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THE OPERA HOUSE: COMPLEXITIES AND CONTRADICTIONS

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1 – SNAPE – BRITTEN'S BRIEF

Throughout the design of Snape Concert Hall, Benjamin Britten confirmed again and again his desire for an auditorium with no compromise of the concert hall acoustic. It was agreed, however, as the design developed that an orchestra pit and opera house lighting would be provided. "We will try it out", said Britten. I had some misgivings about performing opera in such a reverberant acoustic, even though the short side reflections from the walls and roof slopes would ensure great aural intimacy, one of the most important, if not the most important acoustic quality in any auditorium whether for lecturing, theatre, music or opera. When it came to the design of the orchestra pit itself, Britten had very decided views about its geometry. He wrote saying that he considered that the orchestra rail should never be more than ten feet from the edge of the stage. For large orchestras and particularly for Wagner's operas Britten observed how successful the covered or Bayreuth pit was for ensuring that elusive balance between the stage and pit sound. I believe it was Britten who illustrated this with great irony by recounting the story of Beecham rehearsing for the first London performance of 'Elektra' in 1910 with Strauss listening in the stalls. The 'Elektra' was the great American soprano, Edyth Walker who was recognised as the greatest Wagnerian soprano to have sung at Covent Garden. At one point in the rehearsal Strauss stood up, raised his hand and exclaimed in his own particular brand of English "The orchestra is not playing loud enough, I can still hear the soprano".

2 – WORDS AND MUSIC

This was my introduction to one of the most difficult acoustic problems in any auditorium and particularly the opera house, where the balance between voice and orchestra is so important. This central problem of 'words and music' is not primarily related to acoustics however, but to the aesthetics of opera performance. In his 'A Concise History of Opera' [1] Leslie Orney describes this Italian, French dichotomy. "The French adopted the literary approach to drama, and argued that the musical setting of words should be simple, following and reinforcing the natural inflexions of the voice and the cadences of the poetry. This, we have seen was what Lully strove to do. The Italians, while conceding this as a point of departure (it had been after all the fundamental principle of the Florentine Camerata and the New Music), held that purely musical factors, such as melody, harmony, timbre and so on, had their own individual and sometimes overriding contribution to add to the sum total. It is a basic difference of opinion that has endured throughout the history of opera!" This French view is encapsulated by that great literary contemporary of Lully, Corneille, who formed a formidable trio with Molière and Racine, when he wrote "I have taken good care to have nothing sung that is necessary to the understanding of the play, since as a rule sung words are imperfectly heard by the audience".

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3 – AMPHITHEATRE TO HORSESHOE

Against this background of the aesthetic and acoustic debate about 'words and music' I would like to look at certain aspects of the development of the European opera house with particular reference to the various forms and geometry which have developed over 300 years. This review will consider changes to the orchestra pit and to the little influence which acoustic theory and acousticians have had on the opera house.

Just as we see the beginnings of opera in the Florentine Camerata with the added influences of music and drama from the church, the street, the Commedia del Arte and the Singspiel, so the opera house can be seen as a paradigm of these influences. Just as the Camerata grew out of an intellectual movement where the aim was to rediscover the essentials of Greek drama, so the opera house developed from the classical amphitheatre. As composers continuously return to Orfeo and the Greek myths so architects return again and again to Epidaurus and the classical amphitheatre. We can assume that the amphitheatre form evolved to ensure good sight lines for as many people as possible. There is no evidence that the designers and constructors had any special acoustic knowledge. We certainly have no information about such knowledge and Vitruvius's 'Ten books on architecture' often quoted as an authority, were written some 300 years after the building of the inner circle of Epidaurus, which housed 6000 people, was built about 300BC and enlarged for 14000 people about 100 years later. A modern analysis of its successful natural acoustic is given in Professor Lothar Cremer's paper 'Different Distributions of the Audience' [3]. The amphitheatre developed specifically for the spoken work with a minimum of musical accompaniment in a dead, open air acoustic with no reverberant field and a naturally quiet background.

