffered significantly (27). While medallions were even more illogically supplied to the much higher clerestory of Tours cathedral,
rendered as such less legible than Sainte-Chapelle, eventually a solution was discovered in the form of the band window (discussed below).

Also in Paris, Grodecki and Brisac have traced the style of Sainte Chapelle to the richly-coloured north rose window of Notre Dame, which was glazed around 1255 and possesses the same palette and saturation as the king’s chapel (109). A few panels surviving from the refectory and lady chapel of St-Germain-des-Prères also conform to the palette of Sainte Chapelle, thus defining it as a broader Parisian style independent of the personal tastes of St. Louis (96, 108-109). Grodecki and Brisac (108) also identified the saturated style of Sainte Chapelle, perhaps linked to the same atelier, in other locations, in particular at Soissons and St-Julien-du-Sault in Burgundy.

The full colour tradition, however, was also prominent during the middle of the century in Le Mans, a cathedral that did not, according to Lillich analyzing treatment and style, feel much of the aftermath of Sainte Chapelle (Lillich Armor 14, 31-32). A new choir was constructed during the second quarter of the Thirteenth century, and a substantial part of the glazing was undertaken between 1250 and the mid-1260s (with some work continuing perhaps to the 1270s) (12, 42). The full-colour windows, which Lillich describes as “dark opulence,” was partially influenced by Chartres, and even at this late date the Bishop of Le Mans was apparently interested in using Chartres as an example (18). However, only a few windows directly demonstrate the impact of Chartres, and many more indicate the development of a Western style of stained glass, with local legends depicted in windows and non-Chartrain stained glass techniques being gradually developed (20, 23, 31). Similar to traditional programs, predominantly colossal figures are depicted in the clerestory, although medallions were applied to the triforium. The use of full-colour windows in the choir, with only two grisailles installed late in the
campaign and invisible from the ground (42), can be offered as an example of the successful use of a full-colour program in a church with complex Rayonnant architectural forms, epitomized by the delicate foliate work in the triforium, and is thus an example that severely limits the formalist argument that Rayonnant architecture requires predominant grisaille windows. The rest of the cathedral (aisle level) was also decorated with full colour windows from the Romanesque or early Gothic periods (largely destroyed by the Hugenots), thus rendering a substantially full colour interior similar in conception to Bourges or Amiens but within a mature Rayonnant style.

4.5 The Grisaille Revolution: The Development of the Band Window and the Expansion of Grisailles

Meridith Lillich and Louis Grodecki both agree that sometime between 1255 and 1270 a fundamental shift occurred in the aesthetics of stained glass. Lillich herself contends that the “relationship of architecture to its stained glass was beginning a new and fundamental adjustment” during this particular era (Lillich Triforium 34). Suddenly, the colour saturation of important monuments such as Chartres, Sainte Chapelle and Le Mans gave way to much lighter-toned, whiter glass. While summer and winter programs had become prominent in the early Thirteenth century, this strategy did not provide the same sweeping interior lighting increases as the new whitening aesthetic of the grisaille revolution. And stained glass windows in general remained highly translucent from that point until the end of the Middle Ages, first starting with the widespread application of grisaille glass over coloured glass, continuing with the development of yellow stained glass and quarries, and eventually culminating in the richly coloured but also thin and more translucent flashed glass and enamels of the Renaissance. The kind of subdued lighting conditions seen in the great cathedrals of Chartres and Le Mans were no longer seen in most constructions dating from the late Thirteenth century or later, despite the fact that window acreage in churches expanded only modestly at best in the age after the great High
Gothic vaults were no longer attempted. Thus, the argument that grisailles were becoming more prevalent due to the increasing size of windows and associated economic concerns has limitations, especially when considering Le Mans Cathedral (along with the fact that English religious institutions were becoming wealthier and the economy in general was improving at the same time glass was also getting whiter).

The continued lightening of stained glass did, in fact, accompany an increase in the complexity provided to tracery, and the formalist argument cannot be completely disregarded, as tracery and sculpted forms within the cathedral may have had some impact on the aesthetics of stained glass. The windows of most early Thirteenth century stained glass were kept free of tracery, with only the iron support bars providing the major divisions within typical early and High Gothic windows. The clear, primary objective of these windows is to convey the didactic and aesthetic message portrayed in the stained glass, and little tracery was used to distract from the glass. More complex designs, including small rosettes, were provided to some lancets during the Rayonnant Gothic phase, culminating in the full-colour windows in the clerestory of Le Mans (in which each window has been given three cloverleaf tracery designs and divided by into thin lights by mullions). However, the even more complex tracery of Flamboyant churches (late 1300s and 1400s) is often accompanied by lighter glass.

While the increased light may have provided more illumination to intricate architectural designs and tracery, the actual tracery itself might have, at this point in time, been replacing the role of stained glass in providing decorative aesthetic. It is generally assumed that windows lightened to increase the illumination of architectural forms; however, in the case of Tours cathedral, the pivotal monument in which the band window was developed, tracery and Rayonnant architectural form remained relatively unchanged from that of Le Mans and similar
cathedrals. However, by the time the Vendôme Chapel was added on to Chartres Cathedral, window tracery had become very elaborate and the stained glass window was also filled with abundant white space. Similar kinds of glass and lighting conditions likely also existed at the culmination of the Flamboyant style, seen at St. Maclou in Rouen. The same trends are observed in England, where as glass got whiter tracery also became more complex. In general, it is possible that the opposite of what has always been assumed may be true: tracery and architectural embellishments gradually increased in complexity as stained glass became whiter and more formalized to single figures framed by canopies. While increasingly whiter stained glass may be letting in more light, at the same time the more complex tracery seems to gradually replace some of the aesthetic role played by the glass.

As indicated by Lillich and others, the mid-Thirteenth century experienced the greatest single change in interior lighting aesthetic during the Middle Ages, and a number of factors may be involved. Due to the overwhelming popularity of grisailles by the late Thirteenth century, even in wealthy establishments, economic concerns cannot be considered a universal reason for the persistence of grisailles and high transmissivity glass in new construction and glazing projects. Increasingly complex architecture in need of greater interior illumination may be closer to the truth, although full-colour windows were being replaced with grisailles even in institutions that were not undergoing widespread architectural changes, such as Chartres Cathedral (Lillich Redating 11). Similarly, in St. Pierre in Chartres the original full colour program was rearranged and modified, and grisailles were added to the preexisting nave (Arnold 122,133). A general change in the aesthetics of light or the prevailing theological philosophy toward light may have also influenced this conversion. However, brightness has to be viewed as a relative concept (with virtual Augustinian-type sentiments seemingly expressed by Abbé Suger in the 1140s), and the
outgrowth of Augustinian philosophy most prevalent in the first half of the Twelfth century under the predominantly full colour tradition would have been altered by the late Thirteenth century and Fourteenth century with increasingly secular public sentiments and the growing importance of the patron within the design and layout of stained glass fabric (Lillich Armor 6,74). The general evolution of glass or interior lighting aesthetics may have also driven a revolution in style and a conversion to grisaille and other higher transmissivity glass (6).

However, the fact that the glass retained its highly-transmissive character and colouration for the next several hundred years rather than evolving back to the rich colours and subdued lighting of earlier centuries (when other stylistic reactions back to earlier Medieval themes were observed (Raguin 111)) suggests that other factors beyond pure aesthetics were involved in the mass conversion to grisaille-dominated cathedral interiors in France.

In general, however, it can be assumed that a slowly evolving dissatisfaction with the full colour tradition finally culminated in slow but broad changes to overall stained glass transmissivity in northern France. The desire for more light was clearly an important factor (Lillich Band 28). The changes in climate occurring at the time may have been behind some of this desire for more light, as global temperatures had cooled markedly by the mid-1200s, the jet stream had begun to shift south, and the comet-based cloudiness index (based largely on nighttime comet sightings in Europe during the period after 1000) roughly suggests that cloudiness was beginning to increase markedly. It is indeed possible, given the apparent connection of stained glass in England and the Mediterranean with the amount of direct sunlight or cloudiness present (discussed below), that a greater number of cloudy days helped lead to greater dissatisfaction with the kind of interior lighting seen in French cathedrals such as Chartres, where the full-colour tradition was the rule, and that lighter-toned glazing began to be
selected because of this (as well as other) factors. The gradual transition may have begun in the second quarter of the Thirteenth century with the introduction of summer-and-winter programs during this era. Architects and glaziers, able to observe the interior lighting from previously-constructed cathedrals and improve upon past designs, may have decided that a change was needed given even a somewhat cloudier climate by the 1260s, nearly 70 years after the beginning of the cool down that marked the end of the MWP and beginning of the LIA. Greater aerosol content associated with increased volcanic activity might have also altered conditions seen even in sunny weather, the effects of which may have been more directly visible in the high latitudes of northern Europe (where sunlight has a greater path length through the atmosphere for much of the year and is more diffuse generally).

However, it is important to stress that the full-colour tradition died slowly, grisailles increased in use slowly, and the mixed tradition did not become the rule across northern France until nearly 1300. While the transition to grisaille-dominated programs seems abrupt only when analyzing a few prominent churches and cathedrals, such as Sées, Vendome, St. Pierre de Chartres, and Tours, Grodecki and Brisac (142) stress that the conversion was not really complete until the end of the Thirteenth century. Clermont-Ferrand, located further south (and likely also slower to see a change in climate, as the Mediterranean climate has been shown to be the least affected during the LIA), maintained a full colour tradition with rich colours and no grisailles into the 1270s. In the 1280s and 1290s mixed grisaille and figure windows were further installed in this establishment (144). Additionally, in Île-de-France, dark tones were also used in the church St-Sulpice-de-Favières, probably dating from the 1260s (148). Little glass survives from Paris during this period, although the nearby church of Gassicourt, which Grodecki and Brisac (150) believe “attests to the dynamism and quality of the Parisian workshops,” contains
full-coloured historiated windows (dated 1270-1280) with white used only for elaboration of forms. Dol Cathedral in Brittany, perhaps influenced by Le Mans, maintains the full-colour tradition, especially in its “deeply coloured” large east window, considered to be a reflection of the large, bright windows seen in England but occupied with coloured glass (grisailles were added to Dol Cathedral, especially starting in 1280) (Lillich Armor 167). Therefore, clearly the conversion seen at first in two windows glazed from 1255-1260 in Tours Cathedral and then more extensively in St. Pierre cannot be applied everywhere.

