REVIEW LECTURE

MIRROR AND MAP: THEORIES OF PICTORIAL REPRESENTATION

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[Plates 12–22]

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Verbal descriptions, photographs and maps are reviewed for the kind of selective information they impart (§1). The need is established for a critical analysis of the assumption that we can not only map the invariant features of the physical world but also represent the optical world, the changing appearance of objects as it is conveyed to the camera and to the eye by reflected light. As long as this light was identified with the stimulus pattern causing visual sensations it could be assumed that appearances were uniquely determined and could thus be uniquely represented, but this view conflicts with the insight that there are many other variables influencing our visual experience. Visual sensations as such cannot be isolated by introspection but they can be aroused and manipulated by artifice based on the knowledge of the physiology and psychology of visual perception (painting, stereoscope, film, television). The surprise caused by such unexpected visual effects underlies the notion of illusion. Artistic experiments in registering and arousing visual sensations are discussed (§2).

These experiments show the need to give subjectivism its due without falling into the trap of complete relativism. It is here that the consideration of maps and mapping styles is helpful. The keys and symbols adopted by map makers suggest that visual conventions can but need not rest on arbitrary choice and are rarely devoid of psychological effects. These effects, however, are independent of the truth or falsehood of the information compiled by surveying instruments of any kind. It is possible to predict what aspect of a physical array will be visible from any given point in space (§3).

The theory underlying this prediction is that of central perspective based on the 'visual cone'. The procedure is not reversible, the information imparted by a perspectival representation does not uniquely determine the object represented. This multivalence of monocular stationary vision (the tracing on the window pane) has given rise to many psychological puzzles concerning the determinants of appearances such as the constancy phenomena (§ 5).

More recently J. J. Gibson has challenged the relevance of these puzzles and experiments and emphasized the resources afforded by the ambient light for the veridical perception by a moving organism of the invariant environment. This challenge has created a fresh problem for the theory of pictorial representation (including photographs) and made it more urgent to investigate the visual experience aroused by such representations in varying conditions (§5).

A comparison between the information conveyed by pictorial representations and the information picked up by the eye inspecting a real scene may provide opportunities for testing Gibson's account and help to clarify the limits of veridical perception. Probing reactions to distant prospects in reality, paintings or photographs may reveal that the experienced stability of their appearance can be upset. Even the clouds in the sky and the vault of heaven are subject to various perceptual interpretations which rarely impinge on our awareness. Far from justifying a representational relativism these variations confirm the need for an anchorage of representation in the objective procedures of perspective (§6).

It is suggested that the indeterminacy of visual interpretation disposes of the time-honoured problem of the apparent curvature of the phenomenal world. Demands for an alternative system of perspectival representation which appeal to this experience rest on a confusion between the mirror and the map. We can map the physical world but not its variable and shifting appearance. This conclusion, however, is not intended to discourage artistic attempts to record a visual experience. On the contrary: all experiments on the hoardings, on the screen and in paintings probing our cognitive and emotional response to images should be of interest to the student of human reactions (§7).

1. Visual information

In my native city of Vienna the Museum of Natural History and the Museum of Art History confront each other across the square with the monument to Maria Theresa (figures 1 and 2, plate 12). Often on a Sunday morning my father would take us children to that nearby place and I vividly remember hoping that he would turn left and go to the Museum of Science with its thrilling skeletons of prehistoric creatures rather than to the picture gallery. It was only later that my bias changed and that I frequently took the turn to the right, to the Museum of Art History where I got stuck, as it were. The invitation to give a Review Lecture at the Royal Society, therefore, came to me not only as a great honour, but also as the fulfilment of a childhood dream.

However, I did not merely tell this story to indulge in reminiscences. I also wanted to show the normal use of pictorial representation for the illustration and supplementation of a verbal description. We represent or describe *something to someone*. If I had no 'visual aids' at my disposal I could have described the Museums to you at somewhat greater detail, for instance as large two-storey buildings topped by a cupola, and this might have given you some general framework you could have filled in, drawing in your imagination on buildings of the kind you may have seen in other Central European cities. But however long I would have gone on with my description I could never have given you enough details to reconstruct the buildings fully from my verbal account, for language operates with universals and thus no description could ever be complete. There is no end, in principle, to the further questions you could ask about any one feature such as the cupola. Now pictorial representations are also incomplete. The two I have shown would not suffice either for you to imagine or build an identical complex of Museums unless they were supplemented in their turn by a verbal account. One such possibility is neatly illustrated in my example. If it were true that the two Museums are identical (which they are

not in their statuary) one of them might serve as the representation of the other, and if the one were destroyed the companion could be reconstructed on this verbal information alone. But this, clearly, is a limiting case. We do not normally describe any two members of a class as representations of each other and any other kind of representation has by its very nature its limits which its user must either accept or try to transcend by other means. The nature of these limits, on the other hand, will differ with the medium and method employed. It is these methods I have proposed to characterize in my title as that of the mirror and the map. The wide angle photograph (figure 1, plate 12) which tells us something of the elevation and decoration of the buildings may be loosely compared to a frozen mirror image, the map (figure 2, plate 12) indicates their ground-plan and their spacial relation across the square.

We rightly take this use of pictures so much for granted, that it is only in recent years that pictorial representation has become something of an issue in psychology (Gibson 1966, 1971; Gregory 1966, 1973; Hochberg 1972; Jung 1974; Kennedy 1974), in philosophy (Black 1972; Goodman 1968; Wollheim 1973), in technology (Dyring 1973; Evans 1959; Reggini 1974) and in the study of art (Gombrich 1960, 1973; Pirenne 1970). Maps would appear to present less elusive problems (Board 1967). We know about the kind of information they offer; we know that they have a key to explain their use of certain symbols for such 'universals' as churches, post offices, railway lines or rivers. We also know they have a scale that allows us to translate the distance of symbols on the map into distances in the city or country; we know that the grid permits us to locate any of the listed items within a given square. We quickly learn the use and the limits of these handy tools. But what exactly does the wide angle photograph tell us? Where are its limits? Should we regard the gradations of grey as the equivalent of the codes used in maps? And what about the perspective view? Is it a convention of representation, mechanized and standardized by the camera according to pre-established rules? It is to this question mainly that I propose to devote this review.

Like the verbal account and indeed like the map we can use the photograph only because we do not come upon it quite unprepared. We also supplement much of what it does not convey, at least in general terms. Even in a black and white photograph we do not imagine the trees to be red, the walls blue and the lawn black, but given this general framework of previous knowledge the photograph imparts more but less precise information than the map. We could tell, for instance, how many windows the front elevation has, but we could not find out the precise measurements of the windows, for even if we are lucky and find that the photographer included a human being to give the approximate scale that scale would still allow a margin of variation. It is precisely because of this vagueness that an eminent philosopher has recently criticized the use of the term information in the context of pictorial representation (Black 1972). He is quite right in reminding us that the technical use of the term in information theory should not be confused with non-technical parlance, but after all the theory started its career as a theory of communication along a channel and it is well to remember that pictures are now sent by wire or satellite. It would be easy in this way to specify the position and shape of a building on a pre-existent map by using precisely the traditional method of the grid, indicating for instance, which square is empty and which filled, nor would it present any problem to tell how many bits of information would be needed for this operation (Attneave 1959). Obviously a detailed plan would need more than a schematic one, and a photograph in its turn would demand an even denser grid or screen. The power of resolution of the lens and the grain of the film being limited we would want, perhaps, to supplement the overall picture with a close-up of a window

or column. Since we see enough of the general lay-out on the coarser rendering we might say that it would beredundant in the technical sense of the term to provide more than one detailed illustration of these repeated elements.

As a frequent user of both photographs and maps the historian of art, like other people using pictorial material, has many a tale to tell of the limits of information provided by smudged photographs. He knows that all methods of reproduction will inevitably carry a certain amount of visual 'noise' which would be crippling were it not for certain assumptions on which we can draw – for instance that a gap in an outline does not represent a void in the building.

It has also been asked how we can ever know whether a picture or a map represents a particular building. To this the answer is simple. We cannot. In our case there are two buildings of the same plan and elevation, the two Museums, and it may be impossible to distinguish them in a picture which happens to lack a tell-tale detail. Nor is that the full extent of the limits which are inseparable from pictorial representation as distinct from language. Pictures cannot assert (Gombrich 1972*b*). While a verbal account need leave us in no doubt that it claims to describe an existing state of affairs, the uncaptioned pictorial representation may just as easily refer to an existing building as to a memory, a plan or a fantasy. There exists a drawing by the Austrian painter Rudolf von Alt showing the Museums as seen from above (Wagner-Rieger 1969). It is what architects call an 'artist's impression'. At the time when it was made the buildings had not yet gone up, but the need was felt to visualize how the plans would translate into reality. Books on the history of our buildings provide yet another variant – a wooden model was made of the whole complex of buildings which incorporated real features but was intended to demonstrate certain possibilities of extension and modification. Only those who have independent evidence can distinguish the kind of information we are intended to receive from this kind of model.

2. Visual representation and visual experience

This brief consideration of the informational aspects of maps, models and pictures has brought out the need to distinguish between different kinds of information we can receive from representations. There is a common-sense distinction between information about some feature of the physical world (such as a building) and its appearance from a given station point and under given conditions. Maps give us selective information about the physical world, pictures, like mirrors, convey to us the appearance of any aspect of that world as it varies with the conditions of light and may therefore be said to give information about the optical world. It is tempting to regard this 'optical world' as something given, something indeed that can be mapped with the same selective objectivity as can the real world, and those who spoke of the painter 'copying' or imitating' appearances obviously succumbed to this temptation. For the optical world, the light reflected from the features of the physical world, is really part of that physical world, though one subject to more rapid changes than are its solid components. A record of these optical data can indeed convey the changing appearance of such a feature as the Museum with evocative force. Take two artistic impressions of our building from a book of photographs of Vienna (Pflaum 1961): one (figure 4, plate 13) shows the Museum in the distance as seen through the morning haze on an autumn day. We can infer that visibility was low, restricting the information to the general outlines of the building. In the other artistic impression (figure 3, plate 13) it is the photographer who has restricted the information about

the Museum by focusing his camera on the boys in the foreground, leaving the building somewhat blurred.

What these photographs help to clarify is the further need to distinguish between the optical world and its 'appearance'. For even a photographer does not register all light energies but actively selects the ones he wishes to record. Needless to say, the human eye does the same.

It is true that this qualification would have presented little difficulty to the traditional account of what constitutes 'appearances', for this account relied on a rather simplistic view of visual perception. According to this time-honoured view the light rays that enter the eye stimulate the optic nerve and cause those visual sensations which in their aggregate correspond to the image on the retina. The optical world, or that part of it that is sampled by the eye can therefore be inferred from the visual sensations we experience. There is a fixed correlation between the physical world, the optical world and the appearance of this world in our experience. The same stimuli that cause the sensations will also register on the photographer's plate and if we look at his treated image it will of necessity arouse in us the same sensations we would have experienced when standing beside his camera. The camera, no less than the skilled artist simply transcribes the optical data which mediate the visual experience, in other words he maps the optical world by mapping the visual sensations which correspond to it.

As long as this view prevailed visual representation appeared to pose no very interesting philosophical or psychological problems. But of course it no longer does prevail. It has become a commonplace in most discussions of perception to start with a warning against the analogy between the eye and the camera – except, perhaps, if we regard both the camera and the nervous system as a 'black box'. We cannot watch what happens to the input (Blakemore 1973).

To quote question and answer from a recent authoritative account (Bouma)

> 'How does our visual system accomplish the extraordinary operation of converting these highly variable two dimensional light distributions at either retina into one stable, three dimensional perception of the surrounding visual world? There can only be one complete answer, which is that we do not yet know.'

One thing can be taken as established. There is no fixed correlation between the optical world and the world of our visual experience. Granted that the controlled manipulation of optical data can result in an evocative photograph, that photograph in its turn belongs, of course, both to the physical and the optical world and will therefore be fed into the black box which mediates our visual experience which is only partially determined by the sensory input. Some of the reasons for this limitation can be found in any modern textbook of psychology, from whichever point of view it is written. There is the influence of past experience and of expectations, the variables of interest, 'mental set' and alertness, not to speak of variations in the observer's physiological equipment and in the adjustment of the perceptual system to changing conditions.

What makes these findings a little hurtful to our pride is the discovery that we ourselves have no privileged access to the black box. We cannot give a complete account of our visual experience either when looking out into the world or when looking at its pictorial representation. If it were not for this impossibility of telling at any moment which visual experience is due to the optical world and which to memories or guesses, oculists who wish to test our eyesight would not have to use random letters rather than coherent texts. The 'appearance' of the display changes dramatically as soon as we can infer what is in front of us. Psychologists go further and confront their subjects with so-called nonsense figures in the tachystoscope to test the limits of

information we can process in a given time and the strategies we apply in what Thouless called the 'effort after meaning'.

Nobody doubts that this effort will influence our experience when looking at the photographs under discussion. We can never be quite sure what data are actually present and what experiences we 'project' onto the photograph. Where exactly can we discern individual blades of grass and where lies the limit beyond which we merely expect and imagine their presence? Can we really see the flagstaff on top of the Museum's cupola, or do we merely know it must be there? Admittedly, we can always resort to a magnifying glass or to other means of isolating and checking our impressions. To insist on the subjective element in our visual experience does not mean to deny its objective veridical component. I believe much light is thrown on this question by Karl Popper's lifelong insistance (1972, p. 6) that a parallelism exists between the reactions of the organism to external stimuli and that of the scientist evaluating his observational evidence. The elimination of false guesses, the refutation through tests and probings of mistaken hypotheses play a decisive part in any area of doubt that demands attention. Where such doubts do not arise we may go along with a vague provisional hypothesis without much awareness that it is in need of examination. Thus, as we move through the world, we experience a continuous range of visual hypotheses extending from the most general to the minutest particular. We react to movement on the periphery of the field of vision even before we can tell what has moved and normally such a reaction is coupled with movement of the eyes (Gregory 1966). While we thus focus and concentrate on one object in sight the others become indefinite, but they may be present to our echo memory and held in readiness for refuting or confirming a momentary hypothesis – a process that is best studied by recording the eye movements of a rapid reader. I have pointed to the blurring of the Museum in our illustration, but this is at best a vague analogue, not a representation of the way the background would appear to us if we watched the boys in the foreground. The question of what the Museum looks like while we do not look at it is a teaser that has much engaged the attention of conscientious artists, but I do not think it allows of a precise answer. Trying to focus on one picture of plate 13 while watching the impression of the other from the corner of our eye we soon discover the limits of introspection. Not only is it hard to overcome the nearly automatic coupling of eye movement and interest, it is harder still to separate now what we remember, anticipate or really see than it was while inspecting the building in the haze.

To put the matter briefly, seeing, like representing, is a transitive verb which demands an object. I want to see something out there, I cannot quite make it out, at last I believe I see it clearly. In this continuous process we must be as ready to disregard disturbing or irrelevant sensations as we must be to attend to any possible source of information. Dazzle, after-images, double contours, the result of astigmatism or other anomalies tend to be pushed beyond the threshold of our awareness if they regularly and manifestly contradict a visual hypothesis that has stood the battery of reality tests we have at our disposal, at least while we are awake and sane (Gombrich 1973).

But here is the real paradox. While such sensations can be regarded as mere 'noise' in what J. J. Gibson (1971) has called the 'serious business of living', this noise can still be aroused and exploited with comparative ease by those who wish to play with visual effects. After all, vision depends indeed on nervous mechanisms, and just as a knock against the eye makes us see sparks and a strong glare an after-image, so the experienced manipulator, whether conjuror, artist or scientist, has been able to find out how to predict and trigger certain non-veridical visual

experiences through the arousal of visual sensations. Such modern devices as the stereoscope, the cine-camera or the television screen arouse in the beholder visual experiences which he cannot stop and which he never could have predicted if he had been shown the arrangement on which they are based. I would suggest that it is these surprise effects which we tend to describe as visual illusions. Given the unexpected difference between our visual experience and what we know to be really in front of us – a twin image, a sequence of stills, a scanning beam – we reflect on the discrepancy between information and response and remark that the artifice deceives the eye. Admittedly it is difficult to specify at any given moment where such surprise is due to physiological mechanisms and where to mistaken cognitive strategies (Gregory 1973). We may also be surprised at having overlooked a misprint or an inconsistency in a picture, as in Escher's notorious teasers (Gregory 1970, pp. 52–3). Often the visual effects exploited by image makers draw on both mechanisms. An example is in front of the reader – the screen used by the makers of half-tone blocks to which I have already referred is partly invisible, partly ignored. We look for the representation and disregard it as 'noise'.

Where art is concerned the surprise or 'trompe l'oeil' is part of the pleasure; the pleasure does not lie in discovering that what we took to be a real dead duck is merely a painted one – this surely would be the cause of disappointment rather than of enjoyment – it lies in our continued feeling of incredulity that the visual effect of plumes, of gleam or softness has been achieved on a flat hard panel by a skilled hand using a brush dipped in paint. We may want to touch the panel to be quite sure there is no other trickery involved, for the visual effect is so striking as to set up a real conflict between our reaction and our better knowledge: the artist has made us see something different from what is there. He has aroused in us a visual experience of a kind that we know from our encounters with reality.

The difficulty of being more precise in describing this kind of experience stems precisely from the problem of the 'black box'. It is the recognition of this limit to introspection that makes the problem of pictorial representation both more interesting and more complex than earlier theories suggested. These theories were still based on the distinction between visual sensations and visual perception. They postulated that the artist should look into the black box and record what he saw there, and they also suggested that such a record would be processed by the beholder in the same way as it might have been by the artist if he had not trained himself to arrest this information. Indeed it may be claimed that much experimentation in the art of the last two centuries has been concerned with this area extending between the registering and the arousal of visual sensations, though the exact relation between these two activities was not necessarily clear to artists and critics. We find both effects combined in the developed theory of impressionism, with the painter endeavouring to be absolutely faithful to his vision and to map, as it were, the visual field that extends in front of his 'innocent eye', without entering onto this map anything he merely knows about the external world (Gombrich 1960). In doing so, however, he expects, and rightly expects, that the resulting painting would not be seen as a canvas covered with dabs and strokes, but that the understanding beholder would want to step back from the picture to eliminate these interfering messages from the picture surface and experience the sensations of light and flicker that the artist wished to arouse in him as an equivalent of his own reaction to his motif.

Two examples from the painting of our own time illustrate the way these aims have now diverged. A painting by Professor Lawrence Gowing (figure 5, plate 14), a passionate student of Cézanne's visual researches, shows the artist carrying the impressionist programme to its

ultimate extreme. He has painted the still-life as it appeared to him as he focused his eyes on a spot behind the table, thus producing the doubling of images of proximal objects and an apparent curvature of the table edge. We may say he has tried to produce a faithful map of his visual field at a given transitory moment and to enter onto this map even the sensations we are usually set to ignore because they interfere with the perception of the external world. Such experiments (Meinel 1973) are of undoubted psychological and artistic interest, even though it could be argued that no artifice can ever reproduce the experience of binocular vision on a flat canvas. But there is another problem here of more general significance – it is the problem of how we should view his canvas. If we try to repeat the artist's visual experience by focusing in our turn not on the

FIGURE 6. Bridget Riley, *Fall*, 1963, London, Tate Gallery (By permission).

painted objects on the table but behind it, we will experience a double image of his double images. This is a paradox that arises in every case where the artist tries to register his subjective experience regardless of the experience his record will arouse in the beholder. J. J. Gibson has referred to the consequences of this aim as 'the Greco Fallacy', alluding to the naïve belief that Greco elongated his figures because his astigmatism distorted them in this way. If that were the whole story, his astigmatism would also have led him to seeing his painted figures distorted. Only a correctly proportioned painting would have been seen like a correctly proportioned man (Pirenne 1970). The painter is also his first beholder, and all he can aim at is a matching of sensations, not a mapping.

It so happens that another movement in contemporary art permits us to isolate this problem of visual sensations from the point of view of the beholder. I am referring to the experimental school known as 'op art'. These paintings are not concerned with the way the artist sees the world but with the sensations aroused by certain visual tricks resulting in flickering after-images, moirée effects and unexpected colour sensations (Blakemore 1973) (figure 6). The effects

are real enough, but could they ever be registered or mapped in the way Lawrence Gowing attempted to map the effects of unfocused binocular vision?

Both Lawrence Gowing's *Still life* and Bridget Riley's *Fall* can be interpreted as experiments to probe the limits between subjective, nonveridical visual experiences and their objective causes. They are to be welcomed precisely because these limits are often misrepresented and misunderstood. The undeniable fact that our subjective visual experience is not solely determined by the physical or optical world has frequently been used as an argument in favour of relativism and subjectivism in the theory of representation. It must be the aim of any improved theory to give subjectivism its due without making concessions to relativism. It is here, I believe, that the example of maps may prove of use.

3. Objective standards and subjective responses in cartography

Maps are normally designed to impart information about the invariant features of an area, in other words they leave 'appearances' on one side. There are no maps of Vienna in moonlight or of the Museums out of focus. Even less would it be welcome if maps aroused unexpected visual sensations such as flicker. Handling a map we are intent on the veridical perception of what is there on the piece of paper and if we cannot see it well we take it to the light or use a magnifying glass. We speak of reading a map, and its foremost requirement is indeed that it should be easily legible in a succession of fixations. There should be no interference of the symbols with each other and each should be as distinct as possible. Where such differentiation fails the use is put in jeopardy. Only recently a printed warning was added to Ordnance Maps of Wales because some users had confused the lines marking county boundaries with lines indicating footpaths. Provided however that the distinctions are clear it would not seem to matter what key is chosen. The map of the London Underground marks the Piccadilly Line in blue and the Central Line in red; the key could have been switched round without impairing the efficiency of the display. It is true that for habitual users of the map the colours become associated with their designation. I tend to visualize these Underground lines in terms of their fortuitous colours, but this phenomenon belongs to the pathology of symbolization rather than to its logic – a pathology, however, which has never ceased to worry theologians and mystics who wanted to visualize the spiritual world without having their symbolic maps confused with mirror images (Gombrich 1972*c*, 151).

The question to which I am alluding goes back to Plato's *Cratylus* which considers language in the light of the problem so dear to the Greeks – the problem of what exists by 'nature' and what by 'convention'. It is a problem which is very much still with us, but I think that in the theory of signs and of maps it has also led to a certain amount of confusion particularly in the modern classification of 'iconic' and 'non-iconic' signs. For granted that the symbols on maps need not be iconic in the sense of being faithful representations, they are not necessarily arbitrary. We would be puzzled to find a map of London in which the parks were marked blue and the ponds green, because the other arrangement is so much easier to learn and keep in mind. It would be interesting to investigate cartographic codes from this point of view of mnemonics. A map in the Times Atlas representing temperatures in various latitudes shows the warmer regions in darker red and the cold ones blue. No doubt we could also learn the opposite code, but why not make use of these 'natural 'metaphors? (Board 1967, 698).

To the student of representational devices the history of maps offers many observations of

a more general application. He can watch how simple pictographic renderings of areas with little pictures of towns and mountains become formalized through the use of a precise key, indicating what distinctions are aimed at, such as the difference between fortified and 'open' cities (Dainville 1964) (figure 7, plate 14). The schematic pictures as such are not purely arbitrary, but their use becomes conventionalized in the interest of conceptual categorization.

