

GLASS IN EUROPE; 1100-1700

We have already seen that even by 1100 there was an extensive knowledge of glass-making techniques and probably quite a widespread use of glass. This was a solid foundation, inherited from Rome and the eastern Mediterranean, upon which was built an enormous further increase in the use and sophistication of glass-making. There is now a large literature on many aspects of this, so all I can do here is to sketch in one or two of the most salient peaks. Among these it is worth singling out three new developments.

Up to 1100, and including the Romans, the two main uses for glass had been for **verroterie** (beads, toys, jewellery), and **vererie** (vessels and other useful ware). Although there was a little development of window glass, especially in the north of Europe, this was a minor event. The period between 1100 and 1700 saw the continued development of the two earlier uses, especially in relation to fine drinking glasses. But it also saw three major extensions in the use of glass. One was in windows, both stained glass in religious buildings and plain window glass in ordinary homes. The second was in the development of glass mirrors. The third was the development of lenses, prisms and spectacles, that is glass for optical purposes. It was these three new developments which would change the knowledge base of Europe. None of them, as we shall see, occurred in this period to any extent elsewhere, whether in China, Japan, India or Islamic civilizations.

Italian glass and its influence

It seems likely that the tradition of glass-making never died out in Italy after the fall of Rome, especially in the northern Adriatic area around Venice. 'Little is known about the glass-making of southern Europe in the medieval period, but it is evident that good-quality glass had been developed by the thirteenth century at the latest.... there may have been some continuity of the craft in Venice through the Dark Ages, and certainly some form of glass-making was in progress in Venice by at least the end of the tenth century.'¹ It was really from the thirteenth century that Italian, and particularly Venetian, glass making began to influence the whole of Europe. Speaking of the thirteenth century, we are told that 'For the first time since the days of the Roman Empire, glass was being made in an important western urban centre.'² Furthermore, 'There is definite evidence that by the thirteenth century Venetian glass was already being distributed round northern Europe by itinerant pedlars...'³ The production and usage of glass increased dramatically from then on. 'By the early fourteenth century glass production was widespread in northern and central Italy, and archaeological evidence has shown that glass, particularly pruned beakers and colourless goblets, bottles and bowls, was in common use in northern Italian towns.'⁴ In the following century the techniques improved further, probably heavily influenced by events in the eastern Mediterranean. 'By the mid-fifteenth century, glass of a sophistication hitherto unknown in the West [was being made]. There was probably an influx of skilled craftsmen into the city after the fall of Damascus in 1400, and again in 1453 when Constantinople finally fell to the Turks...'⁵

Two particular technical developments in glass-making laid the foundation for a quality of glass which would provide the high quality clear glass which would later be crucial in the development of scientific instruments. The first of them also shows how the recovery of the skills of ancient Roman glass-makers was another important influence. 'The Renaissance glass-

¹Klein and Lloyd, Glass, 51

²Klein and Lloyd, Glass, 68

³ Klein and Lloyd, Glass, 68

⁴Klein and Lloyd, Glass, 51

⁵Klein and Lloyd, Glass, 69

makers of Murano were quick to experiment with ancient Roman glass techniques, often producing a highly individual result that was only distantly reminiscent of the Antique. Thus, towards the end of the fifteenth century they began to create a method for making **millefiori** glass, that is, glass in which thin slices of multicoloured canes are embedded, creating the effect of a carpet of tiny flowers.'⁶ Even more important was the perfecting of new techniques which are summarized in the word *cristallo*, or *cristallo*.

We are told that 'the word **cristallo** is first documented in relation to objects made from glass in the year 1409, but we do not have any extant clear glass of provable Venetian origin until the mid fifteenth century (although there are some wonderful clear vessels dating from the thirteenth century that may have been produced in Venice).'⁷ 'It is not known who invented or perfected it, but it is now thought that Angelo Barovier (d.1460), of the famous Muranese glass-making family, played an important role...All that is definitely known, however, is that two glass-blowers were given the exclusive right to produce the new glass in 1457.'⁸ So what was so special about *cristallo*?

Here are two descriptions which give us some idea of its special quality. It was 'a thin, almost weightless, pure and colourless material that permitted the glassmakers to blow and manipulate the most elegant and intricate of forms. Its feather-light quality combined with its stability provided the **virtuosi** of Murano's glasshouses with the ideal medium for expressing their own imaginative ideas as well as creating skilled interpretations of the fanciful designs for glass supplied by Mannerist court artists.'⁹ Thus it fed into the artistic renaissance that was occurring in northern Italy at this time. 'The **cristallo**, as it was called, was far superior to any glass produced before, and created an insatiable demand for the products of the glasshouses using it. Its purity and thinness were a source of wonder and fascination and **cristallo** gradually superseded the heavier, coloured glass previously used.'¹⁰ Other developments in chemistry had also increased the range and quality of the colours that could be incorporated with the glass. 'By the middle of the fifteenth century the development in the art of glass-making was complete. An increasing knowledge of chemistry had greatly enlarged the range of colours at the disposal of the painter, and the quantity of enamel colours he was provided with enabled him to discard glasses coloured in the mass and to paint upon a single piece of white glass with enamelled colours laid upon its surface.'¹¹

