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STUDIES OF OPERA HOUSE ACOUSTICS

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1. AUDITORIUM FORM FOR OPERA

Select a rectangular shoebox shape room with surface decoration on the walls and ceiling, organise the audience with adequate sightlines and choose a ceiling height to give a 2 second reverberation time and you have probably created a concert hall with good acoustics. Over the last 20 years considerable progress has been made in understanding what design aspects are important for good concert hall acoustics so that copying earlier designs is no longer necessary. For instance, the terraced concert hall as exemplified most famously by the Philharmonie in Berlin achieves good acoustics by means apparently very different from those employed in the classical shoebox hall. An understanding is developing of what acoustic conditions are optimal for concert performance and of why certain concert hall forms, such as the shoebox hall, perform well [1].

Public opera originated in Venice in 1637 and there is evidence that already by 1654 the opera house form with a horseshoe plan and stacked boxes had been developed. The horseshoe form with balconies has dominated subsequent design and grown dramatically in size. But is this Baroque theatre form, as it is it called, also optimal from an acoustic point of view for opera?

The early history of the development of the opera house is marked by the gradual enlargement of houses and experimentation with different plan forms [2]. As well as the horseshoe plan, the U-shaped, elliptical and bell-shaped plan were tried. While these various forms had different sightline conditions, the acoustic implications of the various plan shapes are probably small. All these plan forms run the risk of focussing by curved balcony fronts and by concave rear walls behind the audience; steep raking of floors may 'solve the problem' by making the area of focus above the heads of any audience.

The first large scale opera houses, such as Teatro San Carlo, Naples (1737) and Teatro alla Scala, Milan (1778), employed tiers of boxes, typically six tiers stacked vertically above each other. Vertically stacked boxes can produce exciting acoustics in the stalls and at the front of the boxes, but acoustic conditions deteriorate rapidly as one moves away from the front of the box. The open gallery is England's contribution to theatre/opera house design, which on balance offers more uniform acoustics than tiers of boxes. Seats in an open gallery under an overhang experience much less extreme changes of acoustic character.

Wagner made the radical departure from the 200 year old tradition of the Baroque theatre with his Bayreuth Festspielhaus of 1876. In the interests of equality for the audience he turned back to the Greek classical theatre for inspiration and built with a fan-shaped plan. Subsequently many opera house designs have been hybrids of the Baroque and Bayreuth model; houses rebuilt in Germany in the 1950s and '60s to replace war damage explored several interesting possibilities [3].

The acoustic performance of various elements of opera houses is the major concern of this paper; the argument will be illustrated by measured objective and subjective results from two London houses. One particular point of interest is the acoustic consequences of balcony overhangs.

2. THE ACOUSTIC GOALS FOR OPERA

Of all the types of auditorium the opera house is the most constrained [1]. Of necessity the singers perform on a stage behind a proscenium opening and are separated from the audience by the orchestra. The orchestra itself is constrained and in large houses is usually lodged in a partially covered pit. The audience has to be located within a maximum angle from the proscenium in order to have acceptable sightlines. For opera the maximum acceptable distance from the stage front to the furthest seat is generally quoted as 30m for visual reasons.

The other peculiarity of opera is that one has to design for two sound sources: the singers and the orchestra. The balance between the sound from these two sources has to be satisfactory. But the requirements for each source might also be considered different: for the singer intelligibility of speech needs to be considered whereas experience from concert halls suggests that for the orchestral sound a degree of reverberance and perhaps spatial impression due to early lateral reflections are desirable. These goals are in several respects contradictory and may have to be resolved by compromise.

Selection of reverberation time is certainly a question of compromise. A short value is likely to assist speech