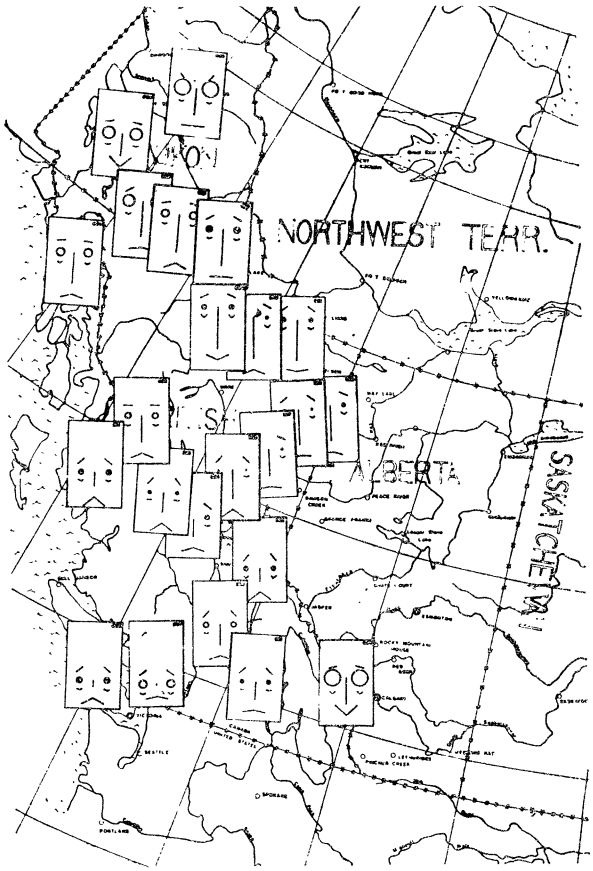

FIGURE 9. The annual growth rhythm of *Pinus contorta* in Canada, after M. Hagner in *Studia Forestalia Suecica*, **81**, 1970, p. 12. Nose, lignified cells (%) (|, low; |, high); eyebrows, dry matter (%), (⌣, low; ∨, high); eye diameter, shoot length (%) (·, low; ⊙, high); mouth, bark colour (∧, green, ∨, brown); eye wrinkle, seedlings with terminal bud (%) (⌣, low; ∨, high).

Because of the advantage that lies with easily memorized conventions, psychology enters map making by the back door, as it were. The conventionalized symbol of hills or mountains has always been a steep outline (figure 8, plate 14), and even in modern renderings of mountain ranges we find the device of conventionally exaggerating height in relation to width by a stated amount – reflecting the tendency of our mind to overrate the vertical extension and therefore the steepness of slopes. Recent experiments in the construction of easily legible symbols have gone very far in thus trying to meet the propensities of our perceptual system. A Swedish forestry journal (Hagner 1970) published a survey of the annual growth rhythm of *Pinus contorta* in Canada which is coded in terms of facial expressive features 'because of the human ability to recognize several features at once if presented as part of a face' (figure 9). As a non-forester I

find the device more amusing than enlightening precisely because the pathology of symbol-reading tends to take over again. The reaction to faces is so compelling that I find it hard to re-translate my response into the desired information.

The immediacy of this response often comes into question in debates about the relative share of 'nature' and 'convention' in representational devices and in the reading of images. It is my impression that several wires tend to get crossed in these discussions, as when it is alleged that those who have never seen a photograph cannot decode and read it. Evidence even about this fact is conflicting (Kennedy 1974), but whatever the truth of certain anecdotes, it would also have to be asked whether any difficulty is experienced in recognizing, for instance, toy animals made of wood or outline drawings of familiar objects, particularly of features of immediate cultural and psychological significance. Investigators appear to have been shy, for instance, to use erotic imagery, though the reactions to this kind of material by the most untutored does not appear to suggest great difficulty in learning its significance.

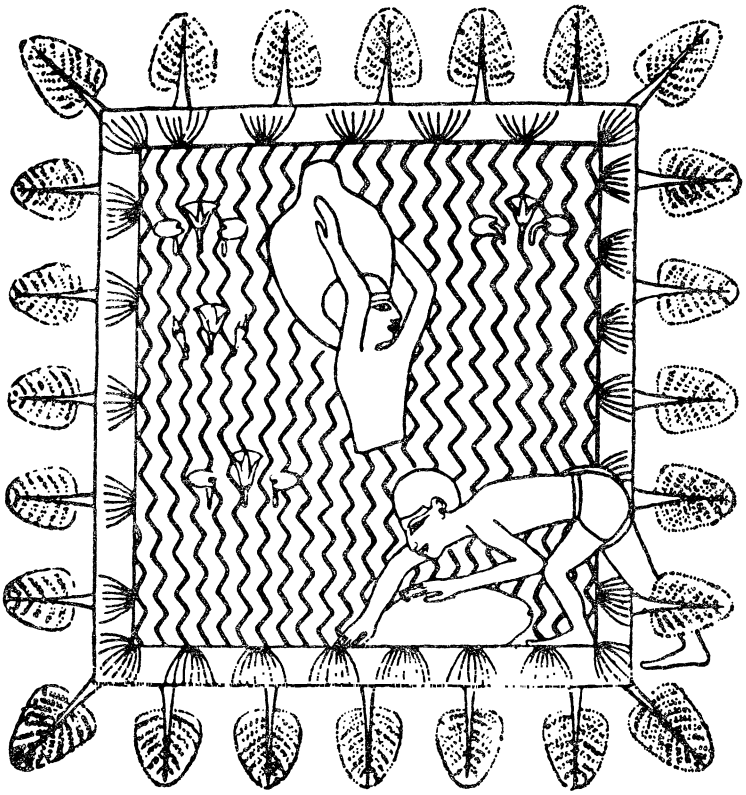

FIGURE 11. Egyptian method of drawing a pond, after a painting of the New Kingdom, from H. Schäfer, *Von ägyptischer Kunst*, Wiesbaden, 1963, Harrassowitz.

It is quite true that we do not normally see our fellow creatures in black and white, and so the notation of greys looks superficially very much like a mapping device. But need it therefore be arbitrary? Should we not rather ask how quickly we can pick up this kind of code and adjust to its notation?

In any case if it were just a conventional notation the inventors of photography would not have evolved the process of turning a negative into a positive. It is most unlikely that it is merely our habituation which makes it easier for us to read the latter. Granted that in looking at the negative of a portrait we will not find it hard to interpret it either, but it turns out that for the

layman, at least, such confidence can be misplaced precisely where his immediate reactions are engaged as in the perception of eyes (Gombrich 1973, 202). Not being a trained photographer I found that looking at figure 10, plate 15, I misinterpreted the direction of the girl's gaze on the negative where the highlights, of course, appear black while the black pupils appear white and elicit the false response.

It may sound chilling to regard the photograph of a human face as a map of its features, but we get nearer to this idea in a series of pictures recently published in the *Scientific American* which shows the systematic transposition of these gradients to establish the information generally used in physiognomic recognition (Harmon 1973).

There are many media and devices in the history of art which might be illuminated by such experiments. Mosaic is only the simplest example of the selective information that can be encoded in a particular artistic technique (Gombrich 1972*b*). Marquetry is another which exploits a particular range of shades for striking spacial effects.

But most of all it is in the comparison of styles with mapping conventions that the historian of art may find a useful corrective to evolutionist theories. Thus the style of ancient Egypt with its rather rigid conventions has often been compared with the 'conceptual' art of children (Schäfer 1974) because of its remoteness from visual experience. In my book on *Art and Illusion* (1960) I have proposed that it should rather be interpreted as a mapping system so admirably adapted to its purpose that it remained in force for almost 3000 years. The study of maps confirms that certain of its devices will turn up any time a particular kind of information is required. The Egyptian convention, for instance, of drawing a pond in the shape of its ground plan but men in elevation (figure 11) is universally used not only in primitive maps but also in tourist guides, because it is so easily intelligible (figure 12, plate 15).

The example strongly indicates that the great variety of styles we encounter in the images of past and present civilizations cannot be assessed and interpreted without a clear understanding of the dominant purpose they are intended to serve. It is the neglect of this dimension which has suggested to some critics that the range of representational styles must somehow reflect a variety of ways in which the world is seen. There is only one step from this assumption to the assertion of a complete cultural relativism which denies that there are standards of accuracy in visual representation because it is all a matter of convention.

Once more it is useful at this point to refer to the example of the map. For it is hard to be completely relativistic about maps. There can be mistakes in maps which can be systematically rectified. We also know how this accuracy has been improved over the centuries – as in the case of the map of Middlesex (figure 8, plate 14) – through the development of the technique of surveying. This technique moreover, has nothing to do with the way the world is seen, for the surveyor who wants to map the invariant features of a region can and will never rely on that elusive guide, his visual impression of the landscape. His surveying instruments are set up in given locations at distances which can be measured and pointed at given natural or artificial landmarks for the purpose of triangulation. Surveying is not an easily acquired skill, but what matters here is only that the individual readings obtained when aligning a sighting instrument must be noted and held, till further data from other station points are obtained and a correct relational model of the terrain can be constructed. It does not matter either by what means these locations are plotted. Modern technology has long supplemented the surveyors' visual methods by photography, radar, echo-soundings, not to mention various methods of mapping the invisible through infrared photography, X-rays or the electron scanning microscope which

translate the information obtained into visual form for those who know the rules of transformation (Dyring 1973).

There can be no doubt that the piecemeal methods of construction used in all these mapping procedures can result in an image that coincides with a visual record. Aerial pictures of cities, not to speak of the exhilarating photographs of our globe from space, turn out to look very much like the maps which were compiled in a long process of measurement and refinement over the centuries. True, we know that maps are usually projected on flat surfaces for convenience sake and that there is no way of developing a spherical surface onto a plane without a choice of evils as it were, but this inconvenience does not contradict the observation that knowing the curvature of the globe and the distance of the station point the exact outlines of any continent from that point could have been predicted long before spacecraft and satellites enabled us to put the theory to the test.

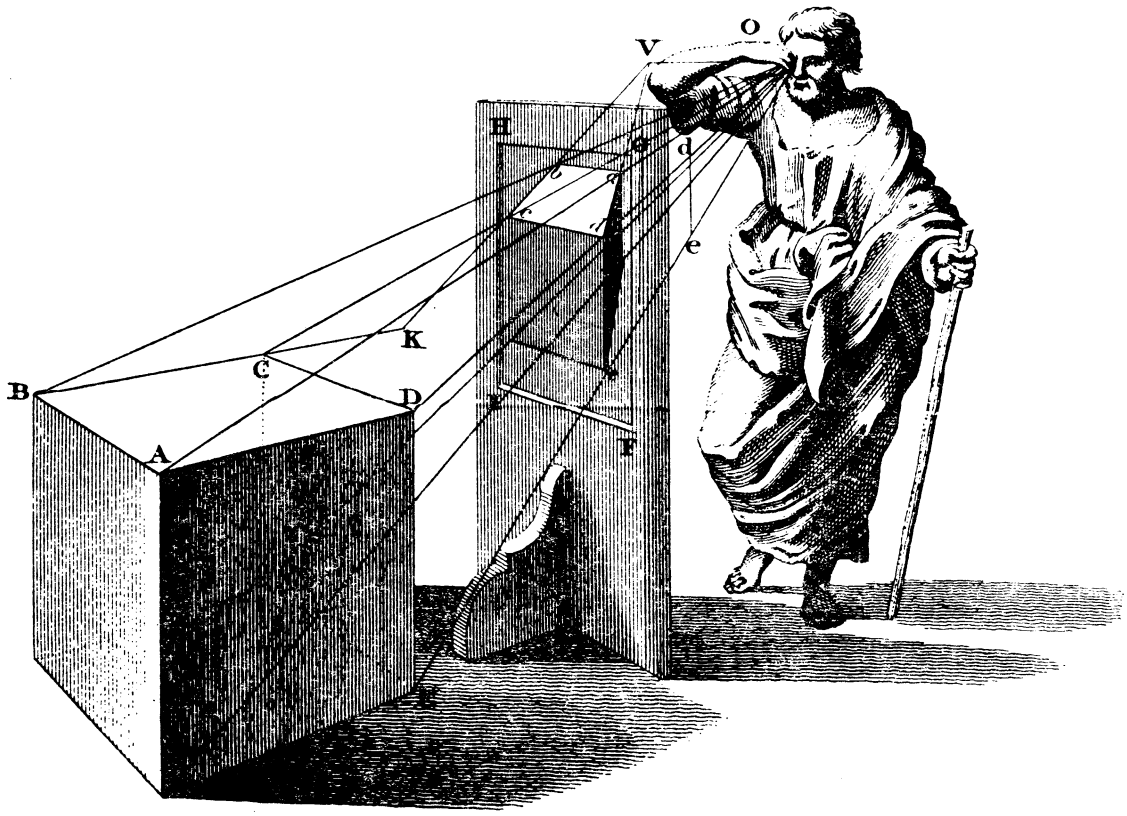

FIGURE 13. The visual cone, from B. Taylor, New *Principles of Linear Perspective*. London, 1715.

4. PERSPECTIVE: GEOMETRICAL PROOF AND PSYCHOLOGICAL PUZZLE

The theory to which I refer is of course that of perspective to which M. H. Pirenne's *Optics, painting and photography* (1970) provides an authoritative guide. It is based on the fact that light is normally propagated along straight lines and that we can therefore work out for any object in space what lightrays from its surface will reach a given point. This is the optical theory of the visual cone or visual pyramid which became relevant to pictorial representation in the Italian Renaissance when such a representation was first defined as a cross-section through a visual cone (figure 13).

This theory was developed as a response to the demands of narrative art. No longer satisfied with the hieratic assemblage of symbols through which the crucifixion of St Peter was depicted in the fourteenth century the public of the early fifteenth century hailed the rendering of such a scene as if the artist had actually been watching it (Gombrich 1960, 1967) (figures 14 and 15, plate 16).

There is no doubt that it was the ancient Greeks who first assigned to the artist this role of an imaginary eye-witness, and it is equally clear that Euclidean geometry would have provided them with the tools of working out the implication of this demand – to what extent this was

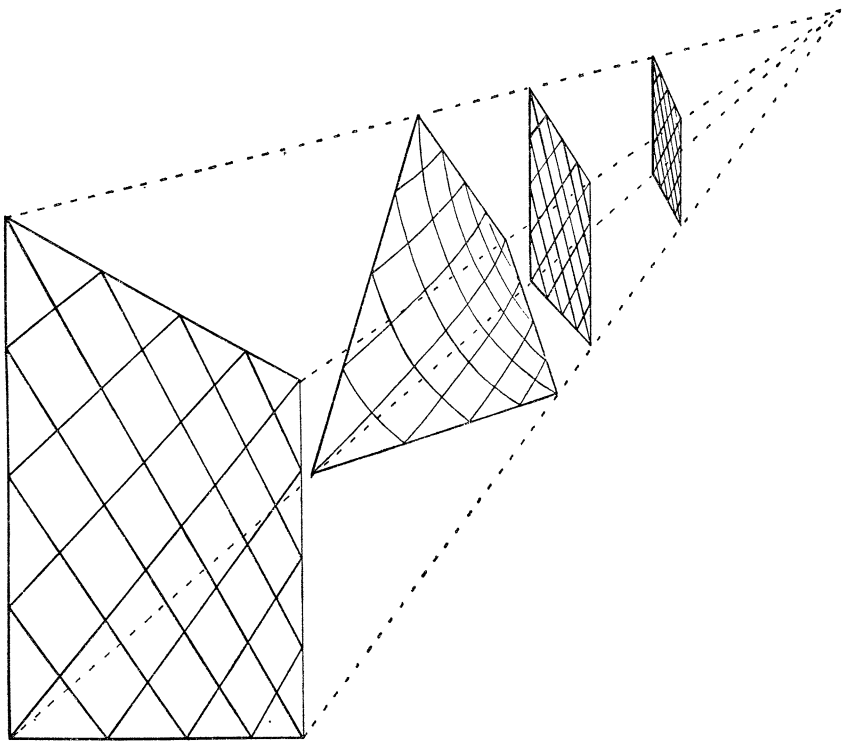

FIGURE 16. Equivalent configurations as seen from one station point. Drawn by B. A. R. Carter for E. H. Gombrich, *Art and Illusion*.

actually done is, however, still a matter of debate (White 1957). On the other hand the discovery or rediscovery of the theory of perspective in the Renaissance and its spread from fifteenth century Florence to the rest of Europe happened in the full light of history (Carter 1970). Though some of the geometrical implications could only be proved in the seventeenth century, the basic assumptions are simple enough. Given the situation envisaged in the demonstration illustrated in figure 13, the conclusions follow from Euclidean geometry. The cube will in fact present the predicted aspects on that intersection of the visual cone which the theory demands. If proof were needed of this point it would be found in the modern application of this theory to computers. Given the plan and elevation of a building a computer can be programmed to work out what aspects the array will present from any chosen station point (Greenber 1974).

And yet it is in the assessment of perspective representation that the approach through the theory of information has highlighted a problem which has been strangely neglected not only by Renaissance theorists but even by more recent commentators. Briefly, the theory was treated

as if it were a mapping procedure. It was claimed that it enabled the artist to represent what has been called 'measurable space'. Yet if you have a geometrical theory you must take the geometrical consequences, and it is clear from the theory of central projection that you cannot reverse the process: while we can work out what the projection of a given three dimensional object will be like on a given plane, the projection itself does not give us adequate information about the object concerned, since not one but an infinite number of related configurations would result in the same image (figure 16), just as not one but an infinite number of related objects would cast the same shadow if placed in the beam emanating from a one point source (Gombrich 1960; Gregory 1970).

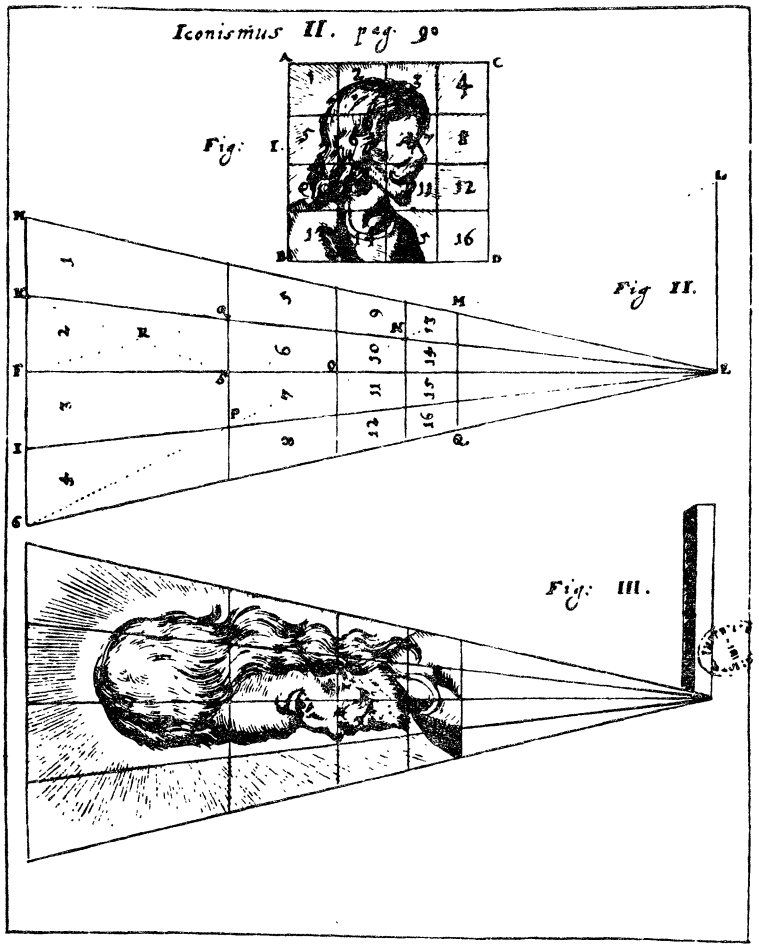

FIGURE 17. The principle of anamorphic, from Gaspar Schott, *Magia Universalis* Würzburg, 1657, after Baltrusaitis, Anamorphoses.

From a logical point of view a perspective representation, therefore, has this in common with a map that it indicates a class of objects, though a class of which only very few members would ever be known in our environment. It is even possible to formulate the problem of illusion caused by perspective representations in this way. We take one specimen of the class – the flat design on the plane in front of us – for another, the solid object over there. Indeed Renaissance artists and their successors used this indeterminacy of the view from a single station point for the construction of a visual trick of this kind – the so-called anamorphosis, a picture that

looks distorted when seen head-on, but which appears to right itself when seen through a peep-hole from the side (figure 17). (Baltrusaitis 1955). The sideway view results in an illusion, not so much of a reality as of a differently oriented painting which tends to be seen as a hovering phantom.

But what is the cause of this illusion? Why do we not see the oblique panel, and why, even if we lack a cue, do we fail to notice the indeterminacy and rather assign the head a given distance and form? The question has been raised into a psychological puzzle by Adelbert Ames, the painter turned psychologist, who applied the principle of anamorphosis in a set of well-known demonstrations which make use of the visual cone and the peep-hole (Kilpatrick 1961; Gregory 1970). What is inside his box is really a criss-cross of wires and unrelated shapes, but they are so arranged that they project the same image from a station point as would a model chair, and so it is such a model chair we seem to see and not a criss-cross, however much we may be intellectually aware of the true arrangement.

These constructions confirm the theory of the visual cone and yet they pose a perplexing corollary. For what is it again that makes us select out of the infinite number of possible readings just the image of the chair rather than anything else? It is tempting to invoke past experience; after all we know chairs but are unfamiliar with the random shapes that are really there. No doubt there is something in this explanation but it hardly suffices. Needless to say, the problem of how we get from sensations to perception, from the multivalent pattern of light on the retina to an image of the world out there is one of the oldest problems of psychology. It is a problem which the theory of the visual cone alone cannot solve. For in its developed form this theory states that the light rays of varying colour and intensity act as stimuli resulting in visual sensations. If we succeed by artifice in so treating a surface that it produces identical stimuli under a given light they must of necessity result in the identical sensations and therefore create an illusion. Granted the first step, the last is inexplicable.

The simplest artifice for the production of such duplicate stimuli would seem to be a mirror. The mirror deflects and reflects the light emanating from objects and since we normally assume the light to have come to us along a straight path we believe we see the object behind the mirror. It is indeed tempting to compare a representation with a mirror because both can present a framed surface on which an image appears. But does it really appear on the surface of the mirror? Certainly not if we look with both eyes. Our binocular vision really fuses two different mirror images just as it fuses two different aspects of the three dimensional world in our proximity. Leonardo da Vinci who urged the painter to use a mirror as his standard of accuracy (Richter 1939, I, 320) also knew that in this important respect no painting could emulate this trick (Gombrich 1959, 83) – how he would have relished the stereoscope and holograph! All the painter can do is what the normal camera does. He can match the stimuli from a surface seen from one point rather that two. But why a mirror? Except for the reversal of the image there is no difference in theory between the view from the window seen in the mirror and the view itself, witness two views towards the Senate House from an upper floor of the Warburg Institute (figures 18, 19, plate 17). To match this view in paint we have simply to keep still, close one eye and scan the window with the other, tracing the outlines and then the colours on the window pane.

