Mechanisms of Visual Perception Related to Aspects of Gothic Cathedrals

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For most observers a Gothic cathedral is ineffably more than the sum of its appointments and its architecture. This discussion deals with physiological and subliminal mechanisms which may in part account for impressions sustained by observers. Recent scientific literature has attempted to trace psychological responses to specific perceptual stimuli. Assuming the vantage point of those theories and data can help the art historian to understand the introduction of achitectural elements for the purpose of affecting the viewer's emotions in a specific direction.

In their article "Aftereffects in Visual Perception" Favreau and Corballis explore visual phenomena in order to discover how the sense organs and the nervous system function in processing information.[1] Based on the hypothesis of J. J. Gibson we shall explore the negative aftereffects and negative afterimages in terms of deviations from an established norm.[2] When one is exposed to any given figure or image for a period of time, the figure or image becomes a norm. Hence new figures viewed after this adjustment are understood in relation to this 'norm.' Gibson gives an example of this phenomenon: a line tilted slightly from the vertical might induce the observer to recalibrate his conception of the vertical toward the line. A truly vertical line would then be seen as being tilted in the other direction.[3] The authors accept this reaction only as a special case since not all aftereffects involve obvious norms (such as the true vertical or horizontal). They therefore rely more heavily on concepts involving the neuro-physiology of the visual system.

Physiologically negative afterimages emerge in the retina and the neurons beyond the receptors, that is the bipolar and ganglion cells, and possibly in the lateral geniculate nucleus. After long stimulation, the cells in the retina and the neurons adapt and become less responsive. The opponent-process cells tire, and fatigue leads to the misinterpretation of images. Unlike afterimages, motion aftereffects depend on phenomena that probably take place in the visual cortex. According to Hubel and Wiesel[4] three types of neuron cells are found in the visual cortex. Simple cells respond to edges, slits or lines which must be precisely oriented in the visual field to cause the cells to respond maximally. The complex and finally the hypercomplex cells react more specifically. Their response may be contingent on a preferred stimulus in motion. N. Stuart Sutherland suggests that these neurons are also subject to fatigue and can produce motion and orientation aftereffects.[5] He asserts that perception is the result of an averaging of neuron activity. When we shift our attention from a stimulus that has created a bias of activity by tiring certain neurons, the new stimulus is analyzed by an unbalanced system. This results in distortion.

Some researchers have stipulated neurons that deal with several aspects of a visual stimulus. McCollough has demonstrated the function of line detectors as recipients of color and orientation, and has established their presence in the visual cortex of the cerebrum.[6] Hepler, Stromeyer and Mansfield have discovered color aftereffects contingent on the direction of motion. Favreau, Corballis and Victor F. Emerson have confirmed color-contingent motion effects.[7]

All these phenomena presume the existence of highly specific feature detectors, even if some scientists believe that neurons in the brain deal with more general visual components such as spatial frequency. Specific neurons in the cortex of animals, for instance, respond to stimuli only within a narrow range of spatial frequency. Others believe that independently functioning neurons become associated with the visual process. This association is learned, proven by the fact that figural and motion aftereffects transfer from one eye to the other, while contingent aftereffects, where one component is color, do not. Contingent aftereffects require input from both eyes since the neurons do not seem to transfer information across separate neural pathways, each of which can form different associations. More evidence for this theory is given by the persistence of many contingent aftereffects. The fact that they remain as long as a week cannot be explained through fatigue.[8]

Masland has hypothesized that the combination of fatigue and the formation of associations may explain the lingering of an aftereffect which has physically faded. Associations through information from more specific receptors would converge, interact, and then be stored through a higher level of processing. These associations—unlike the lower levels of visual perception—can become long-term adaptations.