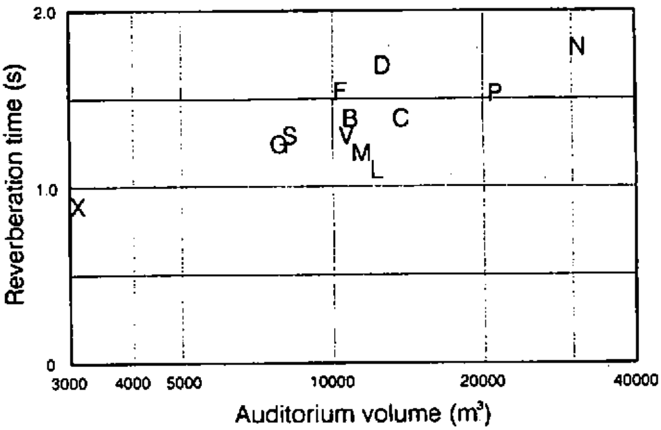

Figure 1. Volumes and mid-frequency occupied reverberation times of twelve opera houses: B, Deutsche Oper, Berlin; C, London Coliseum; D, Semper Oper, Dresden; F, Festspielhaus, Bayreuth; G, Glyndebourne Opera House (1994); L, Covent Garden, London; M, La Scala, Milan; N, Metropolitan Opera House, New York; P, Opéra de la Bastille, Paris; S, Sydney Opera House, Opera Theatre; V, Staatsoper, Vienna; X, Buxton Opera House.

intelligibility but leave the orchestral sound appearing too stark. A long value will favour musical sound at the expense of intelligibility. But the question of whether speech needs be intelligible should to be raised. A survey of audience members [4] found that during true lyrical singing only about 10 to 15 per cent of words are clearly heard by a listener ignorant of the text! Does one conclude from this that intelligibility is irrelevant for opera? It would seem unwise to ignore it but rather to include it as one element among many to be considered in opera acoustic design.

Figure 1 shows the reverberation times and volumes of twelve houses. Occupied reverberation times range between 0.9 and 1.8 seconds. Other than the Glyndebourne opera houses, Britain has only one purpose built opera house in Covent Garden (1858). Covent Garden has a short reverberation time. Other British venues now used for opera were originally constructed as drama theatres; they all have short reverberation times with the exception of the London Coliseum. The Coliseum was built in

1904 as a variety theatre; it is a particularly interesting auditorium which will be discussed further below.

The acoustic goals for an opera house need to be subdivided into requirements for the singers and for the orchestra. They include the following. For the singers the major concerns are likely to be intelligibility and sound level for the listener. For the orchestra there are the questions of clarity, reverberance, envelopment (due to early lateral reflections) and loudness. And perhaps the most important concern of all is the balance between the singers and orchestra.

The means by which a single singer competes with a whole orchestra is one of the paradoxes of opera. Sundberg [5] has discovered the presence of the singing formant between 2500 and 3000Hz which allows the singer's level in this frequency range at least to exceed that of the orchestra. Nevertheless audiences nearly always complain of the balance being shifted too far to the benefit of the orchestral sound. Yet to reduce the orchestral sound the orchestra would need to be less exposed to the main body of the house, by for instance placing them under a more covered pit. But orchestral players are understandably reluctant to perform under deep overhangs. Hence a basic conflict in opera house design. The question of pit design will not be pursued further here but it is likely to remain an ongoing issue.

3. INFLUENCING BALANCE IN OPERA HOUSE DESIGN

Whatever the problems of pit design and the implications for balance between the singers and orchestra, it behoves the acoustic designer to enhance as far as possible the sound from the singers, preferably in ways that do not support the orchestral sound. There is some potential in exploiting the different locations of the stage and orchestra pit, but this is only possible for surfaces close to the proscenium opening. Design of the 'proscenium splay' is thus especially important, Figure 2. If this surface is oriented at a small angle to the axis of symmetry of the auditorium, there is the potential for it to reflect sound from the singers into the auditorium and from the pit back into the pit.

The acoustic function of the proscenium splay should not though only be considered in plan. Above the height of the singers, the surface can be modelled to reflect some sound down; this can both improve the propagation from the singers to the auditorium and also improve mutual audibility of singers and orchestra. Sophisticated treatment of the proscenium splay is thus

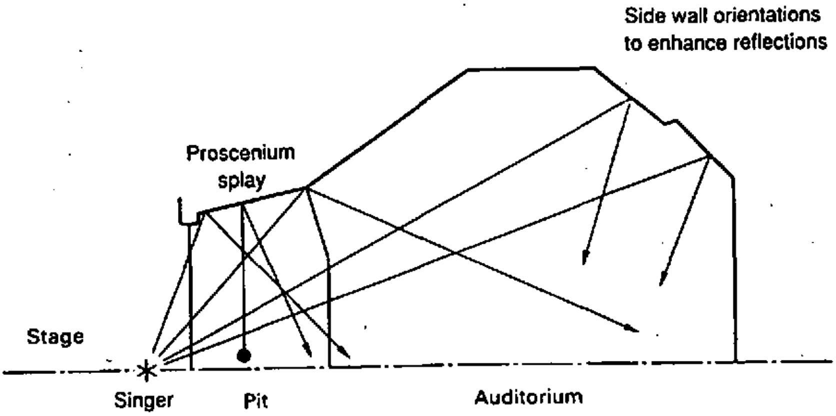

Figure 2. Reflections associated with opera house design form in plan.