This all reminds us that the development of glass in any civilization depends mainly on how it is perceived, but likewise that how it is perceived is dependent on its quality. As glass-making improved, so did the desire for it and hence the money that flowed into further improvements. Thus the glass-making explosion in Italy is not merely an automatic result of the increasing wealth as Europe revived from the twelfth century onwards. It is linked to many other forces, intellectual and cultural, in that period. It is important to give a flavour of these since they anticipate the links I shall try to draw between the development of reliable knowledge in art and science during this period, which was a complex inter-acting process.

One powerful force was the growing fascination with curious and precious substances, particularly among the Renaissance patrons. 'An increased interest in science and natural history

⁶ Tait, Glass, 163

⁷ Sotheby, glass, 60

⁸ Klein and Lloyd, Glass, 74

⁹ Tait, Glass, 166

¹⁰ Klein and Lloyd, Glass, 74

¹¹ McGrath, Glass in Arch., 101

reflected these [Renaissance courtly] aspirations, and princes vied with one another to collect curiosities and examples of precious and figured semi-precious stones, in both raw and worked forms. Rock crystal, a natural quartz, was especially prized: it was held to have magical properties, and was incorporated into religious objects of veneration; only the very rich could afford to use it for domestic purposes. A substitute was eagerly sought, and by the middle of the fifteenth century the Venetian glass-makers, by using manganese as a decolourizing agent, had perfected an almost colourless soda glass in imitation of rock crystal.¹² Thus the connection between rock crystal and glass was intimate and important, but leads us to wonder again why the Chinese, who also had a high regard for rock crystal did not attempt the same trick.

Other precious stones also lured the Italians on to experiment with glass. 'The fascination of natural phenomena in its more unexpected guises led the Renaissance courts of Europe to collect not only carved rock-crystal but also beautifully coloured and veined hardstones (chalcedony, agate, jade, jasper, bloodstone, prase, topaz, lapis-lazuli, etc.) The Venetian glassmakers, once again, seem to have kept in step with fashion, and , by 1500, according to Sabellico, "they began to turn the materials into various colours and numberless forms. Thence come cups, beakers, tankards, cauldrons, ewers, candlesticks, animals of every sort, horns, beads.... there is no kind of precious stone which cannot be imitated by the industry of the glass workers, a sweet contest of nature and of man."¹³ Thus, for example, 'The Venetians also perfected two other types of glass, which again reflected the fascination for rare and curious natural phenomena, collections of which were proudly displayed by the rich and fashionable. Glass was made to imitate agate or chalcedony, and called **calcedonio** glass.'¹⁴

The astounding versatility of the Muranese glass-makers was well captured by Georgius Agricola in his account of a visit in 1550. "'Glassmen make a variety of objects: cups, phials, pitchers, globular bottles, dishes, saucers, mirrors, animals, tree, ships. Of so many fine and wonderful objects I should take long to tell. I have seen such at Venice, and especially at the Feast of the Ascension when they were on sale at Murano, where are the most famous of all glass factories."¹⁵ Glass making had thus become an important art form, an intellectual and cultural fashion, and this fed back into scientific and artistic experiments. 'During the Italian Renaissance, therefore, the humble utilitarian craft of glassmaking had been elevated to a sophisticated courtly art, which led men of privilege....to set up glasshouses not for commercial reasons but for their own personal use, curiosity and education. Glassmaking had become an accomplishment that a prince might enjoy.'¹⁶

Much stress has been laid here on Venetian glass, but it should be remembered that there were other important glass-making centres in Italy, particularly the northern town of Altare. We are reminded of '...the important part played by the little Ligurian town, Altare, as a centre from which glass-workers migrated to all parts of Europe. It is said that the glass industry was established at Altare, in the 11th century by French craftsmen. In the 14th century Muranese glass-workers settled there and developed the industry.'¹⁷ 'By the end of the fifteenth century Altarist glass-makers were organized into a guild or 'university', and their statutes were formalized in 1495.'¹⁸ Although smaller than Murano, the Altare works were particularly influential because it was their policy to spread their techniques as widely as possible, rather than

¹²Klein and Lloyd, Glass, 74

¹³ Tait, Glass, 163

¹⁴Klein and Lloyd, Glass, 78

¹⁵ Tait, Glass, 166

¹⁶Tait, Glass, 174

¹⁷ Enc. Brit., 'Glass'

¹⁸Klein and Lloyd, Glass, 81

to retain them as trade secrets as the Muranese attempted.¹⁹ Nor was glass-making restricted to these two most famous centres. 'It appears that as early as 1295 furnaces had been established at Treviso, Vicenza, Padua, Mantua, Ferrara, Ravenna and Bologna.'²⁰