It is worth every time to repeat this experiment, because the result tends to be strangely surprising (figure 19, plate 17). It turns out that the outline of Senate House on the window pane is no larger than the span of my colleague's hand and each of its windows no higher than the thickness of his fingers. This shock of surprise we tend to experience when measuring size

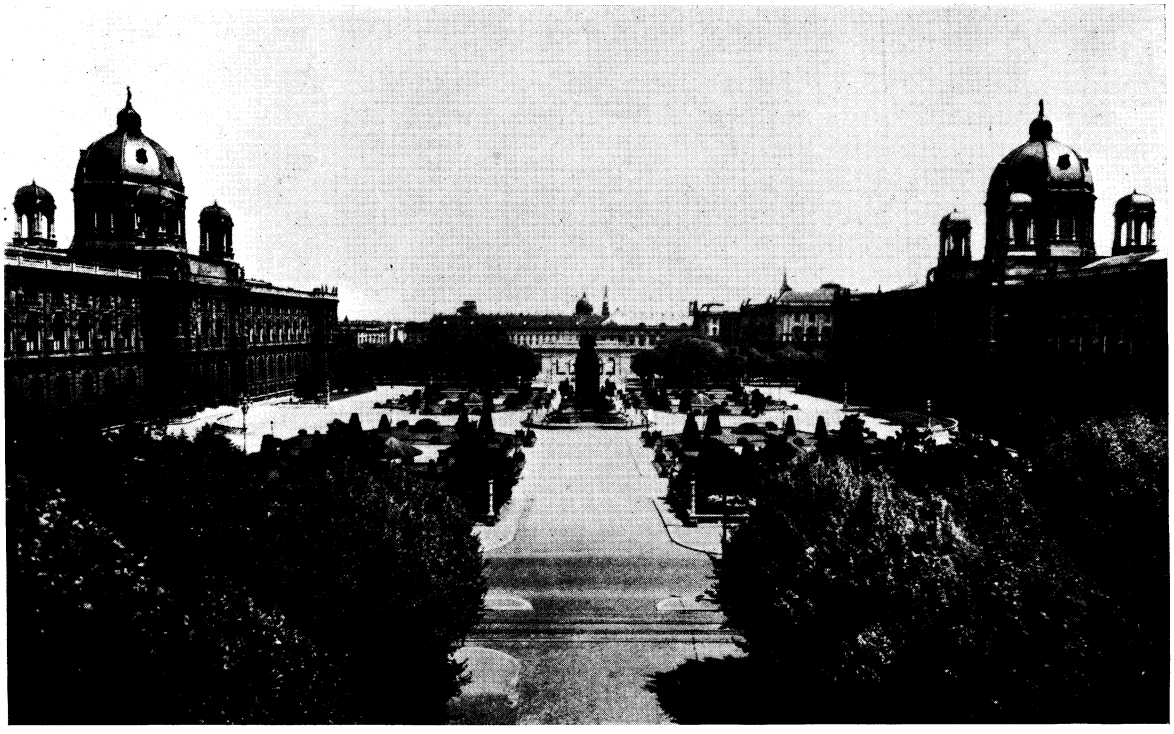

FIGURE 1. The Maria-Theresien-Platz in Vienna with the Museums of Natural History (left) and of Art History (right). From R. Wagner-Rieger, *Die Wiener Ringstrasse* by permission of the publishers, R. Böhlaus Nachf.

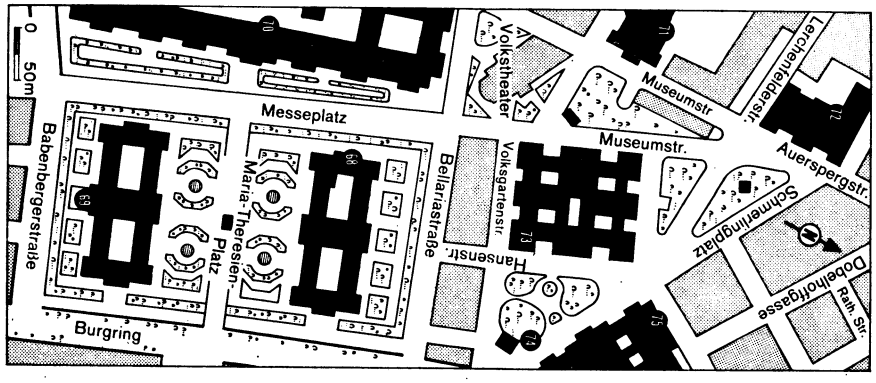

FIGURE 2. Plan of part of the Inner City of Vienna (note the Maria-Theresien-Platz).

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FIGURE 3. The Museum of Art History in Vienna after Barbara Pflaum and Jörg Mauthe, *Wie ist Wien?* E. Hunna Verlag, Vienna, 1961 (by permission of the publisher).

FIGURE 4. The Museum of Natural History from the Volksgarten (source as for figure 3).

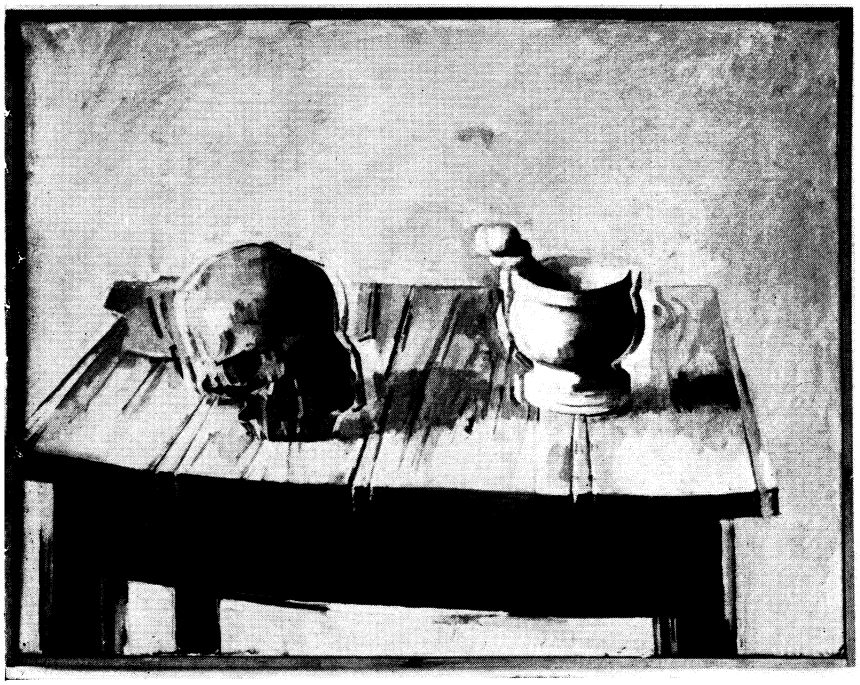


FIGURE 5. Lawrence Gowing, *Still life*, on loan at the Warburg Institute, University of London, (by permission of the artist).

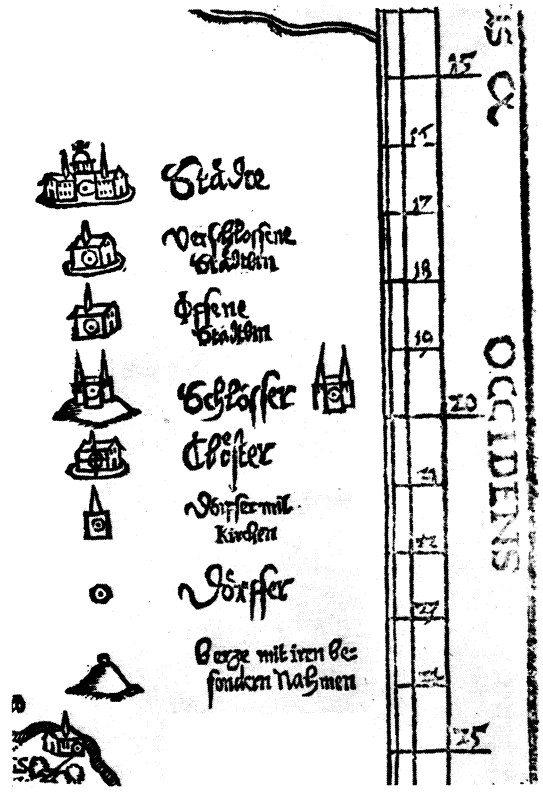


FIGURE 7. Key of a map of Oberlausitz of 1593 by B. Schulz (Scultetus), after F. D. Dainville, S. J. *Le langage des géographes* Paris, 1964.

FIGURE 8. J. Norden's Map of Middlesex augmented by I. Speed, 1610. (After a facsimile.)

FIGURE 10. Negative and positive of a Polaroid pack film by Melvin Sokolsky from an advertisement for Polaroid in *Scientific American*, January 1974 (by permission of the Polaroid Corporation, Cambridge, Mass., U.S.A.).

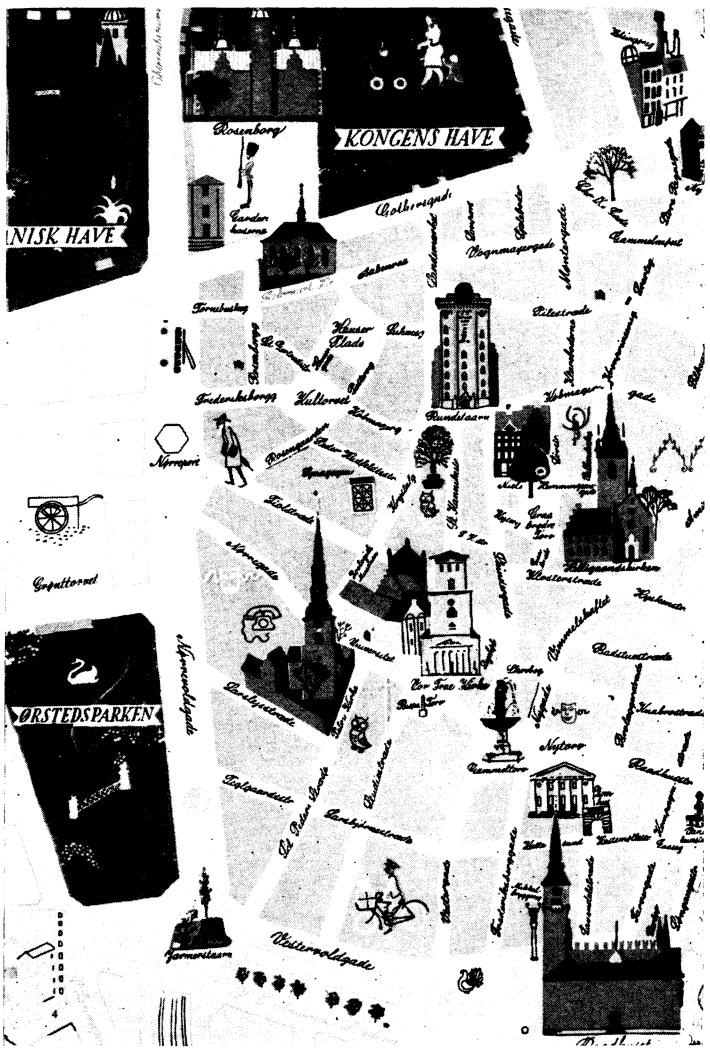


FIGURE 12. Tourist map of Copenhagen by Gustav Hjortland, after R. Broby-Johansens, *Gennem det Gamle Kobenhavn*, Copenhagen, n.d. Gyldendal.

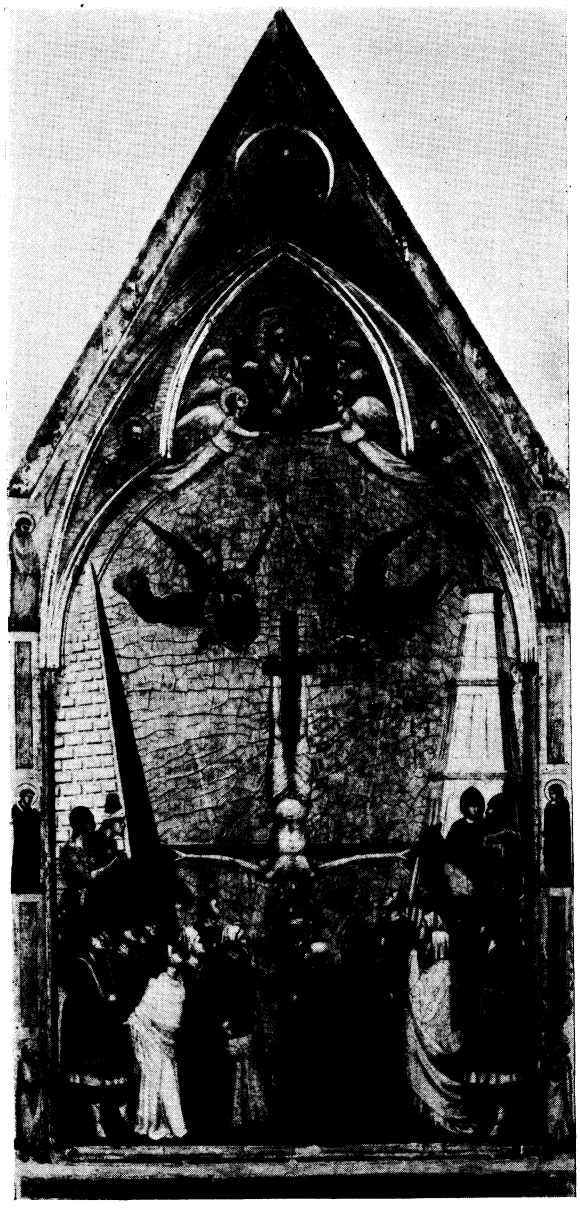


FIGURE 14. Giotto, *The Crucifixion of St Peter*, Rome, Pinacoteca Vaticana. (Gallerie pontificie.)

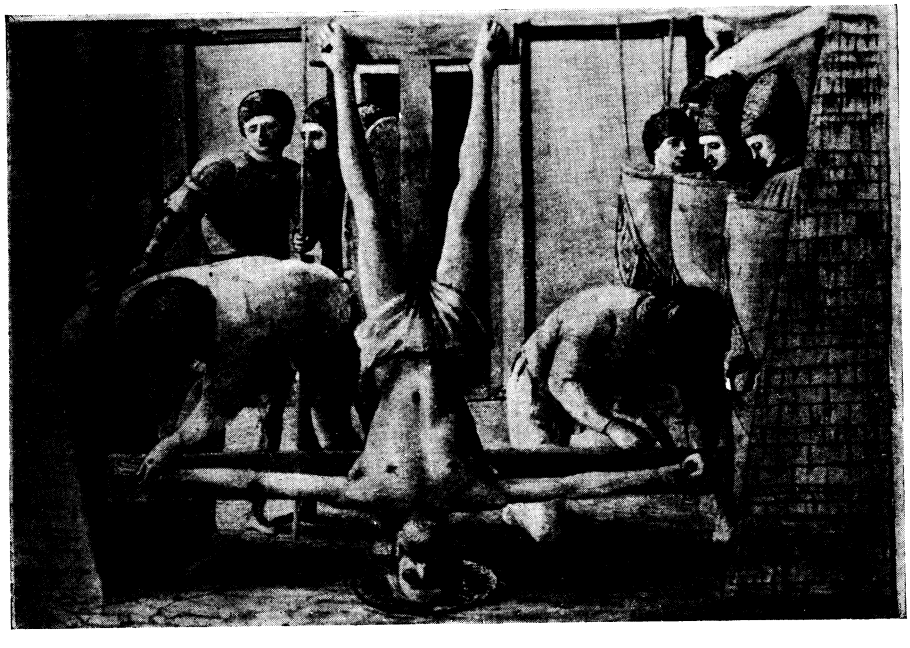


FIGURE 15. Masaccio, *The Crucifixion of St Peter*, Berlin, Staatliche Museen.

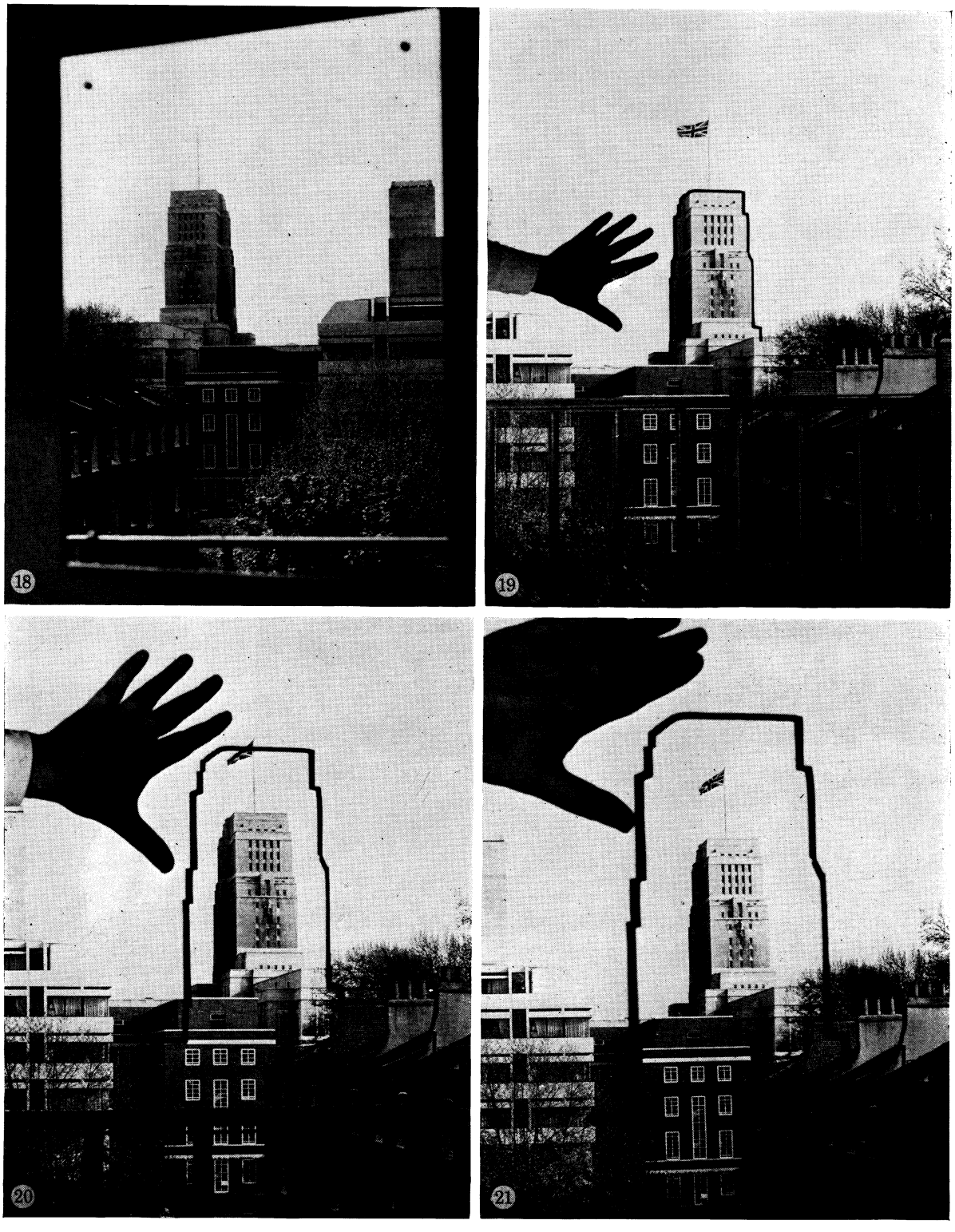


FIGURE 18. View from the upper floor of the Warburg Institute as seen in a mirror.

FIGURES 19–21. The Senate House of the University of London as traced on a window of the Warburg Institute from various distances.

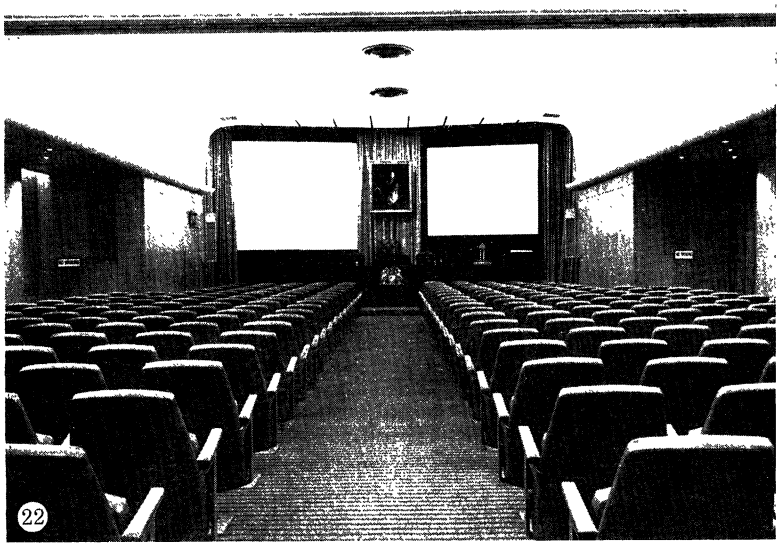


FIGURE 22. The Wellcome Lecture Hall of the Royal Society.

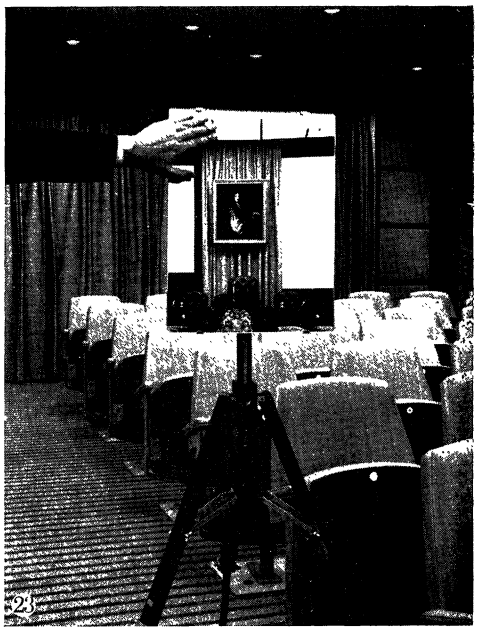
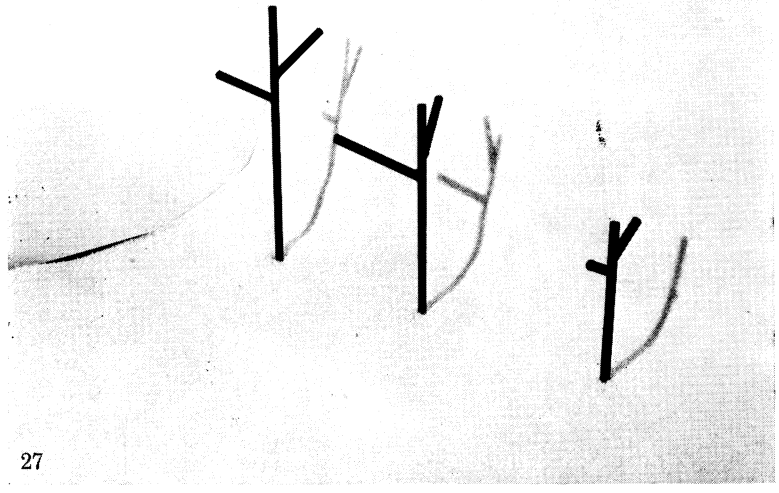


FIGURE 23. The Founder's portrait and the dais of the lecture hall photographed in a mirror.

FIGURE 24. The Lecture Hall of the Royal Society (with a front seat number plate repeated on the door at the back of the hall).

FIGURE 26. Close-up of a head in the Lecture Hall of the Royal Society.