appropriate. The Deutsche Oper in Berlin [6] of 1961 deals with potential visual problems by placing the reflecting and scattering surfaces on the splay behind an acoustically transparent screen.

Careful consideration of the long section is also necessary. If the height of the proscenium is not excessive, the area immediately in front of the proscenium can be used in the way suggested for the proscenium splay in plan: to reflect the singers sound into the auditorium and the sound from the orchestra back down to the pit. With a high proscenium however, the delay of reflections from these surfaces may be too long, in which case diffusing surfaces may be considered.

4. BALCONY DESIGN IN OPERA HOUSES

The auditorium in an opera house can be viewed in terms of three regions: exposed seating in the stalls and at the front of balconies, seating in the highest gallery and thirdly seating overhung by balconies. Some of the issues relating to the exposed seating have been raised above. Acoustic conditions in the gallery, or 'gods', are often the best in the house; an unobstructed view of the ceiling seems important here. Many of the traditional houses have concave domes in the front part of the ceiling which direct sound in unwanted directions; a basically plane horizontal ceiling may well be most suitable.

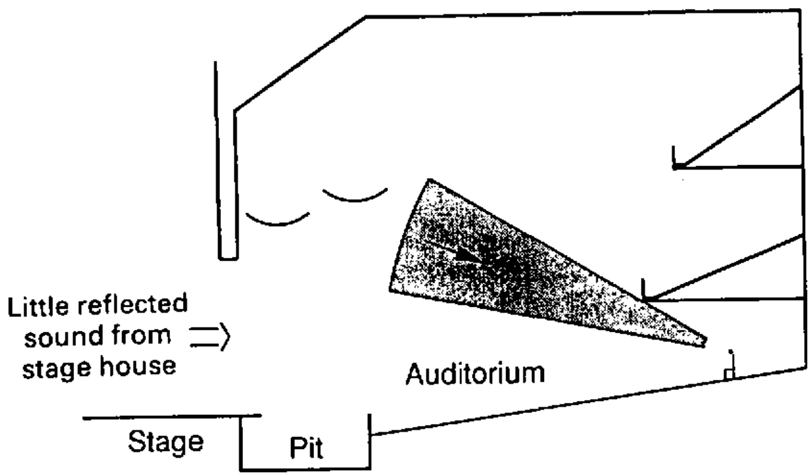

Figure 3. Long section of an opera house, showing the small angle from which later sound can reach seats beneath an overhang.

Suitable acoustic design of overhung seating is one of the challenges of opera house design. A study of sound behaviour under overhangs in concert halls has indicated the following phenomena [7]. It is easiest to separate the sound received by the listener into an early and late portion; the early portion includes the direct sound and reflections within about 80ms. Under an overhang, the direct sound will be unaffected and likewise reflections from side walls. Reflections off the ceiling will be obscured but these generally constitute only a small proportion of the early energy. Thus the effect on the early sound of being under an overhung is often not large. However the effect on the late sound is more marked. The listener receives only the diffuse reflected sound from the main body of the house which has passed through the horizontal slot between the balcony above and the seating below. But the rear wall at the back of the overhang and the soffit above also play a rôle. These local surfaces enhance both early and late sound reducing sound level changes as one moves towards the rear of the overhang; the early sound benefits most from these local reflections.

The net result of an overhang is a minor reduction in early level and a significant reduction in the late level. In a concert hall the acoustic consequences of an overhang are:

- an increase in the early-to-late sound index
- a decrease in the early decay time
- a slight decrease in total sound level

The above are perceived as a reduced sense of reverberance and to a lesser extent a reduction in loudness.

