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THE REAL AND THE IDEAL

IN ROMAN ARCHITECTURE

by

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PREFACE

> When the work of art is also, as in architecture, a work serving a utilitarian purpose, then the form of the art will be further affected by its function. Admittedly the same function - for example, to provide a convenient shelter for a family of human beings - may be served equally well in a variety of ways ...; nevertheless, the functional purpose does set limits to the creative freedom of the artist. It introduces another element into the dialectic of that particular art, though function may be regarded as an aspect of reason, reflection, utility, etc., whose dialectical opposites are unreason, impulse, imagination, etc.; and an art like architecture, in so far as it is an art, is a synthetical resolution of just these contradictions.
>
> Herbert Read, Art and Society

This thesis is a dialectical study of the architecture of Ancient Rome, by which term is meant the architecture of the Roman Republic and Empire, produced under Rome's influence, whether by Romans or others, mainly during the period from the consulship of Sulla to the death of Diocletian.

Previous studies of Roman architecture, in so far as they interpreted the character of the architecture produced, tended to emphasize one or other of the opposing elements of the dialectic contradiction. This thesis considers that it may be the very anatomy of the contradiction, and the manner in which its resolution is attempted, which determines the character of Roman architecture. A new interpretation is attempted, in a Hegelian process of thesis, antithesis and synthesis.

It is postulated that there are two principal opposing tendencies, the practical and the formalist. These tendencies are isolated and analysed independently; and then the main characteristics of Roman architecture are considered as the resultant of this interaction of forces.

Roman architecture has many facets, and turns its various

faces to different observers. It may be seen as the continuation of the Greek tradition, or as the forerunner of Christian art; it is considered by some to be imitative, by others to be exemplary of progressive invention; it may be classified as stern and utilitarian, or as rich and ostentatious; it is criticized on the one hand for its authoritarian standardization, and castigated on the other for its licence and abuse of classical norms. It is, apparently, an architecture of paradoxes, for each of these views can be argued with reason and conviction. Roman architecture is all things to all observers: but it is these things in relationship, not in isolation. There are many separate threads in the fabric of Roman architecture: the weaving of these threads into a coherent and integrated pattern is the purpose of this thesis.

TABLE OF CONTENTS

CHAPTER ONE.	AN APPROACH TO THE INTERPRETATION OF ARCHITECTURE	1.
CHAPTER TWO.	THE PRACTICAL ATTITUDE OF THE ROMANS	21.
CHAPTER THREE.	PRACTICAL CHARACTERISTICS OF ROMAN ARCHITECTURE	49.
CHAPTER FOUR.	THE ROMAN FORMALIST ATTITUDE	128.
CHAPTER FIVE.	FORMALIST CHARACTERISTICS OF ROMAN ARCHITECTURE	157.
CHAPTER SIX.	CONFLICT AND RESOLUTION	196.
ILLUSTRATIONS		283.
BIBLIOGRAPHY		305.
APPENDICES	1 to 5.	313.

ILLUSTRATIONS

1. Roman Vaulting. Durm, Baukunst der Etrusker und Römer, fig. 281.

2. Pantheon, Rome, relieving arches. Rivoira, Roman Architecture, fig. 141.

3. Pantheon, Rome, plan. Ashby, R.I.B.A. Journal, 37:1929, pl.6.

4. Pantheon, Rome, porch and rotunda. Ashby, R.I.B.A. Journal, 37:1929, pl. 3a.

5. Library, Ephesus, plan. Robertson, A Handbook of Greek and Roman Architecture, fig. 119.

6. Trajan's bridge. Choisy, L'art de batir chez les Romains, fig. 95.

7. Old St. Peter's, Rome, roof truss. Choisy, L'art de batir chez les Romains, fig. 90.

8. Palatine Palace of Hadrian, Rome, coffering, Middleton, Remains of Ancient Rome, fig. 13.

9. Palace of Domitian, Rome, Throne Room. Rivoira, Roman Architecture, fig. 115.

10. Basilica of Maxentius, Rome. Durm, Baukunst der Etrusker und Römer, fig. 702.

11. Detail of hypocaust. Neuburger, Technical Arts and Sciences of the Ancients, fig. 346.

12. Hypocaust system, Saalburg, Neuburger, Technical Arts and Sciences of the Ancients, fig. 349.

13. Colosseum, Rome, section. Durm, Baukunst der Etrusker und Römer, fig. 745.

14. Theatre, Assos. Bieber, The History of the Greek and Roman Theater, fig. 315.

15. Theatre of Marcellus, Rome. Bieber, The History of the Greek and Roman Theater, fig. 453.

16. Theatres at Vaison and Orange, Acoustic tests. Canac, R.I.B.A. Journal, 56:1949, figs. 4, 5, 7, 9.

17. Amphitheatre, Treves, area under arena. Neuburger, Technical Arts and Sciences of the Ancients, fig. 494.

18. Colosseum, Rome, animal cages. Middleton, Remains of Ancient Rome, fig. 62.

19. Terme del Foro, Ostia, plan. Thatcher, A.I.A. Journal, 29:1958, fig. 1.

20. Terme del Foro, Ostia, sundiagram. Thatcher, A.I.A. Journal, 29:1959, fig. 5.

21. Terme del Foro, Ostia, sun diagram. Thatcher, A.I.A. Journal, 29:1958, fig. 7.

22. The Pythagorean Triangle, Vitruvius, Wittkower, Architects' Year Book, 5:1953, fig. 8.

23. Hanging arcades, Spalato and Ravenna. Smith, Architectural Symbolism of Imperial Rome and the Middle Ages, figs. 5, 6.

24. Imperial fora, Rome, plan. Von Blanckenhages, S.A.H. Journal, XIII, No. 4, 1954, fig. 1.

25. Imperial fora, Rome, plan. Von Blanckenhagen, S.A.H. Journal, XIII, No. 4, 1954, fig. 2.

26. Fortuna Virilis, Rome, side elevation. Drawing by G. Herbert, after a photograph in Joseph, Geschichte der Architektur Italiens.

27. Theatre of Marcellus, Rome, elevation. Drawing by G. Herbert, after a reconstruction in Joseph, Geschichte der Architektur Italiens.

28. Temple of Augustus, Rome. Middleton, Remains of Ancient Rome, fig. 35.

29. Temple of Bacchus, Baalbek. Robertson, A Handbook of Greek and Roman Architecture, pl. XIII.

30. Temple of Diana, Nimes. Robertson, A Handbook of Greek and Roman Architecture, pl. XV.

31. Theatre, Aspendos, Robertson, A Handbook of Greek and Roman Architecture, fig. 117.

32. Theatre, Athens, 5th century. Bieber, The History of the Greek and Roman Theater, fig. 155.

33. Theatre, Athens, oldest stone skene. Bieber, The History of the Greek and Roman Theater, fig. 173.

34. Theatre, Priene. Bieber, The History of the Greek and Roman Theater, fig. 294.

35. Theatre, Oropos. Bieber, The History of the Greek and Roman Theater, fig. 305.

36. Theatre, Magnesia. Bieber, The History of the Greek and Roman Theater fig. 340.

37. Model of a Stage, Museo del Terme. Bieber, The History of the Greek and Roman Theater, fig. 458.

38. Tragic scenery, wall painting, Boscoreale. Bieber, The History of the Greek and Roman Theater, fig. 344.

39. Painted scaenae frons, Pompeii. Bieber, The History of the Greek and Roman Theater, fig. 446.

40. Septizonium, Rome. Hulsen's restoration in Bailey, The Legacy of Rome, fig. 35.

41. Theatre, Sabratha. Bieber, The History of the Greek and Roman Theater, fig. 478.

42. Septizonium, Rome. Du Perac's engraving in Gaunt, Rome Past and Present, pl. XIII.

43. Theatre, Pompeii, plans. Bieber, The History of the Greek and Roman Theater, fig. 440.

44. Theatre, Ephesus. Bieber, The History of the Greek and Roman Theater, fig. 487.

45. Baths of Caracalla, Rome. Sangallo's drawing in Rivoira, Roman Architecture, fig. 216.

46. Library, Ephesus. Drawing by G. Herbert, after a reconstruction in Robertson, A Handbook of Greek and Roman Architecture.

47. Library, Timgad. Jones, Companion to Roman History, fig. 27.

48. Two examples of curvilinear plans. Smith, Architectural Symbolism of Imperial Rome and the Middle Ages, figs. 117, 118.

49. Two examples of curvilinear plans. Smith, Architectural Symbolism of Imperial Rome and the Middle Ages, figs. 131, 134.

50. Villa dei Misteri, Pompeii. Maiuri, Pompeii, pl. 121.

51. Forum, Pompeii, Sitte, The Art of Building Cities, fig. 1.

52. Temple of Venus and Rome. Rome. Drawing by G. Herbert, after Joseph, Geschichte der Architektur Italiens.

53. Nero's Golden House. Rome. Drawing by G. Herbert, after a plan in Antiquity, 30:1956.

CHAPTER ONE

AN APPROACH TO THE INTERPRETATION OF ARCHITECTURE.

INTRODUCTION

This study consists of an investigation into the architecture of ancient Rome, particularly during its Imperial phase. The characteristics of the architecture are analysed, in order that a deeper understanding of this period of architectural achievement may be reached.