Using a computer system that allowed him to analyze the stimuli presented to each eye, John Ross has recently presented intriguing explanations of depth-perception.[9] The two dimensional information provided by two disparate, though very similar, images is organized by means of a conceptual framework, using insignificant cues to create the third dimension without three dimensional stimuli. Learned spatial relations have turned into an automatic system of interpretation and the response is the "creation" of a three-dimensional image. The modular organization of architectural elements in Gothic cathedrals incorporates numerous spatial frequencies. Large expanses are structured by repeated elements such as arcades, triforum galleries, ribbed vaults (Fig. 1). As analyzed by Corballis and Favreau, our perception of spatial frequencies may be due to neurons responsive to specific repetitive impulses. The resulting fatigue of the neurons may produce the experience of a kinetic effect. When one walks along the nave, the visual system adapts to a stable bias. Upon changing direction to enter a transept, one's attention is shifted to an alternate frequency, and the new space may be perceived as being wider or narrower depending on the bias created by the previous frequency. A rapid succession of such biases continually created and replacing each other may produce a feeling of motion. It can be hypothesized that the changing size of details such as the irregular juxtaposition of arches in the transept of Lincoln cathedral would not allow the visual system to adapt to one, predictable frequency, and consequently make it difficult to establish an actual image of space (Fig. 2). This taxes the expectation of regularity created through the perception of the nave to possibly create visual discomfort. Similarly the extreme vertical frequencies found in Amiens, Beauvais and Cologne may create a strong bias which would produce distortion when new stimuli are added (Fig. 3). This may account for the highly dramatic effect associated with these High Gothic structures.

The notion of fatigue produced by aftereffects can also be applied to stained glass. The windows often present extreme contrasts of light and color that the visual system must assimilate. Complementary colors or highly opposed bright and dark colors produce intensive stimulation of the visual cortex. Setting aside learned religious or aesthetic reactions, the rapid succession of visual stimuli demands a continual readjustment of neural firing patterns and thus puts a stress on the visual receptors of the retina. Afterimages produced by the windows with their high contrasts of color and the changing intensity of light versus the darkness of the architecture create an intense bombardment of stimuli. The afterimages move with the changing position of the eyes, resulting in neural fatigue and multiple strong afterimages. This may lead to an ethereal or even "psychedelic" response experienced by some observers.

In addition the phenomenon of subjective contours may play a major role in the perception of cathedral architecture. As explained by Gaetano Kanizsa the perception of contours which do not coincide with an actual object is a familiar occurence.[10] These distorted perceptions have certain attributes and can be created and explained in a number of ways. A contour that is not actually there but has a strong phenomenal presence, such as a circle, is referred to as an amodal contour. Modal contours also have no precise physical basis but they can be "seen." Subjective contours have two common characteristics: the area is brighter than the surroundings and the subjective contour seems like an opaque surface which is superimposed upon often similar elements. But symmetry is not a necessary attribute of a subjective contour which can also be generated by curved and irregular shapes. Subjective contours are low in resistance to interference. If a real line passes through such a contour, it will continue to exist, but is perceived as passing under the imposed shape. Subjective contours operate like real ones, but they belong to the realm of optical illusions. The contour can therefore be perceived as transparent. A contrast between light and adjacent darker areas, such as in a cathedral wall, would strongly enhance the perception of the bright areas.

A transept lit by a large rose window might therefore appear to be covered by a semi-circular vault and would therefore seem wider than the nave. Even without the contrast between light and dark, the powerful circular shape would tend to create a subjective circular contour of the adjacent zones.

Contour detector cells of the eye can also be activated by short lines in the visual display, and the lines are occasionally interpreted as one continuous line. Repeated elements in an elevation, even if they are a considerable distance from each other, can therefore be vertically or horizontally connected. Generally the brain tends to reorganize a multiplicity of surfaces and contrasts into a simpler and more stable visual grid, and to complete discontinous elements by connecting them within an artificially created surface on which contours are laid out in an orderly fashion. Because of the illusion of depth or, more correctly, layering allied with this phenomenon, Stanley Coren has suggested that the mechanism of binocular depth perception is also involved, and that the stratification of figures is a function of their completion.[11] This occurence is contingent on the probability and need for organization.

The vault of the chapel of St. Catherine in Strasbourg cathedral can be viewed in terms of the visual cortex's need for completion (Fig. 4). There is a relative weakness of rib contours to webbing surfaces. The creation of a straight plane is made extremely difficult by the curvature of the vault, and it is therefore almost impossible to see the basis of the linear design. The fact that it is based on interlocking circles is not easily understood by the viewer, because the circles are low in resistance to the interference of the many interlocking and incompleted lines.

Similar difficulties exist in the perception of buttressing systems (Fig. 5). The row of buttresses in Bourges is experienced as especially satisfying and elegant because the proximity of identical elements can easily be perceived as a steep plane. The absence of a transept enhances the illusion of the buttresses as a single unified envelope or a semitransparent plane curving around the chevet.