As mentioned earlier, Tours Cathedral, through a subtle innovation in the choir, first expressed the style that heralded the new dominance of grisailles. The clerestory windows of much of the hemicycle appear to be similar in style to the glass of Sainte Chapelle and Le Mans, perhaps even richer and more saturated, and these elevated windows also appear to be in medallion format (which would clearly limit legibility) (Lillich Armor 33). On the side of the choir, however, are two windows facing each other that both possess two horizontal bands of richly-coloured figures surrounded above and below by fields of grisaille glass (Lillich Band 28). Lillich maintains that the Tours glazing may have actually been influenced by recently executed windows in the Rayonnant reconstruction of the Basilique St. Denis (still an influential aesthetic trend-setter), which according to pictorial evidence appears to contain a few hemicycle bays with standing figures surrounded by a background of grisailles (although coloured figures appeared to have dominated the hemicycle) (Lillich Armor 68-70). Also, the Rayonnant glazing of the cathedrals of Paris, Auxerre, and Lyon might have also contributed to the aesthetic development of the band window. This new window design not only helped fill the window space with legible subjects—large figures more readily legible even under diffuse lighting conditions—but also allowed more interior lighting into what would have been an otherwise relatively dark interior.
Another design for integrating mixed grisaille-colour windows was developed nearly contemporaneously at St. Pierre in Chartres, where lancets with vertical strips of colour, figures stacked on top of each other, are alternated with lancets with pure grisaille. The stacked clerestory figure design might have been an adaptation of those seen in the Glorification of the Virgin window in Chartres Cathedral, with the addition of grisaille to adjacent lancets. However, this solution to the grisaille integration problem was not widely adopted like the Tours band window, and Lillich suggests that this was because the vertical strips of alternating colour and grisaille have the best aesthetic effect when windows (with four lancets each) are placed directly adjacent to each other, whereas band windows could be applied to more isolated windows with a variety of orientations (Lillich Band 29). The band window glazing scheme was quickly adopted by other cathedrals, the most pure example of which is provided by the glass in Sées Cathedral, executed in the 1270s and 1280s (although Sées was a relatively rural town and economic arguments may have come into play, although the cathedral was sponsored by Parisian sources) (Lillich Armor 168-171). One potential reason for the quick adoption of the band window in Normandy is the location of nearby parish churches with small band window-like forms (a coloured panel, for example, surrounded by white glass) (Lillich Armor 197-198). Also, other churches in Normandy, perhaps the first part of France to be affected by the climate transition, were quick to adopt grisaille patterns, especially at Sainte Vaubourg (1260), Rouen Cathedral (Chapel of St-Jean), the castle chapel at Rouen, and Evreux (150, 160-162). In addition, summer-and-winter programs had also been increasing in prominence by the mid-to-late 1200s, as the churches of St-Germer-de-Fly and Châlons attest (Lillich Armor 67).

Even religious officials at Chartres apparently attempted to create a summer-and-winter program in their cathedral, taking down full-colour windows and replacing them with grisailles
in 1260-1270 and again in the Fourteenth century with the installation of new grisailles in the choir (Window 19 and 20) (Lillich Redating 17). In addition, Cannon Thierry in 1328 installed an entirely white and silver stained window in the south transept in order to permit more light to reach the altar (Arnold 189). Sherrill also maintains that full-colour windows in Chartres were “removed from each side of the apse clerestory” to provide more light, given the cloudy northern climate (Sherrill Spain 19, Austria 12). He also stresses that cross-shaped openings were cut out of Amiens’ windows by monks at some point following the completion of the glazing program to provide more interior light (Sherrill Spain 19, Austria 12).

On the other hand, the work at St. Urbaine in Troyes has often been cited as the perfect example of the new expansive usage of grisailles, with the important papal church containing some medallions mixed with grisailles in lower windows and banded clerestory figures in the upper windows (Grodecki and Brisac 172-175). However, Jane Hayward has recently revealed that a purer full-colour program was likely underway in the 1250s and 1260s before a fire destroyed much of the in-situ glass, and a combination of a post-fire lack of funds in the 1260s and the survival of uninstalled panes of coloured glass led to the mixed window austerity program now evident in St. Urbaine today (Hayward Church 170-174).

Grisailles were also improved in quality from previous early-Thirteenth century forms. Grodecki and Brisac (154) directly states that “the later glass [from the end of the Thirteenth century] is almost milky white and has a previously unknown, regular transparency.” The increasing transmissivity of glass was likely due to a variety of factors. In particular, improvements in technique associated with over a century of widespread, large-scale stained glass production had resulted in the development of glassblowing methods that produced larger, thinner sheets (154). In addition, improvements were also made in ridding the sand silica of other
impurities (metal oxides in particular that resulted in yellowish or greenish hues) and “a steadier means of fusing the glass paste” (154). Cutting methods also improved, and glaziers often worked with larger panes of glass (154). In addition, crosshatching was eventually eliminated from white glass and grisailles in the late Thirteenth century and the beginning of the Fourteenth, further increasing the transmissivity of windows (Lillich Redating 15). Therefore, by the year 1300, an increase in white glass would have led to a substantial increase in interior lighting, more so than the few summer-and-winter programs which started in the second quarter of the Thirteenth century.

4.6 The Fourteenth Century through the Sixteenth Century: The Continuation of Translucency in France

Mixed glazing programs continued well into the Fourteenth century in France, and these are especially notable at Vendôme’s La Trinité, Evreux, the Chapelle St-Piat (Chartres Cathedral) and St-Ouen (Rouen). In all of these window series both grisailles and yellow stain played an important role. In addition, even aisle windows, such as in the fourteenth-century windows of St. Serevin in Paris, were provided with predominately white backgrounds. The introduction of yellow stain, first datable in France to the Norman church of Le Mesnil (from 1311) and quickly adopted in Normandy before the rest of France (perhaps due to climate-related factors), continued the trend of increasing transmissivity in stained glass (Lillich Armor 165). The quarry design, made of relatively large, clear, white diamond-shaped slabs, was developed in France in the 1300s (perhaps originally in one of the replacement windows at Chartres) and became particularly popular in England, perhaps due to their reduction of leading and the general increase in transmissivity associated with using large panes of white glass. In addition, the expansion of the canopy continued to be important in both France and England during this time.
period, which provided ample opportunity for the use of brighter, lighter-toned colours, first pot metal yellow and white and then later silver stain and white

However, the general upheaval provided by the breakout of the Hundred Years’ War, violent uprisings and revolts (the Jacquerie, for instance), and outbreaks of the plague caused stained glass production (and cathedral construction in general) to come to a virtual standstill in France (Arnold 193, Janson 313). The most important programs completed during this time of turmoil over the course of the Fourteenth and Fifteenth centuries included the churches of St. Ouen and Evreux, both providing extensive window space as well as substantially brighter interiors than the churches of the Thirteenth century. The earliest choir chapels in Evreux contain figures placed within extensive grisaille lancets (Arnold 189). In St. Ouen, the quarry made its first appearance as a key element of window backgrounds, and the windows of the choir contain true quarries, yellow stain, and abundant yellow and white canopies (191). Arnold (246) also noted that an Evreux window dating from 1400 is much whiter than those from the early 1300s and late 1200s in the cathedral, with its larger, more elaborate canopy. A tree of Jesse dating from the mid-Fifteenth century, on the other hand, possesses rich colours but also substantial white space (249-250). In addition, St. Ouen has windows dating from the mid-1400s that are decorated primarily in silver stained glass and quarries (247).

With the end of the Age of Disasters and the beginning of the French Renaissance, stained glass production blossomed again in France, and another revolution took place affecting the arrangement and palette of stained glass. The art of glazing quickly felt the effects of both the Italian and Northern Renaissance in painting, and naturalistic, three-dimensional pictorial effects became more important in glazing schemes, with compositions often extending across several lights (a development that took longer to come about in England) (Raguin 111, Richard Marks
A variety of Renaissance stained glass compositions from the Sixteenth and Seventeenth century were executed in Paris, most notably St. Germain l’Auxerrois, St. Merri, St. Etienne-du-Mont, and St-Gervais-St-Protais, and also in Rouen, across the Loire Valley, Brittany, and in the famous compositions of Sainte Foy in Conches-en-Ouches (Raguin 148). Sherrill notes that the stained glass colours of the Renaissance seem anti-adaptive to the climate, becoming deeper and richer again. However, with the substantial use of flashed glass, often obtained from a thin coat of colour placed on white, the use of more light blues and whites for sky, architecture, and some drapery (and continued silver stain), the eventual conversion to painted enamels, as well as the greater purity, smoothness, and translucency of glass of all colours by the Renaissance, would have likely provided the higher translucency necessary for the cloudcover conditions by the time of the Spörer minimum (c. 1500-1600).

5 English Stained Glass: the Early Importance of Translucency in a Cloudier Climate

English stained glass followed a similar pattern in both palette and transmisivity as French glazing, with programs becoming whiter with time by the second half of the Thirteenth century. However, unlike in French cathedrals, English grisailles seemed to play a dominant role as early as the first quarter of the Thirteenth century (a time when ornamental white glass was limited to summer and winter programs at best in most non-Cistercian French institutions). Substantial wall space was filled with grisailles in England, and English cathedrals also maintained some of the earliest and tallest lancets (such as in the transepts at York) with the gradual evolution of the standard English east window occurring during the Thirteenth century (a vast wall of glass, sometimes from floor to ceiling, as seen in the choir of Gloucester Cathedral). While relatively little Twelfth and Thirteenth century glass remains in England today due to
intentional destruction associated with the Reformation and the English Civil War (Nelson 8), along with later renovations, reconstructions, and wars, the cathedrals of Lincoln and Salisbury in particular demonstrate an early concern for mixing colour and grisaille windows, well before French cathedrals adopted mixed windows (which took place largely after 1260). And while in France the full colour tradition did not entirely diminish until the end of the Thirteenth century, in England white glass combinations with coloured windows seemed to be a requirement at a much earlier date. In other words, unlike the French glass, which clearly reversed trends from greater saturation in Le Mans and Sainte Chapelle to the band windows of Tours and other cathedrals, the churches of England maintained a consistently lighter, whiter palette from the early Thirteenth century to the Renaissance (Arnold 214, 218; Drake 31-33, 51). After the Renaissance, less white glass was used, although this is likely due to the thinning of glass at the time (including pot metals), the use of enameled and flash glasses, which would have provided much higher transmissivities than thirteenth century pot metal glass (Drake 82).