Roman architecture is significant in its own right. It is also historically important as the starting point of Early Christian and Romanesque developments, where - throughout the vicissitudes of those styles - the Roman element is traceable, albeit in an ever-diminishing degree. Renaissance architecture is a reflection of Roman on two levels; as the direct and conscious revival of Roman forms and ideals, and as the embodiment of the influences of the immediate, mediaeval past, with its more indirect Roman implications.

Consequently Roman architecture is here analysed not only as a style but as a source of important manifestations of Western European architecture.

This thesis is based upon architecture produced by the civilization of ancient Rome. To that extent it is a limited and specific study. However, from it may be deduced architectural principles of wide generality.

The fundamental hypothesis of this thesis is that the characteristics of Roman architecture derive from certain dialectic contradictions in the Roman approach to design. The thesis seeks neither to blame nor to praise, but rather attempts to define and explain the nature of these contradictions, which are seen to stem from two basic attitudes to architecture, which we may call the practical and the formalist. It is here postulated that the nature of the architectural process is the conflict of the practical and formalist attitudes. This conflict has its source in the utilitarian origins of building, and the innate instinct of man for creative expression. The character of an architecture is

the resultant of this conflict, and the degree of its resolution in artistic, purposeful construction.

Our analysis of Roman architecture will be an analysis of the components of conflict, the manner of conflict, and the nature of the resolution.

Although dogmatic judgements of the architecture discussed have generally been avoided, nevertheless where judgements of quality form a part of this study, I have, in judging and assessing, of necessity looked at history through modern eyes. "It has become evident" a leading Italian critic writes, "that an organic culture cannot, in dealing with the past and specifically with architectural history, use two standards of judgement, one for modern and another for traditional architecture". [1] This is true, not only because we must provide modern, disorientated man with a base, but because, we can never adequately recreate for ourselves, as critics, the conditions under which the design originally was created; and judgements based upon hypothetical reconstruction of sets of standards other than our own, can have little pragmatic value today. We must, of course, judge history in the light of as full a knowledge as possible of all the operative conditions, but the judgement must be made from the standpoint of present ideals and standards.

The present writer believes with Worringer that:

> The earnest endeavour of the historian to reconstruct the spirit of the past from the materials at his disposal is at best but an experiment, conducted with unsuitable means. For however, faithfully we may strive to compel ourselves to an apparent objectivity, the exponent of historical knowledge remains our own Ego.with its temporal limitations and restrictions ... past events are not comprehended and appraised from their own standpoint but from that of our own prejudices. [2]

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1. Bruno Zevi, Architecture as Space, trans. by Milton Gendel, New York, Horizon Press, 1957, p.17.

2. W. Worringer, Form in Gothic, London, Alec Tiranti, 1957, p.1.

If we regard the architecture of any period as dishonest, then we must discuss it on that score, even if in its own day honesty was not considered a relevant criticism. If architecture is extravagant and wasteful, even if produced in a period of conspicuous waste, then it must by today's standards be adjudged faulty. Inconvenience of use must be commented upon, even if the user's standards of convenience were lower than ours. Standards of ethics, economy, utility, vary from period to period. Even standards of taste vary, although we like to think of the principles of beauty as eternal. When we assess the architecture of a past period, we can judge only by what we ourselves perceive: and perception is coloured by our experiential background. Our perception of historical buildings, although it is tinted by our historical insight of past conditions and attitudes, is yet more deeply pigmented by our own current modes of life, thought and experience. Our fundamental standards are those of our own time and experience; and if we believe in the spiralling progress of mankind, then contemporary standards - the ideals, if not the achievements - are the nearest to absolute criteria that, within the limits of our own imperfections, we have yet reached.

Perceiving then as observers of our own time, we cannot regard even beauty in the light of eternal canons. If, to us, concepts such as honesty of expression, economy of means, fulfilment of function do not lead per se to beauty of form, yet we believe that such beauty cannot be created in defiance of those concepts. This is the philosophy which guides this thesis.

ATTITUDES TO ARCHITECTURE.

CATEGORIES OF DISCIPLINE.

Architecture is not merely a personal work of art, the product of genius, ungoverned by conditions of space, time, and human purpose. Its production is a human activity undertaken to satisfy certain physical and psychological needs of men, including the architect himself and the society to which he belongs. It is

an activity undertaken at a specific instant, within a specific social environment, and it is impinged upon by all the physical forces operative within our universe. As such, it is subject to a host of influences and pressures, tangible and intangible; and the forms which it assumes are conditioned, shaped, and modified by every aspect of our mental, spiritual and material environment. The interdependence of the artefact and the universe was perhaps first clearly formulated in the nineteenth century, and the more old-fashioned historians of architecture still meticulously analyse the various influences of geography, geology, climate, politics, social organization, history, economics, ethics, philosophy, et al.

If the nineteenth century was the century of classification and analysis, our present time is marked by an endeavour to bring diversity back within the ambit of unity. This is the age of synthesis, the age of the Holism of Smuts, the Organic Mechanism of Whitehead, the Total Architecture of Gropius, the Organic Unity of Lloyd Wright, and the Synergetic Approach of Buckminster Fuller. This is the age of physical-chemistry, psycho-somatics, space-time: This is the age of seeing things in relationships. A truly contemporary approach to architectural criticism should similarly try to bring together the many strands into one comprehensive vision.

Before the fragmentization resulting from the analytic approach, the categories of discipline had been stated as a trilogy: the classical categories given by Vitruvius as Utility, Strength and Beauty; and the conditions of well-building defined by Wotton as Commodity, Firmness and Delight. These early categories and the advantage of broad generality; they were, however, over-simplified, and not all-inclusive. Modern criticism demands re-classification.

It is possible to re-group these various disciplines into more comprehensive categories, which, for the purposes of this discussion, may be defined as:

i) The psycho-philosophical disciplines, which are the subjective internal disciplines devolving from ourselves as thinking and feeling beings.

ii) The social disciplines, concerning our relationships with others, in that we are social, communicating beings living not in isolation but community.

iii) The physical disciplines, which are the objective external disciplines, the demands and limitations imposed by the material forces of the universe.

It must be emphasized that these are not just new and more complex names for Vitruvius's Utility, Strength and Beauty, but completely new categories of discipline. For instance, while the concept of Strength might be equated with Physical Disciplines, the concept of Utility has implications in all three categories of discipline.

These reduced, concentrated and more generalized categories are useful as a technique for responding the problems of architectural creation. They are, however, still analytic. It must therefore be realized, if we are to have the synoptic vision, that they are not water-tight and mutually-exclusive compartments, but rather over-lapping fields of force.

Architecture must not be considered the result of these disciplines operating directly, but the work of man conscious of the limitations these disciplines impose. A perfect work of architecture is the complete synthesis of the answers to the problems posed by the various classes of discipline, without prejudice to their individual integrity, in a purposeful and beautiful structure. Actual architecture is a striving towards this perfect synthesis, the attainment of which it is usually denied to a greater or lesser degree. The gap between perfection and achievement is partly caused by the limiting factor of human

capability, intelligence and artistic talent; and partly by the degree of incompatability of the various categories of discipline inherent in the particular architectural problem.

In practice, the process of architectural design is one of continual compromise, in the attempt to balance, adjust and reconcile the frequently conflicting demands of the various disciplines. This process of compromise demands a hierarchy of values according to which decisions can justly be made. Sometimes the relative values are implicit in the very nature of the problem, but, more often than not, they are to be determined subjectively by the architect himself.

It will be seen that the process of architectural design implies the making of a series of choices by the architect, according to a hierarchy of values largely self-determined and not necessarily inherent in the nature of the problem or the nature of its ideal solution. The way in which the architect makes these value-judgments depends upon that complex interplay of individual personality, knowledge, talent, idiosyncracy, operating within the flux of a general culture, which we may for convenience classify as his attitude to architecture.

THE NATURE OF AN ARCHITECTURAL ATTITUDE:

It is necessary, in order to achieve understanding of the differences in attitude, to examine the extreme cases of that attitude. It is important to bear in mind that such extremes of attitude are hardly, if ever, met with in reality. Attitudes are to a certain extent flexible, and variation within the spectrum of attitude takes place at all times as personalities mature or the nature of the problem or the cultural climate of ideas fluctuates. While any particular architect's attitude may therefore contain a complex interrelationship of features, it is - perhaps because of this factor - important to study the unchanging anatomy of these features themselves.

An understanding of the poles of attitude will help in the analysis of any particular attitude, containing as it must tendencies

towards one or other of the poles, - except in the rare case of perfect balance - tendencies which colour and give direction to personal attitude. Tendencies to one pole of attitude, although dominant, rarely, if ever, exclude recessive tendencies to the opposite pole. Hence, an understanding of the polarities of attitude, the tensions caused and the balances struck, are of fundamental importance if we are to understand the architecture created.

The two basic genre of attitude in their extreme manifestations we may term the Practical Attitude and the Formalist Attitude.

THE PRACTICAL ATTITUDE:

The practical attitude is that in which, when confronted by the necessity to make the choices and compromises inherent in the design process, the architect is guided to his decisions by a hierarchy of values, whose priorities are in the main determined by the social and physical disciplines. The main criteria for action are objective, and may be sought largely - but not exclusively - in the nature of the problem itself: thus, the synthesis sought by the exponent of the practical attitude is a building which is a social utility and which, as far as possible, is "beautiful".

The characteristics of a practical approach are an over-riding concern with planning for shelter, security, comfort, convenience and health; and a concern with a sound structural fabric created in terms of these functional requirements. The practical attitude is often marked by the advocacy of such concepts as fitness for purpose, honesty of expression, economy of means, and functionally-determined form. The emphatic direction of the attitude is towards utility in its widest sense.