Although the form must have been associated with the researches and classical revivalism of the Florentine Camerata the audience was soon to be covered and the walls brought round to enclose the action of the drama in a U–shaped plan ensuring visual and aural intimacy as in the Teatro Farnese in Parma 1618 – 1628 by Giovanni Batista Aleotti. Within the U–plan Aleotti retained the raked amphitheatre seating, but Venetian architects soon replaced the raked seating with walls lined with multiple tiers of boxes as in the SS Giovanni & Paulo by Carlo Fontana 1654. From these beginnings the Italian horseshoe opera house spread throughout Europe and has retained its prominence to the present day. Two of the most well known are the Fenice of Venice 1792 – 1840 and S Carlo of Naples 1732 – 1780. The horseshoe form invariably has a dry acoustic with an occupied reverberation time of between 1 and 1.2 seconds. It has a powerful direct sound and short side reflections which ensure an intimate acoustic. The influence of acoustic theory was minimal on its development although certain forms were postulated by such people as Athanasius Kircher, who recommended the truncated ellipse where the focusing effect was considered to be beneficial. Teatro Regio, Turin 1738 – 40 was one of the most well–known of the elliptical opera houses and Pierre Patte's design for an ideal 'salle de spectacle' has the same elliptical geometry. This was illustrated in his 'Essay sur l'architecture théâtrale' Paris 1782.

4 – THE BELL PLAN

The other variation of the horse–shoe is the bell or trumpet based plan which was the hallmark of the Galli–Bibiena family. The most well preserved example is the Markgräfliches Opernhaus in Bayreuth 1748, the opera house which because of its large stage first drew Wagner to Bayreuth. The bell shape was supposed to have been adopted for acoustic reasons with the plac-

ing of the singers and orchestra in a position equivalent to the clapper of a bell. It was also considered that in doing this the singer could excite the surfaces of the theatre into vibration and so support and even amplify the voice. Even at the time of the construction of the bell–shaped opera houses these assumptions were criticised. Count Francesco Algarotti (1712 – 1764) courtier, writer and amateur of the arts, correctly criticizes in his "Sapio sopra l'opera" of 1762 the analogy of the bell shape. It is absurd, he says, to imagine that a singer can excite the surfaces of the theatre into vibration by standing in the equivalent position to the clapper of a bell. This superb Bayreuth rococo opera house has, despite these observations, one of the finest acoustics. There is more than sufficient volume as the present seating has 8.5m^3 per seat, and its narrow width which decreases to the rear of the auditorium ensures a powerful and intimate sound. In addition there are no soft furnishings, the whole interior being lined with wood panelling. Here again there have been many misunderstandings about the use of wood in auditoria.

The idea is still sustained today that resonating wooden walls will support or even add to the power of the voice, whereas we know that resonating panels absorb the low frequencies which are so important to provide the warmth or richness in the acoustic response of an auditorium. In the Markgräfliches Opernhaus the panelling is quite thick, but there is nevertheless some low frequency absorption which gives the acoustic a clarity which would have been ideal for the 18C operas. A similar opera house, the Altes Residenz Munich 1753, was built a little later. Although having great similarities to Bayreuth it has been likened by Iain Mackintosh to the softened rectangle of a converted royal tennis court. This opera house has an even greater volume per seat of 11.7m^3 compared with Bayreuth's 8.5m^3. With similar geometry to the Markgräfliches Opernhaus a powerful yet intimate acoustic is ensured. Both these 18C opera houses would have had forestages extending to the full width of the proscenium box, so ensuring that the singer had close audience contact and that the voice was projected into the auditorium and not into the fly tower or the scene. This would always have had great support from the singers and acousticians, but not from the philosophers, producers and designers of the 19C who were all concerned with theatrical illusion and continuously pushing the action behind the proscenium to ensure that 'suspension of disbelief'.

5 – ACOUSTICIANS

The Florentine Lully (1632 – 87) exerted an influence on French music in the 17C comparable to that of Handel in England in the 18C and his association with Molière led to a great influence on French opera where the essence of the 'tragédie en musique' is to be found in the recitative. Whether this had any influence on the geometry and acoustic of the French opera house is difficult to say. Certainly Bordeaux by Victor Louis 1780 is of circular geometry and very intimate, but despite its quite generous volume per seat, is very dry, due to its richly furnished interior. It is currently being restored and the Japanese acoustician Albert Yaying Xu has raised the original reverberation time of 0.7 seconds to a very acceptable 1.1 seconds.