If the flyers are spaced more widely apart they can no longer be connected and become single, vulnerable "lines." Stalk-like buttresses appear around the apse of Notre Dame in Paris (Fig. 6). They are perceived as isolated entities rather than a continuation and are spaced apart too widely to satisfy the mind's ability for completion of the main body of the cathedral. The fluid function of the Bourges buttresses can be compared to the fluid function of a capital which connects the vertical supporting elements with a purely visual horizontal base for the system of arcades. In Amiens, on the other hand, the fliers are spaced more widely and are treated as sophisticated architectural decoration, and their complexity makes it difficult to perceive them as a single wraparound surface.

An image that tantalizes the mind's tendency toward simplification is the facade of Lincoln cathedral (Fig. 7). Many related elements seem to require completion, both in a horizontal and vertical direction. Ambiguous cues produce frustration. The towers are visually somewhat connected with the facade through a tenuous Norman vertical plane which corresponds to the outer edges of the towers. The connection is interrupted by a series of horizontals which are also vying for visual completion. Even the strength of usually stable subjective planes is taxed at the intersections of these horizontal and vertical thrusts. The large and deep central arch cutting through the facade is flanked by four horizontal stories creating a powerfully repetitive thrust, which is almost hypnotically enhanced by seemingly innumerable blind arches. One of these arcades holds additional structurally illogical decorative elements which reinforces the fascination with horizontals. The towers rise, set slightly back above this powerful middle zone design, and can not visually be reconnected with the plain remains of the Norman base. Similar visual tricks characterize the well-known "crazy vaults of Lincoln," and "sliding" rows of arches behind trilobed arches in the boys' vestry. In the corner these arches meet, and rise above the apex of the other arches, thereby indicating some sort of collision. Other highly precise and calculated irregularities in the treatment of large blind and fenestrated arches in the transepts attest to the consummate interest in optical tricks practiced by the English builders who must have been highly trained in architectural graphics (Fig. 2).

Surface color, recently treated in Jacob Beck's "The Perception of Surface Color" can also, on occasion, be perceived as "film colors" (*see* n. 11). While surface color is perceived as an attribute of an object, film color is seen as a homogeneous envelope varying in brightness, saturation, hue and lightness. These differences emerge when one views contrasting luminance variations. [12] According to Beck, colors such as olive green, gray and brown cannot exist within the range of film colors and thus emerge independently. Different textures also give rise to various reactions. The reflection of light may be confounded with our perception of a surface color. Discrepancies between reflected light from the surface, and light from the object itself can also change surface appearances. Beck suggests that we comprehend a pattern of reflected light as a single object. First the pattern of light is discerned by the sensory process, and then visual cues are used to organize the pattern.

Color constancy is the ability to separate the color of a surface from the intensity of the illumination. H. von Helmholtz proposed that we can weigh two components of the visual spectrum simultaneously, and that our definition of the surface color is determined by our gauging in hue and intensity of surface illumination.[13] Ewald Hering stressed the concepts of adaptation and contrast.[14] Accordingly our sensation of surface color depends on the ratio of contrast between an object and its background, the ration remaining constant in various illuminations. More recently it has been demonstrated that visual cues such as shadows and perspective cues which reveal spatial positions can also affect color perception. When cues for spatial position and luminance are not consistent, spatial accuracy takes precedence over color perception, and the area with less light is perceived as a surface of darker color. Three types of cones in the retina mix light to an additive color mixture. Subtractive color mixture is achieved when paints (hues) are mixed. The opposing wavelength produced by the particles of paint absorb each other, the median wavelengths remain to reflect more strongly. Hering assumes that the principles of subtractive color mixture dominate. Transparency effects are therefore not produced by the color receptory, but are perceived by the less complex process of absorption. Impressions of transparency are favored by stimuli that suggest depth and are enhanced by the tendency to see complete and closed figures (*see* n. 11). Most importantly the grasp of incidental illumination and cues for apparent spatial position most strongly influence the extent of retention of color constancy.