Even sources such as Grodecki and Brisac (186) confirm that “on the English side of the channel, this type of glazing [grisailles] enjoyed a particularly wide popularity.” Even more strikingly, according to Richard Marks (30) there is no evidence that the English produced anything other than white glass, preferring to import their colour rather than starting production at home (Norman white glass was also, according to records, considered finer than coarser English glass). Economy might be a prevailing factor in the early use of grisailles and limited application of colour, especially given the massive size of Medieval English windows even during the Early English Gothic period and slower economic progress of England at that time compared to France (Robert Marks 78). However, projects such as at Canterbury clearly demonstrate that full colour programs were possible. And royal patronage, likely less dependent
on economy, indicates that white glass was considered vital in Thirteenth century England, as
generated by Henry III’s example, who, after apparently being inspired by Sainte Chapelle in
France, built Westminster Abbey in London reflecting the Court Style tradition in France but
glazing the walls of glass primarily in white rather than colour (Richard Marks 136).

Even through the Fourteenth and Fifteenth centuries, as England became more
prosperous, marked by abundance of demand for glazing and patronage support for glazing
programs in even remote parish churches (Richard Marks 41-42), colour should have technically,
by economic arguments, become more prevalent in English stained glass. It seems to have even
been desired by some patrons more, as is suggested by requests that John Prudde, glazier of
Beauchamp chapel, use “the finest colours of blew, yellow, red, purpure, sanguine, and violet,
and of all other colours that shall be most necessary… of White Glasse, greene Glasse, black
Glasse he shall put in as little as shall be needful for the shewing and setting forth of matters,
Images, and Storyes” (Richard Marks 23). Beauchamps chapel does employ more colour than
other English churches of the time; however, like other English sacred buildings, it also makes
use of an abundance of white glass and silver stain, which produces a brightening effect (190). In
fact, Richard Marks (65) suggests that the focus of glaziers on brightness and translucency of the
glass was given priority over the desire to provide narrative stories, at least until the Renaissance
when large-scale narratives were displayed across several lights.

The formalist argument is also limited in its interpretation of English glass. Richard
Marks, in discussing the prevalence of white in English glass, maintains a traditional
interpretation:

The Salisbury grisaille windows, together with those as Lincoln and others in the
Transept at York, at Westminster, and in various parish churches provide the principle
evidence for a form of glazing that must have been very common in England from the
Twelfth and first half of the Thirteenth centuries, even in the great churches. These
reasons were partly economic—grisaille was cheaper than coloured glass—but aesthetics and practical issues must have been important considerations in great church glazing. The coloured windows of Chartres permit very little light to filter through and consequently the interior of the building and its architectural details and carvings are very difficult to discern” (127).

However, as is demonstrated below, the same argument does not appear to apply in richly-decorated German churches maintaining the full colour tradition into the Fourteenth century, and, also contrary to formalist logic, Richard Marks (128) describes Salisbury’s early Thirteenth century architecture as “restrained, even somber” with windows serving as “a counterpoint to the regularity of the architectural framework.” An austere architectural interior does not, according to formalist theory, require heavy use of white glass, and yet the clerestory appears to have been decorated with unpainted grisailles, while aisles tended to be given more ornamental grisailles (but grisailles, unlike any major French cathedral from that era, austere or otherwise, appear to dominate the full interior).

Some authorities on stained glass, such as Charles Sherrill and Maurice Drake, suggest that climate played the dominant role in determining the overall transmissivity of stained glass windows. In particular, Drake (48) comments that “perhaps on account of our cloudy skies white glass has always been more in favour in England than on the continent,” and Sherrill claims that “English success in this field [grisailles] came about very naturally, for the cloudy skies that so frequent that comfortable island demand that light-obscuring colour be used more sparingly than in sunnier lands” (Sherrill Austria 11). Both sources, however, do not consider possible changes in cloudiness that may have occurred as well through climatic shifts, which this paper argues is partly responsible for the increased use of grisailles and whiteness in France. The same increased whiteness is seen in England, suggesting that there may have been a change, although some climatic indices indicate that, during the MWP, parts of England (especially the north)
experienced wetter than normal conditions. The south, on the other hand, may have been more closely tied to patterns in France, with Wells cathedral (on the edge of the mean Atlantic ridge) as late as the first quarter of the Thirteenth century given paint on its exterior (this paint has obviously worn off since). Therefore, a brief overview of prominent English examples will be considered here, with particular interest in continuity and changes in palette.

5.1 Canterbury, York, and the Full Colour Tradition in England

Unfortunately, relatively few fragments of late Twelfth and early Thirteenth century glass remain in England; the glazing programs of many churches from this era, such as Durham, Peterborough, Albans, and Chichester, have no trace remaining (Richard Marks 113). However, the glass that does survive in Canterbury (with a few fragments in York as well) is particularly rich and provides the interior lighting typical of full colour traditions in programs such as Chartres (113, 119). Canterbury seems, however, to be the only cathedral known to have been glazed almost entirely in colour, an oddity in England that Drake (48) attributes to the predominance of French continental influences at Canterbury. This fact is confirmed by Richard Marks (124), who emphasizes the close connection between Canterbury and France during the development of the Early Gothic cathedral and stained glass, and in particular the Petronella master working in Canterbury between 1180 and 1207 was probably a Frenchman familiar with the figural designs in St-Remi. Others attribute the full colour setting to the Dionysian tradition of the unknown god and the supposed encouragement of religious contemplation in dark interiors (Nelson 7). However, it should be established that religious philosophical trends may have been different in England than in the intellectual movements of northern France in the High Middle Ages (so pure philosophical arguments cannot necessarily be applied across the Channel with regards to the lightening of glass).
However, certain unique aspects of the English palette shine through, even in the rich full colour windows of Canterbury. In particular, white seems to be a more prevalent element in medallion window design as well as in clerestory windows (Methuselah being a prominent example, with much of the window being largely occupied by the white drapery of the subject). The medallion windows also demonstrate the importance of white; in one particular example, a scene of Adam plowing possesses pale skin, a white tree, white loin cloth, and a white ground, conventions not seen as often at St. Denis. In addition, some of the glass, as noted by Arnold (77), was coloured primarily by a “thin malt” of enamel scratched out to provide figural scenes, a technique used much later during the brightening of cathedral interiors in late Thirteenth century France (such windows in Canterbury would allow additional lighting through, as compared to the richly coloured stained glass).

Despite these small changes, however, the Gothic interior of Canterbury possesses very rich colours and vies with other full colour interiors in France. While cultural factors (including French influences) might have been a dominant factor in glass colouration, clearly economic concerns were not the dominant factor in glass selection, and the willingness of the English to provide a full colour interior when mixed programs had begun in Romanesque interiors of the Norman era and previously (such as Old Winchester Minster) (Richard Marks 105), suggests that southern England chose to adjust to the expansion of windows under the Gothic style with full colour traditions, perhaps attesting to a warmer, somewhat less cloudy climate. In addition, it is important to note that when the glazing of Canterbury was begun, the old Romanesque nave built by Lanfranc was still in place, and it had small windows and may well have not possessed any glazing at all (Arnold 95), thus providing a mixed Romanesque-early Gothic lighting interior that was likely uniformly dark in cloudy conditions.
York provides another example of an interior which once possessed coloured windows, and it is significantly further to the north of Canterbury within a regime that seemed to have experienced, provided with a northward-displaced jet stream, wetter and cloudier conditions in the MWP than other parts of England. Unfortunately, very little of the full colour glass survives, as the church was thoroughly remodeled in later centuries (Fourteenth and early Fifteenth), the wall space being replaced by expansive, bright mixed windows dominated by white in many areas (and some of the earlier glass was recycled in these later windows). Most of the few surviving coloured panels can be approximately dated to the Late Twelfth or early Thirteenth centuries (Richard Marks 114-115). Richard Marks (114) also notes that late Twelfth and early Thirteenth century full colour glass in York is dominated by “brilliant blue, sage green, purple, and white; ruby is also present but used less obtrusively than at Canterbury.” The importance of white glass in the coloured windows, along with the elimination of the most opaque colour (red) may be a northern climatic adaptation. However, the total extent of the colour program in York has always been uncertain, as contemporary to the few full colour panels present in the cathedral are numerous geometric grisailles of various designs, likely derived from quite a few grisaille windows. These grisailles might have, in reality, dominated the cathedral interior in the first quart of the Thirteenth century, if one were to look at the proportions of surviving glass (114). If York had been grisaille-dominated as early as the late 1100s and 1200s, it would be the first Gothic cathedral to possess a predominately mixed interior, and the cathedral’s far northern location might, in turn, have encouraged the more extensive use of grisailles at such an early date.

5.2 The First Half of the Thirteenth Century: The Predominance of Grisailles in England
Not long after the glazing of York and Canterbury (and at times contemporary with it), the cathedrals of Lincoln and Salisbury were also provided with stained glass, with several extensive full colour windows added to Lincoln Cathedral in particular. Both cathedrals, like so many English churches, do not possess a consistent program, with glass having been destroyed and rearranged at later dates. However, unlike York much of their Medieval glass in place today dates to the early Thirteenth century. The full colour windows of Lincoln (most dating from 1192-1225, and probably derived from some local tradition as suggested by Richard Marks), are perhaps best demonstrated by the fairly well preserved glass (at least in terms of iconographical placement) in its north rose window (Richard Marks 125, Morgan 14). Many of the figural scenes in the coloured glass have blue backgrounds, similar to Canterbury in this respect, but they also seem to use an abundance of white as well (Morgan 23). However, Arnold (29) indicates that some of these blues are a lighter, almost grayish-blue, rather than the deeper blues found elsewhere in France, and purple was more abundantly used (a relatively light variation). The rose window and its effectiveness in both sunny and cloudy conditions seemed to be a primary concern for contemporaries; the Thirteenth century text of the Metrical Life of St. Hugh indicates that the two rose windows “sparkle without sun, glitter without cloud,” a language that suggests a conscious thought toward the effect of cloud cover on surrounding windows (Morgan 35). In any case the lighting seemed to be satisfactory, although the author also stresses that “the top row of windows shines forth,” these likely being the grisailed clerestory (38).