In opera houses one finds even larger changes in early-to-late sound indices at overhung seats. One reason for this is illustrated in Figure 3, which shows how limited is the vertical angle from which late sound can reach the listener. The proscenium opening constitutes a significant proportion of the solid angle viewed by the listener under an overhang; since stage houses are normally absorbent, very little reflected sound will normally come from this direction.

In an opera house the effect of the overhang is to increase the early-to-late sound index, which implies improved intelligibility for speech. For the orchestral sound there will be a less welcome reduction of reverberance. However on the evidence of some British houses, the balance moves in favour of the singer under overhangs. Thus the situation under overhangs is much less disadvantaged for opera than it is in a concert hall. Though the reverberance of orchestral sound is reduced, there are compensations with regard to the singers. These may be acceptable as long as the sound from the singers remains loud enough, remembering that audience noise can be loud under an overhang due to the nearby soffit.

The above discussion goes a long way to justifying Beranek's recommendation for overhangs in terms of the ratio between the height at the position of the balcony front H and the depth D in plan from the balcony front to the rear wall under the overhang. He suggests a maximum ratio for D/H of 1 in concert halls and 2 in opera houses. It is clear however that behaviour under overhangs is a three dimensional matter and simple ratios provide only a rough guide. Overhangs with D/H ratios in excess of 2 also become unacceptable on visual grounds.

5. THE TWO LONDON OPERA HOUSES

5.1 Objective measurements

The Royal Opera House, Covent Garden, has an auditorium volume of 12250m^3, seats an audience of 2120 and has a reverberation time of 1.1s. It has a traditional horseshoe plan, vertically stacked galleries but whereas the lower balconies have three or four rows, the highest level extends much further with 14-15 rows. The London Coliseum is slightly larger with a volume of $13600m^3$ and a seat capacity of 2354; its reverberation time is significantly longer at 1.4s. The balconies in the Coliseum benefited from new cantilever techniques which produced much deeper overhangs without the need for columns. Their designer was the most experienced theatre architect of all time, Frank Matcham, who must have clearly understood the risks he was taking. The opportunity to study acoustic performance under these overhangs was particularly interesting.

A full series of measurements was made (overnight!) in these two houses with both an omni-directional source in the pit simulating the orchestra and a source with directivity of a human speaker on stage [1]. Comments will be made relating to perceived reverberance, loudness, speech intelligibility and balance between singers and orchestra. The early decay time (EDT) appears to be the quantity most closely related to reverberance, or perception of reverberation. Mean EDT values in seats not overhung are close to those of the reverberation time, suggesting higher reverberance in the Coliseum. Shorter values of EDT occur under overhangs with extremes in each house of 0.7s. The total relative sound level is comparable in each house.

The early energy fraction is a valuable measure for speech intelligibility, which was measured for the speech source on stage. In theatre conditions values of the fraction above 0.5 are considered acceptable. Values for the early energy fraction prove to be virtually identical in the two houses with mean values of 0.55 and 0.56 and a range from around 0.34 to 0.72 in each case. Marginal intelligibility can thus be predicted in about a third of seat positions in each house. But when this data is considered together with that for reverberation time and EDT, the Coliseum is seen to score higher in resolving the conflicting dual requirements of satisfactory reverberance for orchestral sound and intelligibility of speech. But we would expect refinement of design over the 50 year period between their construction.

The balance between singer and orchestra is measured by comparing sound levels in the auditorium for equal sound power emitted from the respective sound sources. Measured values are shown in Figure 4, together with the values for Buxton Opera House. It is remarkable how small the range for balance is in each case. One notes that the deeper overhangs in the Coliseum do not result in a larger spread for balance. Without measurements in a wider range of opera house designs, one cannot reach many conclusions from this data other than comment that

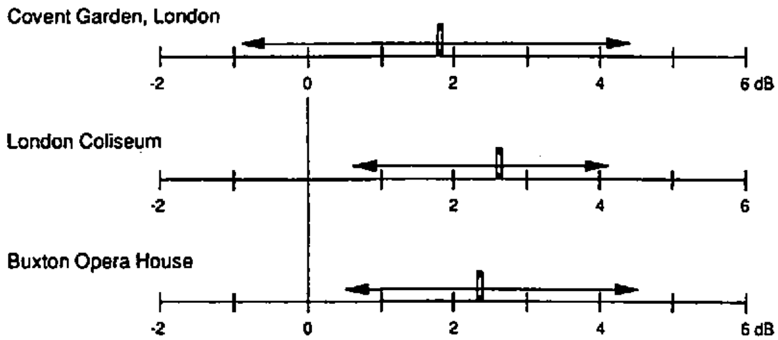

Figure 4. Objective level balance between singer and orchestra in three British opera houses. Range and mean of all measured values.

the balance in traditional opera house designs appears to vary little from seat to seat. One should add though that during the life of these houses modifications have been made to their pits which may well on occasions have been directed towards improving balance.