The influence of Italian glass techniques, as well as the glass itself, spread out all over western Europe, particularly from the sixteenth century. We are told that 'The glass-making phenomenon that occurred at Murano soon spread throughout Europe. Glasshouses sprang up wherever the inf?? felt, answering a new and increasing demand for luxury glass. By the sixteenth century glass-making centres all over Europe were making glass in the Venetian style - **a la facon de Venise** - and it is often difficult to distinguish between glassware from Venice and that from other glass centres where production was in the hand of Venetian-trained glass-blowers.'²¹ One important centre to which the new skills were transmitted was the Netherlands, and it seems more than a coincidence that one of the major northern centres of fine glass should be the other most famous centre of Renaissance painting. We learn that 'Crystalline' glass making, after the famous fashion of Venice and Murano, was brought to Antwerp in 1537. In 1541 a Venetian founded a mirror factory there and in 1552 an artisan from Brescia produced fine goblets and window-panes... Amsterdam glassware was compared in the seventeenth century with Venetian glass.'²² Ironically the spread was often faster than in Italy itself, for instance 'although glass had been made in Florence since the fourteenth century when glass-makers from the Tuscan mountains moved into the town, it was not made in the Venetian manner until 1567...'²³

Glass north of the Alps.

Although the Italian, and particularly Venetian, developments are of enormous importance after about 1400, they tend to distort the picture, especially for the period 1100-1400, in relation to the rest of Europe. As we saw earlier, glass making was well developed in Germany and France at the end of the Roman Empire and this tradition continued, finding its highest development in Bohemia. The recent developments in medieval archeology have now allowed us to see that fine glass was not an Italian preserve. Vose states that 'R.J.Charleston has proved that, during the later Middle Ages, two divergent glassmaking traditions developed in Europe: that of the north, including Germany, France, Belgium, Britain and Bohemia, and that of the south, mainly in Italy. They used different types of furnace, different raw materials, and produced different kinds of glassware.'²⁴

We are reminded that 'Venetian glass-makers led the world in the year 1500; but a century earlier there was very little the Venetians could have taught the glass-makers of southern Germany, and a hundred years before that glass-makers in eastern France were making mould-blown objects of superlative quality.'²⁵ We now know that 'In many parts of Europe, glass-making developed rapidly in the late thirteenth century.' Until the early 1980s enamelled beakers 'were rare; now almost every large-scale urban excavation in Germany or Switzerland produces fragments.'²⁶ These were at first attributed to Venetian glass works, but 'There is little doubt that the skills existed in German glasshouses to accomplish the work. Indeed, recent

¹⁹ Singer, iii, 217

²⁰ Enc. Brit., 'Glass'

²¹ Klein and Lloyd, Glass, 80

²² van Houtte, Economic History, 172-3

²³ Klein and Lloyd, Glass, 81

²⁴ Vose, Glass, 61

²⁵ Sotheby, Encycl. 48

²⁶ Sotheby, Encycl., 52

excavations have revealed the [quality] achieved in parts of central and western Europe in the late thirteenth and fourteenth centuries..... the best pieces from Konstanz and other sites in Germany and adjacent regions rival the finest objects attributed to Venice.²⁷ Put in another way, we are told that 'while there is still a great deal to be learned about European glass in the thirteenth and fourteenth centuries, it is reasonable to suppose that in all probability it was **not** inspired by Byzantine glass from southern Greece; that the driving force behind the new developments was not necessarily Venice; and that glass-makers in Germany were every bit as skillful as their Italian counterparts.'²⁸

Part of the reason for the neglect of the development of fine glass all over Europe from the fourteenth century at least is the bad reputation that 'forest glass' once had. 'Contemporary glasshouses in other parts of Italy, in France, the Low Countries and Germany, especially near the valleys of the Meuse and of the Rhine, were mainly centred near the great forest, but, erroneously, the products have until recently tended to be dismissed as crude "forest glass". In this period, the vertically ribbed beaker....universally popular in Italy, the former Yugoslavia, Switzerland and German - was often made of a thin, clear, almost colourless glass which, although neither entirely free of bubbles nor of a slight tinge of colour, usually had excellent proportions and finely manipulated applied details.... Furthermore, the French developed from the late thirteenth and throughout the [fourteenth an] elegant type of clear wine-glass on a tall slender stem.'²⁹

The major northern centre was in Bohemia. We are told that 'in Bohemia, where the silver mines were among the richest in Europe and brought exceptional prosperity and patronage, a similarly high-quality thin glass, sometimes almost colourless, was being made by the middle of the fourteenth century. Using a remarkably pure potash-lime-silica composition... the Bohemian glassmakers created a range of some twenty different types of tablewares...' ³⁰ This was the continuation of an earlier tradition and in due course the Bohemians would even outdo the Italians. 'In Bohemia, where glass-making had been carried on since early medieval times, there were twenty-four glasshouses by the sixteenth century. There the foundations were laid of a glass-making tradition which was to challenge and eclipse that of Venice during the following century.'³¹