The original arrangement of coloured windows and grisaille is unknown, as much of the glass has been rearranged beyond the point of being able to reinterpret the program, although indirect language in the previously mentioned text suggests that the aisle level of the church possessed figures of saints, whereas the clerestory was likely grisailed, perhaps in full (38).
vast amount of surviving grisailles, forming various geometrical patterns, also seems to suggest
that they played a dominant role in the glazing and were much more extensive than even the
whitest contemporary glazing programs in France (41). In addition, Morgan suggests that,
although perhaps influenced by mere window survival, there did seem to be an increased interest
in ornamental glass with little or no colouration in major English churches in the early Thirteenth
century, and Lincoln may provide an important example of this trend (39). He also indicates that
ornamental coloured glass, such as that at Brabourne (as well as in France at St. Rémi and St.
Denis), seemed to have been more popular in England in the Twelfth century, but it also was
rapidly outmoded by the early Thirteenth century, as evidenced by Lincoln Cathedral (39). In
addition, Lincoln may have been vital to the development of a rudimentary quarry design, with
lattice squares and diamond shapes being the predominate window pattern (rather than the more
popular foliate design; these early quarries also seem to reflect the floor tiling pattern) (40-41).
Eventually the quarry would take over English stained glass in the Fourteenth century (as well as
French glass); however, the presence of quarry prototypes as soon as those in Lincoln expresses
an early desire for utmost translucency in cathedral windows.

Salisbury Cathedral provides another important example of the early adoption of
grisailles in England, and it reflects Lincoln’s arrangement in many ways. The choir of the
church may have had important figural windows (likely provided with rich colour), as noted by a
sixteenth century traveler, although most of that glass was probably destroyed in seventeenth
century renovations (Richard Marks 126). The grisaille glass of Salisbury cathedral, however,
appears to be the dominant lighting agent for the church’s interior space, with at least 16
different grisailles window patterns identifiable, and Richard Marks (127) emphasizes that
Salisbury is the “largest single repository of Thirteenth century grisaille designs in all of
Europe.” Many of these patterns, like their French counterparts, were embellished with small coloured bosses to add contrast and texture to the windows (128). According to Winston, the original, unmodified Salisbury glazing program likely possessed undecorated grisailles at the clerestory level and more decorative grisailles in the lower windows (129). The grisailles are also, according to Richard Marks, more regular than the French examples, and whereas pure, non-crosshatched white space in early summer and winter programs in cathedrals such as Auxerre seemed to be minimized in France, in churches such as Lincoln the crosshatching seemed to be largely left out to provide more lighting (the latter reflects an earlier end to crosshatching in England, first fully evident at Chetwode in 1270, as opposed to some continental locations, like Germany, which kept the device, as well as foliate designs, into the Fourteenth century) (132, 141).

By the mid Thirteenth century, before the development of the band window and associated expansion of white glass in France, grisaille-dominated programs appeared to have won wide appeal in England, and perhaps nothing better expresses this claim than the Five Sisters of York Cathedral, datable to 1250-1260 (Richard Marks 133, Arnold 121). These windows, five tall lancets extending nearly from the clerestory to the aisle level and over 15 meters tall, dominate the south transepts and provide an intricate foliage design, now heavily damaged but not lacking in their silvery effect (Arnold 121). The windows also have some primitive quarries (121). The fact that an English Cathedral such as York would dedicate such extensive wall space (within a legible distance from the ground) to windows, and that these windows would be filled entirely with grisailles, speaks to the desire for greater interior lighting, with perhaps greater window white space being more important in this far northern location than in areas further south in England. In fact, York would be decorated heavily with grisailles and
band windows again when the choir and nave of the cathedral was remodeled in the Fourteenth century, and the city itself would become the centre of one of the largest and most prolific regional glazing operations of its time (Richard Marks 155).

In addition, the whitening trend had become prominent and seemingly irreversible in the south by mid-century. For example, as previously mentioned, Westminster Abbey’s choir, glazed in 1245-1259 (and much of it before 1253) with royal oversight, did not possess many of the characteristics of its contemporary Sainte Chapelle, despite being constructed in the Court Style (Richard Marks 134). It does, however, like York, demonstrate the completeness of grisaille adoption within English glazing programs by the middle of the Thirteenth century, at a time when grisaille-dominated programs were just beginning to be developed in France. Many of the windows of Westminster Abbey were glazed with grisailles, including the aisle windows, and Richard Marks (136) points out many of the differences between the two churches, as well as between French and English mid-Thirteenth century treatment of grisailles and colour palette, in his book:

The extensive employment of green, white, and yellow glass in the Westminster panels differentiates them from contemporary French glass, and they also do not follow the latter’s trend toward greater opacity, evident in Sainte Chapelle; there is no appreciable difference in this respect between the Westminster glass and the Lincoln glazing executed 25 years previously… with rare exceptions grisaille does not occur in the apsidal chapels and chevets of major French churches. At Chartres, Bourges, Rouen, and elsewhere the windows in these parts of the church were reserved almost exclusively for historiated scenes in richly coloured glass. Westminster may have diverged from this formula and even more so than Sainte Chapelle, which had no grisaille in the upper (main) chapel (136).

In general, the Westminster glazing, with its lighter colour palette, was probably a summer and winter-style program at the aisle level, with full grisailles likely used at the clerestory level. Thus, a consistent pattern emerges when considering the major glazing programs at Lincoln, Salisbury, and Westminster: grisailles were adopted early in English cathedrals and used
extensively, much more so than in contemporary French churches. This also seemed to be the case, as provided by Westminster, when funding was less stringent.

5.3 Later Trends in English Glass

English glass continued to be a rich tradition into the Renaissance, developing its own distinct aesthetic characteristics even well after French glazing programs had virtually ceased. In terms of translucency, English glass evolved to become whiter and whiter, making even some contemporary French windows seem darker by comparison. The general lightening trend seen in English glass was similar to that already discussed in the France section of this paper (although magnified compared to France) and will not be discussed thoroughly here. England was quick to adopt the band window in 1270s (Grodecki and Brisac 188), but clearly the English did not rely on the band window to provide the greater transmissivities that had been established by the Early Gothic grisaille cathedrals. Also similar to France, grander and lighter-toned canopies became a prominent feature through the Fifteenth century. The English also first adopted silver stain methods (earliest datable glass from York between 1299 and 1305), which seems surprising from a cultural standpoint (as royalty in France were actively campaigning for its adoption in France at the turn of the century, although the first datable there is from the second decade of the Fourteenth century), and as previously mentioned crosshatching in England abated by the second half of the Thirteenth century (Richard Marks 142). In addition, larger panes were adopted in English glass by the late 1200s, and glass became thinner by the 1300s, thus increasing translucency (142,148).

Major glazing programs also became whiter with time in the mid to late Fourteenth century (Richard Marks 166,169). In addition, windows expanded to sizes never seen before in the Fourteenth century, as seen in the floor-to-ceiling chevet-wide East Window in Gloucester
and the Great West Windows of York and Wells, all of which make prolific use of yellow stain, grisailles, and lightly-toned canopies (157-158). Some previously large windows were also expanded during this era and filled with more white glass and yellow stain, such as at Exeter cathedral (153). In addition, grisailles were gradually replaced by a clear quarry design developed in Chartres Cathedral (as a replacement of one of the original full colour windows in the 1230s), and vast quarry windows with light golden silver stained glass was added to windows in Tewkesbury, Elsing, and other important churches. In order to provide for more light toned glass, the Tree of Jesse design was adapted to the larger canopied figures of the new era. One expects a reversal of the lightening trend at some point, but this did not appear to happen. Some prominent glaziers, such as Thomas Glazier of Oxford and John Prudde, executed a number of works in a variety of new colours, but none truly eliminated the large expanses given to white and silver stained glass (Richard Marks 190). Eventually Flemish glazing traditions were preferred in England, with their large-scale narrative compositions like those seen in France and Germany. Although the Flemish glass did introduce more colour to English churches, many windows were still predominately silver stained and white (with figural skin often completely white and drapery and hair done in silver stain). Also, much of the Renaissance Flemish glass, with its three-dimensional pictorial effects and emphasis on landscape and architecture, was dominated by white (marble architecture) and light blues (sky), and many windows were still given over to quarries (as in the case of new glazing in Westminster Abbey) (Richard Marks 216). In general, the evolution of English glass, which was kept largely white for much of its history, demonstrates a possible connection of interior lighting concerns to England’s generally cloudy climate and may also indicate slightly increasingly cloudy conditions, especially in
southern England where the grisaille revolution was more spectacular than at York, where glass from the late Twelfth century may have largely been composed of grisailles.

6 German Stained Glass: A Colourful Transition to the Little Ice Age

Outside of France and England, various parts of the Holy Roman Empire, including today’s Alsace and Lorraine in France, the Rhineland, Switzerland, Flanders, and Austria also upheld prominent and widely influential stained glass traditions from the central Middle Ages to the Baroque age. The surviving early-Romanesque prophets in Augsburg, mentioned previously, provide an important example of the very early age of some of the stained glass extent today in German lands and the importance of regional trends within Germany during the development of the nascent coloured glazing tradition. In fact, some Medieval glass experts, including Grodecki and Sherrill, believe that the Romanesque glass tradition is perhaps best explored in Germany due to the persistence (past the middle of the Thirteenth century) of both Romanesque architectural forms as well as the Romanesque style of glazing, called Zackenstil, with its characteristic broken folds (Grodecki and Brisac 194). Despite local glaziers’ slow acceptance of French Gothic forms within stained glass designs, many parts of Germany were quick to be influenced by Italy in the adoption of perspective (192).