The great bourgeois tradition of opera going was celebrated in Garnier's Paris Opéra of 1875 and we know that Garnier took no acoustic advice. He was very sceptical about all the ideas and myths generated since Vitruvius's famous or perhaps notorious description in his 'Ten books on architecture' [1]. In his book L'Opéra (Paris) 1889 he made this statement regarding the acoustics "but...nowhere did I find a positive rule to guide me; on the contrary, nothing but contradictory statements ...! I must explain that I have adopted no principle, that my plan is based on no theory, and that I leave success or failure to chance alone....like an acrobat who

closes his eyes and clings to the ropes of an ascending balloon." Despite the fact that from Galileo onwards a number of scientists including Mersenne, Georg Ohm, Helmholz and Lord Rayleigh, had laid the foundation for a very precise 'Theory of Sound' all published before Garnier's book, nobody had tackled the problem of some measurement or calculation which would indicate the essential quality of the acoustic of an enclosed space.

It was not until 1898 when one autumn evening Wallace Clement Sabine, a young assistant Harvard Professor, suddenly shouted from his study, "Mother it's a hyperbola." I often wonder how many Mothers have been excited by such a revelation in the history of science and technology. The realisation about the hyperbola came after plotting all his extensive measurements which showed that the sound absorption of a room multiplied by the reverberation time is a constant. This research work was carried out when he was invited to improve the acoustic of the notorious lecture room in the Fogg Art Museum at Harvard and this takes us back again to the amphitheatre. It was this attempt to improve the poor acoustic of an enclosed and roofed amphitheatre which was the catalyst for the first great breakthrough in room acoustics. Following Sabine's development of the simple reverberation equation which defines reverberation time as directly proportional to volume and inversely proportional to the absorption of a room, and his further experiments to discover the absorption coefficients of common building materials, Sabine was able to accept the invitation of Henry L Higginson, chairman of the building committee to be acoustic consultant for the new Boston Symphony Hall 1900. This first auditorium to have the benefit of acoustic analysis resulted in one of the great European type 'shoe box' halls famed for their acoustics and it was ironical that the equations came out of trying to correct the deficiencies of an amphitheatre.

6 – SEMPER AND WAGNER

This conveniently takes us to the Festspielhaus of 1876 at Bayreuth with a brief look at Teatro Olimpico of 1580 some 300 years earlier. The Teatro Olimpico amphitheatre is small enough with 900 seats to be intimate with a powerful direct sound aided by reflections from the curved enclosing wall which is sufficiently diffusing across a wide band of frequencies, due to the corinthian columns and statuary, to ensure no focusing problems. It was the radical ideas of Wagner and Semper, both of whom had to seek political asylum after the revolution of 1848 in Munich, which led to Bayreuth and the first idea of an amphitheatre as a 'democratic space' and a rejection of the European aristocratic space where everyone sat in a position analogous to their place in society. The story of The Ring and the building of Bayreuth is long and complicated and spaced over a generation in which King Ludwig II, his ministers and Wagner and Semper played leading parts. Semper's great Munich opera house was never built.

There is evidence, however, that he did play a part in the concept for the Royal Albert Hall which was built between 1867 – 71 and designed by two gentlemen from the Royal Engineers, Captain F Fowke and Lieutenant Colonel Henry H Y D Scott. Captain Fowke, before his appointment for the Royal Albert Hall, was a man of many parts whose designs included barracks, libraries, the original South Kensington Museum, a portable bath for officers and an umbrella that could turn into a walking stick! Whether Wagner would have included the Royal Albert Hall in his pantheon of 'democratic spaces' has, as far as I know, not been recorded but on its opening Queen Victoria said the Hall "looks like the British Constitution"! Whatever Semper had to do with the Royal Albert Hall, and certainly the curved facade was influenced by his first Dresden Opera House, it is recorded that he designed an auditorium in Paxton's Crystal Palace based on the amphitheatre form. When in 1865 he presented his monumental Munich Theatre