There are two possible procedural bases for the practical attitude. On the one hand a practical man might proceed on the basis of hypotheses conceived in the light of theoretical knowledge and tested by experiment before adoption as valid: in

other words, by the procedure of scientific method. The alternative procedure is an empirical one of trial and error, which is development based upon experience but uncorrelated by general theory. Both methods of approach are governed by a desire to base action upon the reality of knowledge and objective truth. As a consequence of this duality of procedure, the educative system most conducive to the practical attitude is also twofold. One aspect is the fostering of the faculties of logic and reason, and the other is the cultivation of practical experience. Its philosophy of education in an ideal form is one which therefore embraces theory and experience, and would resemble most closely the principles of Whitehead, Dewey and Gropius.

The practical attitude attempts to deal with the subjective problem of beauty in one of several ways. At its most naive level it considers beauty to be the inevitable and unself-conscious result of the satisfaction of the functional requirements. This explanation of beauty is so obviously untenable that its appeal is strictly limited, and, within the practical attitude, more sophisticated concepts arise. These reflect the ambivalence of theory and experience which so marks the practical attitude. The empiricist tries to derive rules of aesthetics, or systems of beauty, which are based purely upon observation; the theoretician analyses aesthetics scientifically, as in the psychological studies of beauty, or the physical studies of the nature of vision. Thus beauty is rationalized and given a factual basis.

The architectural consequences of the practical attitude may include the following: convenient, economical and efficient planning; advances in structural techniques; the development of new and advanced building materials; technical excellence in such fields as drainage, heating and acoustics. Architectural appearances are radically affected: new and original building forms are created, not preconceived but arising out of the solution of the problem; a utilitarian aesthetic of rather laconic character is

consequently developed. There is, in the architecture, a concentration on inner essentials, and a highly developed sense of realism. Arising out of the empirical approach there develops a respect for tradition, for the evolutionary process in design, which goes hand in hand with more exciting and bolder innovations resulting from an analysis of the problem conducted with inexorable ruthlessness and imagination. Empiricism applied creatively but not arbitrarily tends to emphasize similarities rather than idiosyncracies, and a general anonymity of architecture tends to develop. Originality in architecture for its own sake is not sought, and common denominators and standards are established as the basis of sound, practical design.

THE FORMALIST ATTITUDE:

The formalist attitude is that in which the architect, in making his choices and compromises as part of the process of designing, is governed by values whose priorities are largely determined by the highly subjective psycho-philosophical disciplines. The beliefs which govern his actions are extrinsic to the architectural problem, but not necessarily irrelevant. In seeking to reconcile the conflicting demands of architecture, he strives for a synthesis which is a work of art and which, as far as possible, is useful and stable. Whereas the social justification of the practical architect is that he is creating a social utility, the formalist considers his function is to please the senses and uplift the spirit.

The predominant characteristic of the formalist attitude is concern with aesthetic problems. The nature of line, surface, solid and space are investigated, and their aesthetic possibilities exploited. There is a concern with the sensual attributes of building materials rather than their performance characteristics, and they are studied from the points of view of form, colour and texture. One especial characteristic of the formalist attitude is its preoccupation with the associative connotations, symbolic, literary, historical.

The philosophical and ethical tenets of the formalist attitude embrace such widespread concepts as the absolute value of beauty in terms of good; an absolute and ideal standard of beauty implicit in the universe; and form autonomous, and divorced from content. The direction of formalism may be summed up as art for arts' sake, as an ultimate value.

As with the practical attitude, the procedural basis of formalism is twofold, ranging from the pole of extreme freedom to the opposite pole of rigid control. Formalists are not governed by conditions inherent in the problem: they may therefore operate entirely freely upon the basis of emotional perception and intuition, disciplined only by the creative instincts of genius. Alternatively, artificial and extrinsic sets of rules may be created, formal conditions determined a priori and often arbitrarily, as a framework within which to operate.

The educative system favoured by the formal approach has two aspects. In so far as its philosophy is one of intuition and [illegible]ics, its system must be to create the all-round man of [illegible] a dilettante rather than the trained professional archi- [illegible] so far as its philosophy is based upon set rules of art, its system must be the rigid architectural academy. Its philosophy of education then is compounded of dilettantism and the Beaux Arts or, as it inspires Master-worship, the Taliesin Fellowship.

Within the formalist attitude the problem of purpose and structure is dealt with in one of two ways. Valid structure and sound planning are compromised for the sake of beauty, or, alternatively, structure and planning are solved as a separate problem, by means other than those necessary for the solution of the aesthetic problem.

The formalist attitude is reflected in architecture in many aspects. Architecture may reflect an analysis of aesthetic

experience in terms of the components of aesthetic theory; a sensitivity to aesthetic niceties, and nuances of mood and atmosphere. The characteristic consequence of the formalist attitude is concern with such questions as, how does the building meet the ground and the sky. Such an architecture is marked by conformity to aesthetic dogmas such as proportional systems, symmetry and balance. The forms chosen are thus usually preconceived, either in terms of these dogmas, or in terms of associations of a symbolic, commemorative or literary form. Dogma and associative forms both lead to eclecticism, that is the arbitrary retention of customary historical forms. This in turn leads to stability, thence to conformity as an ideal, and finally to stagnation. An opposing trend, equally within the ambit of the formalist attitude, is a reactionary tendency to licence, to arbitrariness, wilfulness, the deliberate cultivation of originality and idiosyncracy, and the emergence of 'prima donna', individualistic architecture. There is a marked concentration on externals.

LIMITATION OF STUDY:

This study has been limited to Ancient Rome for reasons described below, in the knowledge that the theories and artefacts discussed may be discerned in varying degrees in the architecture of other countries and other times. For practical reasons, it is however necessary to limit and confine the study, and we may affirm that such limitation, if applied in the light of a wider knowledge, can only but focus the beams of the study more closely, and thus illumine the essentials of the problem more brightly.

The application of the dialectic technique of analysis to Rome is apt for two reasons. First, we can consider Rome as particularly interesting in its own right, for it is the crucible in which new architectural ideas and forms are distilled on a scale of magnitude and importance hitherto

unapproached in the ancient world. Second, perhaps even more than Greece, it is the starting point of the main line of development of Western architecture. The continuity of the Roman tradition, particularly in the Italian Peninsula itself is a demonstrable historical fact: and the debt of European architecture to Italy in all phases except the Gothic, is a keystone in the story of the transmission of ideas. The continuity of building activity in the Italian Peninsula from Etruscan times to the present day, embracing as it does both Republican and Imperial Rome, the embryonic architecture of Christendom through all its stages till its full maturity in the Baroque, and the architecture of the industrial age of the last and present centuries, presents in concentrated form the story of the development of architecture, omitting, with the qualified exception of the fully developed Gothic, no major phase from the ancient world to the present day.

Not only does the duration of Italian building through history make it of unique importance, but - equally vital - its quality, power and originality are of the first order. Not only does Italy contain buildings representative of all the panorama of successive historical styles, but, time after time, it contains buildings which are the root and origin of these styles. Italy has not always proved receptive to ideas from outside, as the failure of the Gothic style to take root clearly shows: but as an originator and a source of European architecture, she is without peer. Let us as demonstration of this point, consider the case of Roman Imperial architecture. This architecture - superficially a derivative architecture based on Greek models - was so strikingly original in structure, planning and architectural form, that its influence over subsequent Christian architecture was marked for centuries to come. Indeed, Swift has advanced the thesis that: "Roman influences and the Roman

tradition determined the more important aspects of mediaeval art and architecture, from the earliest appearance of Christianity down practically to th rise of the Gothic style". [3.]

In fact, it can be demonstrated that Roman vitality was the spark for the Renaissance, which received and transmut d its virile inspiration; and evidence is not lacking of even more far-reaching consequences. Sedlmayr, for instance, in discussing the genesis of Borromini's forms, derived the exterior of S. Carlo alle Quattro Fontane from its interior, and traces the derivation of the interior (especially the third scheme, of which the final scheme is but a variation) directly from the Piazza D'Oro of Hadrian's Villa. He also demonstrates the similarity between Guarini's S. Gaetano in Vicenza and the domed hall of the "Little Palace" of the Villa; and the close parallel between Guarini's S. Lorenzo in Turin, and a room of the Teatro Maritimo of Hadrian's Villa. [4.] The originality of Roman architecture is a point which I shall debate at greater length later in this thesis. At this juncture I cite it in .upport of the more general proposition of the originality of Italian architecture.

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3. E.H. Swift, Roman Sources of Christian Art, New York, Columbia University Press, 1951, p.7.
This extreme position, though assailed by Strygowsky and Ainaloff, is supported, more or less completely by Rivoira, Wickhoff, Weigand and Strong. Although Ward Perkins tends towards a more conservative view ("The Italian Element in Late Roman and Early Mediaeval Architecture", Proceedings of the British Academy, XXXIII, 1947) -- he says: "A story so complex cannot without distortion be pressed into such a simple mould" -- yet, because of this very conservativism, his praise of the originality of Roman Architecture, and its far-reaching consequences in planning and construction, is particularly convincing.
E. Baldwin Smith, Architectural Symbolism of Imperial Rome and the Middle Ages, Princeton University Press, 1956 p.180, writes that "fr m the time of Alexander the Great there were successive perio .s of both eastward and westward dissemination and that the development of architecture was never the result of any one-way transmissio n of ideas".