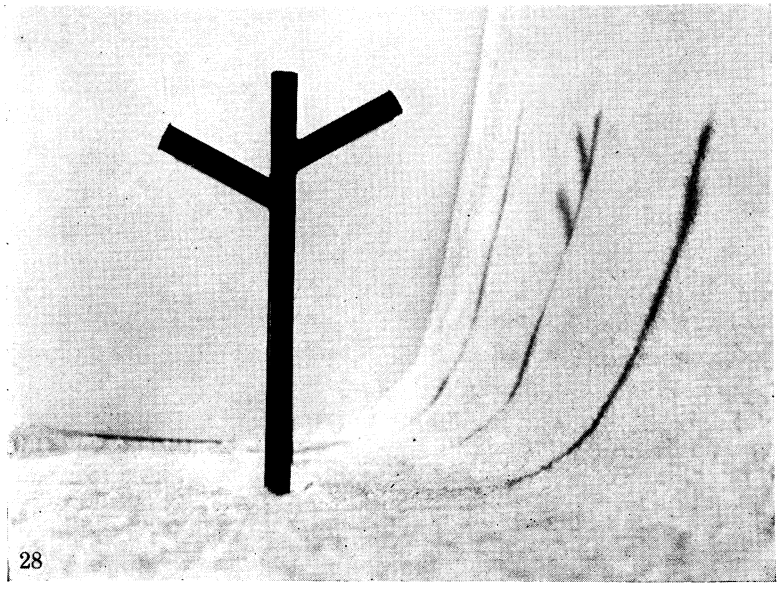


FIGURE 27. Demonstration box: three schematic trees and their shadows (constructed by H. King).

FIGURE 28. The same as figure 27, photographed through a peephole.

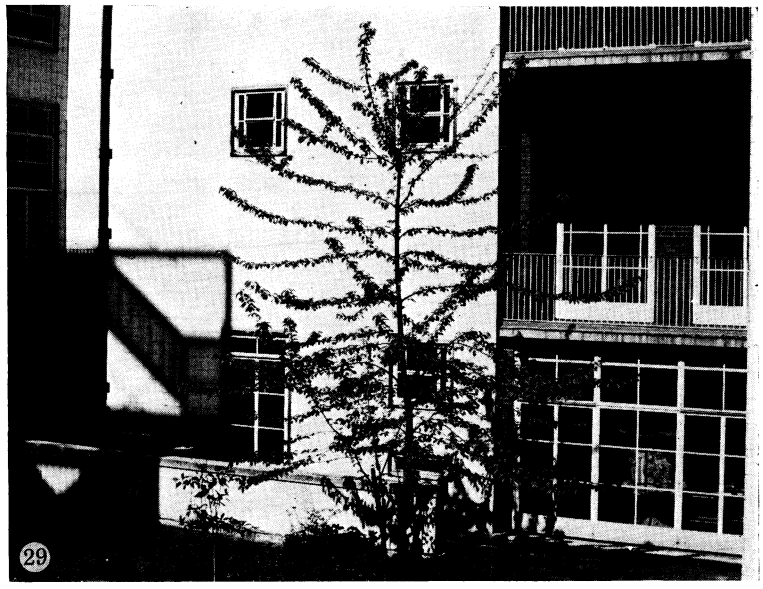
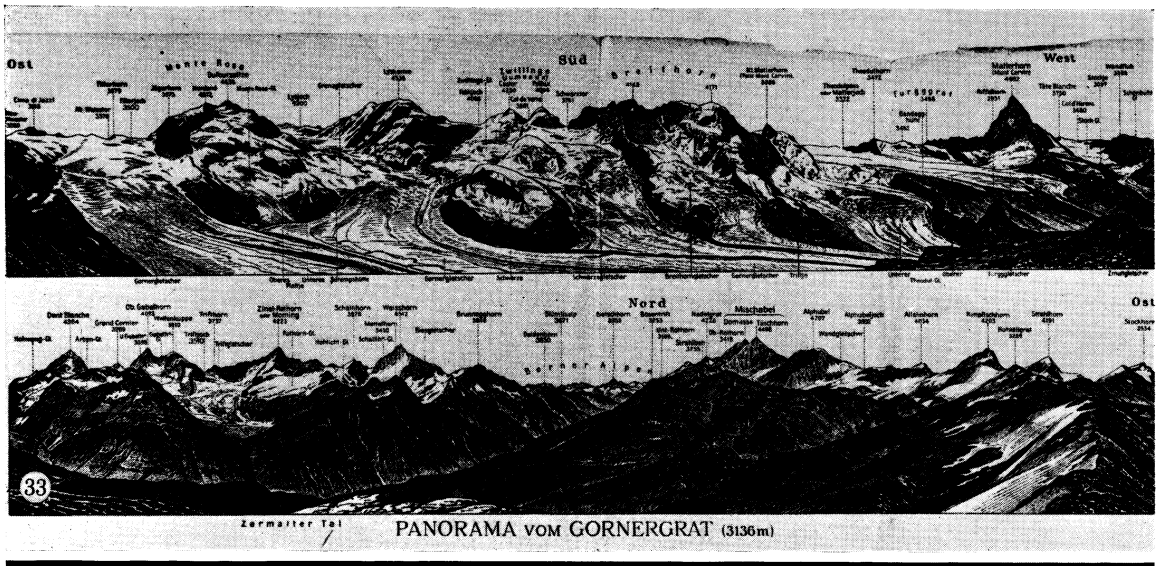


FIGURE 29. Tree in the courtyard of the Warburg Institute.
FIGURE 30. The same tree as figure 29 photographed from above.



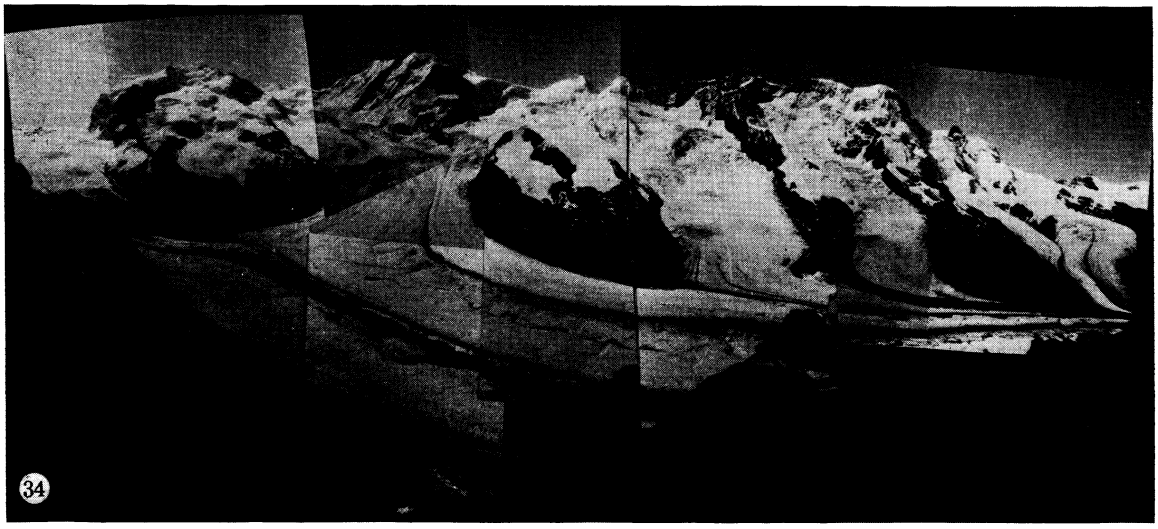


FIGURE 33. Panorama from the Gornergrat after Baedeker's *Switzerland.*

FIGURE 34. Composite photograph of view from the Gornergrat (photographed by Ilse Gombrich).

FIGURE 35. John Wonnacott, *The Family*, 1973/4 (by permission of the artist and the Royal Academy).

FIGURE 36. John Hopwood, *Self Portrait*, 1974 (by permission of the artist).

FIGURE 37. *Beetle and boot*, after E. A. Dyring, *Synligt och osynligt.*

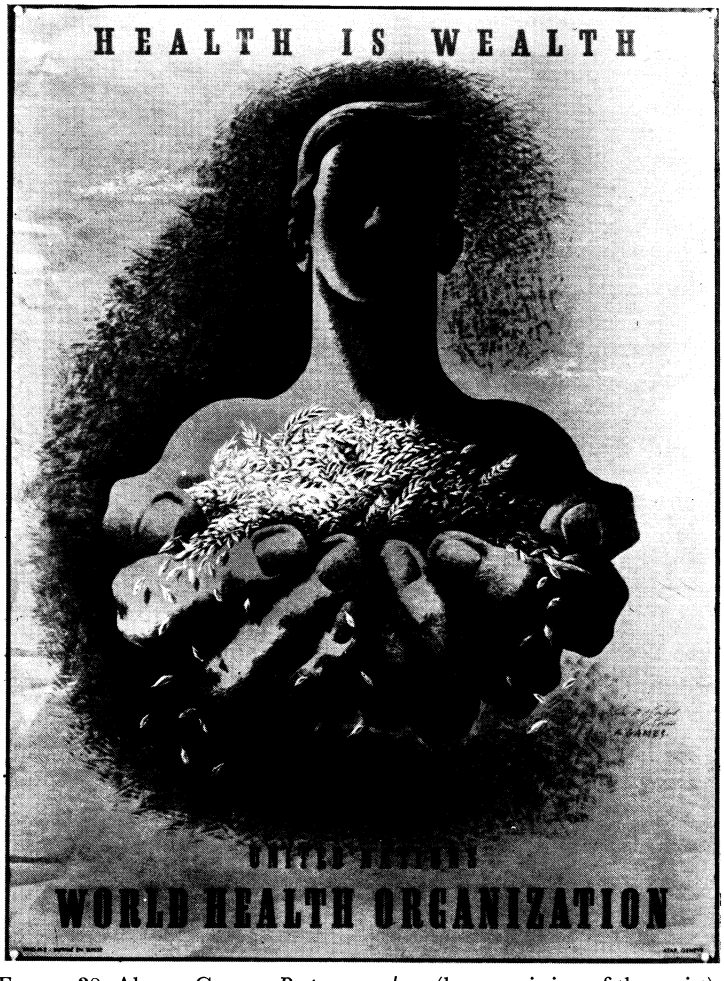


FIGURE 38. Abram Games, *Poster*, 1954/55, (by permission of the artist).

relations in a plane such as a window pane must be attributed to the so-called 'constancies'. Since we know that we see a large building out there rather than a small patch close by, our visual experience is modified. The distant building 'looks' much larger than its projection on the nearby pane. The facts are not in doubt, but the way in which we should describe this discrepancy or rather this surprise, is more open to questioning. The main cause of difficulty here is the term of 'apparent size' which teachers of perspective have used long before the constancies began to figure in the debate. Since by apparent size they meant projected size, we arrive at the paradox that thanks to the constancies distant objects appear to us larger than their apparent size. The formulation almost insinuates that it is our visual experience which rests on an illusion while our tracing tells us what we really see. But we need only shift our position by the window ever so slightly to question the soundness of this assertion, for as we move forward or backward by a yard or two, the view itself will remain more of less stable, but the tracing will radically change. As the hand indicates on the next picture (figure 20, plate 17), the photographer has roughly halved the distance between camera and window pane and the outline has become much too wide. Coming nearer still (figure 21, plate 17), it seems incredible that it should just have fitted so well. But it is precisely at this point that this surprise rather hides than reveals to us what I have called the unsolved psychological puzzle of perspective representation. How can we ever know that we see a distant building and not a patch on the pane? The brief answer is that we may sometimes not know, but merely guess. We *assign* it a distance and a size. Take the flag waving from the top of Senate House – it does not need a lot of imagination to turn it in your mind into a flaw on the pane, and if you have imagination to spare you can even turn the outline into a huge scaffolding and the hand into that of a giant. As soon as we succeed in this game of our imagination we may in fact begin to wonder whether the 'constancies' are rightly named. Should we not rather speak of the 'inconstancies' of the phenomenal world if the apparent size of objects in our field of vision can be so unstable as to be changed by a whim?

The way our perceptual experience can be altered by the adoption of alternative interpretations or hypotheses about what it is we see out there has often been described. Among those phenomena which attest to the plasticity of our visual reactions none is more germane to the subject in hand than Emmert's Law (Gregory 1970). If we stare for a time into a bright light till an after-image forms on our retina we can observe that the apparent size of this luminous patch will differ dramatically according to the distance we assign to it. Look at a book in your hands and the image will only cover a few lines of print, lift your eyes to the distant wall opposite and it will appear to grow to the size of a large picture. It is possible even to train oneself to do without such external props and to change the size of the image while keeping one's eyes closed, merely by imagining it to lie at various distances. Apparent size seems indeed to depend on the arbitrary assignment of a distance (Evans 1959, 29.)

Maybe it is not too difficult to account for this vagary of perception if we remember the multivalence of the visual cone. In terms of the theory of surveying we may say that the stationary eye gives us only a preliminary reading, since we need at least two to plot a point on the map. The situation would be analogous to an incomplete instruction about the location on a map of a particular building, indicating, for instance, only the letters of the grid but not the numbers. Such inadequate information would indeed tell us, as does the visual cone, in what zone to look for the item, but not on what square. Given other sources of information even such an incomplete message could narrow down our search and lead to a hypothesis about the location of the

item to which we might hold on in the absence of convincing alternatives. We thus achieve a constancy *pro tem* though not one that is anchored in valid evidence. This, maybe, is what we are compelled to do in the constraining situation of monocular stationary vision where we are under the compulsion to adopt any one reading, however unsupported by collateral clues. I have argued elsewhere (1959) that here Popper's analogy between scientific procedures and such hypothesis formation is particularly enlightening, for it can be argued that one of the criteria for the selection of such a tentative visual interpretation is the comparative ease with which it could be disconfirmed. This, indeed, may be the value of that principle of simplicity that pervades our perceptual processes and that has been so thoroughly explored by the Gestalt school of psychology. A 'simple' hypothesis is one that can most easily come into conflict with complex facts. Thus I believe it to be a result of this strategy that in the absence of contrary indications we regard the orientation of shapes in our field of vision as normal to the line of sight (Gombrich 1974). This applies to after-images no less than to views through peep-holes or even windows where there are no contrary clues. The frame or scaffolding into which we can playfully turn the outline of Senate House would take on this orientation unless we made an extra effort. But of course none of these readings we might tentatively adopt as alternatives of the view through the window would stand up to reality tests in a real situation. We need only shift our position ever so slightly for the effects of movement parallax to come into play. The forms on the window would detach themselves and refute any interpretation that made them part of the distant view.

5. Perspective representation and perceptual invariants

The relative helplessness of the single stationary eye has in fact led J. J. Gibson of Cornell University to propose a fresh start to the theory of visual perception (1966). He is no doubt right in stressing that we were not endowed with eyes by evolution so that we may look through peep-holes or window panes at multivalent shapes. We have two eyes and these permit us to begin the process of triangulation at the first glance as far as proximal objects are concerned. Moreover we are normally moving through the world and mapping our environment through a continuous series of readings of changing aspects. From this point of view the geometry of the visual cone is much less relevant to perception than is the geometry of developing shapes which give us all the information about the invariant features of the world out there we may need. Coming to the lecture room (figure 22, plate 18) you may first have received a vague mental picture of a space and then used your eyes to modify and refine this map by entering some of the features that concerned you. You may have looked for a seat and had no visual or logical problem in plotting its location on your cognitive map, for as you moved your eyes and yourself the vista changed in a way to which only the film camera could do justice. In Gibson's view this changing vista provides us with quite unambiguous information about the lay-out of the hall, indeed he has gone so far as to maintain that we are programmed to pick up these invariants, the map, from the stream of information which hardly obtrudes on our awareness. From this point of view therefore, the so-called constancies present no problem. I see all the chairs in the row as being of the same size because they are the same size whatever momentary pattern of light they may reflect onto my two retinas.

Gibson's insistence on the perception of the invariants of our environment is of interest to the student of representation because it helps to explain why most pictorial styles of the past contain such a strong element of mapping or what are called conceptual features. Perspective

had to be reasoned out and has to be learned, it cannot be discovered by the eye alone unaided by measurements in the plane. Hence it looks once more as if the apparent size of which teachers of perspective speak was no more than a myth. If we follow Gibson the world appears to me as it is, not as it appears traced on a window pane.

But precisely because of his radicalism Gibson also poses fresh problems for the student of representation. For he has brought out the tremendous difference between our experience of the visible world and the appearance of a picture (Gibson 1971). The photograph, as I said, resembles a frozen mirror image – indeed I have brought a mirror into the hall to do justice to the title of this lecture (figure 23, plate 18). The laws of optics and geometry would enable you to work out exactly where the camera was placed to record the information about the Founder's portrait and its position. If it could be traced on the surface and matched with pigments it would be an accurate representation in reverse of the end of this hall. But we have seen how vulnerable such a view would be to that kind of movement which Gibson stressed as indispensible to perception. Shift your position and you alter the image. Even within the assumptions of perspective theory, therefore, the painting could only claim to replicate the appearance of the hall from the exact point where the camera stood. Yet we disregard this fact when looking at photographs or perspective renderings (Goodman 1968; Pirenne 1970). Indeed we could not show such representations on the screens of our lecture halls if they were as volatile as mirror images, for every member of the audience must see them differently. Why is it that such pictures are so resistant to anamorphosis that they tend to right themselves? Perhaps we come nearer to an answer if we think of maps. A map would also become foreshortened when seen from the side, and so would the printed page of a book, but we are not disturbed by these changing aspects because we see them as they are – or, to use a less radical terminology, because of the constancies. Up to a point we read perspective pictures as if they were maps, but we have also learned that as maps they would be highly unsatisfactory. There is no key, only assumptions to guide us. The picture of our hall (figure 22, plate 18) could also be taken to represent a very unusual and inconvenient space, one in which the floor is slanting upwards towards the dais, while the real chairs diminish in size so that only children could use the front row. Glancing back at figure 16 we would even have to admit that the walls and boundaries of the hall might be cunningly curved while yet looking straight from one viewing point. Once we have prized loose our reading we must admit that any number of model halls could be constructed all of which would result in the same keyhole picture and therefore in the same multivalent map.

But this is manifestly not how we experience the picture. We might say that on the contrary it compels a reading by means of a visual effect that is almost as strong as are the physiological reactions to the stereoscope, the cinema camera or the television screen. Remembering the terminology I then proposed I would claim that the picture creates an illusion. Not an illusion of reality, to be sure, but an illusion that can be assessed by the surprise we feel when we compare what is there with our visual experience. One of these surprise effects is often exploited by guides to galleries – it concerns the apparent shift in orientation of the objects represented. It is a fair guess that anybody in the hall will see the gangway between the seats as oriented towards him, an effect which points to the limits of the constancies and the difference between the picture and the map. The element of anamorphosis takes us unaware, we do not notice to what extent the arrangement in the plane has shifted and we assign this shift to the represented array (Gombrich 1972*a*).

More than that. It can be shown that even when we look at a photograph there is a tendency to assign different distances to the images of different objects and thereby to change their 'apparent size' (Gibson 1950, 1–176; Gombrich 1969). The head of one of my colleagues at the end of the hall fills the same area in the plane as do the number plates under the seats in the first row (figure 24, plate 18). It is easy to demonstrate this fact by repeating one of these number plates by the side of the head on the panel of the door. But the result of this transplantation is only that now the plate, too, looks much larger than in its original setting. If that is so, it follows that even a simple photograph produces an illusion, that is an unexpected visual experience: an experience we find surprising because it is manifestly non-veridical, as when we are shown identical shapes in a perspective setting and are led to misjudge their relative size (figure 25).

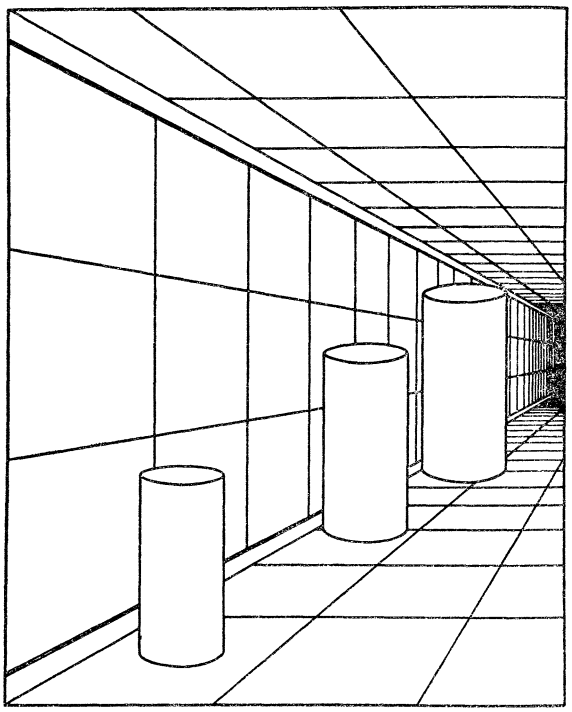


FIGURE 25. Three identical shapes in a perspective setting (after J. J. Gibson, *The Perception of the visual world*, 1950).

I have a protracted friendly debate with Professor Richard Wollheim (1973) about the nature and strength of these illusions since I obviously find it less easy than he does to counteract the pull of virtual depth in pictures. I am all the more happy to find that efforts have been made by Richard Gregory (1970, p. 92) and Kenneth Adam (1972) to measure these deviations from projected size. I am most interested in their procedures, though I confess that I am not quite sure yet what it is they measure. Is it a perceptual compulsion or a habitual reading? We would need more studies of the variables which come into play here. To what extent does familiarity of objects represented or of representational media influence the experience? What effect would it have if we reversed the picture, turned it sideways or upside down? How do colour photographs compare with black and white ones, what are the artifices available to painters which can either strengthen or counteract this effect which they no longer welcome?

Where pictorial devices can fairly well replicate a visual experience as in the cinema the effect may well be the strongest. Even stills may contain more indications of the perceptual invariants

than we usually give them credit for. One of them, as Gibson (1950) and his disciples have rightly stressed, derives from texture gradients, that is from visible microstructure of surfaces such as a carpet or the wall covering. It is here that the 'simplicity hypothesis' will serve us in good stead, for the assumption of uniformity in grain and texture is so safe a bet in normal circumstances that we can take it as a cue for depth.

Now the painter can certainly not replicate this texture gradient in his medium, but he can suggest it in another order of magnitude, and this suggestion, too, will tend to have a comparable effect. How is it with line drawings? We are back at the problem of representational conventions where views are most in flux (Jung 1974). It used to be said that there are no lines in nature and that outlines are therefore a human creation, a mapping device. But here, as in the case of photographs in black and white, we must be careful lest we fly in the face of the evidence. In a stimulating recent book *A psychology of picture perception*, Professor John M. Kennedy (1974) has argued vigorously against the view that the understanding of outlines has to be learned like any other code. The experimental and observational material he has collected to show that not only young children and untutored tribes but even animals accept outline drawings without training is certainly impressive. He speaks of the surrogate function of outlines as indicators of visual discontinuities. Julian Hochberg (1972) has argued independently I believe, that one of these discontinuities is of special significance. Outlines can serve as predictors of the effect of movement parallax, for objects within our reach will always detach themselves from their background but cohere internally if we move our head ever so slightly. Maybe there are other compensatory devices which import an element of mapping even into perspective renderings from one station point. One of them may well be the convention of holding the camera level. It does not correspond with our habits when we look around in the world, but in real life it is our sense of balance which gives us the indispensable coordinate of the plumb-line. When we are deprived of this aid the parallelism of uprights provides precisely a substitute which gives us comfort, though we can learn to do without it, as we can learn to do without outlines.