In the cathedrals an almost hypnotic effect is achieved by the interaction of the sculpted surfaces with light and color, and the mechanism of negative afterimages becomes strongly involved. Sculptures and the walls were covered with colors which themselves were illuminated by stained glass. It thus becomes difficult to differentiate the attributes of the visual display that are due to the painted surfaces from those that are produced by incidental illumination. Cues for the intensity of illumination and the "stability" of colors therefore become unstable. Chartres or the Sainte Chapelle, for instance, undergo dramatic changes in illumination due to the varying position of the sun and the movement of clouds. Colors constantly shift and the maintenance of color constancy is difficult and complex. Sculpted, painted or stained glass figures may seem to move soundlessly, within an ethereal realm. The loss of stained glass and of the painted decoration in most medieval churches has obviously changed their interior effect fundamentally. Some medieval sculptors adjusted their work so that—when viewed from below—the figures remain in proportion; they apparently knew that cues for spatial relations automatically take preference over those for illumination.

The general intuitive capacity of perception was exploited by the architects developing national styles. The highly logical and cerebral structures of French Gothic would appeal to viewers trained in an atmosphere of anthropomorphic art, whereas the highly complex elements of three-dimensional graphics found in English Gothic vaults, arches, hanging keystones or the scissor arches of Wells would appeal to a public trained in complex linear expression. English Gothic therefore might seem to violate certain conceptions that exist at a very deep level of cognition in France, while French Gothic might seem boring and predictable to the English cognitive system.

The complexity of these questions and the fact that they can only be partially answered demonstrates the need for a fuller understanding of our responses to art, responses which are inexorably linked to the biological mechanisms of perception.

1 O. E. Favreau and M. C. Corballis, "Negative Aftereffects in Visual Perception," *Scientific American*, 235, No. 6 (December, 1976), 42-48. See also Edward G. Carterette and Morton B. Friedman, *Handbook of Perception*, vol. I, Academic Press, 1973.

2 A negative afterimage is a dark image that remains on the retina after one has ceased looking at an object. A negative aftereffect is experienced after the viewing of an object moving in one direction. When one shifts one's gaze, the new scene appears to move slowly in the opposite direction.

3 Favreau and Corballis, p. 42.

4 *Ibid.*, pp. 43-44.

5 N. Stuart Sutherland, *see* Favreau and Corballis, p. 44.

6 Celeste McCollough, *see* Favreau and Corballis, p. 44.

7 Hepler, Stromeyer and Mansfield and Corballis, Favreau and Emerson, *see* Favreau and Corballis, pp. 44-45.

8 Favreau and Corballis state that Richard F. Masland demonstrated that his "spiral effect" can persist as long as 24 hours. The spiral is rotated on a turntable at 33 1/3 revolutions per minute, and when stopped it appears to move in the opposite direction. For Favreau the aftereffect lasted for a week.

9 John Ross, "The Resources of Binocular Perception," *Scientific American*, 243, No. 3 (March, 1976), 80-86. Ross asserts that moving objects create instantaneous spatial disparity, or a phase difference with objects passing through common reference points, and thus in both cases a perception of depth.

10 Gaetano Kanizsa, "Subjective Contours," *Scientific American*, 243, No. 4 (April, 1976), 48-52/11. See Kanizsa, p. 52 (St. Coren).

11 Jacob Beck, "The Perception of Surface Color," *Scientific American*, 233, No. 2 (August, 1975), 62-75.

12 Webster's *Third New International Dictionary* defines *luminance* as "The luminous intensity of a surface in a given direction per unit of projected area. . . the effectiveness of a given light on the eye regardless of its origin (R. M. Evans)."