Therefore, German stained glass conventions seems to have evolved differently than other parts of Europe and often in contradiction to glass aesthetics in France and England (192). In addition, Charles Sherrill suggests that “the German had and kept his colour from sheer love of it, and not at all because of climatic requirements which exerted so much influence in cloudy England or sunny Italy and Spain.” Indeed, the German tradition is perhaps most distinguished by its abundance of colour (Sherrill Austria 11, Grodecki and Brisac 192). However, Grodecki
and Brisac (192) also indicate that colour saturation in German churches never reached the levels seen in Sainte Chapelle or Le Mans. In many cases more greens, whites, and yellows were used than in French early-Thirteenth century glass, perhaps making German windows more transmissive in many cases as suggested by the brightness values recorded by Robert Sowers (indicating yellow, green, and white as the most translucent glasses) (Sowers Blues 220). On the other hand, unlike the stained glass of France and England, which became much whiter with time (with the transition to whiter glass largely complete by 1300 in France and even earlier in England), many parts of Germany actually maintained a rich full-colour tradition well into the fourteenth century, thus providing an important challenge to the stained glass-climate relationship.

Due to the delayed acceptance of Gothic in parts of Germany (with the maintenance of the German Late Romanesque style in architecture well into the mid-1200s) and Germany’s prolonged employment of richer glass, Grodecki and Brisac (192) go so far as to suggest that the relationship between stained glass and architecture was fundamentally different than in other parts of Northern Europe. However, broader trends in German stained glass also suggest a transition to more transmissive colours and greater white space, even within the regional full colour tradition of Thirteenth and Fourteenth century. In addition, when considering interior lighting concerns in German churches and cathedrals, the extent of coloured glazing undertaken, the size of the windows (which in many cases took up abundant wall space similar in conception to Sainte Chapelle), and the whitewash given to walls (which would have allowed greater light diffusion and interreflectance) in German churches become important concerns as well. The fact that windows maintained large sizes, and the German palette was generally lighter in the first place than the deep French blues and reds of the early Thirteenth century and the saturation of
mid-century, may help explain the delayed evolution of lightening tones in German churches. Perhaps nothing better expresses the generally lighter and less opaque character of German stained glass (compared to French glass) than the c. 1260 Bible Window in the central apse of Cologne Cathedral. Cultural forces and preferences were also likely at work, undoubtedly reflected in the German emphasis placed on narrative glass, whereas the band window formula and similar mixed grisaille strategies of the French late Thirteenth and Fourteenth century, with a simple parade of saints and figures, was likely less attractive for this reason (Grodecki and Brisac 192-194). Patrons also seemed to be more attuned to producing bright full-colour windows, and their desires were largely adhered to (unlike in England) (Sherrill Austria 22). At the same time, essential interior lighting was also important to highlight the colour of interior decoration, such as painted sculpture (which was a common and popular feature in sacred German interiors).

Therefore, despite the fact that the band window and similar French adaptations to grisaille were rarely employed in German lands, local glaziers provided alternate ways of combining grisailles and coloured glass (using white as a background, for instance, at the former Cistercian church of Namedy in Andernach) (191-192). In other words, the adherence to strict full colour rules largely waned in the Fourteenth century through the mixing of white and coloured glass in innovative ways rarely done in France. And by the heart of the LIA, the transition to lighter tones seemed complete, with German, Flemish, and Swiss glass possessing a much brighter palette and silver stain, enamels, and flashed glass having long overshadowed traditional mosaic methods. Flemish glass in particular became popular in England, as the abundant whites and light blues (in architecture, drapery, sky background, etc), transmissive
flashed colours, and detailed pictorial effects of Flemish glazing seemed to be in tune to both the
English climate as well as growing Renaissance tastes.

**The German Romanesque Tradition in Stained Glass and Early Fourteenth Century Glass**

German Romanesque glass, similar to its contemporary French glass, possesses larger
panes and tends to include bright colours (Sherrill Austria 20). Raguin (59) notes that the
prophets of Augsburg, with their abundant use of red, green, yellow, and white and blue only
provided in a few small details, “set the tone for subsequent German glass.” In the French
Romanesque palette, a light blue tone (such as Notre-Dame de la Belle Verrière and the
Ascension windows of Poitiers and Le Mans) plays a much more prominent role, although in
both French and Germanic Romanesque glass white is often an important element as well. On
the other hand, unlike in early French iconography ornament appears to be important in German
glass, starting as early as Augsburg (Raguin 59, Grodecki and Brisac 192-194). Beyond the
rudimentary beginnings of stained glass visible in Augsburg, Zakenstil glass, with its
characteristic German colouration, survives in the Late Romanesque St. Kunibert’s in Cologne
(1220s), and various fragments survive in Cologne Cathedral as well (194-196). Some early
Thirteenth century glass, although rarer than the more mature Zakenstil of mid-century, had
particularly deep colours, such as Bucken un Der Weiser’s central choir window, strikingly large
for a Romanesque window with twenty full panels (with the term ‘panel’ referring to a scene
framed by iron support bar divisions). Large Late Romanesque windows often sported deeper
colours than smaller-windowed interiors, depending on the completeness of the glazing program.

After the mid-Thirteenth century, the Romanesque tradition quickly gave way to the
Gothic architectural style at a time when Zakenstil was still in its mature stage. One of the classic
eyearly examples of Romanesque glass within the Gothic framework is provided by Naumburg,
approximately contemporary with Sainte Chapelle. The glazing produces a bright effect that, in an apsidial structure, illuminates the surrounding architecture and painted sculptures. The windows themselves have strikingly simple tracery, with long window lancets but little in the way of elaborate tracery to distract from the messages in the glass itself. In addition, while the architectural style seems far from flamboyant, there are foliated highlights in the vault bases. The coloured windows, in the presence of sculpted and architectural art, appear to provide enough interior lighting to highlight all the forms present and provide an integrated interior aesthetic, and this was made possible through the use of an abundance of white and yellow and strong (but more sporadic) reds as well to better define a glowing colour. And indeed, according to Virginia Raguin, “the interrelationship of architecture, sculpture, and stained glass [in Naumberg] is one of the most telling demonstrations of medieval artistic integration extant” (Raguin 95-96).

_Zakenstil_ remained popular not only in the early years of Gothic in Germany but even well after the conversion; for example, Regensburg cathedral maintained a strongly Romanesque program, with some Gothic figural arrangements but also extensive reuse of Romanesque fragments (Grodecki and Brisac 196).

Strasbourg Cathedral possesses some of the most important surviving examples of German-style stained glass from many eras, including the late Zakenstil of the mid-1200s. In fact, Strasbourg’s cathedral also represents a fusion of French and German ideas, showing substantial architectural and sculptural links to workshops in Paris and Reims but a glazing atelier that appears to be Rhenish in origin (196). The Strasbourg workshops also further developed the extended canopy, especially during the end of the Thirteenth and beginning of the Fourteenth century, which became an important feature of stained glass windows in the Upper Rhine and near Alsace (200). In particular, Grodecki and Brisac (200) note the importance of
increasing colour saturation during this time period, with the adoption of blues and reds as typical background colours.

Perhaps one of the best examples of this kind of window can be provided by the Crucifixion window from the axial bay of Sankt Mauritius at Mutzig (dated 1310), which displays blue and red backgrounds behind many of the figures (Grodecki and Brisac 201). However, at the same time, many of the blues, especially in the upper part of the window, are a brighter, sky-blue, lighter in tone than the blues of Chartres or Canterbury. In fact, Sherrill claims that deeper blues (such as those seen in Canterbury analyzed by Sowers) are rare in Germany (Sherrill Austria 89-90). In addition, the reds and blues are provided in quarry form, so they occupy much more space by minimizing lead caming and consequently allowing in more light. In addition, the canopies and canopy borders, made entirely of yellow and white glass, take up a large proportion of the window, with more decorative white space provided above in the decorative leaf-and-star details. This variety of window design is typical of full colour glasswork in the upper-Rhine around 1300, yet in terms of transmissivity the expansion of the canopy does provide an important additional source of translucency, despite the greater saturation given by the red. According to Sherrill, the canopy strategically served as an important source of additional light, and the expansion of canopy designs at a time when a rich palette was maintained might be an attempt to increase lighting (Sherrill Austria 11). Similarly, a reduction in narrative space and increasing prominence of the canopy occurred throughout much of Europe, although canopies in southern Europe, when provided, tended to be richly coloured (Sherrill Spain 24). In France, on the other hand, the expanded canopy itself did not lead to a transition to a single figure style; this was achieved before the Fourteenth century in the
conception of the band window (the reduction in narrative is strikingly visible by Sées, constructed around 1270).

Similar to the French, the Germans did not exclude white glass from their palette in the Thirteenth century, and grisailles were executed in the glass programs of Augustinerkirch in Erfurt, Elizabethkirche in Marburg, as well as the churches of Weisenburg, Nordhausen, Hersfeld, and Hereford during this period (Sherrill Austria 21). The application of grisailles expanded in the Fourteenth century to Altenburg, Haina, Strasbourg, and Heiligenkruez (exclusively grisaille windows) and mixed substantially with figures in the cathedrals of Cologne, Marburg, Freiburg, and Herford (21). Cologne Cathedral (glazed 1280-1310) provides a particularly good example of an early desire to sacrifice colour for light (Raguin 10). The central window, the focus of the churchgoer’s view, has coloured bust-medallions and figural scenes throughout its tall lancets; however, the windows to its side have only one, band-like row of figures at its base (closer to the audience view) and a much broader region of grisailles extending to the vaults, intended to provide additional light (10). The dark band of glass and the largely white panels above are generally linked by a white canopy and architectural frame surrounding the figures, as well as by a restrained but prominent network of colour defining the geometrical forms of the grisaille (103). The windows themselves, unlike many French models, still possess trumeaux between each pair of double lancets, yet the mullions between adjacent lancets are relatively thin, and the lancets are very tall, providing in total a much greater abundance of light than seen in the choir of Le Mans. The architectural detailing of the vaults is no more elaborate than at Naumburg, and the tracery is still heavily concentrated to trefoil arches and a small rose at the very summit of each window. As a result of the simple tracery and
vaulting, the grisaille revolution at Cologne does not appear to be heavily tied an elaboration of the architectural framework but a real desire for more light.