5.2 Subjective assessments

The two London houses have been tested at dress rehearsals with questionaires completed by listeners (mainly acoustic consultants). Four positions were tested in each opera house; the positions were selected with the intention of sampling the variety of acoustic conditions in a house of this sort.

It is possible to make many detailed comments about these results with discussions for instance about how listeners reacted in the stalls to the orchestra not being visible and thus there being no true direct sound. The following is selective with an emphasis on the perceived effects of overhangs and on judgements of overall preference by listeners.

Judgements of reverberance proved to be well correlated with measured early decay time for the sound from the pit. This is the result one would expect and shows that listeners were perceiving two things: the difference in reverberance between the two houses and the effect on reverberance of an overhang. Listeners also perceived the improved balance for the singers in the overhung seat in the Coliseum, which is corroborated by objective measurements of balance.

While the overall assessment of the acoustics of these two houses was 'Good', what was particularly striking were the differences between individuals within one house. For instance in the Coliseum, there was no uniformity in the rank ordering for preference of the positions tested. Apart from the severely overhung seat in the Coliseum, each of the other three was preferred by one or more listeners. In Covent Garden the average assessments of the various positions were quite similar, each position appeared to have its compensating features. Overall one can conclude that there is a considerable divergence of taste between listeners.

6. CONCLUSIONS

In concert halls the acoustics can be basically uniform and one can aim for excellence throughout most of the seating area. In opera houses most seats are disadvantaged for various reasons: seats in the stalls have no direct view of the orchestra, many seats are under balcony overhangs etc.. Opera house acoustics are therefore a matter of compromise. The designer can try to trade off improvements in the orchestral sound against that from the singers. Such trade-offs are particularly relevant under overhangs, where the singer's voice is enhanced relative to the sound from the pit. The evidence from a subjective survey suggests that individual listeners have different preferences, so that the inevitable non-uniformity of acoustics in opera houses need not be inegalitarian.

REFERENCES

[1] M BARRON, *Auditorium acoustics and architectural design*, E & FN Spon/Chapman & Hall, London (1993)
[2] M FORSYTH, *Buildings for music*, Cambridge University Press (1985)
[3] H SCHUBERT, *The modern theatre - architecture, stage design, lighting*, Pall Mall Press, London (1971)
[4] A ALEXANDER, About the house (the magazine of the Friends of Covent Garden), Spring edition 1982.
[5] J SUNDBERG, 'The acoustics of the singing voice', Scientific American 236, 82-91 (1977)
[6] L CREMER, J NUTSCH and H J ZEMKE 'Die akustischen Massnahmen beim Wiederaufbau der Deutschen Oper Berlin', Acustica 12, 428-433 (1962)
[7] M BARRON, 'Balcony overhangs in concert auditoria', (submitted to J Acoust Soc Am.)

The Origin and Antecedents of the Glyndebourne Auditorium

Iain Mackintosh

In *The Times* of August 23 1994 Bernard Levin wrote

"I walked into the new opera house and I was stunned by its beauty. Now before you say that I am getting sentimental, let me say something about beauty in opera houses; I consider myself a considerable expert in the subject, having spent a great deal of my life visiting even the ones in the most remote places. Basically, there are two kinds of beautiful opera house interior: the ornate, however lavish or delicate, and the geometrical, however severe or magical. And I swear by Pythagoras and Archimedes, nay, by the very squares of their hypotenuses, that the new Glyndebourne is so stupendously magical that it hypnotises the visitor into the belief that it could win prizes for lavishness.

The sheer warmth of the wonderfully chosen timbers is perfectly set off by the architectural genius that has set the curves of the balconies so exactly that I thought for a moment the whole building would, at the press of a button, start going round".