The development of glass did not come to a halt with the superb glass of Venice in the fifteenth century. Nor did glass making remain basically an Italian and German activity. In brief, the history from the sixteenth century was the gradual movement north until, by the end of the seventeenth century, the most advanced glass-making area in the world was England. How this happened is a complex story, but here are a few of the events which summarize the developments.³²

At a general level, we are told that 'The seventeenth century in Europe saw unparalleled changes in both the decoration of glass and in the metal itself.... To facilitate deeper carving,

²⁷ Sotheby, *Encycl.*, 53

²⁸ Sotheby, *Encycl.* 55

²⁹ Tait, *Glass*, 153

³⁰ Tait, *Glass*, 153

³¹ Klein and Lloyd, *Glass*, 87; according to the *Enc. of Glass*, 96, there were about forty glassworks in Bohemia by the early sixteenth century.

³² For a good general account of glass-making in England, see Godfrey, **English Glass**. For particular aspects of this, see also Charles Henry Ashdown, **History of the Worshipful Company of Glasziers of the City of London** (1919) and G.H.Kenyon, **The Glass Industry of the Weald** (Leicester Univ. Press, 1967)

water power was harnessed to drive the grinding wheels. A better understanding of chemistry and constant experimentation heralded the introduction of colour, particularly ruby red, and new processes led to large sheets of glass to create larger windows and mirrors of unflawed glass.³³ What happened was basically the industrialization of glass in England. From being a relatively backward area, England started to benefit from the refugees from the Catholic Counter-Reformation on the Continent.³⁴ The shortage of wood led to another important development. 'In 1610 a patent was granted to Sir W.Slingsby for burning coal in furnaces, and coal appears to have been used in the Broad Street works. In 1615 all patents for glass-making were revoked, and a new patent issued for making glass with coal as fuel, in the names of Mansel, Zouch, Thelwall, Kellaway and Percival. To the last is credited the first introduction of covered crucibles to protect the molten glass from the products of burning coal. Simultaneously with the issue of this patent the use of wood for melting glass was prohibited, and it was made illegal to import glass from abroad.'³⁵ During the time of Sir Robert Mansell's patent 'revolutionary coal-burning furnaces took over from wood-burning ones, thus industrializing production and enabling furnaces to reach higher temperatures.' (hence glass factories near Newcastle and Bristol).³⁶ These developments led into what was to be England's greatest contribution to the art of glass manufacture.

We are told that 'a revolutionary discovery was made in England - the invention of a remarkable lead glass with great powers of light refraction...Experiments brought to fruition by George Ravenscroft in London between about 1674 and 1676...' ³⁷ This flint glass, 'made from a mixture of potash, lead oxide, and calcined flints', was to rival the Venetian glass and could be mass produced. It also had different light-bending properties which were essential, in combination with Venetian glass, in the development of powerful telescopes in the eighteenth century. The development in glass manufactures in England can be seen from the work of Houghton, who in 1696 listed 88 glass factories, whose work was divided as follows: bottles (39), Looking-glass plates (2), Crown and plate-glass (5), Window glass (15), Flint and ordinary glass (27).³⁸ Twenty-six of these were in or near London. Once this development had occurred, the power source for the making of glass was soon extended from water power to a new source of energy. 'From the 1770s, plate glass could be made by steam power. That transformed the history of the window. In the nineteenth century, the demand for window glass in Europe, with so much new building, exceeded all expectations. 'Great windows open to the south' (in Yeats's formulation) could be easily and cheaply built...'³⁹ But that is another story.

This last technological break-through which we have seen here, that is the use of coal in glass manufacture, is worth emphasizing since it is often forgotten. Glass is very expensive in fuel and the fact that from about 1600 (and probably before) the English learnt to use coal instead of wood for heating the elements, opened up the production of glass and, particularly from the later seventeenth century the lead glass associated with Ravenscroft.

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Another way to approach the history of glass in western Europe during these six centuries is to look at the various uses glass was put to. The use as substitutes for gems, and for utensils has already been largely covered in the preceding discussion, so there remain the three major new

³³ Sotheby, Glass, 81

³⁴ Enc. of Glass, 130

³⁵ Enc. Brit., 'Glass'

³⁶ Sotheby, glass, 76

³⁷ Tait, Glass, 182

³⁸ Enc.Brit. 'Glass'

³⁹ Thomas, History of World, 412

innovations of this period, namely windows, mirrors and lenses.

Window glass.

The development of flat planes of glass for windows took two major forms in the period, evolving from the earlier tentative steps we have seen in the period to 1100. These were related but also separate, namely plane glass for secular purposes in domestic architecture and stained glass for religious buildings. Both of these were specially developed in the cold and wet areas north of the Alps and particularly in northern France, Germany, the Netherlands and England. The consequences of this development would be unexpected, both in terms of the technology of glass and its influence on thought, so let us briefly examine what happened.