However, despite mass conversions to grisaille in cathedrals like Cologne, the coloured tradition was preferred in the Holy Roman Empire, so other strategies were also developed by Germans to increase the content of white glass in windows without resorting to dedicating large areas of window space to grisailles. One method, essentially equivalent to canopy accentuation, placed grisailles within the window’s depicted architecture (Grodecki and Brisac 202). Another means of increasing white space included the filling of the upper portion of the window above the canopy with grisaille glass, readily demonstrated by the St. Thomas window at Strasbourg dating from 1325 (202). The expansion of white space within the upper part of a window was a popular convention in Germany starting, according to Sherrill, in the late Thirteenth century, and executed in the cathedrals of Shwabishgmund, Schegerkapelle, Nuremburg, Freiburg, and Munich, among other places (Sherrill Austria 12). This strategy ensured both adequate lighting as well as coloured panes at eye level, although the increased contrast associated with this setup provided a substantial drawback (12-13). During the Late Gothic era, the white glass was replaced with whiter, more transmissive panes (22).

Another Fourteenth century strategy for increasing interior lighting while maintaining a largely full-colour tradition included the use of what Sherrill describes as “geometric glass” (Sherrill Austria 16). Geometric glass uses “light admitting geometric patterns,” or a pattern of white glass decorated heavily within a pattern of coloured glass (6). The effect of geometric glass is similar to the Late Twelfth-century glass (1176-1180) of St. Rémi in Reims, France (Caviness 186, Grodecki and Brisac 202-203). This influential Early Gothic church retains much of its original glass in its choir clerestory and triforium, largely a full-colour scheme with each window
heavily saturated. The overall impression of this interior is relatively dark (Caviness 186). In many ways, however, St. Rémi represents a relatively unique development in early stained glass; instead of adopting the dark, rich blues and reds of St. Denis, St. Rémi possesses many pastel colours, such as green, red and purple, giving in places a greenish-white effect (185). The aisle, clerestory, and tribune glass cover much of the wall space in the choir, providing a large abundance of window space generally, which probably provides adequate lighting under sunny conditions (180). However, in many of the triforium windows, St. Rémi possesses what has sometimes been referred to as thick, rich ‘coloured ornamental grisaille,’ with lights filled with alternating white and colour mosaic pieces, often forming a wide border framing a coloured figure (186). The choir at Orbais may have also had similar early combinations of alternating colour-and-white mosaic glass, although as Caviness indicates, “the overall effect of true grisaille ornament is much lighter than the impression that can be gained from the single light in the tribune of Saint-Remi that is entirely filled with coloured ornamental glass” (186, 188). Even though pure grisailles are more effective in transmitting light, geometric glass such as that provided in the early example of St- Rémi rejects the lifeless glow of grisailles and allows a church to retain its richer full-colour characteristics. In other words, despite the limited increase in transmittance, this kind of grisaille-colour combination seemed to be popular in parts of Germany, which perhaps indicates a cultural concession to keep colour. Sherrill probably describes geometric glass best when he states that “even when the Fourteenth century demanded grisaille, he [the German glazier] touched it with colour, shot it through with brilliant lines, embellished it with rich bosses and borders as to make it far warmer and richer than France’s pale quarries or England’s silvery grisailles” (Sherrill Austria 29).
Cistercian monuments also appeared to retain large grisaille windows, although many churches in both France and Germany were beginning to scale down on the edict by St. Bernard in the early-mid Thirteenth century, or at the very latest by the Fourteenth century. As a result, coloured glazing began to be used in Germany in the Fourteenth century, so Cistercian institutions provide an interesting example of increasing colour saturation and may reveal at which point windows were considered overly saturated with colour. The transition was gradual, with economical blankglazing used for many of the Cistercian institutions after the edict, and few institutions as a whole, except the most elaborate, likely used any kind of full colour program before the edict’s passage in the middle of the Twelfth century (Hayward Glazed Cloisters 96). The cloister glazing in the Babenberg window of the Brunnenkapelle in Heiligenkreuz also provided an important example of the introduction of the full colour tradition in the Fourteenth century, with a geometric style used in tall four-lancet windows and an abundant use of lighter colours, which pervade the window beyond the relatively small, medallion-like enclosing of the figural rows provided in the middle two lancets (103). At Altenberg, on the other hand, Cistercian glazing with an abundance of grisaille remained important, but colouring was also included to provide an effect, according to Hayward, similar to the cathedral glazing of the second half of the Fourteenth century in France and England (104).

Other trends in stained glass design demonstrate a general interest in increasing interior light after 1300. Grodecki and Brisac (207, 211) note that tones generally did become lighter with time. In addition, like in France and England, attempts to increase the translucency of stained glass appear to have been in full swing before the widespread adoption of silver stain, which became prominent in Germany at a relatively late date of 1350 but remained a crucial element of stained glass design until 1500 (Sherrill Austria 21). The choice to use silver stain
also increased the transmissivity of windows. Early examples of silver stain are visible in Konigsfelden, a vital monument of upper Rhenish workshops glazed (1325-1330), provided with bright colours and silver stain highlights in the architecture along with attempts at Italian perspective (Grodecki and Brisac 208-210).

After the beginning of the Renaissance, enamelwork dominated stained glass in Germanic lands (and enamel glass reigned supreme from 1500 to 1650) (Sherrill Austria 22). The simple process entailed painting on a surface of (usually) white glass followed by glazing it in a furnace (22). Like much of the rest of Europe, the lands of the Holy Roman Empire developed strong pictorial traditions within glass, which transformed the landscape of the window. German artists were heavily involved in this transition, and designs developed by the influential Northern Renaissance artist Albrect Dürer and other artists spread not only across Germany but also into France and later England (Richard Marks 46, Raguin 114-115). Even following the Reformation, an age in which a prevailing attitude of iconoclasm ceased stained glass production in England and quelled it in other parts of Europe, Swiss glaziers maintained glazing programs in Protestant and Catholic churches alike. Many of these windows possessed large areas of white, light blue, and silver stained yellow. Raguin also notes that in German churches at the beginning of the Sixteenth century glaziers applied large amounts of silver stain, producing a general golden tonality (Raguin 104). At this time conversion to old themes in glass were popular, although windows were still maintained with bright, translucent colours.

The Renaissance clearly marked an age of high transmissivity glass in Germanic lands as well as other non-Mediterranean parts of Europe. Therefore, clearly, despite the maintenance of the full colour tradition into the Fourteenth century, a variety of grisaille-colour mixes and brighter colour combinations generally tended to produce lighter, higher transmissivity windows
before the conversion to silver stain, and the increase in translucency was complete by the
Fifteenth and Sixteenth centuries. This transition, seen ubiquitously in northern Europe, despite
different cultural traditions and stylistic developments, and the lack of such an evolution in the
south, suggests not only a broader northern style but also perhaps external northern influences
such as that which the climate change hypothesis affords.

7 Mediterranean Stained Glass

While Italian and Spanish stained glass demonstrate remarkable stylistic and aesthetic
variation over the course of the late Thirteenth century to the Renaissance, in terms of palette,
Mediterranean glass varied little over time, using primarily deep colours with occasional touches
of silver stain and coloured ornamental glass (such as the ‘coloured grisailles’ of St. Rémi).
However, before evaluating the importance of stained glass transmissivity to interior lighting, it
is important to note that stained glass was relatively rare in both Spain and Italy as well as the
Mediterranean in general. The stained glass tradition itself was neither native to Italy nor to
Spain, and thus the style was diffused through cross cultural currents. The Gothic style itself was
still a relatively new architectural language to Italy by the age of Giotto (~1300), and Gothic
cathedral construction in some areas of Spain was limited by the efforts of the Reconquista.
Also, the Romanesque tradition prevailed in Italy, Spain, and southern France even more than in
Germany (and even today a great number of churches in the Mediterranean were never built in
the Gothic style and remain Romanesque or mixed Romanesque-Gothic in style). In France in
particular, the general cutoff point between the two styles is the Loire Valley, with Gothic
prevailing north of the Loire and Romanesque south, and the same is true for other climatic
architectural adaptations, such as pan roof tiles (see Atlas de la France Romane).
In addition, stained glass was often only adopted in certain regions. For example, stained glass is very common in Florentine churches from the Late Medieval and Renaissance eras, and it also common during the Renaissance period in parts of northern Italy, such as Milan and Venice, as demonstrated by programs in San Giovanni e Paolo (Venice) and Milan Duomo. Also, the spread of stained glass was limited by an actual lack of need for it; for example, when the Gothic style translated to Spanish and Italian churches, it often took on much smaller windows than those seen in England or France. The same is true in parts of southern France, where relatively thin windows taking up a limited proportion of the wall space were decorated with grisailles or sometimes mixed windows (Grodecki and Brisac 175). Simply put, glass houses were rarely (if ever) attempted in the Mediterranean, and when particularly large windows were introduced to a Mediterranean church it often derived from external influences, such as at León Cathedral in Spain or some of the churches of Naples under Angevin rulers (188). Indeed, vast walls of glass such as the Great East Window of Gloucester would be unthinkable in Tuscany or Catalonia, where mean conditions associated with bright sunshine would likely introduce exceptional glare, especially given the high transmissivity of large grisaille or quarry windows (Sherrill Austria 11).

The adoption of slightly larger Gothic windows, on the other hand, did often bring about the inclusion of stained glass, and this glass often adhered strongly to the full colour tradition (so that, as Sherrill suggests, excessive brightness could be avoided). One example of the larger window-full colour strategy can be found at León in Spain. This cathedral is located far from the French border, but it experienced strong influences from France and Northern Europe in general as a primary pilgrimage stopping point on the route to Santiago della Compostella (Grodecki and Brisac 188). León remains one of the earliest glazing programs in Spain (as much of the Iberian
Peninsula at the time still used Islamic-style apertures), and it possesses stained glass from the second half of the Thirteenth century to the Renaissance, thus displaying the full array of stained glass evolution in Spanish lands. It was built by a French architect and maintained a pierced triforium, similar in plan to Reims cathedral (188). León received substantial patronage from King Alphonse X (northern Spain) as well, who commissioned stained glass in his own palace and is also thought to have advocated the use of silver stain techniques in a well-known document on the subject (as described above). Alphonse X also directly encouraged stained glass practice by declaring León’s glaziers exempt from taxes in 1277 (Sherrill Spain 45).