4. H. Sedlmayr, Die Architektur Borrominis, Berlin, Frankfurter Verlags-Anstalt A.G., 1930, figs. 6-10, 37-40, pp. 58 et seq.

Similar support for this contention can be found in the contribution of Lombardic architecture to the field of mediaeval construction and decoration; in the creation, in the architecture of the Renaissance, of what became almost an international style; of the vitality which the Italian Baroque infused into a decadent European architecture; and in the vigour of the contemporary Italian architectural scene. It is our contention that Geoffrey Scott's words, penned in praise of the Renaissance, are capable of wider application: "Yet if we wish to watch architectural energy where it is most concentrated, most vigorous and most original, it is to Italy that we must turn". [5]

If Rome proves a fertile field for architectural study of world problems in isolation, as it were, it is because of the originality - in terms of external inspiration - of its architectural contribution, and the length of the unbroken building history which it generates. In the perpetuating of the Roman way Italy provides a picture of the deliberate and conscious maintenance of a design tradition for which, other than in ancient Egypt, there is no parallel. The extent to which there is a traditional Italian character in architecture, which transcends historical style and personal taste, is a matter which can be debated. But, even if that aspect were arguable what is indisputable is the conscious returning to past inspiration - the Renaissance idea - which is a recurring theme in the story of Italian architecture.

We find Greek revivals, in both the base and inspirational sense of the term, in Roman architecture of the Imperial Period, particularly in the reigns of Augustus and Hadrian. [6]

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5. Geoffroy Scott, The Architecture of Humanism, London, Constable & Co., 1914, p.11.

6. Swift, op. cit.

According to Middleton [7] the eclectic Augustan period saw able Greek artists in Rome [8] imitating, and to some degree reviving "the glories of ancient Greek architecture and sculpture". The emphasis appeared to be as much literal as inspirational, however, and we find that "not only the highly-developed styles of Praxiteles and Lysippus were imitated by these Graeco-Roman artists, but that they even produced archaistic imitations of the sculpture of Pheidias and his predecessors".

Trajan's employment of Apollodorus, followed by Hadrian's enlightened rule, brought about "a fresh revival of Hellenistic art of various styles; and then, for a brief period, architectural and plastic works were produced in Rome and its provinces which almost rival in beauty the finest works of the Augustan age". Hadrian's eclecticism, as was to be so frequently seen in Italy, was an eclecticism of the spirit, and the Greek 'renaissance' which his reign stimulated produced not dead copies of ancient monuments, but rather a revitalized architectural spirit, which engendered some of the most original architectural thinking of the ancient world. The love of tradition evident in the Roman makeup proved, in this and so many other instances, not to be the shackles of architectural initiative, but the catalyst stimulating the next bold step of a continuously developing

7. J.H. Middleton, The Remains of Ancient Rome, London, Black, 1892, I, 33.

8. If the Romans frequently used Greek artists, it is interesting to note that the reverse situation sometimes applied. We are told by Clement Gutch, for instance, that Antiochus Epiphanes selected a Roman architect, Cossutius, to continue the building of the Theseion at Athens in the first half of the second century B.C.

   C. Gutch, "Architecture", in A Companion to Latin Studies, ed. J.E. Sandys, Cambridge University Press, 3rd edition, 1929, p.526.

architectural evolution. Roman architecture, in its most daring and progressive phases was always radical, in the sense that Walter Gropius uses the word, [9] that is - from the roots.

Gest [10] tells us of the remarkable "persistence of the Roman type of construction and the influence of the Roman tradition" in the centuries that followed the collapse of the Empire. These centuries were chaotic years, hardly conducive to great structural developments. War, disorder, invasion, economic regression, all these things hampered the maintenance of Roman traditions created in an era of stability and plenty. Yet, the tenuous link of the Roman tradition bridged the centuries. Down the years the chain passed, from the Romanized conquerors of Gaul and Northern Italy, to the builders of Charlemagne, to the Benedictine monks, who became the preservers of more tangible relics than only the literature of the classical era, right down to the Fratres Pontis, those "Brothers of the Bridge" who, in their twelfth century construction of bridges in Southern France "followed Roman models closely, using the full centred arch, the heavy piers of large cut stone, with narrow waterways", and echoed in their works albeit dimly, the great achievements of the mighty past at Nimes and Orange.

The inspiration of ancient monuments thus stimulated positive research into ways and means of developing forms to suit the more limited economic and material resources of the times.

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9. Walter Gropius, in the forward to G. Herbert, The Synthetic Vision of Walter Gropius, Witwatersrand University Press, Johannesburg, 1959.

10. A.P. Gest, Engineering, in the series "Our Debt to Greece and Rome", George G. Harrap, London, 1930, p.203 et seq.

Rivoira has this to say of the 9th century Lombard Guilds: "Indeed, from this time onwards, we see them eager in searching among the ancient buildings of Rome and Ravenna for elements which, when developed, would lend themselves, by means of a rational evolution, and supplemented by new ones, to transform Roman architecture into a new style, thought out by themselves, and destined to serve new needs, as well as to adapt itself to changes of taste". [11] This process of creative identification with the past and transmutation of past achievement into the promise of a new living style, is typical of the deliberate continuity which one finds in Italian architecture.

Foligno [12] in commenting on the Roman influence so evident in mediaeval building in Lombardy and Southern France, casts some doubts upon the Rivoiran theory of the enlistment of specialised corporations of Italian masons by Charlemagne, but concedes that "it is most likely that the Lombards had recourse to local masons retaining some tradition of the proficiency to which their craft had risen in the past .... and it seems the more likely that the secrets of craftsmanship were traditionally retained and kept alive by some loosely constituted associations which survived despite the hostility of German legislation, or by families .... At any rate", he concludes "there seems to have been no absolute break of continuity in the development of

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11. G.T. Rivoira, Lombardic Architecture, trans. by G. McN. Rushforth, London, William Heinemann, 1910, 1, 5.

12. Cesare Foligno, "The Transmission of the Legacy", in The Legacy of Rome, ed. C. Bailey, Oxford, at the Clarendon Press, 1923, p.20.

necessary crafts". [13].

Again, in the twelfth century there is, in what Pevsner [14] calls the "Proto-Renaissance" and Scott [15] the "false dawn of classic style", a return to the root inspiration of traditional forms. "One is prompted to ask", writes Summerson [16] "if there was not some kind of 'renaissance' in the 12th century which made it possible for the vestigial memories of Roman decoration to coalesce once again into a nearly classical form of expression. The answer to such a question is unambiguous. There was such a Renaissance, and in other spheres of 12th century life its reality is easily recognised and has long been admitted by historians". [17].

Upon the full renaissance of the 15th century, it is not necessary to elaborate, for here was the perpetuation of the ideals of a past culture on an unprecedented scale. It is however, symptomatic that this greatest of all renaissances should originate in Italy. Later, in the revolt against Rococo, and the classical revival of the mid-18th century, the voice of continuity which is Italy - although now speaking in

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13. Foligno, loc. cit., makes the intersting comment: "Possibly the Roman elements in Frankish architecture are to be traced to the influence and the study of Vitruvius". This appears to be an exceptional reference to Vitruvius's influence in the Middle Ages.

14. Nikolaus Pevsner, An Outline of European Architecture, London, Penguin Books, 1953, p.58.

15. Scott, op. cit., P.20.

16. John Summerson, Heavenly Mansions, London, Crosset Press, 1949, p.22.

17. Vide C.H. Haskins, The Renaissance of the 12th Century.

dry academic tones - is that of the Algarotti, a great admirer of Palladio, who in 1758 writes deprecatingly of the architectural style of his day. [18] Finally, in our own time, we have the work of architects such as Gio Ponti, who, without stylistic implications, denotes his Montecatini and Edison buildings as classical, because, for Gio Ponti, as for so many Italian architects, "classicism involves a continuity of thought transcending models and classical forms". [19]

Cesare Foligno, in his discussion of the transmission of the Roman legacy to the Western world, differentiates between two processes.

> One part of the legacy reached the modern world by a natural process, handed down from people to people and by one generation to another, through traditions, which could not be rooted out, through legends, customs, intellectual outlooks, rough elaborations of artistic conceptions; and it is this part of the legacy which, independently of its intrinsic value, bore the best fruits in the modern era. The other part, which was perhaps richer in itself, was gradually recovered by the ceaseless efforts, the toil and study, excavations and investigations of scholars during the last centuries of the Middle Ages and the Modern epoch. Thus the process of transmission was twofold, natural and artificial ..... [20]

Put in other words, these two processes of perpetuation of the Roman tradition were, on the one hand, practical and empirical, and on the other, intellectual and theoretical.

If our study of Rome is to bear fruit as a help to the understanding of subsequent world architecture, it must

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18. Pevsner, op cit., traces the revolt against Rococo, in the period 1730-1760. He mentions Burlington's publication of Palladio in 1730, Algarotti's writings in 1758, and ultimately Winckelmann's nausea at Baroque when he saw it at Dresden in 1748, his returning to the work "a la Greque" and his writing: "The only way for us to become great, nay inimitable, if that be possible, is to imitate antiquity".

19. D. Guarnati, "Espressione di Gio Ponti," Aria d'Italia, 8, 1954, p.9.

20. Foligno, op. cit., p.10.

pay attention to the monuments themselves, from which originates the empirical chain of transmission; and the Roman theoretical concepts - their philosophy of structure and design, indeed their very philosophy of life - which later students attempted to adduce from Roman monuments and manuscripts. Such scholarly research into <u>temps perdu</u> was, in Italy, not only a disinterested and abstract investigation into history, but was largely motivated by that passion for tradition, that drive for continuity, which stems from the Roman attitude itself.