to Ludwig it also included the scheme for a temporary theatre to be built inside the Glas Palast, a high glass and iron structure similar to and based on Paxton's. Semper's ideas were presumably derived from his own connection with the Sydenham Crystal Palace. Both monumental and temporary versions followed Wagner's principle of a sunken orchestra pit and amphitheatre seating. When Bayreuth was finally built, Semper was otherwise engaged, but since his fees had finally been paid, his plans were the property of the King and were available to Wagner as a guide. The architect or Hochbaumeister Otto Bruckwald finally built the theatre in consultation with the theatrical consultant Karl Brandt though entirely to Wagner's instruction. The Festspielhaus was opened in 1876 with Richter conducting The Ring. It has some of the advantages of a narrow shoebox. The heavy pilasters which terminate the walls, which introduce the audience to the three rows of seats, provide strong side reflections. All the surfaces are hard and the effective volume per seat is high giving a reverberation time of 1.55 seconds in the mid frequencies. It was, together with Teatro Colon in Buenos Aires, Britten's favourite opera house acoustic, but built and used specifically for Wagner's music dramas. Its acoustic was also part of and sustained a new performance aesthetic where the audience sat in the dark, unaware of the sunken orchestra and separated from the 'mysteries and the myths' by a double proscenium. The new Festpielhaus was an essential part of Wagner's 'gesamtkunstwerk'.

7 – THE ORCHESTRA PIT

In one hundred years the opera had changed completely, particularly in the size of the orchestra, the power of the instruments and its relationship to the audience and stage. It is difficult to imagine the change in 101 years between the painting of a performance at Esterhaza and the cartoon of the pit at Bayreuth. The painting shows Haydn directing 'L'Incontro improviso' from the harpsichord in the Esterhaza Opera House in 1775. Haydn is at the harpsichord on the left with 2 'celli, a double bass and probably a bassoon, not shown, looking over his shoulder at the score. Arrayed in front of the stage at a table facing each other are the strings, woodwind and brass. There are probably no more than 20 players in the orchestra. Compare this with the Bayreuth pit which Wagner himself described as 'der mystische abgrund'. In this cartoon we see over 90 players in the pit with Wagner tapping Hans Richter on the shoulder through a flap in the leather hood which was placed there just for that purpose.

The growth of the orchestra, the position of the pit and their effect on the forestage have been central to the design of that ambivalent area between proscenium and audience. These complexities and contradictions are not new. As early as 1740 a painting of a performance in the Teatro Regio in Turin shows the traditional orchestra seated at stalls level with the harpsichords, bass instruments and brass separated on either side to maintain tolerable sight lines for most of the audience in the stalls. Even earlier at Versailles when Lully's 'Alceste' was performed in the open air in 1674, the orchestra of 40 players, had been split in two to enable the King in the centre to have an uninterrupted view of the opera.

8 – FROM ESTERHAZA TO MONTE CARLO – THE RECTANGULAR AUDITORIUM

It was 16 years after the 29 August 1775 performance of 'L'Incontro improviso' at Esterhaza that Haydn was brought to London by the great impresario Salomon. The contrasts between the life style of Austro–Hungary and England, of concert going and particularly architecture must have presented him with a series of cultural shocks. I am always intrigued by the comparison between the plain almost minimalist performing space of the Hanover Square Rooms opened in 1775 and the Rococo interiors of the concert rooms in Eisenstadt and Esterhaza 1769. There

are plans and sections available of the Opera House 1768 and Theatre at Esterhaza but no details of the interiors which we can assume were even more richly decorated than the concert rooms. The Esterhaza Opera House is of the horseshoe plan, whilst the Theatre is of rectangular plan. There were many small opera houses and theatres built in Europe during the 18C. Drottningholm 1766 has a rectangular plan like the theatre at Esterhaza. These small opera houses ensured a very powerful direct sound, and visual and aural intimacy between singers and audience. Drottningholm has an appreciable volume per seat of some 5.9m^3 and so will be quite reverberant for its size, combining a fairly warm sound with clarity from its very short side reflections.

The most famous rectangular opera house in England is at Glyndebourne, opened in 1934, now accommodating an audience of 850, but with a volume per seat still not as low as our British lyric theatres. There is of course a richness lacking in the Glyndebourne acoustic, but enormous clarity and intimacy which many find, if not ideal, very good for the 18C opera and chamber operas of the 20C. The other example is from Ireland; the Wexford Opera House last extended in 1987 and originally an 18C street theatre. The addition of 150 seats in 1987 occasioned the investigation of the roof structure to see if there was any way to increase the volume to compensate for the additional absorption of the larger audience. This was done by opening up the roof space and exposing the old king post roof trusses, ensuring that the new acoustic was more comfortable than that of the original theatre. There is one more example of the rectangular plan opera house and this is the Salle Garnier in Monte Carlo 1878. For me this is the ideal opera acoustic, aurally and visually very intimate with 640 seats, a rich acoustic with a volume of 7.9m^3 per seat which combines with very short and powerful side reflections from the diffusing side walls, and with an excellent balance between the stage and pit sound.