However, the Thirteenth century glass present at León, mostly datable to 1260-1300, does not demonstrate any adherence to the grisaille-type programs growing in popularity in France, England, and gradually in Germany, nor does it make any use of silver stain (even windows believed to be from the King’s palace do not possess silver stain, being composed of pot metal mosaic glass). In fact, quite the opposite, thick, coloured mosaic glass with heavy enamel outlining (and coloured canopies) characterizes the glass, similar, as Grodecki and Brisac (190) suggest, to the saturated windows in France dating from the 1240-1250. In addition, the same authors actually claim in a rather disparaging manner that León’s glaziers were “so dependent on the archaizing principles that had become outmoded from the third quarter of the Thirteenth century” (190). However, while the adoption of grisailles by 1300 may not make sense from the perspective of Northern glass, the full colour windows do appear to have a strategic purpose from a climate perspective. They also suggest that the Mediterranean maintained a tradition that generally expected direct solar radiation to satisfy interior lighting needs.
Stained glass grew slowly in popularity in Spain during the Fifteenth and Sixteenth centuries, with programs being executed in the windows in the cathedrals of Toledo, Granada, and Seville, many of which were composed by foreign artists (particularly from Flanders, which was part of Spanish territories during this particular time). Also, Flemish stained glass compositions, with their pictorial effects and remarkable detail, were becoming popular throughout Europe as well). According to Sherrill, however, certain techniques that provided increased transmissivity, such as enameling, “was not welcome in Spain, and deeper glass was preferred for shading” (Sherrill Spain 28-29). Flash glass, however, was popular in Spain, and thus transmissivity measurements need to be taken on this glass to see if it differs generally from the often light toned flash glass of Northern Europe in terms of transmissivity. Sherrill in particular maintains that the deep colour was necessary, and in other cases where windows were too bright they are often blocked up by stones or alabaster slabs, which has been the practice at Seville, Tarragona, Oviedo, Segunto, Valencia and León due to intense direct radiation (39).

Similar trends in stained glass can also be observed in Italy. The new basilica of San Francesco in Assisi provided the first stained glass program south of the Alps, and this important church was not surprisingly also the first major expression of Gothic architecture in Italy (in fact, the Franciscan movement greatly influenced the diffusion of Gothic architecture) (Martin 177). The stained glass executed in Assisi’s rather large windows for Italy (but significantly less extensive than the French windows of the time) were done in a full colour program, with some white mixed with colour in some windows but others dominated by stronger colours with dark greens and blues (Grodecki and Brisac 224). However, other authors, such as Martin, suggest that an Italian artist (rather than German glaziers) were responsible for the stained glass in Assisi, and that this glass, richly coloured, was perhaps influenced by Pope Innocent IV’s expressed
disapproval at the consecration of the basilica (the pope had just returned from exile in Lyon, where he had been exposed to the stained glass tradition) (Martin 177). The artist or artists demonstrated strong adherence to the richly coloured painted tradition in Italy, and even expressed the prevailing Maniera Greca (Greek Manner style prevalent in late Thirteenth century Italian art) in their work, clearly demonstrating the prominence of the painted tradition in glazing (180). Some windows in Assisi have coloured St. Rémi-type coloured grisailles, but in general, very similar to St. Rémi, the tradition maintained in Assisi was full coloured and the overall effect rich (179). Unlike French cathedrals, such as Chartres and Sainte Chapelle, where the glass itself provided the dominant aesthetic, the Italian basilica also hosted a number of richly coloured frescoed by the greatest artists of the day, and in order to be fully appreciated they had to be adequately lit, and apparently the full colour glazing of Assisi satisfied this need.

Other churches in Italy, particularly those around Florence, also demonstrate the importance of a full colour tradition in Italy from the Thirteenth century well into the Renaissance. For example, in Siena, stained glass was applied to windows in the Duomo during the late Thirteenth century, with mosaic-style glass and yellows, reds, and blues dominating the composition (Grodekci and Brisac 227). In Florence, the first stained glass in the city was adopted at the Bardi Chapel and the nearby church altar, maintaining standing saints in tabernacles not unlike the northern formula (and probably stylistically influenced by French glass) (Cook 266-267). In these windows, however, white was avoided except for narrow borders, quite unlike the increasingly grisaille-engulfed saints in the north. Other stained glass windows were supplied to relatively small, half-circle windows in Renaissance churches throughout Florence following the Bardi Chapel (such as in Santa Maria Novella and many other churches in town), sponsored primarily by patrons. Even the relatively small, early Gothic-sized
windows of the Florence Duomo are decorated in coloured stained glass designed by such Renaissance masters as Ghiberti, Donatello, and Castagno (Raguin 106-107).

In summary, Sherrill notes that “in sunny Italy deep colour continued throughout, and of course this was equally true in Spain and for the same reasons of strong sunlight” (Sherrill Spain 24). However, Sherrill does not consider the fact that the European climate was in a period of transition. Some climate proxies indicate that Mediterranean lands (at least those away from the Alpine region) experienced slower or less distinct climate changes during this time period, certainly not as prominent as the faster changes suggested for northern Europe. With slower or little changes in cloudiness and the continued dominance of the sunny Mediterranean climate, there would have been little need for change to larger windows and/or lighter tints of stained glass, and this appears to be what is observed. However, more research needs to be done to see if there is indeed a difference in interior lighting in southern churches by time of the Spörer Minimum (1500s), or a change in the transmissivity of well-preserved glass. However, it can generally be established that Italian glass, flashed or otherwise, used more reds and darker colours (olive, purple, and many others) and less white space and light blues as compared to, for example, Flemish glass.

8 Criticisms and Conclusions

The importance of stained glass to the aesthetics of Gothic churches and cathedrals cannot be underestimated, nor can its affect on interior lighting provided under different climate regimes be ignored. On a regional scale (for example, in northern France), trends in stained glass seem to only reflect aesthetic developments and perhaps, in some cases, economic, architectural, or cultural trends. However, when considering the tradition across Europe, a broader trend emerges that seems to be correlated to climate regimes. English glass is generally whiter than the
rest of Europe, and this is consistent with the fact that the English climate tends to be cloudier,
both in today’s warm period as well as likely in the previous one, than the rest of Europe. This is
especially true in northern England, where grisailles were always important, with southern
England seeing a little more of a transition between Canterbury to Westminster Abbey. In
general, English glass also remained highly translucent until the death of the tradition during the
Reformation.

In complete contrast to English trends, the Mediterranean glass tradition, which
essentially began in the mid to late Thirteenth century, did not adopt England’s white grisailles
but instead chose a full colour tradition (and maintained much smaller windows than in England
all the same), and full colour windows remained important through the Renaissance in the same
way that white glass (or lighter toned flashed glass) predominated in England through the
Renaissance. While cultural differences and the aesthetics of lighting may play key roles in
these different interior lighting conditions, the fact that the Mediterranean’s sunny climate
provides completely different daylighting needs than England’s cloudy climate, and thus climate
may indeed be an additive, enriching factor affecting stained glass development.

Between the two extremes lies France, and with a rapidly changing climate beginning as
early as the late 1100s and cooling substantially below the MWP average by 1300, the changes
in climate might have affected the evolution of stained glass from one that seems more
Mediterranean in terms of its lighting requirements to one more northern over the course of the
Thirteenth century. This trend is not dramatically apparent, however, until about 70-80 years
after the cooling began. If cloudiness was increasing, French architects, glaziers, and church
officials studying past works may have been increasingly dissatisfied with the aesthetics
produced by their forefathers and allowed their new work to transmit more light as needed. The
fact that several full colour windows in Chartres were replaced in the late Thirteenth and early
Fourteenth century in favour of predominately clear glazing seems to demonstrate this overall
dissatisfaction, and in a case where formalist arguments cannot apply (because the interior
architecture of the cathedral remained relatively constant at that time).

However, as has been demonstrated, the issue of climate connection to interior lighting is
a complicated one. The dramatic transition from full colour to brighter interiors in French
cathedrals has been thoroughly noted and discussed by many art historians, who all generally
agree that the increase in whiter glass evolved from a desire for more light. A variety of other
factors are equated into this brightening of cathedrals, making the picture more complicated than
just a simple climate-glass relationship. For example, economic concerns may mandate grisaille
austerity programs or in general provide incentive to use white glass (which was often half the
cost of coloured glass, at least as quoted in most English glazing fabrics). In addition, it is
possible that the waning of the enthusiasm for great cathedral construction which had so
characterized the early Thirteenth century had an impact on glass palette, and economic
constraints following a relaxation of zeal might have lead to a whiter palette; however, at the
same time personal (family, guild) patronage was becoming more important during this time
period, and each window needed to express the splendor of the donor’s legacy. In addition,
expense appeared to be applied to increasingly complex tracery, and thus a waning of religious
zeal does not seem to have led to increasing austerity regarding cathedral aesthetics. Nor does
this explain the return to more coloured glass during the Renaissance when purifying methods,
flashing, and enamels lead to more translucent glass.

Another often-discussed theory is that silver stain led to a lightening of tones and colour
palettes. While this may be true to a certain extent, it also allowed the expansion of colour
(yellow tones produced by silver) into regions that would have otherwise been filled with grisaille. In other words, the widespread adoption of grisailles in the second half of the Thirteenth century, well before silver stain was in use in window design, indicates that the desire for more light precedes this technological innovation. Other technological innovations, such as the thinning of glass, increasing size of panes, the use of new flashed and enamel methods, and the invention of better purification processes also likely increased the translucency of glass after the Thirteenth century as well. Although this is an easily quantifiable influence, the fact that grisaille use was increased before these major developments suggests that some other impetus led to the change in interior lighting conditions (although the technological changes may have helped make increases in interior lighting more permanent).