CHAPTER TWO.

THE PRACTICAL ATTITUDE OF THE ROMANS.

"The best preferred doing to talking." Sallust.

ROMAN MATERIALISM.

"Roman architecture..... was above all practical, simple, orderly, dignified, majestic, vast in its conceptions, solid, made for eternity; in a word the expression of the Roman character and Roman power." 1.

An architect's attitude is part of the general attitude of the times. He may be an individualist or even a rebel, but his thoughts, ideals and processes must be modified, if not determined - as it is in the great majority of cases (for most of us are conformists) - by the ideas current in his time.

Although these current ideas are by no means uniform, and diverse, if not conflicting, attitudes are in evidence in any society at any time, yet - because certain ideas are, (to use Mumford's biological analogy) dominant, others recessive, and still others emergent, - it is valid to generalise according to dominant aspects, and classify the attitude of a period according to its most important trend. In other words, by way of example, we might say that the old social system of tribe, phratry and gens was a communal system; that American civilization today is capitalistic, or that at the commencement of the First Crusade the attitude was that of religious idealism. In such ways, generally by seizing upon the dominant characteristics of a period, may epochs in history be categorised according to the "spirit of the times." Such classification by itself, in a study of architectural history, may be of small assistance: but as a matrix in which more detailed analyses take their place, it is valubale in setting the key in which the contrapuntal threads may be developed.

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1. G.T. Rivoira, Roman Architecture, trans. by G. McN. Rushforth, Oxford, the Clarendon Press, 1925, p.86.

The key to Rome is materialism. It is a period when, politically and socially, it is the material things which count -- power, wealth, force, position, It is a period of doing rather than reasoning, action instead of philosophy, practice instead of theory. It is a period marked by notable material expansion and progress - the political consolidation of an Empire; the taming of nature by vast engineering projects such as roads and aqueducts; the systematic exploitation of the human and material resources of Europe, Africa and Asia.

These characteristics of Roman civilization, interae diritta, [2.] and "essentially constructive" [3.], have been catalogued by Giavannoni in the following terms: a centralized political and financial power; a materialist people concerned with means rather than ends; a regulated and orderly system of administration; and an emphasis, leading to their gradual perfection, upon technical ideas transmuted into technical methods. [4.]

Roman genius found its incentive in the vast practical tasks of extending and maintaining the Pax Romana in giving physical form to the most complex urban civilization that the world had ever known. Aelius Aristides, in his paean of praise to Rome tells us how magnificently the Roman responded to this challenge:

> ....you have measured the whole world, spanned rivers with bridges of divers kind, cut through mountains to make level roads for traffic, filled desolate places with farmsteads and made life easier by supplying its necessities amid law and order. Everywhere are gymnasia, fountains, gateways, temples, factories, schools ..... cities are radiant in their splendour and their grace, and the whole earth is as trim as a garden. [5.]

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2. According to the Italian poet, quoted by Giovannoni, "Building and Engineering," in Bailey. op. cit., p.429.

3. Loc. cit.

4. Ibid., p.431.

5. Cited by R.H. Barrow, The Romans, London, Penguin Books, 2nd ed., 1953, p.130.

In the accomplishment of these things lies Roman greatness. "That is the true art of Rome, the spontaneous expression of the Roman Spirit, its keen realization of the adaptation of practical means to practical ends, its will-power and enduring effort, its tremendous energy and audacity and pride." 6.

Merely to list the practical achievements of the Romans does not, of course, prove that their outlook was materialist - although it does give grounds for making that assumption. However, the writings of the Roman authors testify to the value which the Romans placed upon material things. For instance, it has been pointed out that: "The utilitarian character of much of Roman architecture is summed up in the classic remark of Frontinus (The Water Supply of Rome I.vi): 'With so many indispensable structures for so many aqueducts, compare, if you will, the idle pyramids or the useless, though famous, works of the Greeks'". 7.

Strabo, in his "Geography" also strikes the materili note.

> For if the Greeks had the repute of being the most felicitous in the founding of cities, in that they aimed at beauty, strength of position, harbours, and productive soil, the Romans had the best foresight in those matters which the Greeks took but little account of, such as the construction of roads and aqueducts, and of sewers..... In a word, the early Romans took but little account of the beauty of Rome, because they were occupied with other, greater and more necessary matters; whereas the later Romans, and particularly those of today and in my time, have not fallen short in this respect either but have filled the city with many beautiful structures. 8.

The important point which emerges is that sewers, roads and other manifestations of the practical spirit are "greater and more necessary matters" than beauty. Here the Roman materialism is given chapter and verse. And how better can this materialist, practical attitude be exemplified than by Lucian, talking of the Thermae. "Moreover, it is beautified with all other marks of thoughtfulness -

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6. Edith Hamilton, The Roman Way, New York, Mentor Books, 1957, p.116.

7. N. Lewis and M. Reinhold, Roman Civilization, New York, Columbia University Press, 1955, p.227.

8. Strabo, Geography, 111, 8, cited by Lewis, ibid.

with two toilets, many exits, and two devices for telling time, a water clock that makes a bellowing sound and a sundial." 9.

Whatever aspect of Roman life and thought is our concern, we are conscious of underlying strata of materialism and practicality. Materialism is the bedrock upon which the structure of Roman philosophy, religion, science, politics and law, upon which the structure of all Roman thinking, is erected.

Even in our discussion of Roman philosophy, that most speculative and theoretical of studies, we are always aware of the stamp of practicality. Just as Panaetius 10. divided virtue into two classes, the theoretical and the practical, so Cicero would have us remember that philosophy similarly was concerned with two such fundamental problems. He deals with the theoretical aspect of philosophy in the Academica, where he is concerned with the criterion of truth; in his De Finibus, on the other hand, he is concerned with the very practical problems of the chief good, that is, with desirable ends for action. 11.

Most commentators 12. stress the view that Rome had a characteristic dislike of abstract thought and philosophical speculation, and point to the emphasis placed by Rome upon the concept of morals or ethics, that is, upon philosophical ideas only in so far as they facilitated a way of life, a course of action towards desirable ends. As we shall see, when the Romans adopted Greek philosophies, there was generally such a reorientation away from abstract idealism towards concrete materialism. Comparisons between Greece and Rome in such matters lead usually to conclusions favourable to Greece, detrimental to Rome. The decline of dispassionate research in Rome is of course an indictment of the

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9. Lucian, Hippias, or the Bath, cited by Lewis, ibid. p.228.

10. According to R.D. Hicks, "Roman Philosophy," in Sandys, op.cit. p.705.

11. Ibid., p.701.

12. See for instance E. Barker, "The Conception of Empire," in Bailey, op. cit., p.51; and Hamilton, op. cit., p.146.

Roman attitude; but the picture is not wholly negative, for as Edith Hamilton points out: "When the question had to do with the guiding principles needed for life, they knew better than the Greek what was important. They were men of practical vision: they perceived the struggle between good and evil as the Greeks never did." 13.

Stoicism, as propounded by the Greek philosopher Zeno, was based upon the trilogy of logic, physics and ethics, with the emphasis on a teleological viewpoint of the structure of the universe, and a preoccupation with ethics. With the purity of its search for ultimate truth thus somewhat tainted in Greek purist eyes, it had little appeal to the intellectuals of the Stoas. On the other hand its bias towards an incipient materialism gave to it a readier acceptance in Rome. "Stoicism crossed the Adriatic to find the conditions ready for its growth." 14.

This Stoicism was assimilated and modified by the practical Romans. Inevitably, its form became more materialist.

> The Stoics adopted an empirical theory of knowledge; not however, without concessions to rationalism. At first, we are told, they were content with right reason as the standard, but, as their doctrine became definitely more materialistic, they looked for their criterion in sensation, empirical notions or preconceptions, as well as in notiones (notitiae).....Everywhere we see the adaptation of means to ends: as in human actions, so in nature, every event fulfils a purpose. 15.

In Roman hands, Stoicism becomes increasingly eclectic, and may be considered as a philosophy concerned largely with morals as a guide for action in the immediate problems of everyday life.

Coupled with its inherent materialism, Stoicism has one other aspect which is of importance to our understanding of the Roman character -- not that Stoicism was effective in moulding the Roman outlook, but that the Roman character predisposed the thinking Roman towards a readier acceptance of Stoicism. Barrow cites Stoic philosophy as an interesting example of the impact of "Eastern influences on classical thought," 16. for in its heavy

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13. Hamilton, loc. cit. 14. Hamilton, loc. cit.

15. Hicks, in Sandys, op. cit., p.703.

16. Barrow, op. cit., p.161.

reliance upon precept and authority, upon the dicta of the Stoic sage, there are strong echoes of Eastern devotion to prophet and seer. Precept, proved by time and use rather than ultimate truth, becomes the criterion for action. We shall see the reflection of this trait in many other aspects of Roman life and thought, and nowhere more prominently than in the balance of social forces, and in the Roman juristic system. Although not to as marked a degree as Stoicism, one other philosophy, also of Greek origin, was to make some imprint upon Roman thinking. Epicureanism became acceptable to Rome when its ideas were transmitted, worthily and with understanding, in the De Rerum Natura of Lucretius, that apostle of "passionate materialism". [17] This is not the place for a full exposition of Epicureanism, with its physical basis stemming from the atomism of Democritus, and its ethical creed of hedonism where pleasure of the agent (in of course the noblest and most elevated sense) is the motivation of all behaviour. What does concern us most directly, however, is the materialist aspects of Epicureanism, particularly in regard to the theory of perception.