9 – OPERA-GOING IN BRITAIN

The British audience have limited opportunities to experience a range of opera house acoustics as we only have one real public opera house, Smirkes original Covent Garden which has been through many adaptations and alterations mainly by Albani in 1847 and Barry in 1858. We had to wait until 1986 before London and Britain gained its second opera house in the Britten Opera Theatre for the Royal College of Music by Sir Hugh Casson and his partner David Ramsey. This small opera house had the benefit of the latest current techniques in acoustic analysis. It has a volume per seat of 5.3m^3 and it was one of the early attempts to equate the acoustic of the empty condition with the full. The latest techniques were used for measuring seat absorption, with and without audience, and these were very successful. The reverberation time for the two conditions does not vary by more than 0.05 seconds.

With this chronic shortage of real opera houses the British audience has become accustomed to the dry acoustic of the lyric theatre. The commercial street theatre of Britain thrived during the 19C and the aim was to pack as many seats in as possible. With the development of the wrought iron and steel frame the tiers of the European opera houses became balconies and pushed out into the free air of the auditorium with the audience soaking up the 'flux of reverberation energy'. Theatre Royal Glasgow 1895 was one of the first lyric theatres to be restored, with the seating reduced to 1566 and even then giving as low a figure of 3.2m^3 per seat. Records showed that in the original theatre over 4000 people were packed in on a Saturday night! It was essential in the restoration to minimise the absorption in the auditorium and all the surfaces were kept as hard as possible with simple hard backed seats and carpets limited to the

aisles. The one radical departure was to follow the example at Snape and insert a covered pit. This pit certainly solved the problem of balance between the stage and pit sound. Singers were very happy, but musicians under the stage cantilever were deeply critical of the conditions.

The restoration at Buxton 1979 gave the opportunity to further develop the design of the covered pit and a much more comfortable acoustic was achieved by decreasing the proportion under the cantilever and increasing the volume and space for the individual musicians. This is one of Matcham's great lyric theatres put together with consummate skill and opened in 1903, a year before his great work the Coliseum opened in 1904.

10 – COMPLEXITIES AND CONTRADICTIONS

As that "exotic and irrational entertainment", as Doctor Johnson is supposed to have called opera, develops in even more irrational and exotic ways, the contradictions and complexities for the architect and acoustician multiply. Let me try and summarise a few. Everyone expects intimacy both aural and visual. For visual intimacy we expect eye to eye contact between performers and audience. For acoustic intimacy or envelopment, as the acoustician calls it, we need enclosures narrow enough for those powerful side reflections, preferably in rectangular spaces to avoid all focusing. For the visual intimacy we would prefer to get everybody as near the stage as possible and the geometer or engineer in us will produce the amphitheatre. But the theatre man will say that there must be intimacy and interaction within the audience, and he will question what to do with those great blank walls and ceiling when we enclose an amphitheatre. The acoustician will agree but for other reasons. With the wide amphitheatre he has lost the short, powerful side reflections. If we wrap the people around the performance then the acoustician wants sufficient volume to provide, if not a sound as rich as a concert hall designed for Bruckner's symphonies, at least one with sufficient reverberance to give a comfortable acoustic for Strauss and Wagner. At the same time the theatre man does not want it so high that it feels like a basilica where the eye does not come down to the action within the proscenium. Perhaps the biggest problem remains with that ambivalent area between the proscenium and the audience.

Most conductors like all the orchestra in front of the proscenium, so for Wagner and Strauss singers face a gulf across which only the most powerful or, may I say, freakish voices can be heard. This relationship ensures that the orchestral sound will dominate the whole performance. The growth of the opera orchestra to Wagner and Strauss dimensions, together with the theatrical and operatic theories of the 19C, has meant the loss of the forestage. This was also encouraged by the sight lines which result from the deep cantilever balconies of the lyric theatre. One of the biggest problems facing architects, acousticians and theatre consultants today is the size and disposition of the orchestra and the relationship of the front of the stage to the proscenium opening. Wagner solved it at Bayreuth, but only for his own very special music dramas. How can it be resolved for a modern opera house which must accept modern interpretation of operas from Monteverdi to Birtwistle and beyond, from the original instruments of the early Baroque to the orchestras of Wagner and Strauss?