13 Herman von Helmholtz, *see* Beck, pp. 67-68.

14 Ewald Hering, *see* Beck, pp. 67-68.

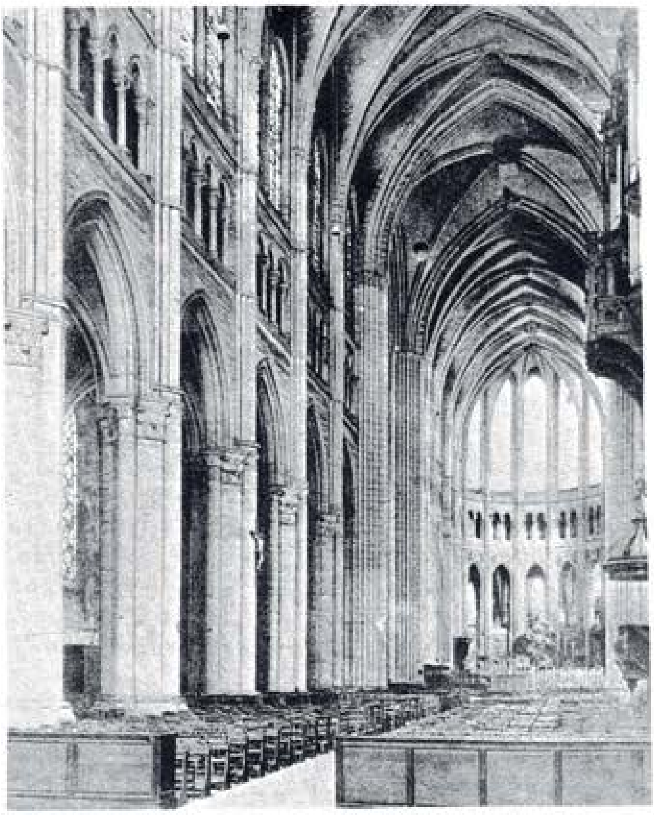

Fig. 1, Chartres, cathedral, interior.

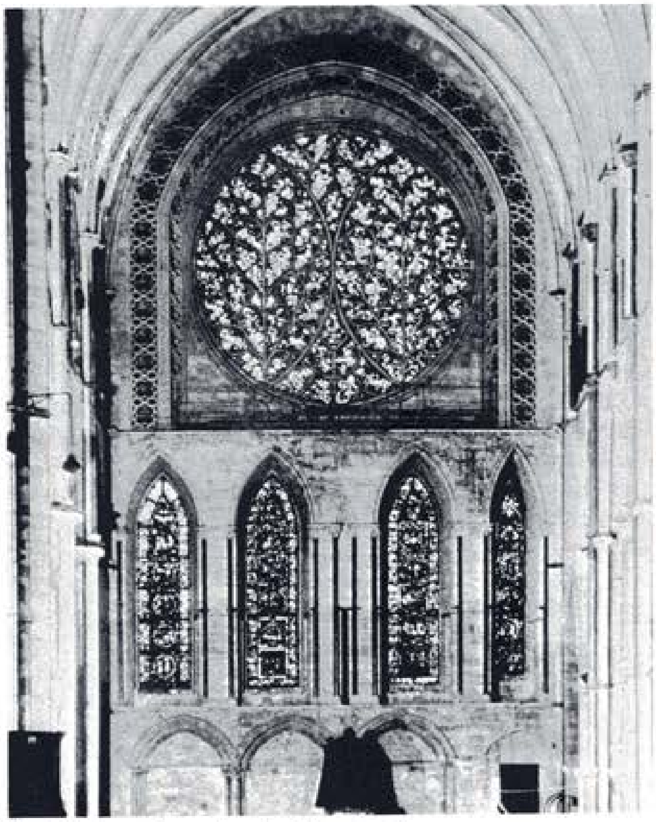

Fig. 2, Lincoln, cathedral, transept.