> It is in keeping with the rest of the system that Epicurus derived all knowledge from the senses: no one sense could correct another; for their objects are different: nor could reason correct impressions of sense, for reason is ultimately derived from sense. This implicit trust in sense made Epicurus sceptical of the mathematical sciences, which he supposed to contradict it; and the current views on astronomy he rejected, whenever they conflicted with the evidence of the senses. [18]

What was there in these philosophical attitudes to answer the religious needs of the times? The anxiety of Epicurus to free men from the 'myths of the gods' was taken over and advanced vehemently by Lucretius. Yet Lucretius was fundamentally no atheist, and it is apparent that he believed in some mystical form of communion between man and the gods, on an elevated spiritual plane. It is this ambivalence between avowed intent and inner purpose which leads Barrow to comment on Lucretius as one -

"whose passion it was to discredit religion and whose achievement to display perhaps the most sincere religious enthusiasm in the

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17. Ibid., p. 154.

18. Hicks, in Sandys, op. cit., p. 698.

whole of Roman literature." [19] However, it was the patent materialism of Epicureanism, rather than its inherent spirituality which must have appealed to the Romans. Similarly, while Stoicism offered its disciples a way of integrity, it had for the Romans little direct spiritual content -- although, as Professor Arnold has pointed out, there is a considerable element of Stoic philosophy discernable in Christianity. [20]

The main tenets of Stoicism tended to underwrite and reinforce the ancient Roman virtues of gravitas and pietas, and thus bolstered the traditional Roman concept of duty to family, state and the gods. Despite the eclecticism of Roman religion, and its tolerance -- even ready acceptance -- of exotic cults, we must not underrate the strength of traditional religion centred about the sanctity of the household gods. However, traditional worship of this sort was a factor of domestic and social stability and well-being, rather than an index of powerful spirituality. The ritual of worship was concerned with religious practice, not religious belief.

> Beyond practice, they never went. Enough has been said to show that there was nothing in this religion of a spiritual character; its object was not to make men spiritually good, but to protect them from material evil; for that purpose practice (cult) would suffice; without doctrine or exhortation to right doing. As Cicero said, the Roman did not ask the gods to make him virtuous, but to give him health and wealth. Practice can only produce virtus in the sense of obedience to rule and law; and so far only this religion had an ethical result.[21]

To the materialism of the more commonly held philosophies, affecting but relatively few, must be added the predominantly materialist religious practices of the multitude. The ethos of Rome was thus consistent in its materialism. Within the web of this materialism was enmeshed the reciprocal sanctity of the gods,

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19. Barrow, op. cit., p.150.

20. According to Bailey, "Religion and Philosophy," in Bailey, op. cit., p.255.

21. W. Warde Fowler, "Religion and Mythology," in Sandys, op. cit., p.152.

the housbhold and the state. The concept of politics, the administration of public affairs, becomes the inevitable field for the extension of materialist beliefs. The religious connotations of the paterfamilias are soon extended to the head of state, and filial piety and obedience become the cornerstone of the concept of patriotic duty.

This is not the place to detail the intricate structure of Roman government and administration, nor to chronicle its mutations during the varied fortunes of Republic and Empire. What is important, however, is to note the manner of formulation of the Roman constitution, the way in which it adapts itself to new circumstances. If we study the process rather than the pattern, we will learn much about the Roman attitude. Cicero sets the keynote for the discussion:

> Cato used to say that our state excelled all others in its constitution; in them, for the most part, an individual had established his own form of state by his laws and institutions .....; our state, on the contrary, was the result not of one man's genius but of many men's, not of one man's life but of several centuries and periods. Genius had never been so profound as to enable any man at any time to overlook nothing; nor, if all genius were concentrated in one man, could he have such foresight as to embrace everything at any one moment; actual experience stretching over the ages is needed. [22]

These points emerge: the Roman constitution was not an a priori document, but an aggregation of customs and laws empirically established, checked against usage, and constantly modified against the criterion of experience. The constitution was not formulated upon the basis of an abstract and ideal political theory; on the contrary, it was a practical and workable codification of a way of life. As in so many things Roman, it was excellent not in the theory but in the application. It is not the creation of genius; but the product of slow evolution in time. It is the work, as has been pointed out of

> a people with a deep respect for tradition (mos maiorum), which led them to supplement rather than discard the outworn organs of the body politic, leaving the new to find its modus vivendi with the old, and often to adapt old structures to new purposes, especially by the use of the convenient fictions which serve to disguise changes, to smooth transitions, and to economise thinking. [23]

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22. Cited in Barrow, op. cit., p. 43.

23. H. Stuart Jones, "Administration" in Bailey, op. cit., p. 96.

No ideal, pre-formulated, political theory embraces the 'convenient fiction'. Rather does it press matters to "logical and unworkable conclusions," as Barrow rather unkindly puts it.[24] Written constitutions, defined aims, rigid principles, these are matters for the philosopher, the idealist. The practical politician prefers the more common-sense approach of the convenient fiction, the compromise, the apparent anomaly. This leads to the political stability of a Rome, rather than the chaos of Greece. Unfortunately, it may also lead to cant, hypocrisy, dictatorship and emperor-worship. It is true that on the whole the Roman system was workable, and despite convulsions, stood the test of the centuries. A common-sense approach ("Vote for Bruttius: he'll keep the rates down," as an election poster discovered at Pompeii reads) may lead to stability: but a political system with no reference to principle, only to utility and expedience, can be a dangerous thing, as Cicero bitterly reveals: "It is due to our own moral failure and not to any accident of chance that, while retaining the name, we have lost the reality of a republic." [25]

The strength of the main pillars of Roman stability, however, lay not in its materialist political philosophy, but in two factors: respect for tradition, and a great juristic system. Classical Roman Law, which acquired its fundamental characteristics under the Republic, was not developed by legislation, but was essentially a product of jurisprudence.[26] de Zulueta has summed the matter up by stating that "the development of private law was in the main not by enactment, but by progressive interpretation and by the gradual formulation of custom." [27] The coming of the Empire inevitably brought about increasing legislative pressure upon the process of law-making, but, Reid asserts, "the looser method of making law was not, and could not be, superseded." [28]

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24. Barrow, op.cit., p.44.
25. Ibid., p.43.
26. For the definition of classical Roman law as that of the period 150 B.C. to 300 A.D., and its comprehensive evaluation, see F. Pringsheim, "The Unique Character of Classical Roman Law," Journal of Roman Studies, XXXIIII: 1944, pp. 60-64.
27. de Zulveta, "The Science of Law," in Bailey, op. cit., p.188.
28. J.S. Reid, "The Roman Constitution," in Sandys, op. cit., p.301.

The Roman legal system would thus appear to have no central theory of Justice, no abstract formulation of rules. We are concerned, as de Zulueta reminds us, not with "the fundamental sanity of Roman Law, but the merits of its technical elaboration." [29] The formulation of the body of Roman Law is an empirical process, and is comparable in that respect with the Roman constitution. Bentham is said to have sneered at republican law as 'judge-made' law, [30] but it would appear to have been in more responsible hands there than the constitution in politicians.' "The unenacted law was not a confused mass of shifting customs, but the steady tradition of a learned class, a tradition which at first sight appears rigid, but which in fact was ever expanding and absorbing, and becoming at the same time more scientific and systematic." [31] Roman law had thus always the advantages of a flexible, empiric, practical approach: and if it lacked an emphasis upon an abstract, centralized principle of justice, it substituted for it as a stabilizing force a respect for tradition and the devotion to service of its practitioners.

The influence of Stoic philosophy must be mentioned at this point, for many lawyers - in common with other educated men - were affected by Stoic principles. To 'live according to Nature' was one such principle; and so, according to Barrow, "the lawyers and the Stoic Emperors, in their interpretation of law rather than in new enactments, brought the law into closer touch with what they conceived to be 'natural law'; and thus the idea of 'natural law' was started upon its long history in European thought." [32] In addition, the Stoic reliance upon precept and authority found echoes in a juridical system based upon precedent.

Stoicism, as the philosophy of the learned classes, was to have an effect upon the development of another compartment of Roman learning, and that is Science. Stoicism tended to explain the

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29. de Zulueta, in Bailey, op. cit., p.175.
30. See Sandys, op. cit., p.300.
31. de Zulueta, in Bailey, op. cit., p.188.
32. Barrow, op. cit., p.165.

nature of the universe in fixed, rigid terms. It was authoritarian, and purported to give the complete answer. Its techniques were based upon precept, rather than upon hypothesis. Such a philosophy provided no incentive for the free speculative thought essential for scientific progress. "Thus", writes Singer, "in place of knowledge accumulating progressively on a basis of a wide and far-reaching theory, we get either a type of exact but intellectually motiveless observation or a rejection of all knowledge not of practical importance." 33. We must be careful here, however, not to overstate the case. We cannot lay at the door of the Stoics the entire blame for the Roman lack of interest in speculative, theoretic science. Rather let us consider science and philosophy as two parallel streams, with similar basic characteristics, each stemming from the Roman materialist attitude to life, and each entirely compatible with the other. The Roman attitude is thus an entirely consistent one: it is admirably expressed in Cicero's comment that the investigation of nature seeks to find out either things which nobody can know or things which nobody need to know. 34.