The modern opera house is expected to house all these conflicting demands. The new opera house at Glyndebourne with some 1200 seats will be small enough to be intimate both visually and aurally with no one more than 30m from the stage. The side balconies are some 18m apart which will ensure strong early side reflections and there is over 6m^3 per seat which will result in an acoustic which is sufficiently reverberant to provide the necessary warmth and richness for

Verdi but will not mask the clarity so essential for the classical operas. All aspects of the acoustic have been checked using the current technology including analysis in a 1:50 scale model. Irrespective of the measurements we will make in the finished building to compare with our calculations and predictions, the performers and public will be the final judges when the opera house opens in 1994.

11 – POST SCRIPT

One of the most difficult aspects of auditorium design and acoustics today is the influence of recorded sound on public taste. For many people their musical and acoustic experience has been conditioned and continuously nurtured by the long playing record and now the compact disc. As recording and play back techniques improve they remove us further and further from the 'real thing'. Many people do not attend concerts and opera regularly and when they do they often suffer a sonic disappointment. They have become used to the skills of the recording engineer who, particularly in opera, will balance a voice against a rich reverberant orchestral sound which can never be realised in a natural acoustic. Peoples' expectations have been raised and there is in many large opera houses the temptation to amplify the voice by electronic means and to use the euphemistic word "enhancement". If opera is to be brought to large numbers as has recently been tried at Earls Court and other venues, this is perhaps a development which we must accept.

If this is so I would much prefer to synthesise the music in a suitable way for electronic amplification, and use robots in a specially designed 'in the round' auditorium, when the idea of seating 30,000 people originally planned for the Royal Albert Hall would become a real possibility. I do believe that a Ring with robots could be a great artistic and financial success. I feel that at least it would be as much loved and hated as any Ring performed today with the audience sharing the views expressed by Thomas Mann in his 'Pro and contra Wagner' [4].

I would like to finish my lecture by acknowledging and thanking the many people with whom I have worked on auditoria over the last 25 years, and the many others with whom I am continuously exchanging views, experience and prejudices. I would particularly like to thank my colleagues in Arup Acoustics, Richard Cowell, Robert Harris and Dr Rafal Orlowski, and, of course, the late Professor Peter Parkin. I have always enjoyed meeting and talking to the architect and historian, Dr Michael Forsyth, and I am indebted to him for discovering some of the best quotations about auditoria and acoustics. I find the theatre consultant and historian, Iain Macintosh, continuously stimulating in a dialogue about auditoria in which we have been engaged over the last 20 years.

Finally, I would like to thank Sir George Christie and the architects, Michael & Patty Hopkins for permission to use slides of the model of Glyndebourne. The opera house is now taking shape on the site.

Perhaps we should leave the very last word on auditorium acoustics to the architect, Adolf Loos, one of the important fathers of the Modern Movement. In 1912 he had been asked for his opinion on the Bösendorfer Hall in Vienna, and as a result wrote a quaint essay entitled 'Das Mysterium der Akustik' so that the secrets of the subject did not go with him to the grave. He concluded that concert halls become acoustically excellent when fine music played in them is gradually absorbed by the walls. In the mortar, he said, live the sounds of the great composers. The music of our symphony orchestras and the voices of singers impregnate the building ma-

terials, causing mysterious changes in the molecular structure, as in the wood of old violins. But brass instruments, he warned, have a bad effect, and military music, played in a fine hall could ruin its acoustics within a week. For the same reason, opera houses have poor acoustics on the side where the brass players sit.

This article was published well after Sabine's work, so we can assume that Loos was either an arch victim of acoustic myths, or the article was a vicious satire on the subject. We must remember that he was a great friend of Karl Kraus, that apocalyptic satirist, as Edward Timms describes him. I leave my audience to decide.

16 June 1992

[1] Leslie Orney, '*A Concise History of Opera*', Thames & Hudson 1972, (out of print)
[2] Vitruvius, '*The Ten Books on Architecture*', Book V, chapters III, IV, V, pp 137–145, Dr Morris Hicky Morgan's translation, Dover 1960
[3] Professor Lothar Cremer, 'Different Distributions of the Audience' : Paper 13, '*Auditorium Acoustics*', Edited by Robin Mackenzie: London, Applied Science Publishers Ltd 1975
[4] Thomas Mann, '*Pro and Contra Wagner*', Translated from German, A Blunden, Faber 1985

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