As we have seen, the use of coloured glass in windows was not unknown to the Romans, the Islamic civilizations and to the Anglo-Saxons. From the twelfth century, however, partly related to economic recovery but also due to other factors, an astonishing and magnificent expansion occurred in the use of coloured glass in windows. We are told 'The craft developed in the Mediterranean lands in the twelfth century. One of its chief aims was to keep churches pleasantly cold by excluding excess of light.'⁴⁰ This may have influenced the northern developments in the same century. Likewise it is often claimed that a major influence came from the Islamic area. 'Stained glass for windows became popular in both sacred and secular buildings after the Crusaders had become acquainted with the enamelled and tinted glass of Syria.'⁴¹ The influences are complex and probably powerful. 'To what extent the coloured window of the Gothic church was influenced by its Eastern prototype is hard to say, but the debt is probably greater than is commonly realized. Gothic architecture has been explained as the result of the East acting on the West, mainly through the contact of the Crusades, but also in subtler and more indirect ways that cannot be illustrated by any event or series of events...'⁴²

There can be no disputing that the central change, that is from the rounded Roman to the pointed Gothic arch, which transformed architecture and hence the use of glass, did come from observations of Islamic architecture. The change is summarized in various ways. 'In Romanesque churches the decoration consisted principally of frescoes and mosaics, but the development of Gothic, which presented narrow spaces unfavourable to mural painting, led to the transference of decorative colour to the windows which had increased correspondingly.'⁴³ It was not just the negative fact that there was not room for murals. There were now huge areas to be filled with glass. 'The evolution of Gothic architecture, bringing about an enormous increase in the window-area of ecclesiastical buildings, stimulated a considerable development of the window-glass industry of the district between the Seine and the Rhine.'⁴⁴ Thus 'Twelfth-century stained glass was designed to fill the tall, narrow lancet windows that were a hallmark of early Gothic architecture.'⁴⁵

Thus began the construction of those amazing Gothic buildings, starting with the twelfth-century church of St Denis, Paris, and culminating in Chartres and King's College, Cambridge. As McGrath points out 'The Gothic cathedral presents the first unqualified use of glass as a building material and in many ways as daring a use of it as any ever attempted.'⁴⁶ Anyone who has visited such buildings will know how extraordinary is the effect of the staining of the light. 'Thus a cathedral, in one aspect, was a stone shrine made with enamels of storied

⁴⁰ Singer, iii, 240

⁴¹ Edwardes, East and West, 61

⁴² McGrath, Glass in Arch., 100

⁴³ McGrath, Glass in Arch., 100

⁴⁴ Singer, iii, 237

⁴⁵ Sotheby, Encycl., 52

⁴⁶ McGrath, Glass in Arch., 104

glass... a stone cage with films of stained glass suspended in the voids, a marvellous jewelled lantern.⁴⁷ The wondrous colours were even aided by the relative simplicity of the technology. The glass was imperfect, but these 'imperfections contributed to that glowing quality remarkable in ancient glass. When the light falls on glass of an uneven surface and containing all manner of irregularities it is scattered and refracted so that the glass appears almost self-luminous.'⁴⁸

The wealth of the church was poured into the glass, which wrote God's message in light for the congregation to see. The glass of King's College, Cambridge, for example, next to where I write this, contained the whole history of the Old and the New Testament in glorious colours that stained the white radiance of eternity, as Shelley put it. The huge demand and the technical developments in glass manufacture that flowed out of them are summarized by McGrath. The reasons for the development he believes are 'climate on the one hand and on the other the development of Gothic and the consequent increase of window space in the buildings of the richest and most powerful section of medieval society.' The resulting 'specialization in window glass developed two methods of producing a sheet of glass - the cylinder method and the crown method, the latter more or less peculiar to Normandy. Theophilus gives a full description of the cylinder method, which was common to Lorraine and the German states concerned.⁴⁹ Thus there was an immense financial, practical, artistic and religious impetus given to the development of this material. It was highly valued, tinged with mystery and heightened emotion, much in demand. The contrast with China, Japan, India is complete. Even in the place from which many of the ideas and techniques had come, Syria and elsewhere within Islam, the use of stained glass was much less developed. This is one of the most dramatic examples of what was transforming the world of vision. Light was split into its various colours and a puzzle as to what constituted light would fascinate scientists from Roger Bacon to Newton.

The ecclesiastical stained glass revolution was also important because it helped to develop the techniques for a further major development, the use of windows in ordinary homes. We have seen that glass had been used sporadically for windows in Roman times, but it is really only from about the fourteenth century that it begins to become a serious alternative to the wooden shutters, oiled paper, parchment, translucent shells and other materials with which people had tried to solve the problem of how to let in the maximum amount of light, and the minimum amount of cold. Almost all of the early development occurred in the northern half of Europe, partly it would seem as a result of the climate, partly because it was there that the techniques for making large sheets of glass, originally for ecclesiastical purposes, were the furthest developed. We can see something of what happened negatively if we look first at the south, that is at the wonder of the glass world, Venice.