The article continued in this vein save for a waspish criticism of the production of *Don Giovanni* of Deborah Warner. Levin forgot to mention the name of the architectural genius and hastened to remedy that the following day, giving due credit to Michael Hopkins and Partners.

It is they - Sir Michael, Lady Hopkins - Patty that is - or the project architect Robin Snell (now in practise on his own account) who should be introducing this theatre to you. Instead of Hamlet you've got Horatio or rather one of the spear carriers.

But as we are met to discuss the design of the auditorium rather than the whole magnificent building I suppose I can speak with a little authority : it was my role to change the direction of the original design from fan shaped auditorium to the present semi-circular plan which the more pedantic amongst you will point out has been misnamed 'horseshoe' (however this is not sloppiness on the part of publicists - the first departure from the fan shape was in fact towards the horseshoe which was not quite as circular in form as what was finally built).

The Origin and Antecedents of the Glyndebourne Auditorium

So you have before you the grit, the piece of sand in the Hopkins oyster : the irritant, the abrasive rubbing of which contributed to the creation of this pearl.

In the late autumn of 1989 John Bury who is an old, old friend whom I had first met in 1961 and who had known Theatre Projects Consultants and its founder Richard Pilbrow for almost the same time, rang me. Hopkins had been appointed earlier in 1989 after the nine short listed architects had been reduced to two (the other being Stirling Wilford). Alan Russell and I for Theatre Projects Consultants were appointed and attended an interview with both architect and client (Michael and Patty plus Sir George Christie and John). Our team was subsequently extended to include Anne Minors on seating and sight lines, George Ellerington on stage engineering and Randy Cormack succeeded by Richard Borkum on sound.

At that time Sir George had chosen an architect rather than a design. He had also not written a brief the size of the Cardiff telephone directory but rather had written some simple thoughts such as those on "the feel" of the auditorium. "What it's going to be dressed in. It's got to be hugely welcoming. Timber-clad, not gilt or velvet. It has to be both functional and friendly". There was also no cumbrous programme of accommodation that millstone which invariably drowns any design team in detail much much too soon.

And there was Derek Sugden who shares my distaste for written briefs. I think he regards them as smokescreens which often hide the fact that the Emperor has not only no clothes but does not know where he is going.

Derek and I had a secret which we kept from Glyndebourne. After a successful collaboration at Buxton we had spent two years on the very first studies for an opera house at Compton Verney. I had sketched a design for an auditorium and stage inspired by Le Grand Theatre at Bordeaux (it is, you see, the neo-classical of France and England at the turn and the end of the 18th century rather than the earlier Italianate horseshoe that evolved in the late Bibiena era which is the inspiration of the Glyndebourne design). So when in March, April and May 1990 I made a move it was toward something that Derek and I had already decided could be made to work despite the familiar objections to the circular form.

Here is a simple image of the abandoned Compton Verney concept. Remember in summer 1989 we had both been sacked from the Compton Verney project which like Topsy had grown and grown (a stage big enough for both Kirov Ballet and Opera, three wagon stages, 1250 seats - in our view it had been talked up to the unattainable).

The Origin and Antecedents of the Glyndebourne Auditorium

Derek had put only two cards down on the table: first the new Glyndebourne should have 6 to $7m^3$ per person (and the closer to $7m^3$ the better - it was only $4.8m^3$ in the old theatre) and second he would control the shape at size of the pit and hence revise Glyndebourne's initial request for a 4.6m distance orchestra rail to stage edge (in the old theatre it was 2.7m.

Beyond this Derek was keeping his powder dry.

Hence when we made our move in March 1990 I took the ideas first to John Bury - it was after all his fan shape that would be supplanted and then to Derek. Once they had accepted the horseshoe things moved very quickly from April to July 1990 at a series of friendly meetings at the Hopkins office with Sir George Christie in attendance most of the time. In July 1990 an A3 design concept was prepared and presented to Sir George and to Michael and Patty. The following illustrations are taken from that report.

Of course there is a rationale behind this neo classical approach - "the geometric however severe or magical" as suggested by Bernard Levin. It is the sacred geometry of the interlocking circles which represent the worlds of actor and audience. That sacred geometry has three aspects:

- it provides a plan for the circulation of energy between actor and audience (said Albert Finney of a theatre which often fails to deliver, the Olivier, "If you stand on the stage of a 'proper' theatre. There is a circuit of energy flowing out to the audience and back to the performer again. Here the circuit wasn't completed. The energy going out of me did not come back. Instead of being recharged like a dynamo, I felt like a battery running down").