Another potentially influential factor leading to the observed brightening could involve general theological and philosophical outlooks, with the increasing prominence of Augustinian tradition (emphasizing light) over the Dionysian tradition (promulgating reflection on the unknown god) (Lillich Armor 6). However, as demonstrated by Suger, how light something is perceived to be is a relative term. But on a broader level, aesthetic philosophical outlooks may in turn be related to a general ‘aesthetics of light’, which may change over time as well. Church officials and laypersons, coming out of the relatively dark Romanesque interiors, may have gradually adjusted to higher lighting levels and come to expect more and more interior lighting, thus intentionally commissioning churches with lighter and lighter interiors and providing a completely new religious environment. Light as an aesthetic is perhaps secondary in importance after economic concerns, and this factor is even more difficult to conceive as it is virtually impossible to prove or take into account on a broad level, except to note cultural factors that may
lead to darker interiors, such as the German adherence to the full colour tradition throughout much of the Thirteenth century.

Another theory is the often-quoted formalist’s argument that increasingly complex architecture, such as tracery and the delineation of architectural forms inside cathedrals, mandated the conversion to whiter glass. This argument may well provide some explanation of the observed trend, but it is not nearly as strong as the economic arguments, as cathedrals such as Tours, which helped develop the band window (or was among the earliest to adopt it), did not possess an intricately carved interior. Also, quite a few major constructions with delicate interior decoration and architectural forms, such as Le Mans, Sainte Chapelle, and various German churches, used coloured glass in spite of the formalist argument. In addition, it can also be considered that some of the increasing architectural complexity and window tracery was a response to fill some of the aesthetic void caused by an increase in white glass.

Also, a different interpretation on the conversion from strongly coloured to strongly white interiors in France and England has been heralded by Robert Sowers, in which he claims that “Sainte Chapelle was too much light for its time,” and that “backlighting” from direct sun coming through the south windows serves to literally blacken the colours on the north windows (Sowers Stained 24). This is indeed true, directly observable on a sunny day in the chapel. He claims that as a result of increasing window size, Medieval architects needed to provide better equalization of light between the outside and inside, and they did this by using grisailles and higher transparency windows. However, this theory has several faults, as it can be readily demonstrated that backlighting is just as much a problem in Cologne Cathedral on a sunny day (with the choir band windows on the north aisle often turning black). The same phenomenon is visible in Chartres, where newer grisailles produce excessive backlighting on nearby early
Thirteenth century full colour windows, although in chapels where only full colour windows exist there is little mutual effect of backlighting (or not enough to be readily apparent visually). Similarly, in Le Mans Cathedral on a sunny day, virtually no backlighting can be detected by the human eye, with the southern windows still visible when the northern windows are illuminated by direct sunlight, and vice versa. Therefore, the need for equalization of light is a more dubious explanation, especially with the problem of backlighting seemingly more extreme for grisailles than for full colour glazing programs (and is probably more a function of the width of the enclosed space and height of the individual windows).

In closing, the evolution of stained glass in important Medieval European cathedrals provides a unique opportunity to study the potential influences of climate regimes on how societies conceive lighting design. Daylighting was particularly important in the Medieval Period in the absence of strong artificial lighting, and the evolution of stained glass and its role within the architectural framework may, as discussed above, provide an indication of changes in conception of daylighting, and, as a consequence, indirectly infer information regarding changes within the climate regime (with particular respect to cloudiness, which often determines daylighting design according to modern theory). While other factors are likely at work in this evolution, a quantitative analysis of stained glass in different regions and changes over time in the same region (with comparison to available proxy data concerning temperature and precipitation) will likely provide a useful indication of the degree that the changing climate may have influenced stained glass and interior lighting design according to the qualitative arguments already presented above.
Glossary of Fenestration Terms

Aisle Windows: Windows that are located along the side aisles or ambulatory of the church (these are the lower windows closer to ground level), often maintained in side chapels of the nave or ambulatory. The aisle arcade, which separates the nave and side-aisle, is open so that aisle windows can also be seen from (and provide light to) the nave and choir (when a choir screen is not present).

Canopy: An architectural device depicted in stained glass that mimics a niche. The importance of the canopy increased considerably in the late Thirteenth century and remained a prominent device through the Fifteenth century. In Early Gothic, High Gothic, and Mediterranean glass, the canopy was often constrained in size and possessed rich colour; in Rayonnant, Decorated and Late Gothic Northern European glass, canopies were often predominately white or yellow stained and occupied much of the window space, acquiring pinnacles and greater detailing through the Late Gothic era.

Clerestory Windows: The upper level windows of the church and the primary providers of interior light within Romanesque and Gothic churches, particularly within the nave and choir. However, sacred gothic architecture developed such that clerestory windows are often readily visible in the opposite nave or ambulatory aisle of the church to provide additional lighting and visual interest to these regions.

Crosshatching: A mode of decoration in which white glass is given additional texture by applying intersecting black lines of enamel to them. Crosshatching is also called cages à mouches, and it reduces the transmissivity of white glass. It was most common in the Thirteenth century.

Enamels: A term for the black or brownish glass paint, with a low melting point, applied to a window surface to provide figural details. Enamels during the Medieval period were often thick and reduced the transmissivity of the glass panes on which they were applied. During the late Middle Ages and Renaissance they were thin and more liberally applied to create fine details, often providing the only colour to the glass and thus allowing greater translucency. Enamels are also believed to better protect the glass from vitreous network destabilization.

Grisailles: A term that applies generally to windows of the Twelfth, Thirteenth, and first half of the Fourteenth century that are kept predominately white, often provided with geometric forms or foliated patterns, sometimes relieved by small bosses of colour. Early white windows from the Twelfth or Thirteenth centuries also often possessed a grayish (grisaille in French) hue. The term ‘grisaille’ can also refer to the enamel itself that is applied to stained glass to provide additional details, and backwash grisaille is a term used to refer to a very light darkening wash applied to many Thirteenth century windows.

Lancet: A window aperture, longer than it is wide (and usually placed directly adjacent to other similar windows), and bordered by mullions or trumeaux.
**Lead Cames:** Thin strips of lead that were molded around individual glass panes. They play a vital role in pictorial outlining in the mosaic glass of the Thirteenth century. Lead cames themselves did not provide enough support to secure window glass, and thus additional iron support bars were also required.

**Mosaic Glass:** A form of window glazing in which small strips of glass are cut and welded together using lead cames. A distinguishing feature of mosaic glass, particularly that of the Thirteenth century, is that it often contains dozens of separate pieces of glass within a small scene and possesses relative opacity compared to earlier and later glass.

**Medallion Windows:** A style of stained glass arrangement in which individual, usually narrative or foliated, scenes are separated by medallions formed by iron support bars (which can themselves be welded into a variety of shapes). Medallion windows are most typical of the mosaic glass of the Twelfth and Thirteenth centuries (legendary windows) and are often fully coloured, although the medallion format is mostly determined by the arrangement of iron support bars and could also be used in Thirteenth century grisailles. Otherwise, the term medallion by itself may refer to the regular lead-support divisions in the windows.

**Quarries:** White glass composed of diamond or square-shaped panels arranged in a pattern, free of crosshatching and allowing for minimal lead came usage. Quarries were popular in Northern France and England from the mid Fourteenth century to the Late Gothic period.
A Guide to Medieval Architectural Periods and Terms

Approximate Dates for Architectural Periods

**Early Romanesque**: 950 - 1080 A.D.
**High Romanesque**: around 1100 A.D.
**Late Romanesque**: 1130 - 1200 A.D.
**German Late Romanesque**: 1140-1215 A.D.

**Early Gothic**: 1140 - 1215 A.D.
**High Gothic**: 1215 – 1240 A.D.
**Rayonnant Gothic (Decorated)**: 1240 - 1300 A.D.
**Flamboyant Gothic (Perpendicular), also Late Gothic**: 1300 - 1500 A.D.

Architectural Terms

**Ambulatory**: A passageway, usually partly semicircular, that extends around the choir to allow the circulation of people through the church.

**Apse (Apsidial)**: Most often used in reference to the easternmost radiating chapel (aligned with the main axis of the church) or to the circular or semicircular end of the church formed by the chevet. (Apsidial--relating to an apse).

**Buttress**: A structure used to support the thrust of the ceiling vaults of a church or cathedral, often extending beyond the exterior wall (however, internal buttressing is also used in some locations).

**Buttress Pier**: A tall, narrow tower extending upward from the aisle level to support buttresses flying outward from the upper clerestory or roof level.

**Choir (Quire)**: The eastern end of the church, where the altar is generally located.

**Clerestory**: The upper levels of the interior of a church, where large windows are often placed.

**Flying Buttress**: A buttress that arcs outward from the exterior wall, used in many Gothic churches (especially in Continental Europe).

**Jamb**: A figural sculpture placed to the sides of a portal in a Romanesque or Gothic church.

**Lintel**: A rectangular frieze above the door but below the tympanum in a portal, sometimes stretched beyond the portal along the sides of the building in Romanesque churches (but often contained to the portal in early Gothic churches and eliminated altogether in later Gothic churches).
**Pinnacle:** A steep, small, spire-like extension that often sheds rain outward and provides stability to buttress supports.

**Nave:** The main centre aisle of the church before the choir and crossing (western half of the church). On Latin cross church plans, it corresponds to the lower vertical component of the Latin cross church plan.

**Radiating Chapel:** A small chapel attached to the wall of a church, usually radiating outside of the main body of the church off the semicircular ambulatory.

**Spandrel:** The wall space between individual arches in an arcade, usually lining near the mid levels of a church and often decorated with paintings or mosaics in the Romanesque period.

**Tracery:** Thin, often curving stone decoration added to windows or architectural facades.

**Transept:** A north or south aisle extending away from the main aisle of a church; on Latin cross church plans, the transept are the wings making up the horizontal component of the cross.

**Tribune Gallery:** A passageway at the mid level of the church, formerly used to hold persons directing a service.

**Triforium:** An arcade (series of columns and arches) at the mid levels of a church between aisle level and the clerestory, most common in Romanesque and Early Gothic churches usually possessing a tribune gallery.

**Tympanum:** A half circular or bent triangular stone slab above the doors in a church’s entrance, often possessing relief sculptures during the Romanesque and Gothic eras. This term can also refer to the upper part of a window with the same general shape as a portal tympanum.
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