We are told that 'A corresponding diminutiveness characterized Venetian window glass which was apparently made by the spinning method, their **rulli** or **rui** being little panes of thick green glass called **occhi di bo** or bull's eyes and very like the bullions of crown tables....' McGrath asks 'Why the Venetians, who made transparent colourless glass earlier and more successfully than anybody else, made no attempt at a more convenient window glass...' He suggests that it 'was probably due to two reasons, the lack of any urgent local necessity for it and their apparent ignorance, until the sixteenth century, of a method of making sheet glass. A contributory reason would be provided by their inability to compete in this field with the glassmakers of France and Germany who, besides being more favourably placed with regard to the areas of demand, had already developed two efficient methods of making sheet glass.'⁵⁰ Thus, summarizing the

⁴⁷ W.R.Lethaby, quoted in McGrath, *Glass in Arch.*, 104 - cf. Michelet description AM.

⁴⁸ McGrath, *Glass in Arch.*, 103

⁴⁹ McGrath, *Glass in Arch.*, 33

⁵⁰ McGrath, *Glass in Arch.*, 33

difference in the two parts of western Europe, 'In Italy...they were making a beautiful clear crystal suitable for the finest vessels, while northern Europe continued to concentrate upon window-glass.'⁵¹

The spread of glass throughout Europe, mainly in the north and particularly from the sixteenth century, is well summarized by Braudel. 'It was really only in the sixteenth century that transparent panes appeared, and they spread only haphazardly.' Northern Europe was the earliest into this revolution. The progress of glass panes 'was rapid in England, for instance, where peasant houses had glass panes in the 1560s with the increase in agricultural prosperity and the development of the glass industry'.⁵² But glass windows were to be found much more widely. 'Aeneas Sylvius de Piccolomini found in 1448 that half the houses in Wien had glass windows, and toward the end of the sixteenth century glass assumed in the design and construction of the dwelling house a place it had never had in any previous architecture....'⁵³ Yet it was not until the developments in the use of coal in glass making which we described earlier, as well as improvements in making flat glass, that the full impact of the window revolution was felt. 'This substitution of the window for the wooden shutter, or for oiled paper and muslin, was not fairly complete until the end of the seventeenth century: that is, until the processes of glass-making had been improved and cheapened...'⁵⁴

The regional variations in Europe continued to be great. Some areas, because of climate, building styles or technical difficulties did not make or use glass windows until the eighteenth century, others were much earlier. A brief sketch of some of the evidence for these differences is also provided by Braudel. In 1556 'Charles V, who was coming from Flanders to Estremadura, was anxious to buy panes of glass before reaching the journey's end. Montaigne, on the road to Germany, noted that from Espinal onwards, 'there is no village house however small, that has not glazed windows'. And the Strasburger Brackenhoffer said the same thing sixty years later of Nevers and Bourges. But two travellers from the Netherlands to Spain in 1633 noticed a southern demarcation line: after crossing the Loire at Saumur, they saw no more glass in the windows of the houses. Meanwhile further east, in Geneva, at about the same time, even the grandest houses were content to use paper and even in 1779, when glass was letting the daylight in to the rooms of the humblest Parisian workers, oiled paper was still being used in Lyons and certain provinces, particularly for silk workers according to our informant, because the light it gave was 'softer'.⁵⁵ Thus we see a sort of line across Europe - the cold northern half, roughly where the vine gives way to the apple and to beer-drinking country, was the original glass window area.

Summarizing the situation bluntly, we can say that until 1100, flat glass panes, whether coloured or plane, were rare. Between 1100 and 1500 they became enormously important in religious architecture, especially in northern Europe, and this was something new and deeply influenced glass technology - as much as the fine glass developments in northern Italy. Then, mainly between 1500 and 1700 a second major development occurred in the application of clear glass in domestic architecture. The consequences on comfort, cleanliness, perception and many other areas were immense and will be considered later. What is important to establish here is that this dual glass window revolution only occurred to its full extent in one part of the world, western Europe, and particularly north-western Europe.

⁵¹ Derry and Williams, *Technology*, 109

⁵² Braudel, *Structures*, 296-7; on Tudor mullion windows see also McGrath, *Glass in Arch.*, 106

⁵³ Mumford, *Technics*, 124-5

⁵⁴ Mumford, *Technics*, 124-5

⁵⁵ Braudel, *Structures*, 296-7

Mirrors.

The development of the glass mirror is another way in which European glass technology after the twelfth century went in new directions. How did this happen and why was it only in western Europe and only after about the twelfth century that qualitatively superior and quantitatively numerous glass mirrors began to be made? The puzzle is made greater by the fact that the central technical knowledge, namely that one could coat glass with a metallic film and obtain an excellent reflective device, was very old. 'The principle of applying metallic films to glass seems to have been known to the Romans and even to the Egyptians...'⁵⁶ Yet neither the Romans nor any other civilization, including I believe, the Islamic civilizations, made much use of this knowledge. For a long time even up to the middle of the thirteenth century the knowledge and the practice differed. Thus 'the method of backing glass with thin sheets of metal for mirrors was well known in the middle ages, at a time when steel and silver mirrors were almost exclusively employed. Vincent of Beauvais, writing about 1250, says that the mirror of glass and lead is the best of all...'⁵⁷ Yet from about the thirteenth century the art of mirror making developed rapidly in several parts of Europe.