Who knows whether response to perspective convergence is not of similar importance in our reaction or representations? This, at any rate, is what Richard Gregory (1970, 1973) would make us expect in his explanation of the Müller-Leyer and other illusions. If he is right the arousal of illusions in photographs of this kind may be as deep rooted as is the illusion of movement on the television screen. The trick had to be reasoned out and tried, but it stuck because it worked. It has seemed to me for some time in any case that the discussion of perspective has got too much entangled with the psychological problems of apparent size and subjective sensations. Richard Wollheim and I may slightly differ about the size we assign to the head of the person in the last row. We are sure to agree what happens to us when we ourselves sit behind that head (figure 26, plate 19). Since it is not transparent it occludes the hall and how much of it it occludes from any given point can be worked out with ease from a knowledge of central projection.

6. Objectivity and indeterminacy

It may be worth dwelling for a moment on what I have called this objective aspect of the theory of perspective, the possibility of working out not how things will appear to me from a given station point, but what things cannot appear to me at all because they will be occluded at that point (Gombrich 1972*a*). I have asked an artist to construct a little box which resembles the Ames demonstration, though its purpose is a little different (figures 27, 28, plate 19). Seen

from the viewing point the three schematic trees occlude each other though objectively they differ not only in size, but as far as the middle one is concerned, also in shape and orientation. The first point I want to stress is that this objective fact of occlusion is quite unaffected by the subjective appearance. It is quite irrelevant to this demonstration whether the viewer is astigmatic or even whether he looks through the peep-hole through a distorting lens. More surprising perhaps, it is also irrelevant whether he looks at the trees straight on, or whether he tries to roll his eyes to gaze in a different direction. Certainly if he does, the image will get blurred but there will be no movement parallax and no other tree will come into view (Doesschate 1964). Naturally the situation will change if he turns his head rather than his single eye, for then he sees the arrangement from a different angle and the two other trees will emerge. He may also see them indirectly as it were, if they cast strong shadows which indicate their presence, and given a strong texture gradient he will be able to estimate their relative distance. In other words his knowledge may again influence his visual experience. Our box could possibly be used to investigate this tendency from yet another angle. If we allowed our subjects to inspect and to handle the box before applying their eye to the peep-hole they would be likely to be influenced in their experience by the information they have. Thus removing the foremost tree in their presence might lead to an alteration in the apparent size of the silhouette despite the fact that the retinal image has remained constant. If this prediction could be confirmed it would suggest a generalization of Emmert's Law discussed above. As in the case of Emmert's Law and germane phenomena we would also expect that the apparent orientation of the tree seen through the peep-hole would remain normal to the line of vision despite the fact that the real orientation of the branches is irregular, unless our memory, or contrary indications due to illumination, make us revise our spontaneous hypothesis.

It is true that in this and in some other respects our model box can present no more than a partial analogue to a real situation which allows free scope to binocular vision and accomodation, but the analogue may still be instructive because these and similar helps let us down with an increase of distance or a decline in illumination as at dusk.

I have chosen trees for this little demonstration precisely because unlike halls, chairs and even people they come in all sizes and orientations and offer little scope for the use of past experience. They therefore constitute good material for testing Gibson's claims for the information we receive through the eye. Take photographs first. How much can we in fact tell about that tree in the courtyard of the Warburg Institute? (figure 29, plate 20). Could anyone have predicted even approximately what the view of the same tree would turn out to be when photographed from above? (see figure 30, plate 20).

It seems to me that such simple questions are surprisingly rarely asked. True, members of primitive tribes are occasionally grilled by anthropologists about their reading of spacial relations in pictures (Deregowski 1973), but the same interviewers show less curiosity about the precise limits of their own interpretation of photographs. What one would like to see is a systematic comparison between the informative value of a photograph, a stereoscopic picture, a moving picture and that of the real view when seen from a given station point either through a peep-hole or in free ranging vision. All we would have to do is to ask subjects more searching questions than, I take it, J. J. Gibson (1971) asked in front of a photo mural of an area they knew from experience. We might even ask them to attempt wire models of trees or, best of all, sketch maps of the whole area they see in front of them, preferably under various conditions of illumination and visibility.

Such tests are likely to confirm the degree to which we account for our perceptions of the physical world in terms of 'universals'. We identify 'a' mountain, 'a' tree, 'a' house, as if we were reading a map, and we attribute to these objects qualities and spacial relationships of a general nature allowing much latitude to subsequent adjustments. We only feel we have made a mistake if what we took for a house turns out to be a stone or what we described as a blue flower turns out to be white. This cognitive map, moreover, is always likely to react back on our visual experience. We rarely have occasion to compare notes about all the details of such an experience, but if we did it is likely that we would be surprised at the range of interpretations the same sight can evoke.

Once this is established we can be more specific about the demands we can make on what we call a faithful rendering of the scene. Far from forcing us to adopt any one of these various interpretations, such a representation should afford the same range of interpretations as does the real scene. This range would of necessity also include the correct one, though we might never know without external aids where along the continuum of readings it is to be found.

I hope this rather laborious way of describing a very commonplace thing such as a picture postcard may pay some dividends in clarifying the issues on which so many arguments in the theory of representation have turned. It is undeniable for instance that a distant mountain looks subjectively both larger and steeper than its tracing on the window pane would suggest. No wonder it has been claimed that only a record of this subjective experience can communicate to us what the artist really saw (Goodman 1968). But here as always we must beware of the 'Greco Fallacy'. When one of Whistler's students claimed she only painted what she saw he gravely replied: 'But the shock will come when you see what you paint.' There is more psychological wisdom in this witticism than in many books on art.

Even leaving art on one side and speaking of picture postcards it must be expected that a view of Zermatt which exaggerates the height and slope of the Matterhorn would lead us to overrate its soaring quality even more, so that if we now copied this view and our copy were copied again we would soon produce a fantasy landscape. The tracing or photograph on the other hand, may possibly cause us a fleeting disappointment, but if it were placed in the right setting, say as the backdrop of an illusionistic stage, it should ideally result in the same visual experience as does the real view.

It is the advantage of the informational approach that it allows us to sort out these issues without falling into relativism. Let us return here to the view of the Vienna Museum as seen in the morning haze (figure 4, plate 13). Gibson is certainly right in reminding us of the value of light and texture in gaining a great deal of information about the foreground array. Moreover there is our equipment in what he calls 'ecological optics', the behaviour of things in our world. The figure of the man striding on the path would prevent us from misinterpreting the brighter strip as a wall standing normal to the line of sight as we might otherwise do. But the same principle of simplicity asserts itself more strongly in the case of the trees, for there is nothing much in these silhouettes which clearly indicates the orientation of branches and twigs and so we read them more or less as stage props without really taking them to be flat. What seems to me noteworthy here is not so much the limit of information at our disposal, which is natural enough, as our reaction to these limits. Jerome Bruner (1957) has spoken in this connexion of 'gating'. We do not normally ask questions in perception to which we cannot expect any answers. Just as we have learned not to reach for the moon, so we do not fret about information which is excluded from the situation we recognize. This resignation of course is called for when

our eyes reach a distance where change of focus, binocular disparity, texture gradients and even movement parallax yield progressively little return. All we have at our disposal here is the information contained in the light and this information is not particularized. It does not yield to the reality tests which Gibson has shown to play such a part in our dealings with the stage of our actions. The backdrop to this stage remains an unsubstantial world of 'appearances' to which Gibson's radical realism cannot be applied. It is here, indeed, that the phenomenal world, the distant blue hills and snowcapped peaks, the clouds and the gleam of the ocean are perceived in the way in which we perceive not a map but a painting.

It would be interesting to find out to what an extent the habit of taking up a purely contemplative, aesthetic attitude towards such prospects is culturally determined by our exposure to landscape paintings and photographs. Maybe members of a nomadic tribe who have to scrutinize the distant horizon for landmarks experience such sights in a very different way. We may recapture something of this difference when we watch our own response to a distant prospect of a familiar scenery, or even of a view we have just examined through binoculars (Gombrich 1969, p. 48). It is then that we will come to realize that our healthy refusal normally to scrutinize the distant view for precise information about the size and orientation of its components tends to give it the misleading appearance of a static and unalterable phenomenon. We have the illusion that this view at any rate, is 'given' to us and that it allows us to watch our visual sensations 'neat' as it were. A little effort at introspection will disabuse us of this thought which hides from us the very flexibility of appearances which it had been my purpose to bring out in this discussion. Both in reality and in pictures we can, if we so wish, see these distant phenomena in various ways. They can acquire all the plasticity and variability that belongs to our unconfirmable visual hypotheses. We can play at Emmert's Law with the indeterminate clouds in the sky and with the fading mountain ranges. After a little training in visual gymnastics we can make them take on a subtly different appearance according to the shapes and relations we tentatively attribute to them.

I realize that my contention that our visual world is much less definite and stable than it is often supposed to be, and that it should rather be described as slightly elastic at the edges, is likely to arouse not only scepticism but even resistance. It is not hard to see the roots of such discomfort. For it must be granted that our aim will always be to see a stable world since we know the physical world to be stable. Where this stability fails us, as in an earthquake, we may easily panic, for we appear to lose the cognitive anchorage we need in our effort after meaning.

I believe however that the nature of this anchorage changes as we leave the proximal world with which we interact and scan the distance. I have postulated elsewhere (Gombrich 1974) that we may have to return here to an old distinction which was much discussed at the turn of the century. At that time artists such as the sculptor Adolf von Hildebrand became critical of impressionism and stressed the importance of 'tactile values' in our perception of the immediate environment. Gibson has shown us why this appeal to other sense modalities is somewhat redundant in accounting for proximal vision. But where lies the limit between this world which we see as it is and the world which we can only conjecture? I have suggested that there can be no such limit, but that the visual hypothesis with which we respond to distant impressions will tend towards certain characteristics, such as the prevalence of the simplicity principle. Where all other information lets us down we adopt the provisional assumption of objects silhouetted normal to our line of vision, with the consequence that this limit of our environment will assume

the form of a dome enclosing the stage of our actions. It is this limit which proves particularly flexible. It may enclose us at dusk, and recede on a clear day or after the use of a telescope.

7. Why appearances cannot be mapped

I should like to propose that this variability of distant vision has an important bearing on a problem that has bedevilled the discussion of representation for a long time. I mean the quarrel about the curvature of the phenomenal world (Panofsky 1924, 1925; White 1957; Gombrich 1972*a*). Neither the sky that vaults over us nor the horizon that surrounds our vista is straight. How can we claim therefore, that the theory of the visual cone with its isomorphic projection of planes onto parallel planes correctly represents the phenomenal world of our experience? I have indicated before that I find it difficult to give a clear operational meaning to the concept of phenomenal size or shape, as distinct from real size and shape which can be measured or mapped. And I should like to propose that the source of that unending quarrel rests on a confusion between the mirror and the map.

Figure 31. An astronomer with his quadrant (from Sebastian Münzer, *Organum Uranicum* Basle, 1536).

Before the psychology of perception was ever thought of the ancient Greeks realized the problem to which I am alluding. It was they who coined the phrase of 'saving the appearances' in relation to the appearance of the stars. I have postulated that saving the appearances is what we are always concerned with when faced with the indeterminacy of the single view point. What we see can and indeed must be consonant with an infinite variety of possibilities out there, between which we cannot decide on the visual evidence alone. From this point of view the starry heavens may be described as a gigantic Ames experiment which nature has set up for man. Falling back on the simplicity principle we assign the luminous dots a tentative place and order in the sky normal to the line of sight. This expedient allows us even to turn the apparent constellations into pictures of things, but we also know perfectly well that their real configuration in space must remain unknown to us as long as we rely on the naked eye alone.

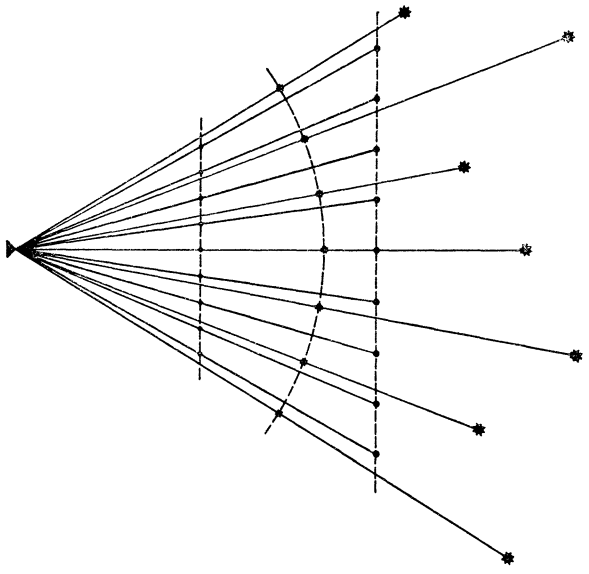


FIGURE 32. Diagram of the vault of heaven (drawn by H. King).

The early astronomers who wished to map the heavens certainly lacked the resource of parallax. They used the method of alignment with their quadrants (figure 31), but they had to be satisfied with the relative position of the stars along an imaginary circle. In other words they measured the visual angle a constellation subtends because that is all they could measure with the means at their disposal. It seems immensely plausible to go on from there and to say the phenomenal size depends on the visual angle, yet this is precisely the moment when we must watch our step (Ronchi 1971). Like all measurements from one station point the visual angle provides us with information of an infinite class of things in space and here as always this geometrical fact is masked from us by our tendency to fill the void in our knowledge by a general hypothesis. The vault of heaven, to repeat, is such an assigned distance, not phenomenally very precise or rigid, but coherent enough to create a puzzle.

A diagram of the situation should make it clear how I propose to settle this conflict (figure 32). One set of lines points to a number of stars which can be aligned by moving the quadrant by 15 degrees. Having no further information about their real distance we hold them, as it were, along those first readings at an approximately similar distance, that is on the imaginary vault of heaven, on which, of course, their assigned intervals will be the same from dot to dot. If the

imaginary vault of heaven were the solid surface of the earth, such equidistant spots would not come out equidistant in a flat projection and it is this fact that has led to what seems to me a Babylonian confusion of tongues. Only points equidistant in a plane will come out isomorphic, i.e. equidistant on our window pane. I have tried to postulate such a row of equidistant stars somewhere out in space. These, it is clear, would not look equidistant if measured by the visual angle on the vault of heaven, but barring complications of refraction they should project equidistant on the plane and it is thus that we should project them if we kept our eye still and looked up to the sky, or, to put it in a different way, if we pricked equidistant holes into a piece of flat cardboard all these stars should remain potentially visible to our eye.

Of course the experiment would demand a fixed station point which seems a particularly artificial restraint when scanning the heavens. But I think that trying some such experiment would also show why the comparison between the phenomenal vault of heaven and the solid globe is in any case misleading. Since the sky is the result of a vague hypothesis it is much less determinate than we tend to think – in any case the notorious moon illusion which is related to Emmert's Law reminds us that it is not imagined as a perfect hemisphere (Gregory 1970).

I should like to propose that what goes for the sky also applies to the distant panorama from a mountain top. No doubt the horizon is round because the earth is round. No doubt also that we can point in any direction and identify a particular peak. It is easy to imagine a tracing of that view on the inside of a spherical glass dome. Guide books sometimes print such panoramas as the one from the Gornergrat in Switzerland (figure 33, plate 21), Going up we can confirm the accuracy of the horizon line, but find the foreground features distorted. How, then, can we justify taking our cameras up to the Gornergrat and making a succesion of snapshots, claiming them to represent the view correctly? If we take a succesion of such views and paste them together (figure 34, plate 21), they will again fail to fit. We must arrange them in a fan-like fashion and we have to choose which horizontal line we want to cohere. Could we ask for a better proof of the conventionality of the single perspective view or the snapshot? In my opinion this argument rests on the same confusion as does the argument about the vault of heaven. What a picture can show us objectively is what lies behind what when we look out into the landscape. The further we move into the distance the less do we guess or want to guess about the real lay-out. The chain of the Alps as seen from a plane on the flight to Zurich looks indeed like an apparition, merging with the sky, but this apparition does not tell us anything of directions and occlusions, it is a highly multivalent assigned configuration which I can see both as straight or curved because I cannot tell how the mountains are really arranged. I can tell even less if I keep my gaze fixed in one direction, for peripheral vision is even more indeterminate. We are back at the problem of what mountains look like while we do not look at them.

Books on perspective rarely dwell on the very narrow limits of foveal vision, because their topic is geometry, not psychology. Instead they frequently discuss certain somewhat unexpected consequences of the geometry of central projection onto a plane which increase with the width of the angle on either side of the line of sight (Pirenne 1970). A row of identical columns, for instance, will represent the outer ones as thicker than the ones close to the centre, just as spheres will only project as circles when placed in the line of vision but will project as ovals of increasing flatness the further they are removed from the centre.

I have tried to analyse the geometrical reasons for this effect in *Art and illusion* (1960, p. 216) and have emphasized that it cannot be used as an argument against the isomorphism of parallel planes. Unlike spheres, circular wire hoops parallel to the picture plane would not project as

ovals but as circles. The disconcerting effect of solid columns or spheres is merely due to their extensions beyond the plane and our inability to distinguish their various aspects. Once more I would contend that the surprise that is felt about these consequences of the theory of perspective rests on a confusion of the mirror with the map. In maps we want identicals to show as identical regardless of the angle from which we happen to look at them. It is different with the projected image. All the theory claims, and rightly claims, is that it records the multivalent information the single eye would receive when placed at the apex of the 'visual pyramid'. What else can we ask for?

The malaise caused by the effect of the wide angle views indicates however that we do want something else. We want perspective representations to share certain characteristics with maps. In other words we do not want them to function only in peep-boxes for monocular viewing from a fixed point, but to convey their information much as maps do to the moving and scrutinizing eye. Now even pictures taken at a normal angle extend beyond the area of foveal vision unless we look at them from an unreasonable distance. Hence they, too, do not replicate the visual information received at a single glance, but are read sequentially as an account of what was visible to the scanning eye from a given point. We have seen (p. 137) that this attitude to pictorial representations makes them nearly as resistant to anamorphosis as the printed page.

If the lateral distortions which are inseparable from central projection cause us discomfort in reading such pictures, this is due to the fact stressed by Gibson that we are unaware of our retinal sensations while we scan the environment for its invariant features. No wonder mapping styles are easier to learn and that alternatives to central perspective remain of interest to artists and engineeres (Dubery & Willats 1972; Reggini 1974).

Geometrically a wide-angle photograph is neither more nor less correct than one taken with a normal focal length. The difference is one of psychology. The photograph of the two Museums facing each other across the square with which I opened this enquiry (figure 1, plate 12) is certainly informative, but to those who know the situation it may look odd, for there is no point from which we could take in both without turning our heads. True, if the architecture of the city allowed it (which it does not), we could take up a station point far enough to see both buildings at one glance, but from that point the facades towards the square would be much more steeply foreshortened. And yet I can see no advantage in adopting an alternative system of representation. To introduce curvature in order to indicate the effect of turning my head seems to me to destroy the informational value of the wide-angle photograph without adequate compensation. The photograph, corresponding to central projection, gives me the information that certain lines are straight and that parallel planes are isomorphic. Of course if I turn my head the line that has just projected at a certain length will be stretched or shortened on the projection plane, but mercifully the elasticity of our visual experience does not extend to this incessant transformation of the optical world. Far from seeing straight lines bend and contract while we turn our head we use these evolutions for the perception of their invariant shape.

Even so, one champion of a curvilinear system of perspective, R. Hansen, has accused me of dogmatism (1973). He assures his readers that he can make them see the walls and doors of their rooms curve as they move their heads from left to right and back again. I would not want to be dogmatic here for I have no doubt that he can so see them. What I doubt is only his contention that this possibility reveals to us what we 'really' see. Mr Hansen, of course, is in excellent company in the belief that our visual experience is uniquely correlated to the optical world which it is his business to map. It so happens however, that a great biologist, Erich von

Holst (1973) used very similar diagrams but came to the opposite conclusion. In an important paper on the 'Active function of human visual perception' he asks precisely why we do *not* see our walls curving and our rooms tapering. His answer which is partly indicated by his title includes a reminder of the fact that the eye does not register impressions during saccadic movements and that we therefore do not normally experience that continuous displacement which Mr Hansen has taught himself and his disciples to observe. Mr Hansen's world, in other words, is even more elastic than mine and infinitely more so than Gibson's but he regards this rubbery world as more real than the stable world about which we seek information both in reality and from pictures.

I agree however that it would be dogmatic to deny the psychological and artistic interest of this chase after appearances. Lawrence Gowing's attempt (figure 5, plate 14) to catch and to map his sensations in unfocused vision is a case in point. Contrary to a widespread prejudice painters of our day continue to be fascinated by the elusive questions of what we really see. We need only pay a visit to the current Exhibition at the Royal Academy to see many such experiments. The one by Mr John Wonnacott (figure 35, plate 21) deals precisely with the problem of wide angle vision and its consequences. It shows the painter's family in the garden; near the centre of the field of vision the figures and objects are undistorted, but the closer we come to the margin, the more the painter has used the technique of anamorphosis, pulling the shapes apart and curving the fence to compensate for the fact that his picture is flat and his horizon round. It would be interesting to put his large canvas into a peep-show and to experiment with the result of foreshortening it through a swivelling eyepiece held close to the picture. Obviously Mr Wonnacott regards it as his task to map the optical world rather than his experienced world as unconpromisingly as he can. The self portrait by Mr John Hopwood (figure 36, plate 22) does the same, though in a less startling way. He takes the mirror theory at its word and shows us the kind of apparent distortion which certainly follows from projective geometry once we choose a very close station point. The question whether or not Mr Wonnacott or Mr Hopwood really saw his motifs like that is less easily answered. Gibson would certainly deny it for within our immediate world of action the invariants win every time over our momentary retinal image. I find it hard when using my hands to remain aware at the same time of the way their apparent size grows and shrinks in my field of vision. But before dismissing such experiments as misguided, consider the way such effects can gain meaning and urgency as soon as our emotional reactions become involved as in these two memorable images of menace (figure 37, plate 22) and of welcome bounty (figure 38, plate 22),

Maybe that is the point from which this review of representation should have started, but then it might never have come to an end. For our reaction to the visible world in not primarily cognitive. We can be triggered by an infinite combination of stimuli. Ethologists have shown the way such reactions can be explored by the systematic variation of dummies which act on the internal release mechanisms of animals. We are daily subjected to a battery of such experiments trying to arouse our appetites, our anxieties or our curiosity by ever fresh inventions of visual images combining realistic photography with the weirdest distortions and the most unexpected symbolism. How is it human beings can be expected to respond to such a range of devices? Is it not precisely because we always use our eyes to explore, to search, to seek and to avoid at the slightest hint? These reactions as I have said, are largely outside the range of our introspection but they can be manipulated and even made conscious through artifice. It is sometimes said that images teach us to see. This is a pardonable over-simplification, but images may indeed

teach us to recognize and specify a visual and emotional effect which has always been present in our experience. The search for these effects is much older than the science of psychology. It is known as the history of art.

I should like to thank the photographers of the Warburg Institute Mr S. G. Parker-Ross and Mr P. N. Wright for their tireless help. Mr H. King kindly made the demonstration model and the diagram to my instructions. My student Mr Kim Veltman with whom I have frequently discussed these problems proposed improvements of the MS.; I am also indebted to my sister Dr Lisbeth Gombrich for drawing my attention to the map illustrated in figure 9.