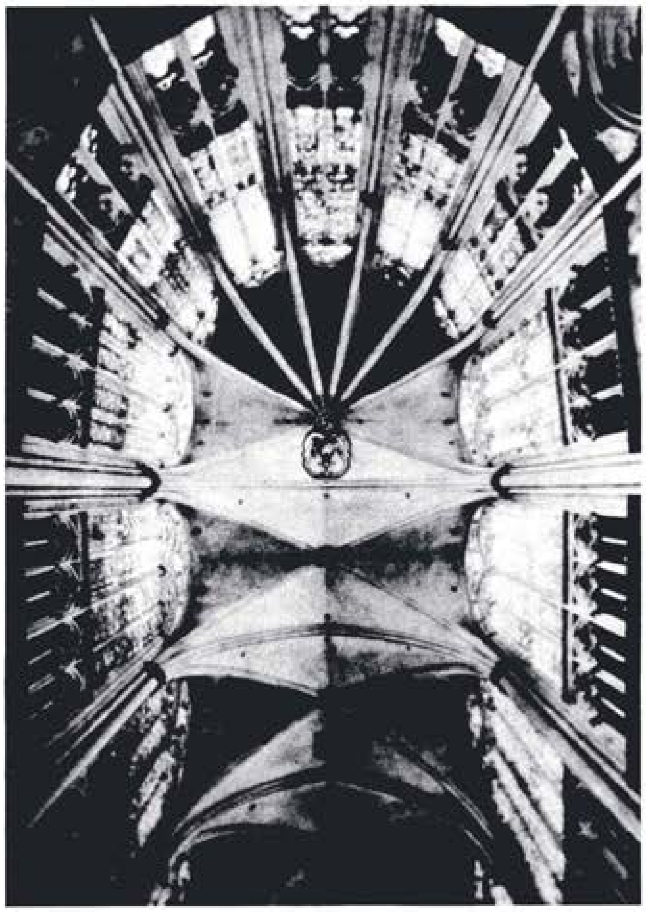

Fig. 3, Cologne, cathedral, choir.

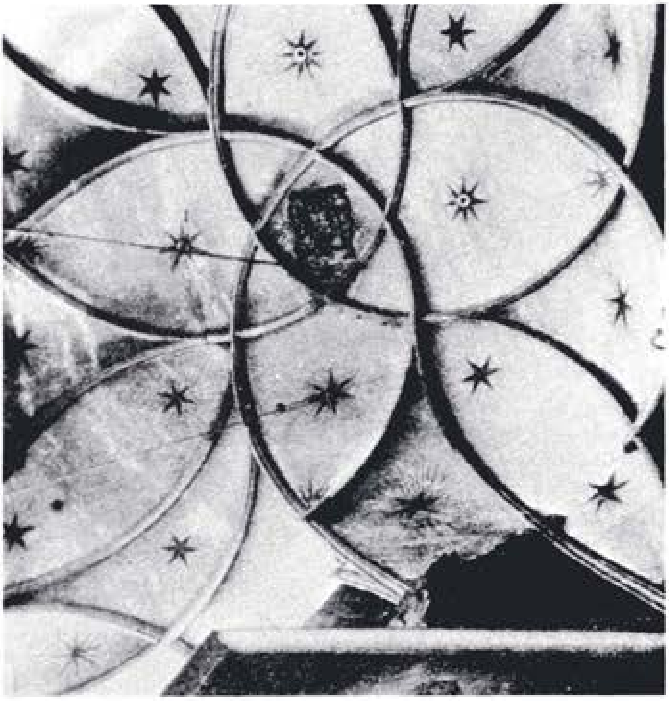

Fig. 4, Strasbourg, cathedral, St. Catherine's chapel, vault.

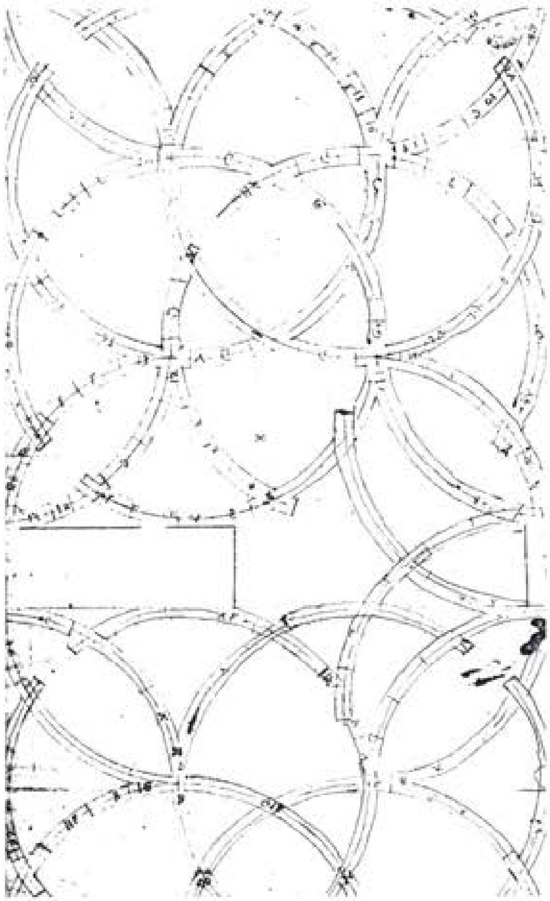

Fig. 5, Strasbourg, St. Catherine's chapel. Placement Plan. (By permission of Oeuvre Notre Dame, Strasbourg.)