This basic attitude to Science manifests itself in "the characteristic emphasis placed by the Romans on the practical application of scientific knowledge...., their suspicion of, and contempt for, theoretical science..." 35. The stress is on the utilization of knowledge, rather than on disinterested research. For instance, mathematics was studied simply for practical purposes, with the emphasis upon applied, rather than upon pure mathematics. Geometry advanced only in so far as it was useful in relation to land-surveying. Cicero points the difference in the Greek and Roman attitude, when he says. "In short geometry enjoyed

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33. C. Singer, "Science", in Bailey, op. cit., p.268.

34. Hamilton, op. cit., p.118.

35. Lewis and Reinhold, op. cit., p.298.

an honorable position among them (i.e. the Greeks) and therefore no study was more brilliantly pursued than mathematics; but we have limited this art to the practical uses of measurement and surveying." [36] The Roman numeral system, supposedly derived from the Etruscans, [37] certainly did not lend itself to the manipulations of higher mathematics - and yet we see no successful demand for the reformation of the system.

The emphasis upon the empiric approach in all fields of applied science is pronounced. Yet such empiricism, and the stressing of experience at the expense of theory - so typical of down-to-earth practicality -- was parodoxically far from being a truly scientific attitude. "The cry of Pliny for 'experience' as against 'theory' has been plaintively echoed by the 'practical' man down the ages. Yet there are subjects and there are conditions in which man without a theory may be the most impractical of all," writes Singer. Medicine is one such subject; and in Rome medicine, despite notable contributions by Hellenic doctors such as Galen and Celsus, is a science "based on no theory, it is supported by no doctrine, it is founded on no experiment." [38]

Consequent upon this attitude, we find in Roman medicine some advances in empirical knowledge, but no fundamental advancement of the frontiers of theoretical knowledge. It is characteristic that it is in the organizational aspects of medicine, and particularly in the field of public health, that Rome's contribution to medicine is most substantial. Singer has given us a detailed description [39] of the complex medical organization of the Roman army, with its *medici legionis* and *medici cohortis*, and mentions the elaborate planning of the military *valetudinarium* or hospital, such as that at *Novaesium*, near Dusseldorf. It has been suggested [40] that the development of the hospital system, firstly on a military basis, and later extending as a public service for civilians, was

36. Cited by Gest, *op. cit.*, p.20.

37. According to J.F. Payne, "Natural History and Science", in Sandys, *op. cit.*, p.713.

38. Singer, in Bailey, *op. cit.*, p.286.

39. *Ibid.*, p.292. 40. *Ibid.*, p.293.

the greatest contribution of Rome to medicine. As in other fields, this contribution is on the level of administration, organization and the practical application of empiric knowledge.

This discussion leads inevitably to the conclusion that the spirit of the Roman Empire was materialist and practical, rather than idealist and theoretical, and that its basic philosophy was a pragmatic one. It would therefore seem to follow that the Roman architect operated within a materialist environment, and was inescapably permeated by a materialist spirit.

MATERIALIST HERITAGE.

The materialist attitude in Rome stems partly from its cultural heritage. The cultural background to Rome is confused and varied. Many diverse streams of influence mingle in Roman veins. In its formative stages, Roman culture is perhaps deeply influenced by the ancient and vigorous civilization of Etruria. The Etruscans contribute to the Roman character a strong element of practicality, a resourcefulness in dealings with the mundane but vital problems of everyday life. From the Etruscans, the Romans learned many technical skills and many crafts. [41.] In this connection, it is significant that the Roman goddess of handicrafts, Minerva, was adopted from Etruria. [42.] She became the patroness of most of the Roman guilds, and it has been suggested that these guilds did in fact develop under the Etruscan kings. [43.] Roman skill in hydraulic engineering may also derive from the Etruscans, who are credited with an advanced technique in this field. [44.]

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41. Particularly in the field of metal working.

    Vide R.A.L. Fell, Etruria and Rome, Cambridge, the University Press, 1924, p.29 et. seq., and

    M. Pallotino, The Etruscans, trans. by J. Cremona, Penguin Books, 1956, p.220.

42. Fell, op.cit., p.72, demonstrates that the Minerva cult comes from the Etruscans.

43. Ibid., p.71.

44. Pallotino, op. cit., p.126, refers to the Etruscan city near the present-day village of Marzabotto, which had a "fairly evolved water supply", and also deals with the search, exploitation and transport of water, the canals in the lower Po valley, and the draining of the marshes; p.220.

In the practical arts of war "the primitive military organization of the Romans owes much to the Etruscans" 45., while in the field of commerce, the Romans acquired some of the Etruscan instinct for trade, [46.] which was to dominate their materialist outlook, of which the 'profit motive' was an important characteristic.

As Roman culture matures, the influences which are brought to bear upon it become more sophisticated. The Greek influence, already felt via Etruria, becomes more directly operative; and we find that Roman practicality has Greek antecedents, both in the Golden Age, and the later Hellenistic period.

Although Greece is renowned for its intellectual and artistic contribution to Western culture, there is evidence of the development of the practical arts of civilization from the earliest days. It is true that they do not approximate to the Roman scale, in any way, nor do they display the Roman single-mindedness of purpose: but, particularly with the transmutation of Hellas into the Hellenistic world, do the demands of an expanding civilization impose an ever-increasing complexity of physical equipment for living the good life. At first, we see practical ingenuity bent to the task of solving the problems of health and amenity. Building and water-supply are amongst the first tasks of civilization-makers. Hence we see even in stern Mycenae a water-supply system running underground from the spring-source to within the walls of the fortress [47.]; and in Samos in the 6th century B.C. Eupalinos of Megara built the famous water-system which incorporated a tunnel over half a mile long, the water probably being conducted along clay pipes. [48.] Herodotus (III:30) says of this feat that it is one of the three greatest works to be seen in any Greek land. Still more advanced in technical concept and competence is the great aqueduct of Pergamum, built, according to Neuburger about 200 B.C., "for it

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45. Ibid., p.221.

46. Fell, op. cit., p.26.

47. A. Neuburger, The Technical Arts and Sciences of the Ancients, trans. by Henry L. Brose, London, Methuen and Co. Ltd., 1930, p.419.

48. Ibid., p.420.

is a hydraulic aqueduct, whereas that of Samos is based only on the fall of water along a gradient. Difficult technical problems had to be solved in this case." [49]

Pergamum of course is Hellenistic; [50] and in Hellenistic times we are approaching a far more complex state of affairs. This expansion of the practical attitude is important, for more a more are the paths of Greece and Rome intertwining. In Pergamum there are baths and showers; and public toilets, probably with some system of flushing; the drainage systems of Miletus, Athens and Olympia were particularly extensive; and a bathing establishment found at Priene has been compared to the ablution block of a modern factory. [51] "In the days of Alexander the Great (356 - 323 B.C.)", Forbes tells us,

> the engineer Crates undertook to construct two tunnels through the limestone hills surrounding the lake (i.e. Lake Copais in Boetia). He was prevented from completing this work through political pressure. Modern excavation however, has not only proved the existence of these tunnels, each of which is nearly 2,000 feet long, but also has shown that an older system of canals and dikes existed to harness the waters of the lake. [52]

Whether we look at the great engineering feats of the Hellenistic age, the harbours, the lighthouses, the canals; or if we study the mechanical genius of Hero of Alexandria, with his reaction steam engine and his heat engine, and Ctesibius, inventor or pneumatic pumps and water clocks, [53] or if we look at the

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49. Ibid., p.422.

50. Forbes (a) considers the syphonic aqueduct at Pergamum to be Roman, and not Greek. Elsewhere (b) however, he admits that the Roman contribution at Pergamum was the removal of the syphon, and its replacement with a series of bridged aqueducts.

    (a) R.J. Forbes, Man the Maker, New York, Henry Schuman, 1950, p.80. (All further references to Forbes are to this work, unless otherwise stated).

    (b) R.J. Forbes, "Hydraulic Engineering and Sanitation," in C. Singer, ed., A History of Technology, Oxford University Press, 2:1954 p.669.

51. Neuburger, op. cit., pp. 441-3.

52. Forbes, op. cit., p.67.

53. Ibid., p.68; Ges'. op. cit. pp. 20-22.

ingenuit of Greek mechanical theatre equipment, such as the periaktoi, forerunner of the revolving stage; [54] on all sides we are confronted with a growing evidence of Hellenistic practicality, which was to serve as stimulation to the native Roman talent. Nor must we forget the lessons in administration, in 'scientific management', which Rome learned from the successors to Alexander and the Hellenistic monarchies in Egypt and their dependent cities, which

> did much to elaborate the machinery of commerce, banking, and so forth, and to develop a system of legal conceptions applicable to such matters which were ready to hand when Rome became the dominant Mediterranean power and was compelled to study the technique of Imperial Administration. [55]

Both directly, and through its contacts with the Hellenistic world, Rome established channels of cultural communication with the East. We have already made brief reference to some of the problems besetting a study of Rome: Orient relations. It is a field where much work still remains to be done; and we are not here required to comment on the difficult questions of precedence which the controversy of scholars has raised and answered. What is important in our present context is the knowledge that, apart from the disputed structural field, there is in the East, in areas which were later to become Graeco-Roman spheres of influence, some not inconsiderable evidences of technological development.

These materialist achievements must without doubt have infiltrated into the Roman cultural heritage.