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FIGURE 1. The Maria-Theresien-Platz in Vienna with the Museums of Natural History (left) and of Art History (right). From R. Wagner-Rieger, *Die Wiener Ringstrasse* by permission of the publishers, R. Böhlaus Nachf.

FIGURE 3. The Museum of Art History in Vienna after Barbara Pflaum and Jörg Mauthe, *Wie ist Wien?* E. Hunna Verlag, Vienna, 1961 (by permission of the publisher).

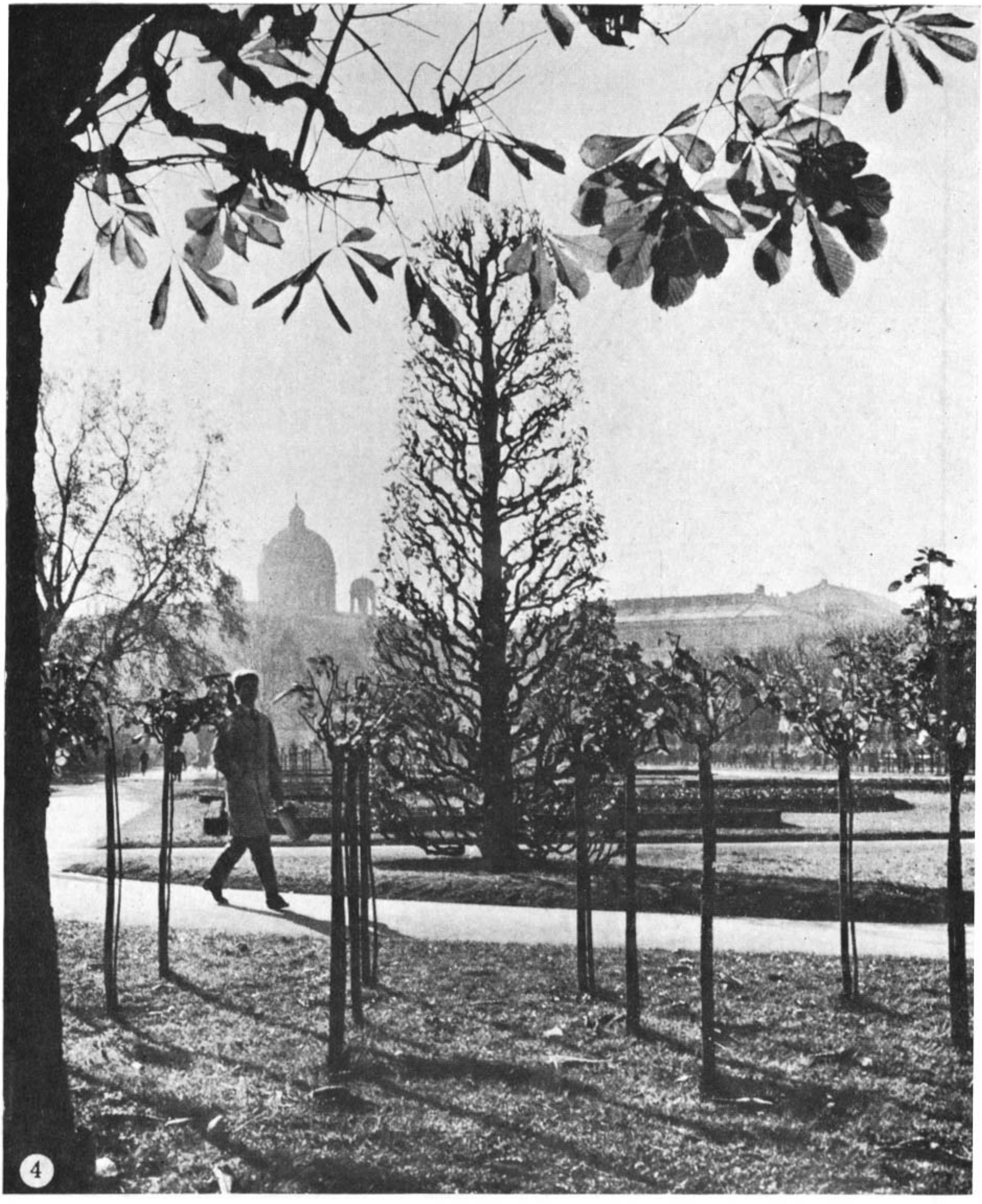

FIGURE 4. The Museum of Natural History from the Volksgarten (source as for figure 3).

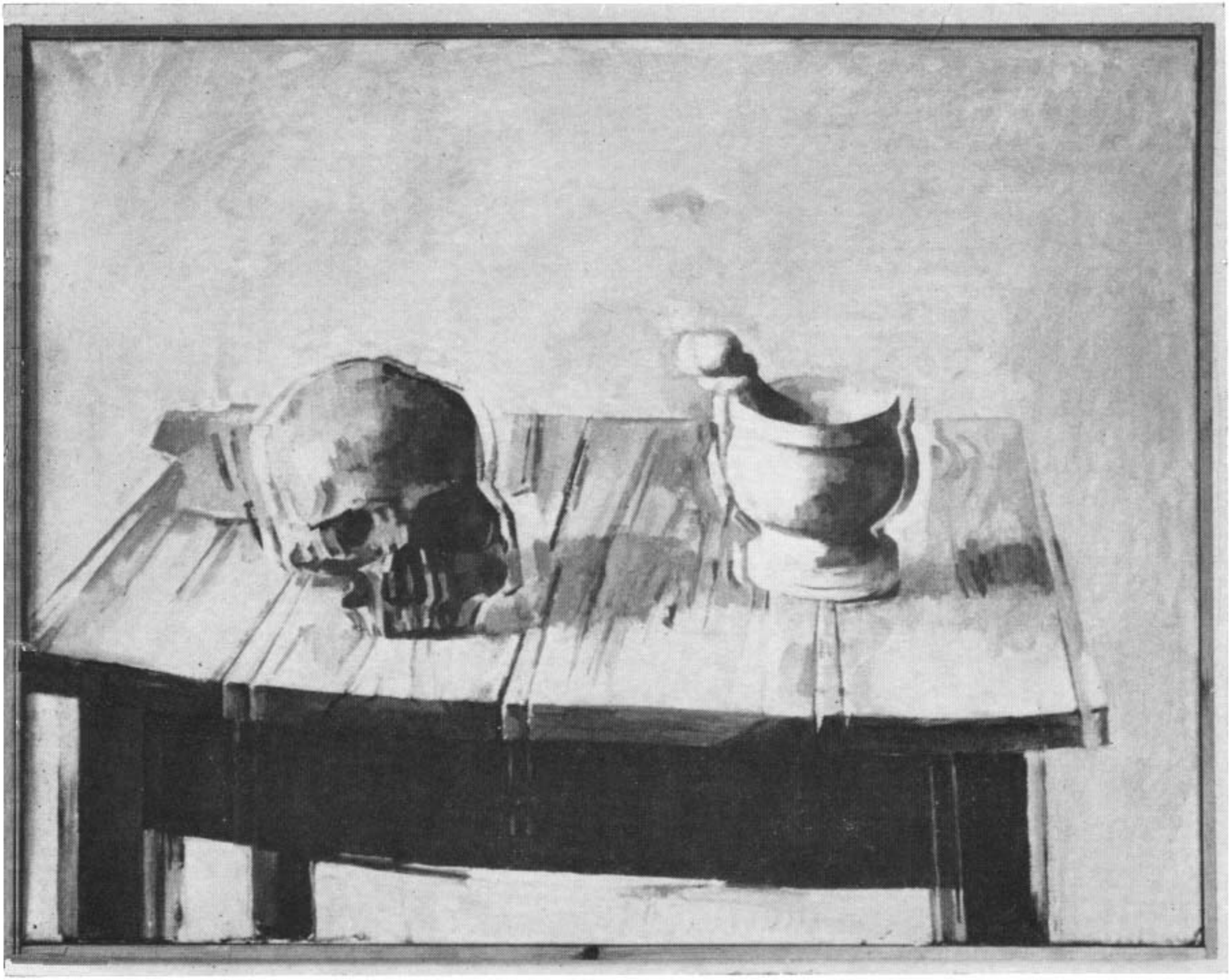

FIGURE 5. Lawrence Gowing, *Still life*, on loan at the Warburg Institute, University of London, (by permission of the artist).

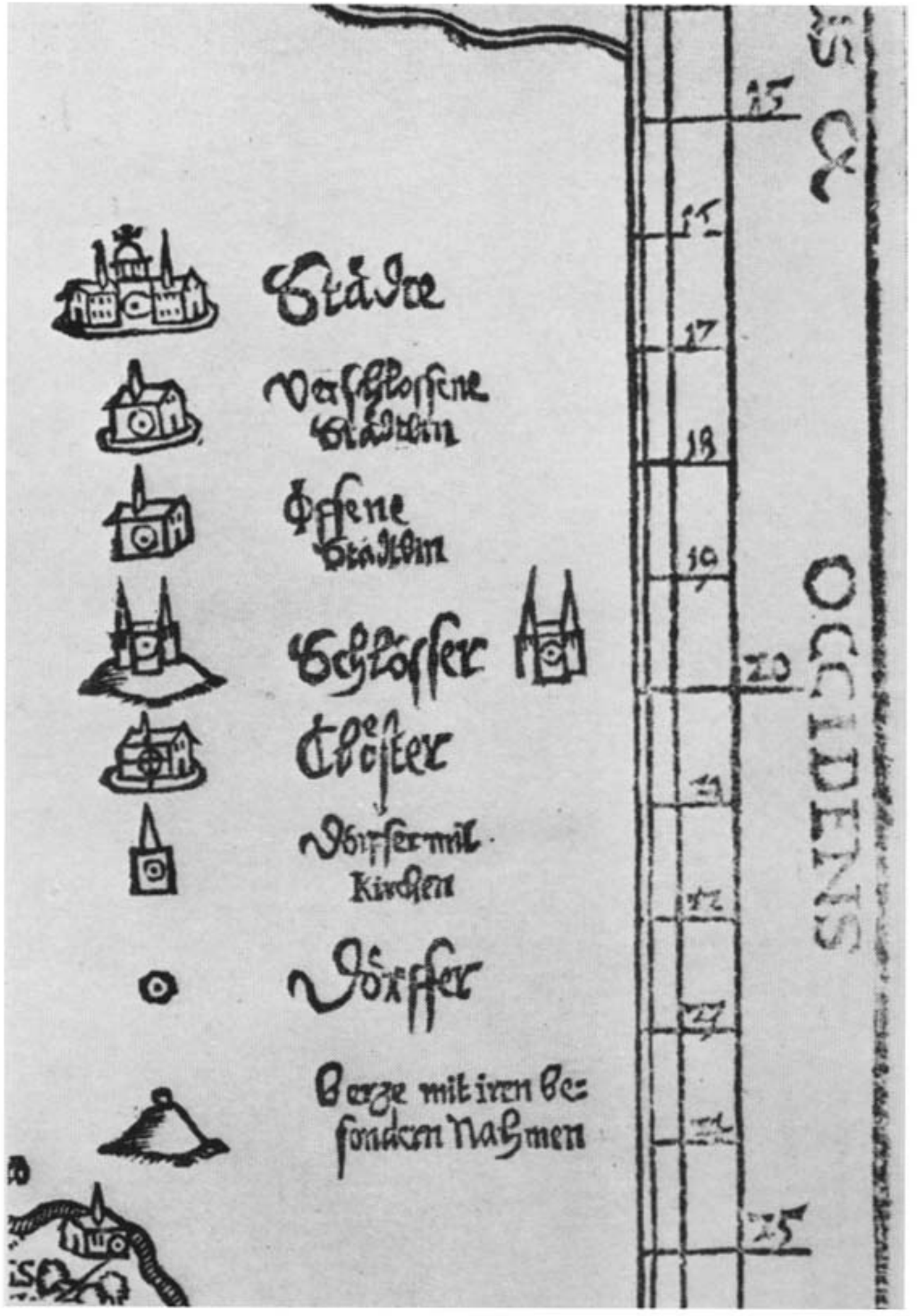

FIGURE 7. Key of a map of Oberlausitz of 1593 by B. Schulz (Scultetus), after F. D. Dainville, S. J. *Le langage des géographes* Paris, 1964.

FIGURE 8. J. Norden's Map of Middlesex augmented by I. Speed, 1610. (After a facsimile.)

FIGURE 10. Negative and positive of a Polaroid pack film by Melvin Sokolsky from an advertisement for Polaroid in *Scientific American*, January 1974 (by permission of the Polaroid Corporation, Cambridge, Mass., U.S.A.).

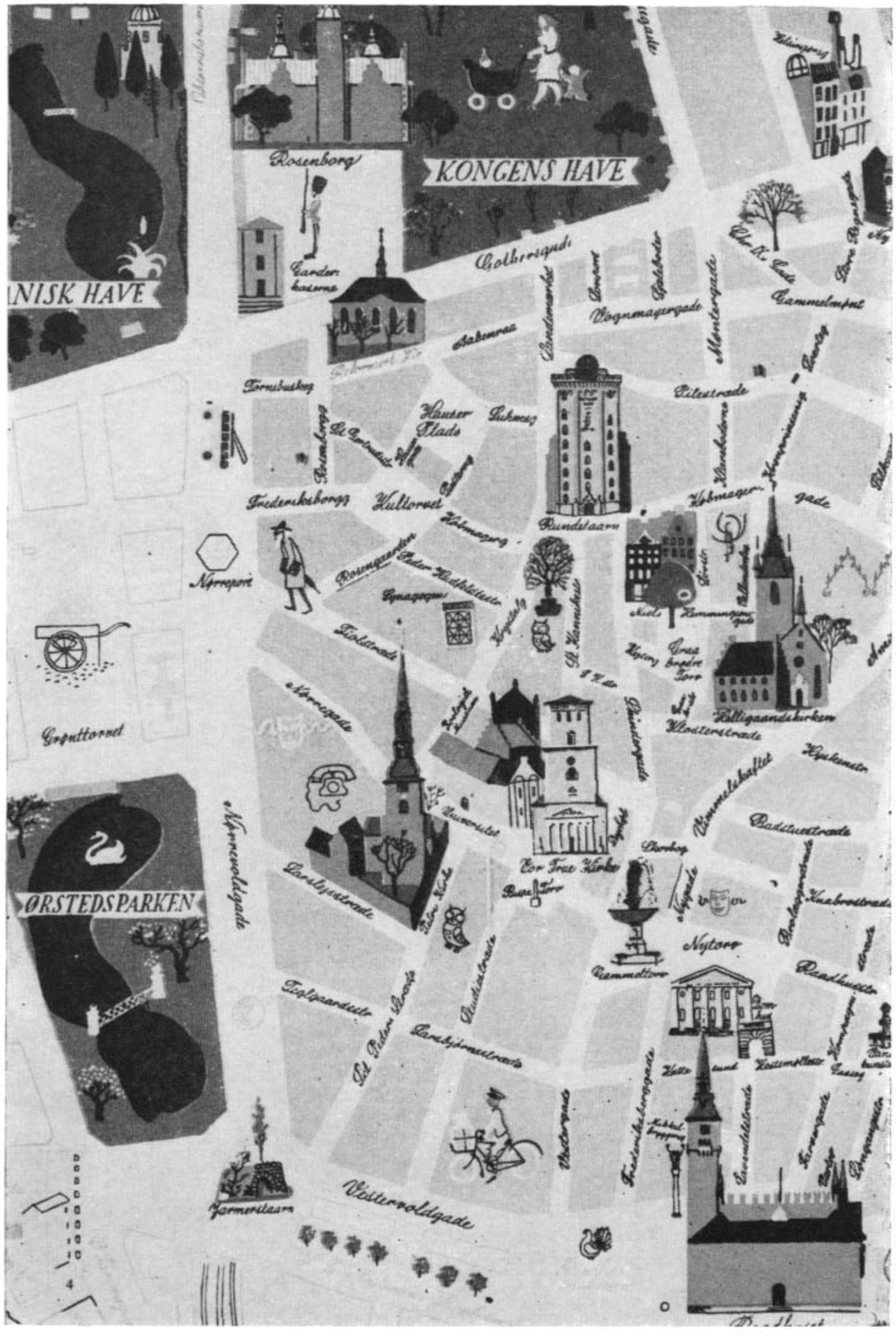

FIGURE 12. Tourist map of Copenhagen by Gustav Hjortland, after R. Broby-Johansens, *Gennem det Gamle Kobenhavn*, Copenhagen, n.d. Gyldendal.

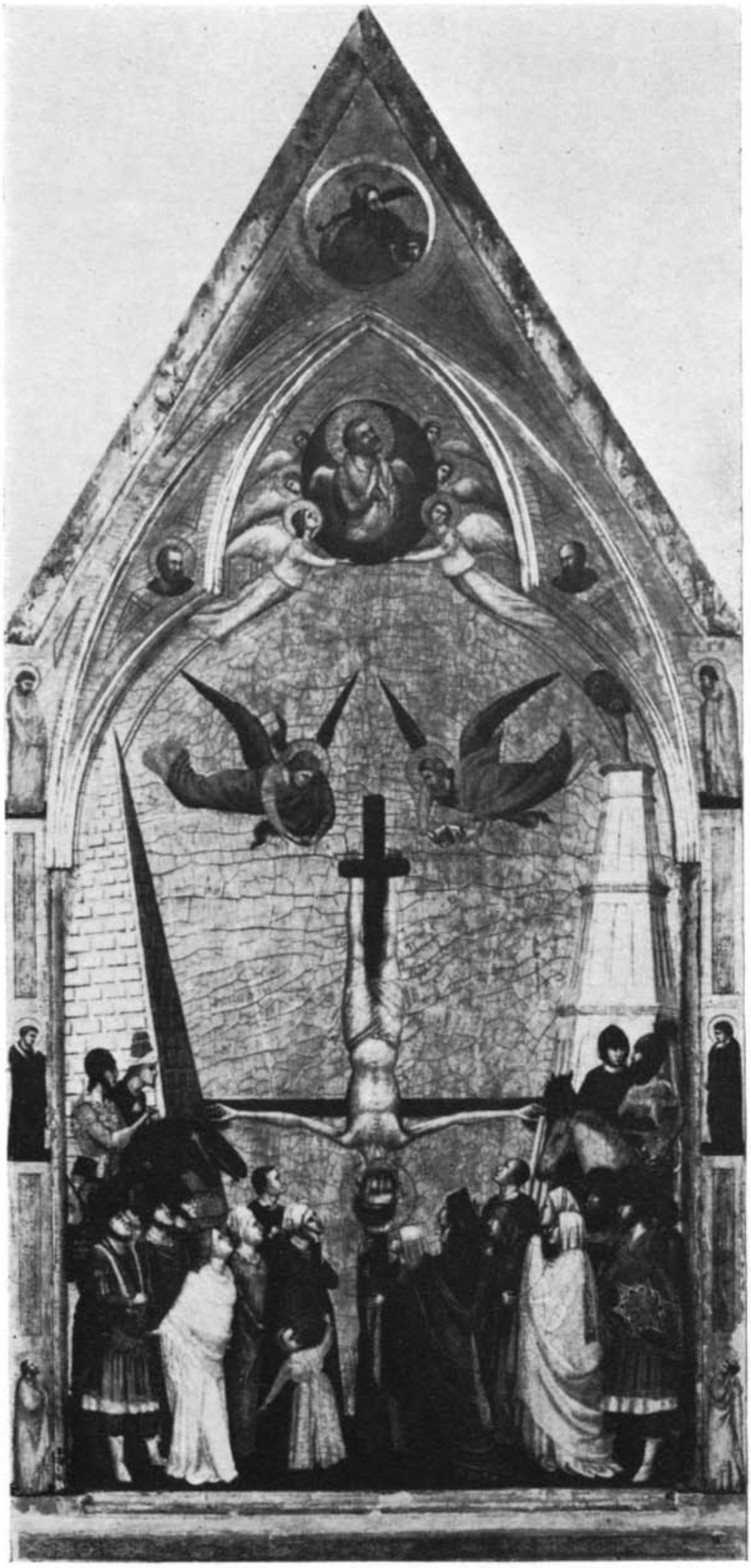

FIGURE 14. Giotto, *The Crucifixion of St Peter*, Rome, Pinacoteca Vaticana. (Gallerie pontificie.)

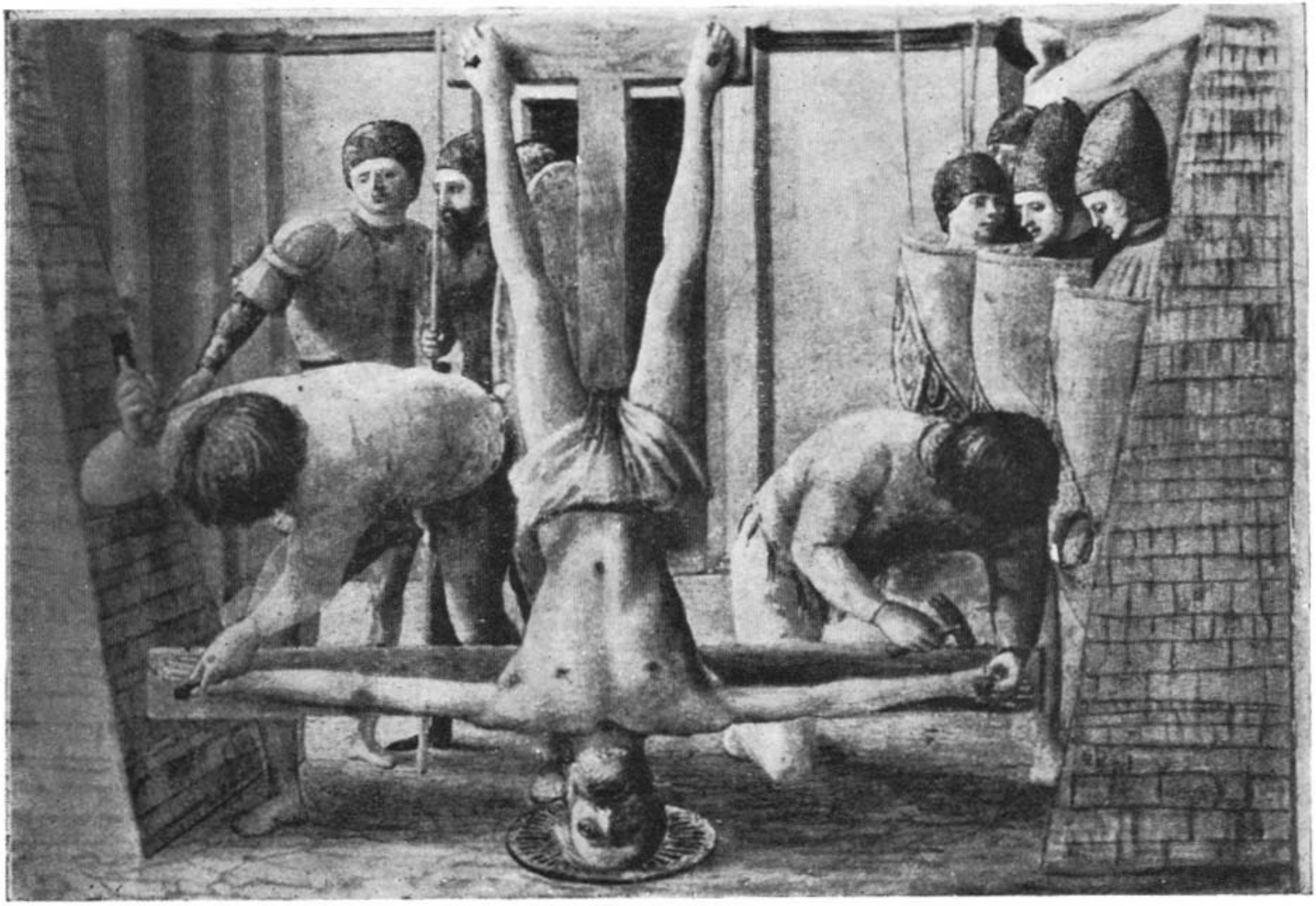

FIGURE 15. Masaccio, *The Crucifixion of St Peter*, Berlin, Staatliche Museen.