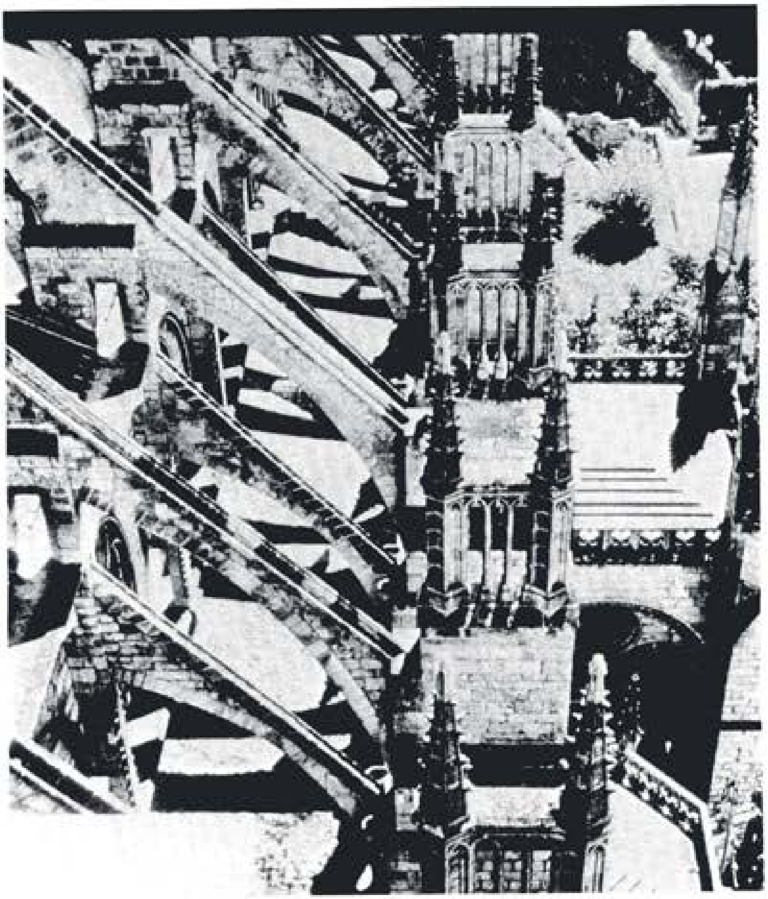

Fig. 6, Bourges, cathedral, buttresses, south.

Fig. 7, Paris, cathedral, apse.

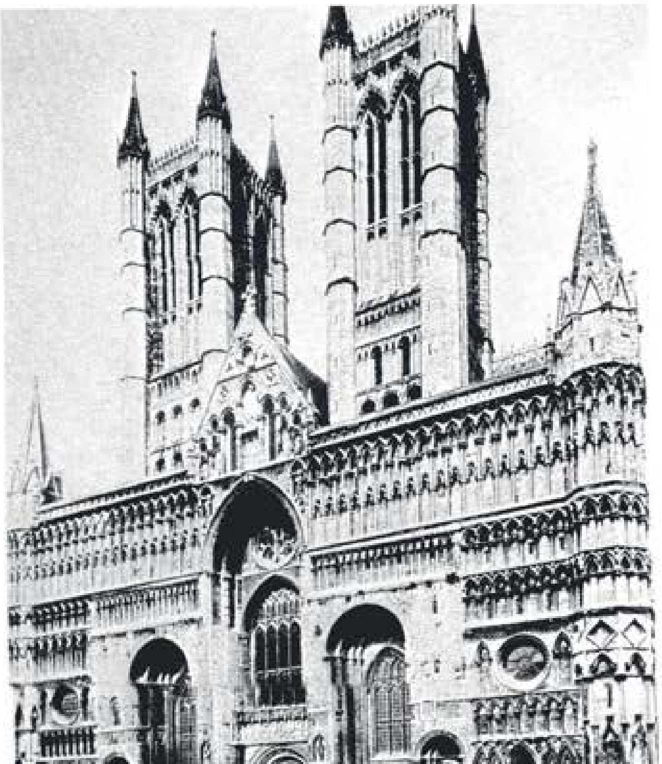

Fig. 8, Lincoln, cathedral, facade.