- it harks back to the days when a building could be set out with only a few drawings or just a peg and some cord.

- it results in harmonious space as defined by the neo-platonists and others including Palladio.

At the centre of a theatre set out according to these principles is the *vesica piscis* where the two worlds of audience and player overlap.

We can compare this to the crossing in a cathedral to which the Roman church has recently moved the altar for the celebration of mass in the realisation that this is a position of power possibly greater even more than that of the east end.

In an opera house this is the area occupied by the conductor, orchestra and downstage soloist.

It is here that things have slightly changed here from July 1990. In June Michael Hopkins said memorably "I think I can turn Iain's mumbo jumbo into architecture". Only one thing went wrong : I failed to state clearly enough my understanding of the significance of that overlap between the two worlds of audience and player.

We - and that includes all at TPC, John Bury and I think Derek - favoured a more ambivalent proscenium zone : stepped boxes and sliding side stages that slid inwards at right angles to the stage. We favoured providing alternative options, first of audience right up to the arch, second of scenery between the end of the circles and third a flash gap at the arch. We ultimately got, as you can see, the third of these not as one of three options but as the fixed form. You can still peg scenery to the proscenium if you wish and these are strange sliding stages which slide out from under the lip of the stage but the whole zone is not so flexible as originally intended. We're back to the fixed frame of the romantic opera house and the singer inside the pictorial frame.

This is the consequence of two strategic decisions the purpose of which is to control running costs: the fixing of the orchestra pit in one place in plan thus simplifying the box office's role and the controlling expenditure on scenery by limiting the extent of that scenery. Partly it is also due to the tidy mind of many of the design team : we the architects and consultants design and build the auditorium here and you the theatre profession do your bit there on the stage.

It was not ever thus. Wrote Fabrigio Carini Motta in 1676 who advocated that the acting stage be placed within the 10 feet, 3 metre or 6 brazze deep arch itself, that this is the area which "should not be less than 1.4m and no wider than 2.8m" deep, measured from the upstage edge of the proscenium arch where the scenery commences to the edge of the orchestra pit. This is the area "in which the players and speakers who walk on-stage, that is to say those who do not have to depend on machines, perform. Voices that are usually restricted by this thickness (i.e. are upstage of it) gain added projection toward the audience because of the shaping of the opening ... Some say that performing in the aforementioned space is to come out of the stage picture and consequently not to be a part of the scene, but in order to be heard in the auditorium it is best to do this, a lesser evil than to be behind the scena (i.e. the proscenium arch) and not be heard".

But as early as 1767 Count Algarotti writing of opera - he refers to the singer as the actor reversed this: "Who that reflects does not see such a proceeding is subversive? The actor - instead of being so brought forward, ought to be thrown back at a certain distance from the spectator's eye and stand within the scenery of the stage in order to make a part of that pleasing illusion for which all dramatic exhibitions are calculated".

Algarotti was therefore against "dragging them from the scenes into the midst of the parterre which can not be done by them without showing their sides or turning their shoulders".

Shock! Horror! Exactly what we want to happen today. The tide having ebbed now flows once more.

And yet if you look at the Teatro San Carlo Naples in the middle of the eighteenth century you can see that the forestage occupied almost precisely the area of the *vesica piscis*. Of course that forestage has vanished along with 5 metres of the forestage at the Teatro Scala at Milan.

You may ask whether all this history relevant to today? I will suggest there are at least three reasons why the modern opera house needs to offer an ambivalent zone between picture frame stage and auditorium.

As a consequence of the cutting back of the late eighteenth century the sightlines suffered from the side as this illustration shows. What of the acoustics? Well the layman can not but ponder that if the house was originally shaped to help the downstage singer and than that singer is moved 5 metres upstage to stand inside the scenery and while the brass occupies the position formerly occupied by the singer then the singer, who is now much further upstage, must sing louder to be heard over the band.

The result is the increase in the size of fees for tenors. There are not many who can cope with losing the reflective surfaces each side of the arch, the consequence of the actor being moved upstage into the picture. Hence they are paid more.

But I digress.