We tend to think of the mirror revolution as having found its centre in Venice, but although it became important later, it may well have been in the northern German and French glass-making areas that some of the crucial breakthroughs were first made. We are told that 'The frequency of literary references to mirrors, first attested in the ninth century, greatly increased in the late twelfth century. The first recorded transactions involving mirrors date from shortly afterwards; in 1215, for example, Arnulf of Basel in Switzerland sent glass to Germany for making mirrors. A recent study suggests that Germany in general and Nuremberg in particular were regarded as Europe's leading mirror makers in the later Middle Ages...'⁵⁸ Earlier it had been pointed out that 'References of the 12th and 13th centuries seem to show that their manufacture was chiefly carried on in Germany, though there is also record of mirror-making as early as the 14th century in Lorraine. At Nuremberg and elsewhere in Southern Germany, by the 15th century at latest, convex mirrors were made of 'crown' glass.'⁵⁹ 'A guild of glass-mirror makers existed at Nuremberg in 1373, and small convex mirrors were commonly made in southern Germany before the beginning of the 16th century...'⁶⁰

At first the mirrors tended to be small hand mirrors. 'Mediaeval mirrors were hardly of a size to lend themselves to interior decoration and were generally of the sort that might be peddled around by hawkers...'⁶¹ But over the thirteenth and fourteenth centuries the 'convex Nuremberg mirrors and the **cinquecento** Venetian **lustr** represent the emergence of the wall mirror, though still of diminutive size compared with plate glass mirrors of the late seventeenth century.'⁶² The mention of Venice here indicates the movement south in the fifteenth century of the skills of the northern mirror makers to reach an even higher perfection for a century and a half in Venice.

We are told that it was 'in Venice that the making of glass mirrors on a commercial scale was

⁵⁶ Enc. Brit., 'Glass'

⁵⁷ Enc.Brit, 'Mirrors'

⁵⁸ Sotheby, Encycl. 51-2

⁵⁹ Honey, Glass, 7

⁶⁰ Enc.Brit, 'Mirrors'

⁶¹ McGrath, Glass in Arch., 313

⁶² McGrath, Glass in Arch., 313

first developed; and the republic enjoyed a much-prized monopoly of the manufacture for about a century and a half. In 1507 two inhabitants of Murano, representing that they possessed the secret of making perfect mirrors of glass, a knowledge hitherto confined to one German glass-house, obtained an exclusive privilege of manufacturing mirrors for a period of twenty years.... The products of the Murano glass-houses quickly supplanted the mirrors of polished metal, and a large and lucrative trade in Venetian glass mirrors sprang up.⁶³ The development was particularly dramatic because of the technique of coating mirrors with 'an amalgam of tin and mercury discovered by the Venetians in 1317'.⁶⁴ This process is described a little more fully as follows: 'the necessary reflective surface behind the mirror was made of tin. This was a Venetian process, in which the clear and polished glass was coated with sheets of tinfoil, and mercury was poured on it, forming an amalgam.'⁶⁵

As with other aspects of glass-making, the seventeenth century began to see the monopoly of Venice disappear. The French and the English began to vie with the Italians. 'In 1623... Sir Robert Mansell...claimed that he then had 500 Englishmen engaged in 'making, grinding, polishing and foyling looking glasses'.⁶⁶ The technology developed dramatically during the seventeenth century. 'The first requisite of a mirror is that the glass should possess perfect planeness and parallelism. For this reason the development of the mirror depended on the development of polished plate, the various compromises with blown plate and other imperfect glasses having to be endured until Perrot's invention at the end of the seventeenth century.'⁶⁷ Perrot (check XXX) was presumably a French inventor, and this reminds us that it was in France that the final transition from the wondrous stained glass of the medieval west to the next great glass edifices was achieved. 'The **Galerie des Glaces** (Hall of Mirrors) at the palace of Versailles was opened on 15 November 1684. It was a wonder of the age. Spanning the full facade of the central pavilion and overlooking the park, its colossal mirrors reflected the light of seventeen huge windows and seventeen colossal chandeliers. It was the secular counterpart to the medieval stained glass of Chartres.'⁶⁸

Thus a second divergence, both from the ancient and oriental worlds had occurred in relation to another crucial instrument of knowledge, the glass mirror. It still surprises one how recent, and local, the glass mirror is. No ancient civilization up to the twelfth century seems to have used glass mirrors extensively; Asia never developed such mirrors until the last few centuries. It seems to have been a combination of the development of better flat glass and new methods of backing the glass, with wealth and curiosity and vanity, which from about the twelfth century onwards led to this revolutionary new device. Its development again shows the interplay of rival centres; first it developed in Germany, then the centre moved to Venice, then to France and England. These glass mirrors combined with plain glass windows framing the view and stained glass breaking up light, seem to have had an extraordinary effect on human conceptions of space, the person and many other things, as we shall see. The original motivation may have been, as Samuel Johnson sardonically suggested partly at least because mirrors enabled 'the beauty to behold herself.'⁶⁹ The later consequences may have been, as is often the