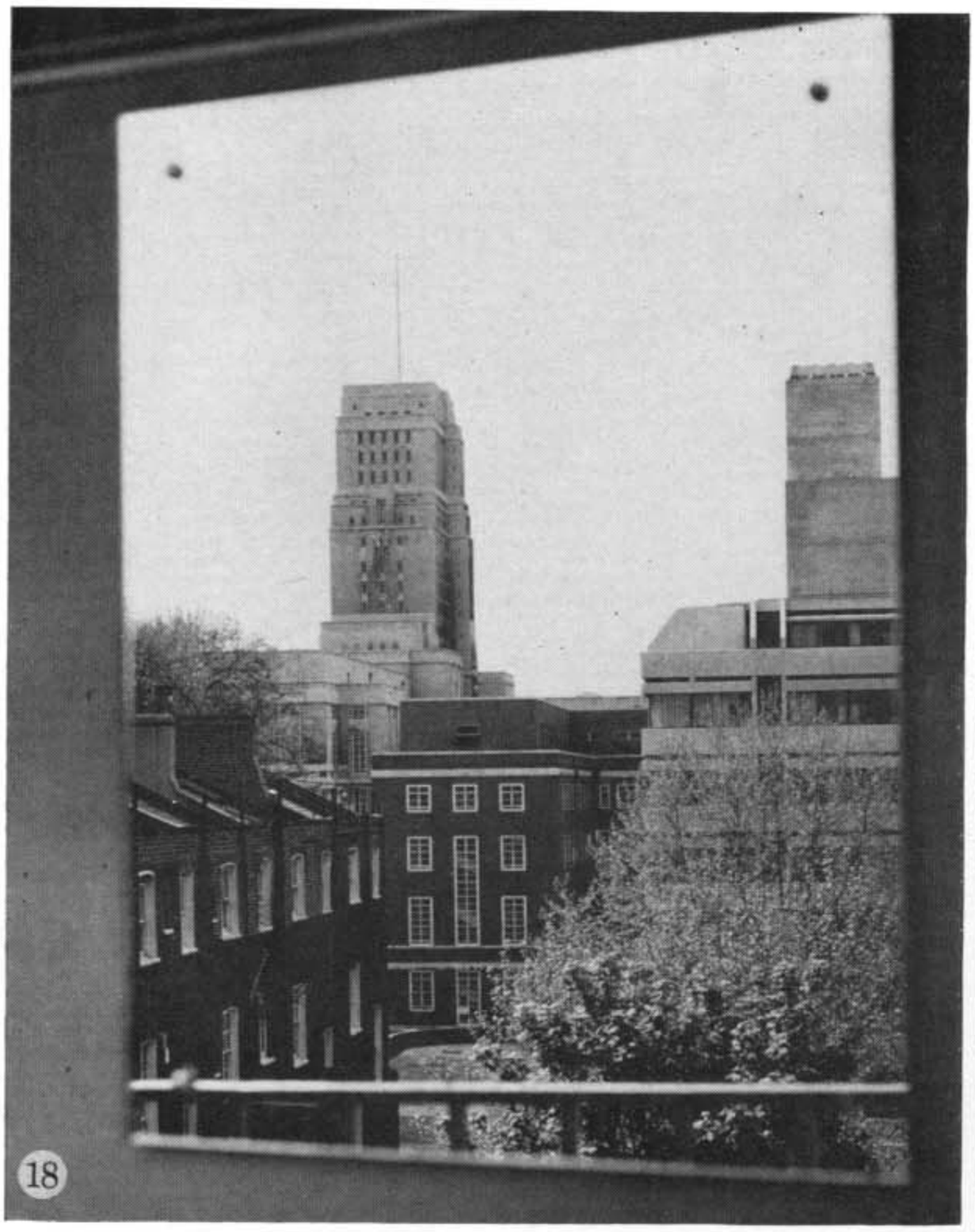

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FIGURE 18. View from the upper floor of the Warburg Institute as seen in a mirror.

FIGURES 19–21. The Senate House of the University of London as traced on a window of the Warburg Institute from various distances.

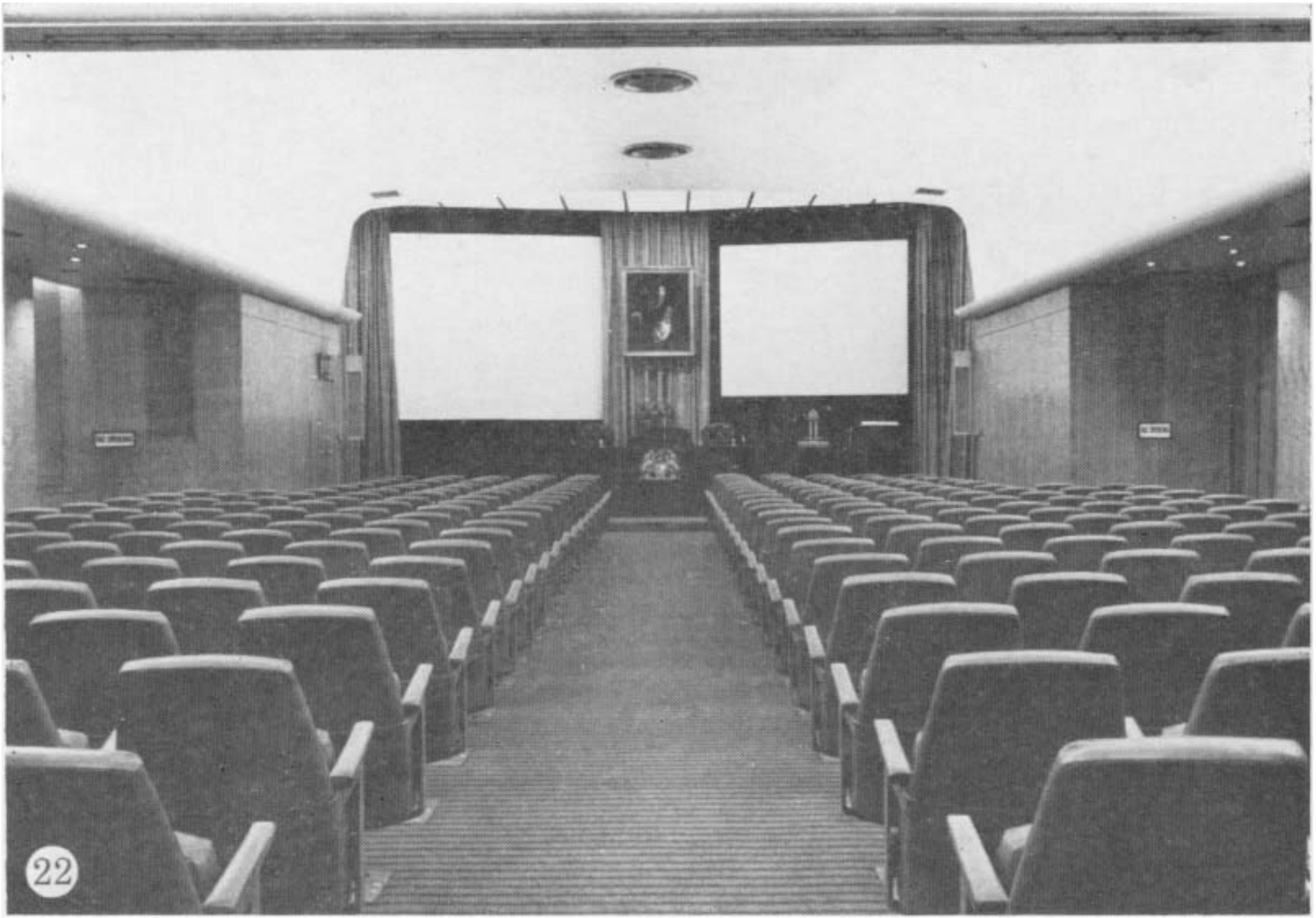


FIGURE 22. The Wellcome Lecture Hall of the Royal Society.

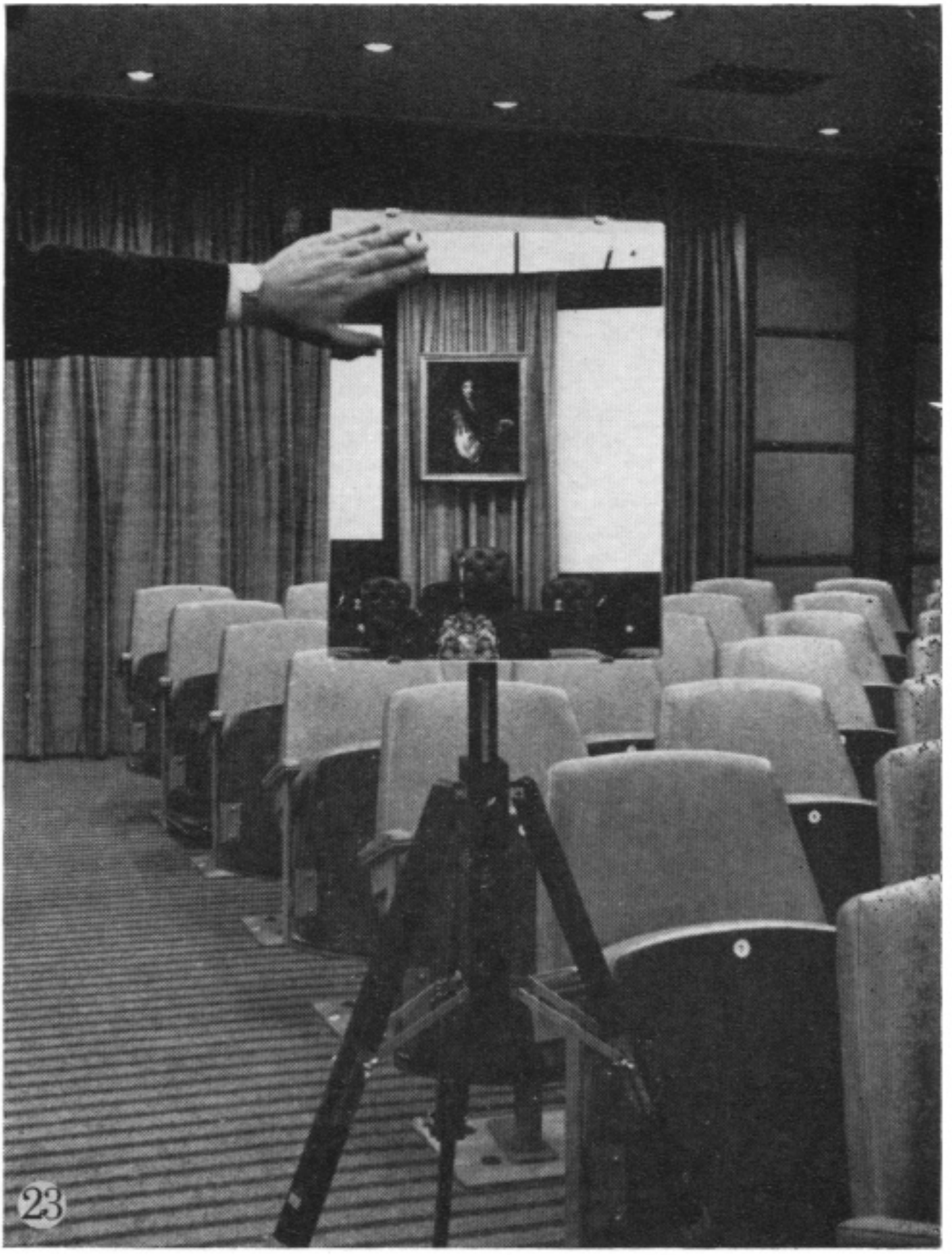


FIGURE 23. The Founder's portrait and the dais of the lecture hall photographed in a mirror.

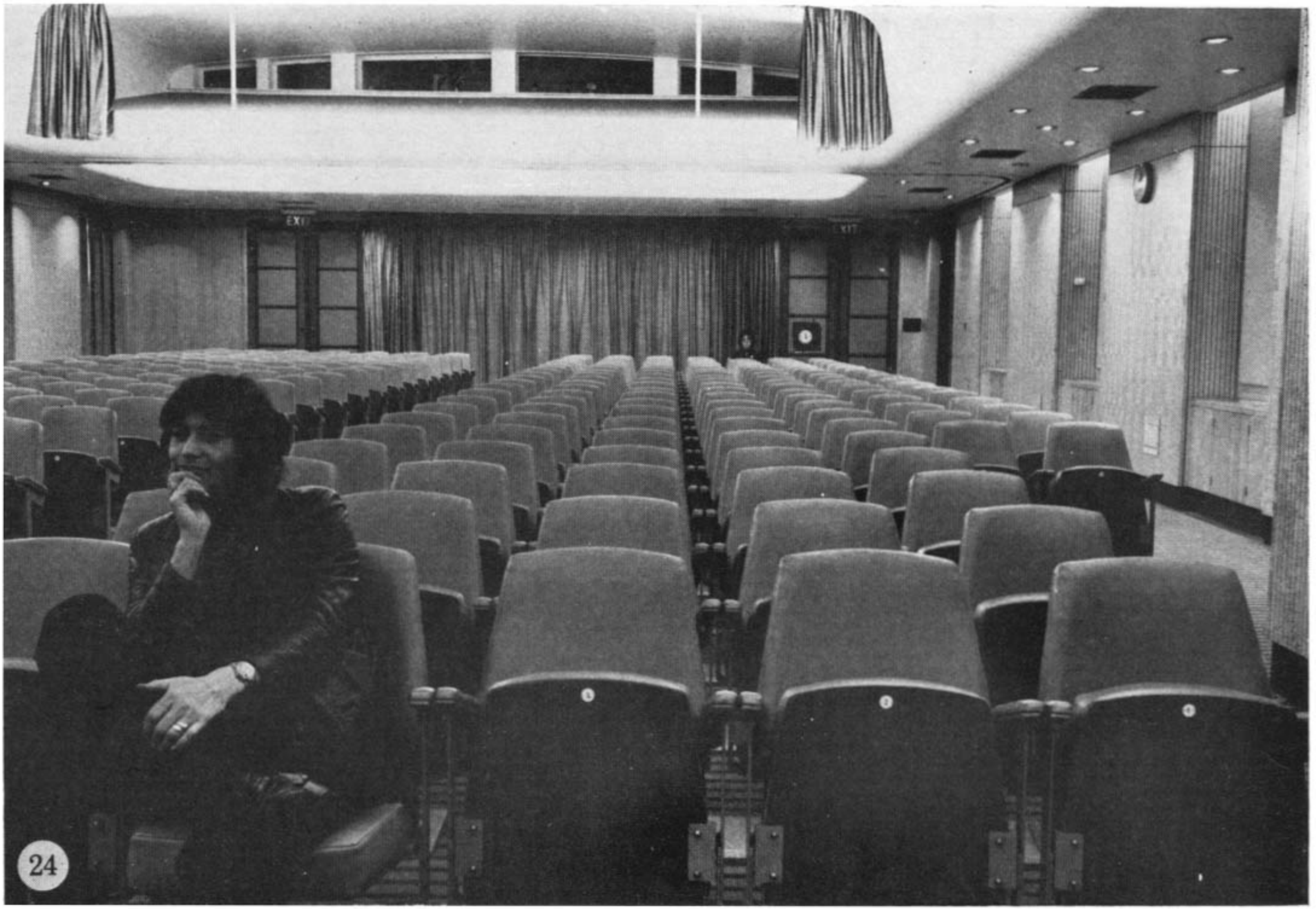


FIGURE 24. The Lecture Hall of the Royal Society (with a front seat number plate repeated on the door at the back of the hall).

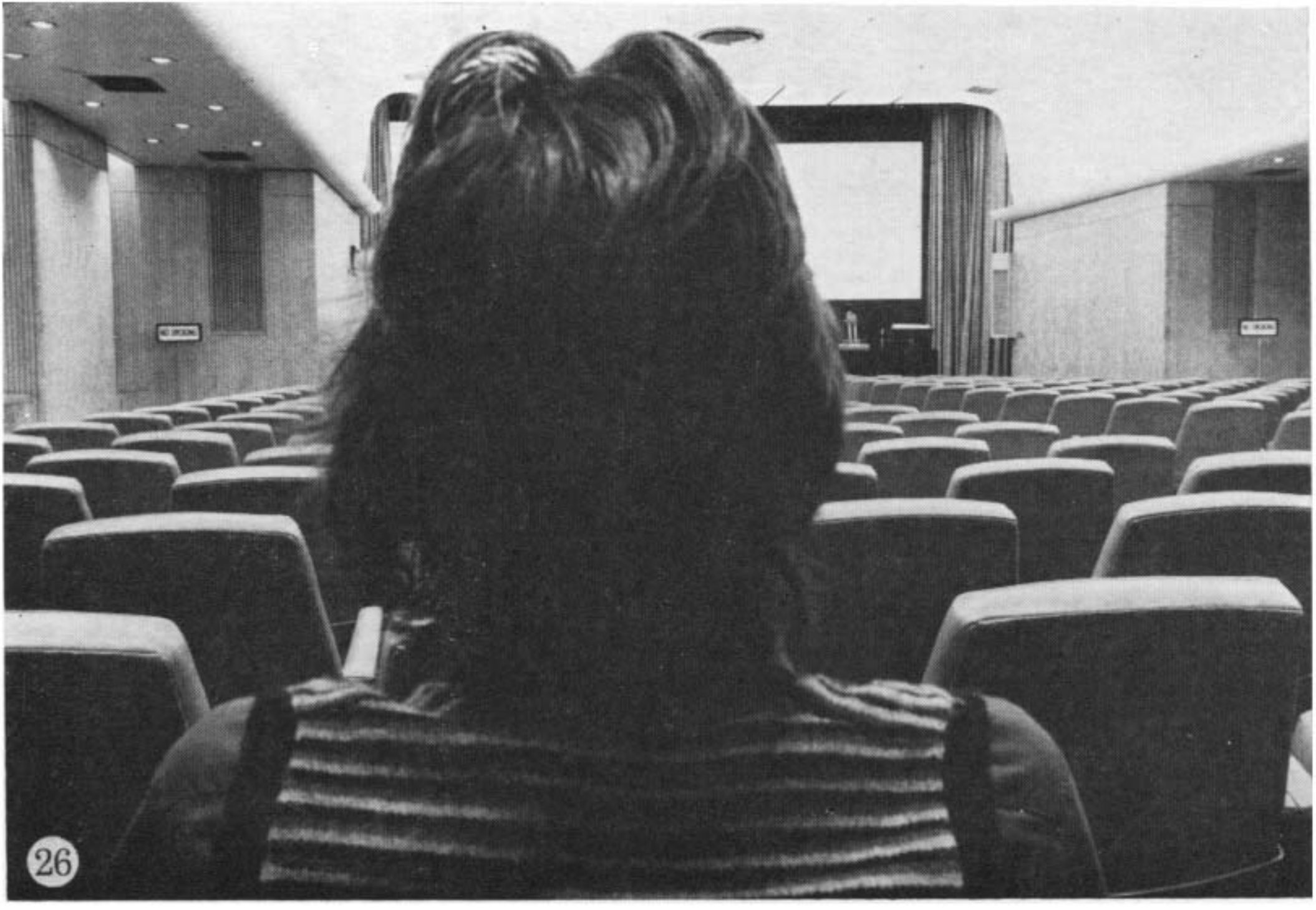
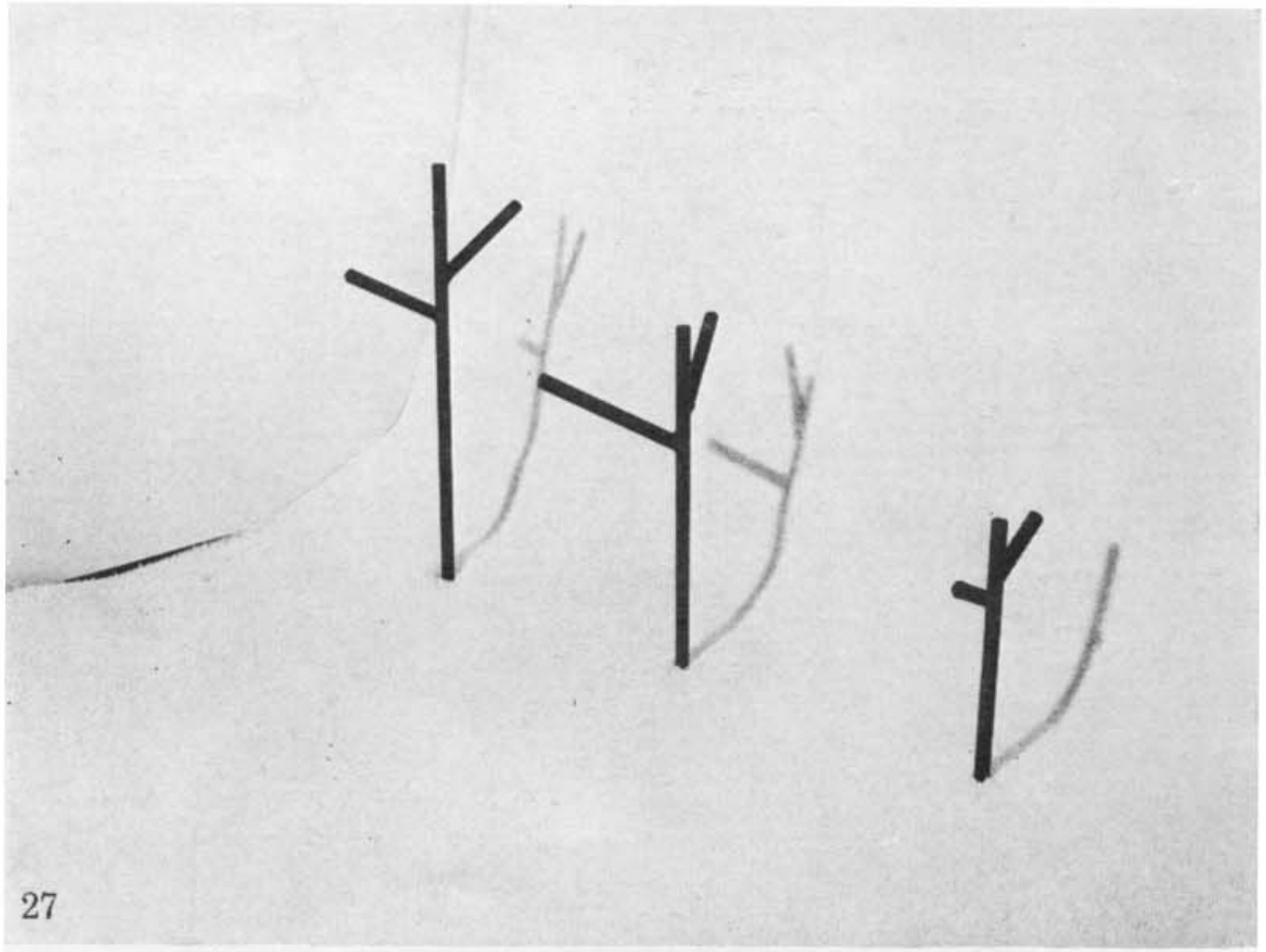


FIGURE 26. Close-up of a head in the Lecture Hall of the Royal Society.