The three reasons why a director or stage designer may want to come through the proscenium arch today are:

- in comedy of manners whether operatic or dramatic, the closeness between actor and audience possible on the eighteenth century forestage can bring the action and the character more vividly to life than if the actor is stuck upstage. If the larger part of the audience can see those on the stage boxes relishing the comedy then that electric charge present in a good theatre to which Albert Finney alluded is intensified.

- in works which have a chorus like Britten's *Lucretia* and early operas a singer may need to step out of the action to present it to the audience.

- in works of great dramatic intensity the director may want either to widen the pictorial effect to the obvious limit or to thrust the scenery and singer over the pit in order to grab the audience, so to speak, by the throat.

Enough of the proscenium zone. Let us conclude on the plan form and let us give Count Algarotti the last word "What then is the most commodious shape that can be given to the interior part of a theatre and which of the curve lines is the most eligible for the disposing of the boxes in the best manner? Our answer is the same the ancients made use of in their theatres, the semi circular".

Let us move on to the section. In the proposals of July 1990 there was one more balcony. The three were reduced to two in July 1990 : I was told on grounds of cost. I suspect there was a better reason : with two galleries it would be possible to connect galleries inside with the proposed open ambulatories outside. Very reasonable and the result is a better reconciliation of inside to outside than has ever been achieved in a classical theatre.

But it posed a problem in how to treat the wider vertical gap between the horizontal galleries and the side. Algarotti again:

"The architect's principle care should be to let no gaping chasm appear by any space remaining unoccupied and lost to every serviceable purpose. Let him also contrive that the audience may form part of the spectacle to each other, ranged as books in a library".

The solution to filling those empty shelves here has been somewhat unkindly christened the witness boxes. Yes, I see their oddity and understand their unpopularity as parties of six are split three and three with the rearmost three outside the acceptable angle of vision. At this point it must be said that what was built is wider than we originally envisaged by reason of the purity of the architect's geometry. But what else to do? It will be interesting if this audience of architects and acousticians have a suggestion.

Then the height, necessary for acoustic reasons. Some of us were concerned that the auditorium might appear too large and diminish the scale of the performer. But strangely this is not so - the eye may travel up when one first senses the space but it does not wander up when it should not.

To sum up. The client wanted intimacy although his requirement for 350 more seats than the old house and a better acoustic resulted inexorably in a house with twice the volume of the old. The client did not dictate a form though John Bury had done a valuable design exercise to show that the additional seats could be accommodated within a fan shaped auditorium not too much longer than the old.

This problem led to my offering a solution of a certain form underpinned by a philosophy of geometric purity. The architect endorsed this philosophy but simplified it further, removing one gallery and positioning the walls of the auditorium on the outer semi circular line.

This is where the acoustical problems started : Rob Harris will tell us about this. And the sight line and seating problems : easy to sketch drawings at 1:100 but to turn them into a building where every sightline has been optimised was the concern of Anne Minors - and she did it before we went over to CAD for sightline checks at TPC! Over to them.

To end that Levin quote again because it is the best contemporary layman's statement of the difference between romantic and the classical in architecture. And this is decidedly a classical building, at the opposite end of the scale from that of the winner at Cardiff or that of the notorious Nicoletti. I think Count Algarotti had it in for the romantics in 1767 when he wrote of recent theatres - which must have included the Cuvillies Theatre in Munich of 1763 and the Margrafliches Opernhaus of Bayreuth of 1748 the following:

The Origin and Antecedents of the Glyndebourne Auditorium

"Let the ornaments above be narrow and confined but in all parts of a light and delicate workmanship".

Said Bernard Levin of this theatre:

"Basically there are two kinds of beautiful opera house interior : the ornate, however lavish or delicate, and the geometrical, however severe or magical. And I swear by Pythagoras and Archimedes, nay by the very squares on their hypotenuses, that the new Glyndebourne is so stupendously magical that it hypnotises the visitor into the belief that it could win prizes for lavishness.

The sheer warmth of the wonderfully chosen timbers is perfectly set of by the architectural genius that has set the curves of the balconies so exactly that I thought for a moment the whole building would at the press of a button, start going round".

Who set those curves? Michael and Patty Hopkins is the answer. But William Blake also provided an answer. So did Shakespeare, *Hamlet* Act V Scene II Line 10.

"There's a divinity that shapes our ends
Rough-hew them how we will"

Thank you