⁶³ Enc. Brit., 'Mirrors'

⁶⁴ McGrath, Glass in Arch., 315

⁶⁵ Derry and Williams, Technology, 111

⁶⁶ Singer, vol.IV, 362

⁶⁷ McGrath, Glass in Arch.,313

⁶⁸ Davies, Europe, 369-70

⁶⁹ McGrath, Glass in Architecture, 5

case, accidental and unintended. Yet they were immense.
The development of lenses in the West.

It became clear from very early on that glass was not merely a marvellous substance for holding cool liquid in and enhancing its beauty, or for letting in light but not cold, but it could be manipulated to alter vision. As we saw, at least as early as Greek and Roman civilization, people had noticed this property in relation to drops of water, but glass was permanent and easy to manipulate. Thus the idea of examining microscopic objects through glass was present from at least the twelfth century and magnifying glasses must have been quite common by the sixteenth century.

Spectacles seem to have been invented around 1285 in northern Italy, though there is no exact location or date.⁷⁰ refs.) Once they had been invented they spread very quickly. Although 'Spectacles were almost certainly not invented at Venice, but they were soon being made at this principal centre of the glass-industry...'⁷¹ These first glasses were to correct presbyopia (far sightedness). 'At first spectacles were provided with convex lenses only, to aid presbyopia; the lenses were ground to curves of small radius, and were comparatively easy to work. No reference to concave lenses for the correction of myopia [near sightedness] appears to precede that of Nicholas of Cusa (1401-64) in the mid-fifteenth century.'⁷² The knowledge about eye-sight and the quality of the glass progressed alongside each other. In relation to knowledge, for example, 'The manner in which lenses correct the natural defects of the human eye began to be studied in geometrical terms in the sixteenth century. Francesco Maurolico (1494-1575) of Naples showed how the lens of the eye focused light upon the retina...'⁷³ Alongside this was the rapid development of skill. The Venetian glass industry led the way at first through its division of labour. In Venice in the thirteenth century 'Each important aspect of the glass-making craft was separately organized. There were the makers of glass vessels, the makers of flat glass, or **rui**, the **fiolariii**, or bottle-makers, the lens-grinders, and the **contarini**, or bead-makers.'⁷⁴ These lens grinders applied their skills to spectacle lenses as well as lenses for use in optics more generally. Thus though the 'Venetian glass-industry was making a product of sufficiently high quality for use in spectacles before 1300, it was much below the excellence it afterwards achieved'.⁷⁵

As for the reasons for the spread in the use of spectacles, one important factor was the development of printing and popular books, as opposed to the large (and expandable) calligraphy of the East. Hence the need for glasses in the West. The whole question of the distribution of literacy, and the nature of the distortions of the eye is also relevant. We shall look at this in more detail in chapter XXX.

* * *

It is not easy to disentangle the strands that came together in western Europe to take it in a new direction. There was clearly the general growth of affluence which led to the emergence of demand for glass - for the stained glass windows of the Gothic cathedrals, the drinking glasses of the re-emergent glass industry, the window glass for richer households. This built on the Roman techniques, many of which had not disappeared and others which were re-discovered.

⁷⁰ See e.g. XXX

⁷¹ Singer, iii, 230

⁷² Singer, iii, 231

⁷³ Singer, iii, 231

⁷⁴ Klein and Lloyd, Glass, 68

⁷⁵ Singer, iii, 231

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Glass was still being used mainly for comfort and luxury during this period but during the key period between about 1200 and 1450, three key developments which would have immense significance occurred in windows, mirrors and lenses.

The course of development in western Europe over the six hundred years from 1100 is, from a comparative perspective, extraordinary. Glass had lingered on in Spain, Germany, England, the Netherlands, Italy, Bohemia and elsewhere and as archaeological research continues, and as we read accounts of twelfth century glass-making we become increasingly aware of the sophistication and ubiquity of glass. But from about the C12 there seems to have been an explosion of glass in the north (Gothic windows, window panes) and in the south (drinking glasses and later mirrors). Glass was widespread in this period and many middling and upper class individuals would be aware of its peculiar nature. A combination of growing affluence, urban competition, weather, wine, Gothic architecture, the influences from Syria and so on led to the re-emergence of Roman glass civilization, but on a far grander scale. The domestic uses were not as extensive as in Rome; the Romans used glass for eating, cooking, drinking utensils in a way unrivalled since then. But they used it far less for windows, both domestic and stained glass for religion, than medieval societies. And they did not develop three of its major uses, though these were potentially known to them, in other words as glass mirrors, and as the spectacles to correct and prolong sight, as lenses to magnify, and as prisms to speculate about the properties of light.

(7100 words)