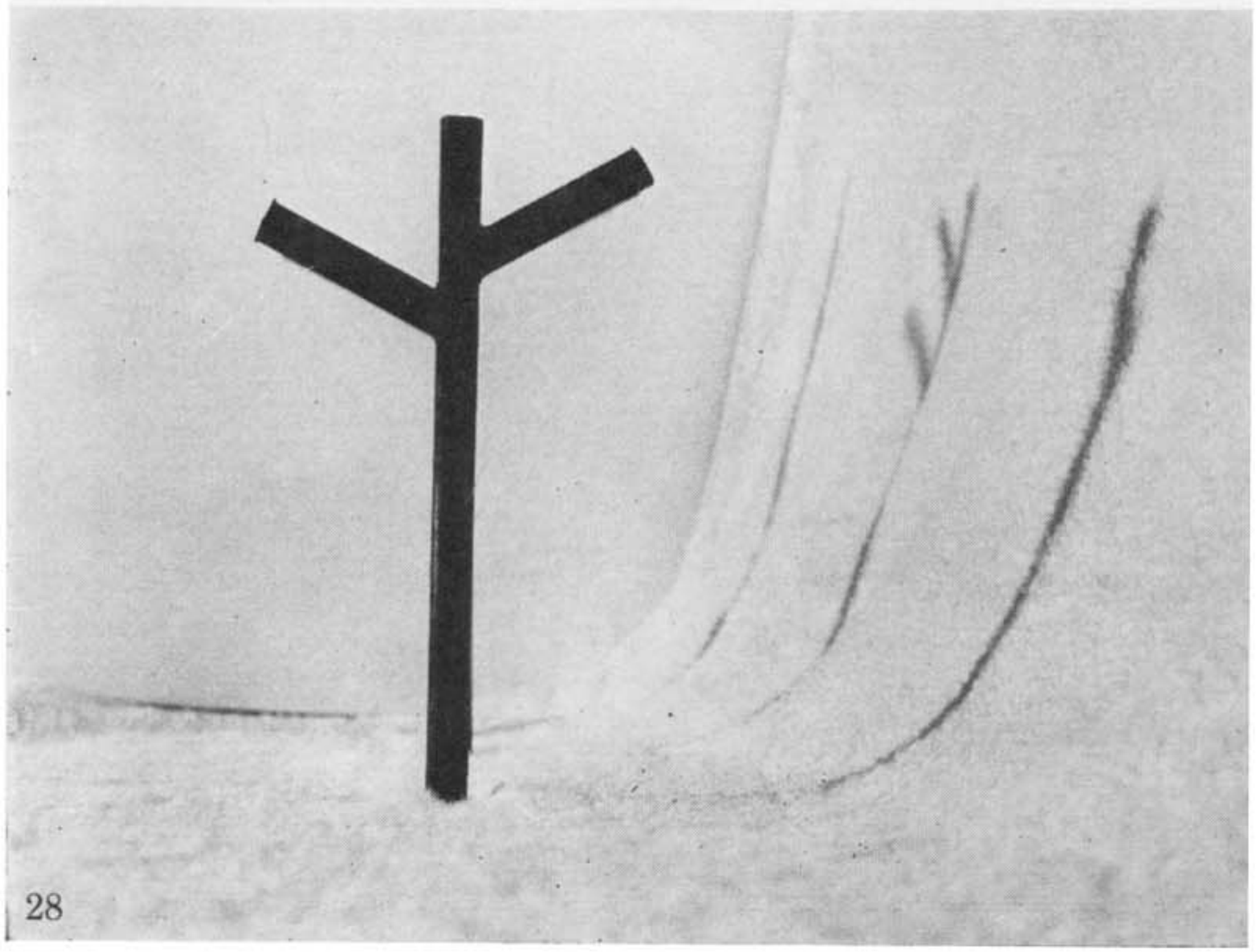
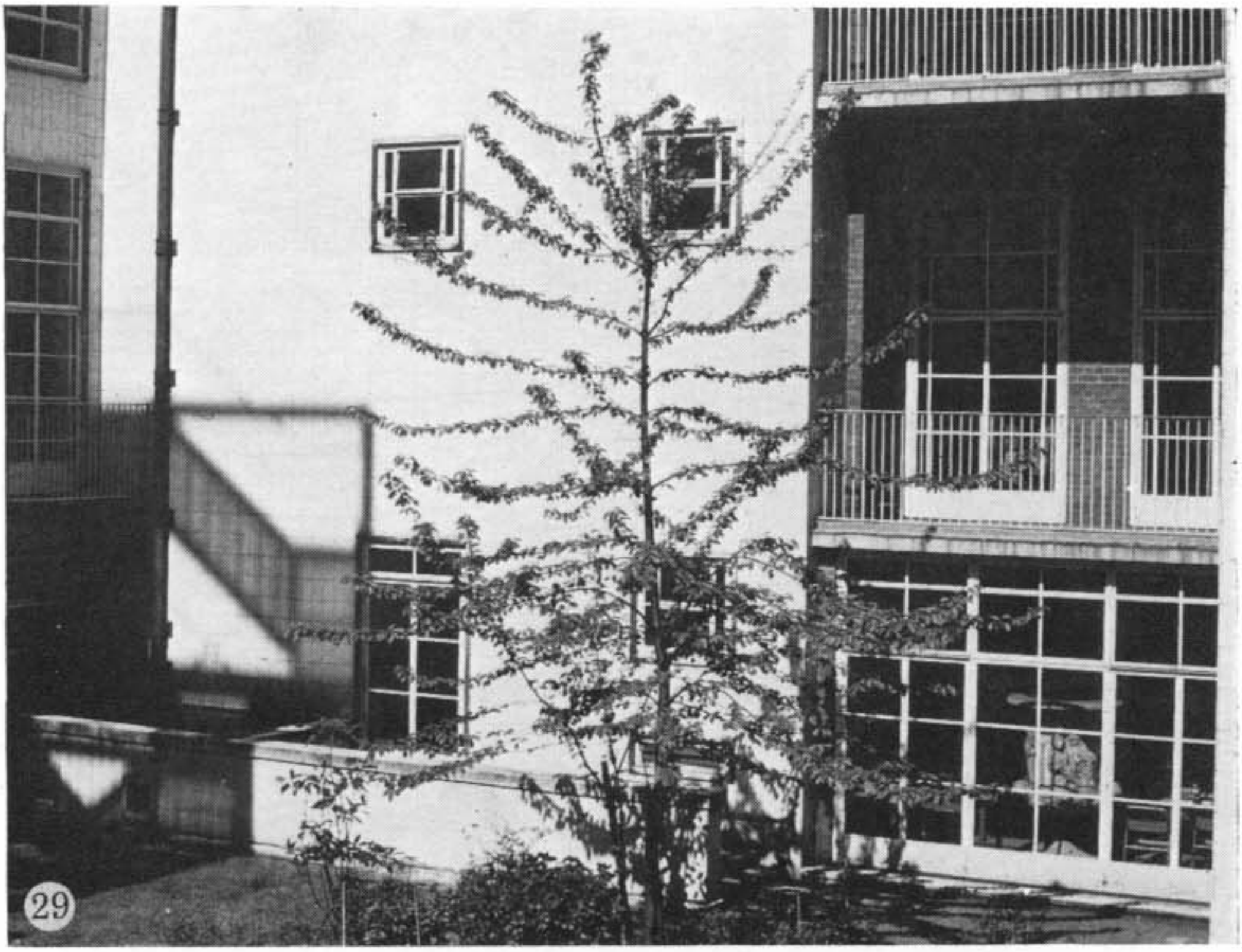


FIGURE 27. Demonstration box: three schematic trees and their shadows (constructed by H. King).
FIGURE 28. The same as figure 27, photographed through a peephole.



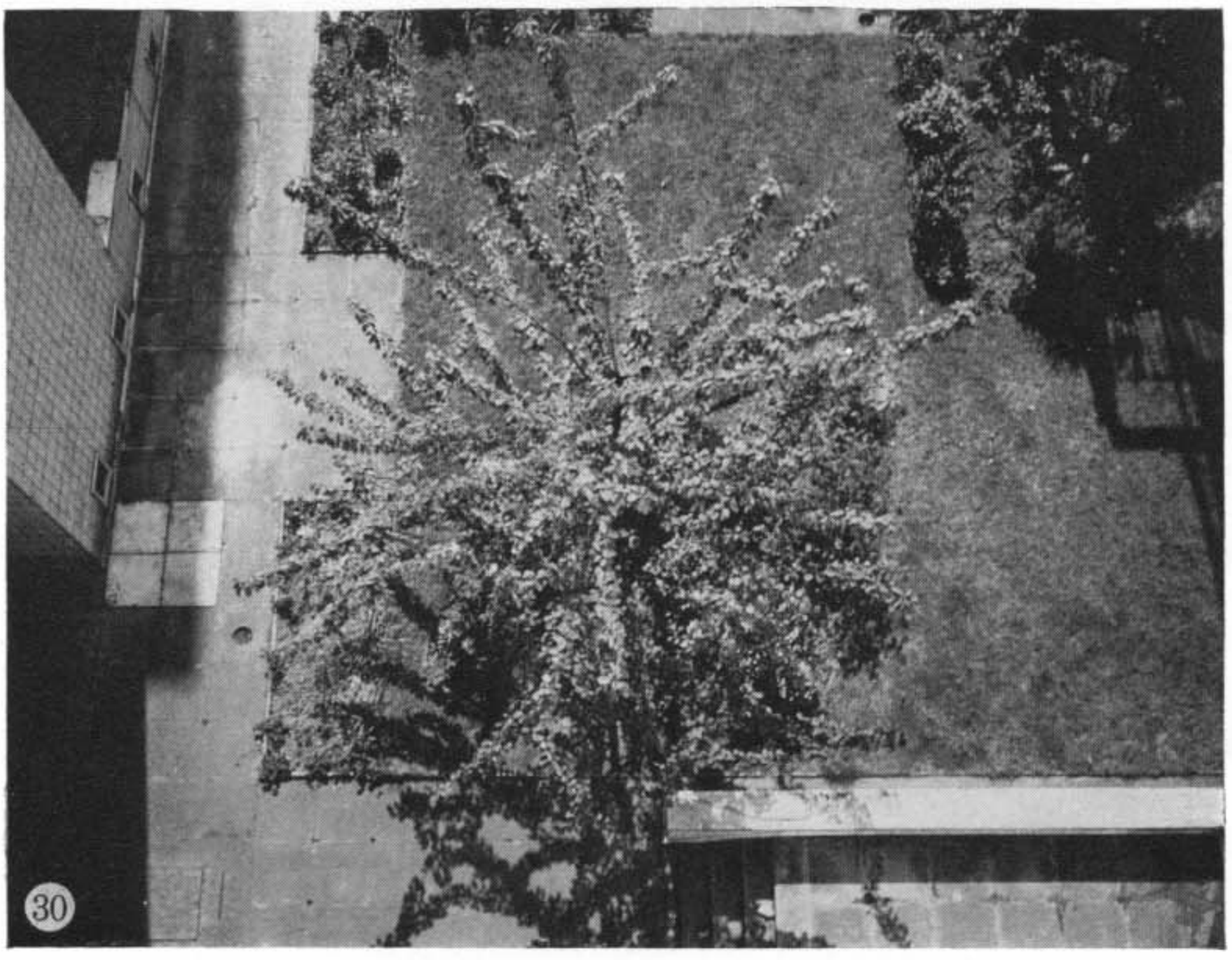
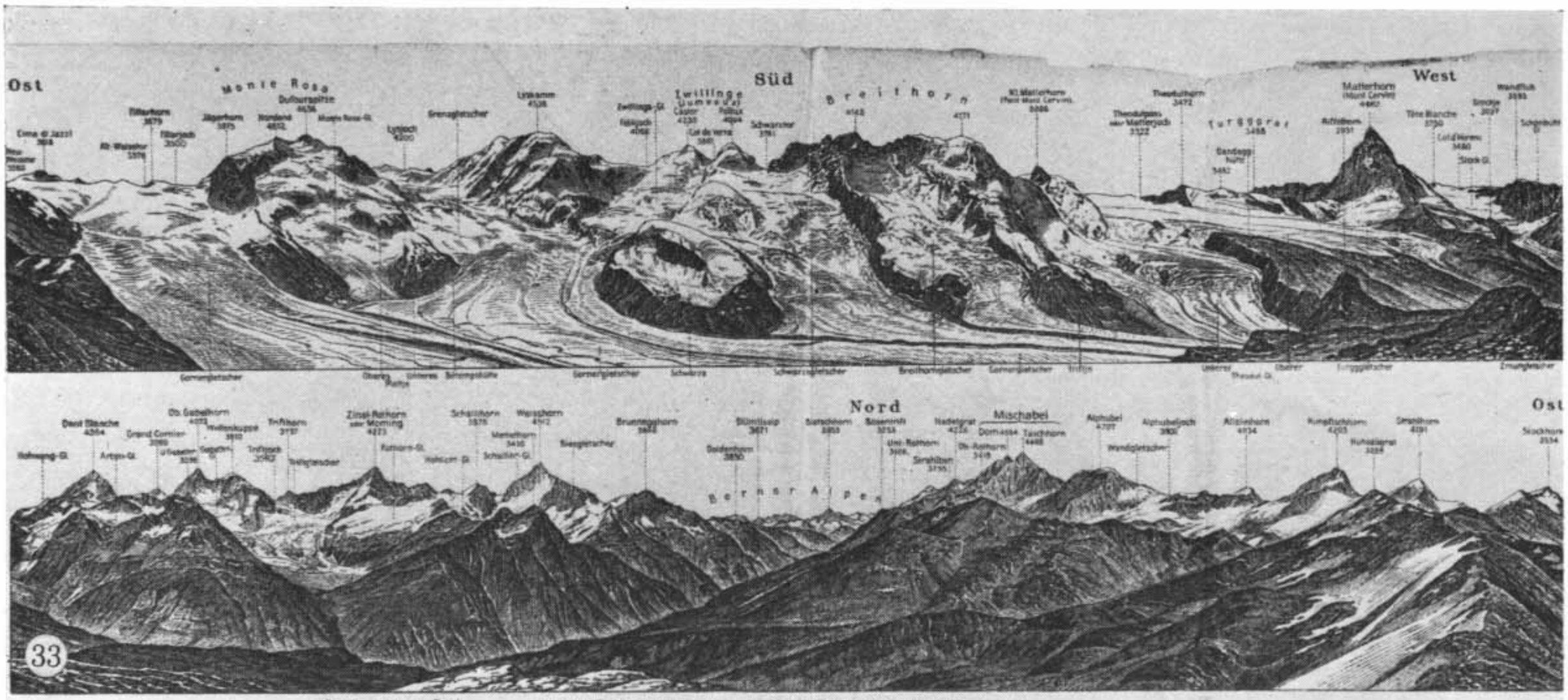


FIGURE 29. Tree in the courtyard of the Warburg Institute.

FIGURE 30. The same tree as figure 29 photographed from above.



PANORAMA VOM GORNERGRAT (3136m)

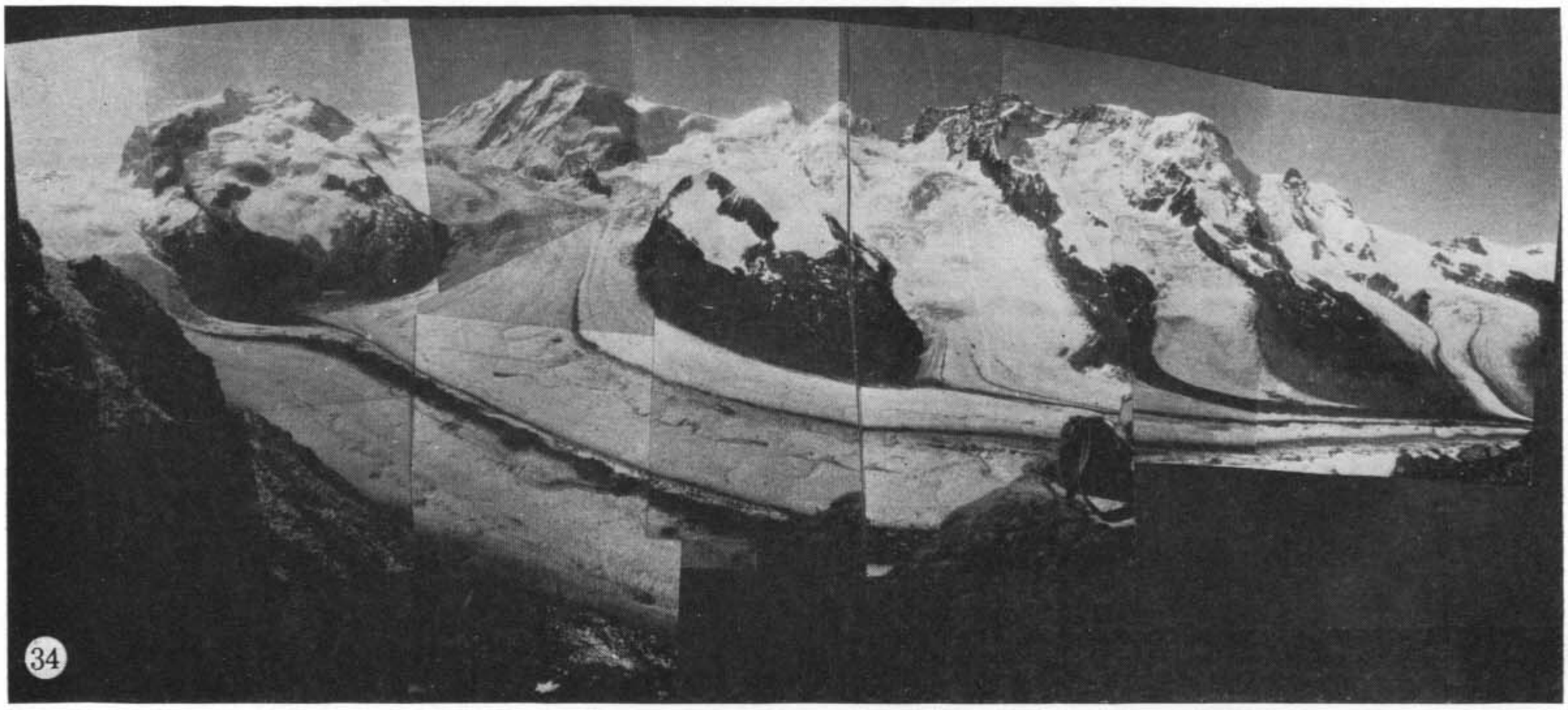


FIGURE 33. Panorama from the Gornergrat after Baedeker's *Switzerland*.

FIGURE 34. Composite photograph of view from the Gornergrat (photographed by Ilse Gombrich).

FIGURE 35. John Wonnacott, *The Family*, 1973/4 (by permission of the artist and the Royal Academy).

FIGURE 36. John Hopwood, *Self Portrait*, 1974 (by permission of the artist).

FIGURE 37. *Beetle and boot*, after E. A. Dyring, *Synligt och osynligt*.

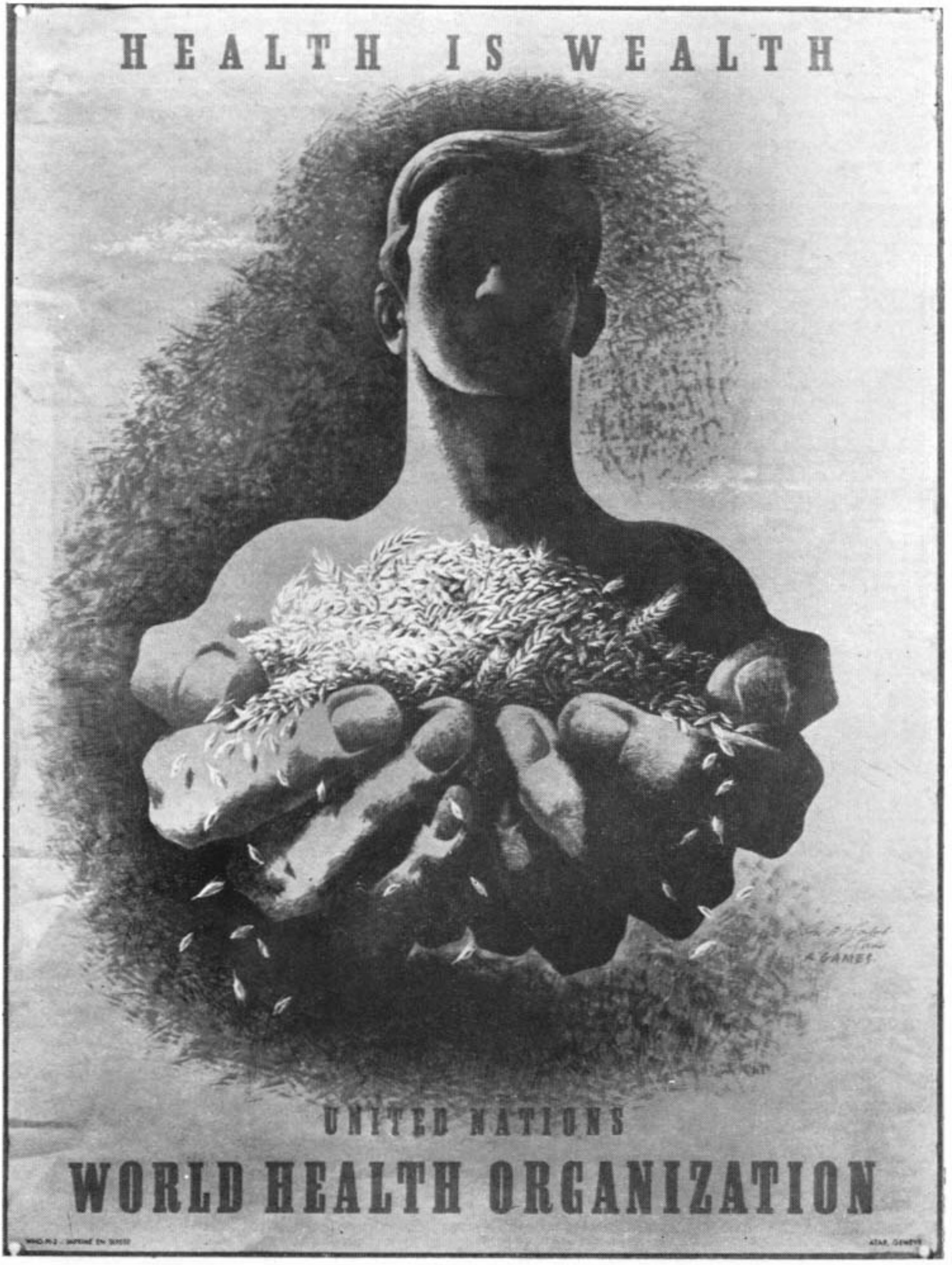


FIGURE 38. Abram Games, *Poster*, 1954/55, (by permission of the artist).