Not only do we find the basic techniques of lever and pulley mastered early in the history of Egypt and Mesopotamia, but, even more significantly, the early institution of major engineering proj- s. Thus we have in Egypt and Babylon and Nimrod; early and extensive drainage systems, while the elaborate installations in Jerusalem and Fort Zion, which Schick investigated, are of the time of - and even antedate - King David, that is, about 1055 B.C. [56] King Solomon's water-system included three

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54. M. Bieber, The History of the Greek and Roman Theater, Princeton University Press, 1939, p.141.

55. Bailey, op. cit., p.93.

56. According to Neuburger, op. cit., pp. 437-8.

great reservoirs and a pipe line carried through tunnels and over bridges, a technical tour de force which anticipates the later Roman work in the same region. [57] While in Solomon's temple we find an early development of the two-pipe drainage system. The water-systems of Kurdistan of about the 6th century B.C. incorporated a pipe-line of socketed pipes, based on a pressure system such as that we are to meet later at Pergamum. The earliest dated Sumerian aqueduct, according to Forbes leading from the mountains to Nineveh 20 miles away, was built in 700 B.C. He continues:

> It is interesting to note that the great works of engineers find their expression in early mathematics. The achievements of Egyptians and more particularly Sumerians and Assyrians in mathematics and astronomy were closely linked with practical engineering. We have no theoretical discussion of any mathematical problem but only ries of practical solutions for certain typical ns. They deal with the areas of fields, the slope . yramids, the quantity of stone needed for a cylir l well, masses of earth to be removed in canal b , and similar practical problems. Even astronomy we ly used to predict the rise of rivers. [58]

This applied, non-theoretical, treatment of mathematics forcibly reminds us of Rome: and seems to point to a materialist attitude in the ancient near east upon which Rome must have drawn in the formulation of her own way of life.

The philosophical background to the Roman practical attitude is found in the Greek philosophies of Stoicism and Epicureanism, which we have examined in some detail. The more mundane generator of the Roman attitude is the body of Greek literature from which encyclopaedists such as Pliny claim [59] to have derived their theses.

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57. Ibid., pp. 411-15.

58. Forbes, op. cit., p.50.

59. "Although Pliny in his preface makes a great show of acknowledgment to his authorities..... a very slight acquaintance with his work is sufficient to show that for no part of it did he ever read a Greek author systematically, through; while for the history of the artists we are safe in asserting that not one of these authors was directly consulted..... they are there simply because Pliny found them quoted by the Roman authors from whom he habitually drew (in this case Varro)."

Jex-Blake and Sellers, The Elder Pliny's Chapters on the History of Art, London, Macmillan and Co., 1896, p.XV.

Despite the second-hand nature of Pliny's sources, his natural history is undoubtedly based upon Greek models; and indeed, we are told that the first natural history of civilization was attempted by the Epicureans. [60.]

The philosophies of the Stoics and of Epicurus are Hellenistic, and it is to the Hellenistic age that we must turn for the antecedents of the Roman practical and material approach. Bosanquet [61.] sees in Hellenism a sceptical divorce from metaphysics, and an emerging characteristic subjectivity based positively upon materialistic science. Hauser, too, in his penetrating analysis [62.] classifies the outlook of the Hellenistic age as 'rationalistic.' "This rationalism" he writes "which the state now prizes above all shows itself in all fields of cultural life", and he sees it particularly in "a super-national organization of scientific and artistic production." Rome owes much to Hellenism. Imperial Rome derives more from the grandeur of Alexander's Empire than from the citystate of Pericles, and the materialist concepts of the Hellenes bulk larger in the cultural heritage upon which the pragmatism of the Romans is built.

3. LITERARY SOURCES OF THE PRACTICAL ATTITUDE.

We have examined in some detail the Roman practical attitude in general terms. It is now time to see the specific implications of this attitude upon architectural thinking. Architectural thought may be regarded as explicit in architectural theories, that is, in the literature of architecture; or, in so far as it may be deduced from actual buildings, it is implicit in architectural practice. We must examine both sides of the coin. In this chapter our analysis of attitude leads us naturally to reflections upon the practical approach to architecture, as it is explicit in Roman literature. Subsequently, we shall turn to an examination of the characteristic expression of this attitude in actual Roman building. Apart from

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60. B. Bosanquet, A History of Aesthetic, London, George Allen and Unwin, 1922, p.83. Bosanquet quotes Wallace, Epicureanism

61. Ibid., p.85.

62. A. Hauser, The Social History of Art, London, Routledge and Kegan Paul, 1951, p.114.

incidental comments, which may prove surprisingly illuminating, our source of architectural commentary occurs in two general categories of books, encyclopaedias and specialized studies; in practice, we are reduced to the study of two specific works, each representative of a particular category. Of the encyclopaedists dealing inter alia with architecture, only Pliny's Natural History[63.] is extant; while of the specialist works on Architecture, Vitruvius's De Architectura[64.] is the only one known to Roman literature. We are faced here with an interesting problem. Can a study of only two books be a satisfactory way of analyzing the literary sources of Roman architectural materialism? The sample is embarassingly small, and we are in danger of demonstrating personal viewpoints, rather than those far broader streams of opinion which constitute an architectural attitude. Fortunately for our purposes, we are able to demonstrate that these are representative books; that the authors are neither original nor isolated from the great body of Roman opinion ; and that they reflect generally accepted views.

Vitruvius himself gives us a bibliography and acknowledges his sources. "I own myself under the highest obligations to all those authors, who by their great ingenuity have at various times on different subjects, furnished us with copious materials, from which, as from a fountain, converting them to our own use, we are enabled to write more fully and expediently....." [65.] In addition to the many Greek authors cited by Vitruvius, mainly on formalist topics, are three Roman writers, the lesser-known Fussitius and Publius Septimius, and the oft-quoted Terentius Varro who "in his work on the nine sciences, includes one on architecture."

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63. Pliny, Natural History, trans. by Bostock and Riley, London, 1857.

64. Unless otherwise stated, the following is the edition of Vitruvius's De Architectura Libri Decem referred to in this thesis:

Vitrivius, The Ten Books on Architecture, trans. by M.H. Morgan, Harvard University Press, 1914.
Other translations occasionally referred to are:
(a) J. Gwilt, London, 1826; (b) F. Granger, London, William Heinemann Ltd., 1931.

65. From the introduction to Book VII.

J. L. Ussing, who disputes the dating of De Architectura, [66] considers Vitruvius to be heavily indebted to Varro; and Sir John Sandys also considers that "he owes much to the lost Disciplinae of Varro." [67].

Pliny is shown by Sandys to be similarly indebted to Varro; and Pliny's translator, Jex-Blake, refers to the Roman authors from whom Pliny habitually drew [68]. Charles Singer has this to say of Pliny:

> Learned and curious, Pliny is entirely devoid of critical faculty. In his Naturalis Historia he collected an enormous amount of material, entirely unsifted,..... By Gibbon it was described as 'that immense register where Pliny has deposited the discoveries, the arts and the errors of mankind.' It was drawn from about 2,000 works -- most of them now lost -- by 146 Roman and 326 Greek authors. [69].

Middleton is equally hard on Pliny, and states categorically: "All the parts of Pliny's Historia Naturalis which relate to practical matters of construction appear to be taken from Vitruvius..." [70].

This lack of independence of judgement may detract from our two source books as milestones in the history of ideas. But their very dependence upon the precept and authority of earlier works renders them ideally suited for our purposes: they approximate the norm, and we feel entitled to draw fairly wide conclusions from them. A word of caution must be stated, however. They are both early works. Vitruvius, if we accept the customary dating, wrote at the time of Augustus; Pliny died in the eruption of Vesuvius which destroyed Pompeii. Neither can be considered representative of the late Imperial period. Unfortunately, that is perhaps the most stimulating and rewarding period of Roman architectural endeavour, and we are

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66. J.L. Ussing, Observations on Vitruvii de Architectura Libri Decem, trans. from the Danish by the author, London, Spottiswoode and Co., undated. The author gives evidence on grounds of language and style, historical fact, architectural knowledge, and anachronisms, to prove that the books of Vitruvius could not have been written in age of Augustus, as claimed, but in the 3rd century A.D. He makes a good case for Vitruvius as plagiarist, taking building materials knowledge from Pliny, and hydraulic knowledge from Athenaeus. The chief source, however, he ascribes to the time before Augustus, namely Varro's 'De Architectura', which, he says. "we are justified in considering as the principle source of Vitruvius."

67. J.E. Sandys, "Literature", in Sandys, op. cit., p.666.

68. Jex-Blake, op. cit., p.XV.

69. Singer, in Bailey, op. cit., p. 276.

70. Middleton, op. cit., 1, 6.

inestimably the poorer in that it lacks a contemporary recorder.

The aspects of the "Natural History" which deal with art and architecture are almost wholly concerned with materials and their physical rather than aesthetic qualities. [71]

The whole framework is the study of materials. For instance his comments on Sculpture occur in Book XXXIV, The Natural History of Metals, and XXXVI, The Natural History of Stones. Book XXXV, An Account of Painting and Colours, includes the history of painting but also some twenty chapters (out of forty) which deal with pigments and technical problems of application. His study of architecture -- historical and anecdotal, with more statistics than criticism -- occurs in Book XXXVI, The Natural History of Stones.

It is characteristic that in describing buildings Pliny is more concerned with the material of the column rather than its style and order. For instance, of the Temple of Diana at Ephesus, he gives sizes, nature of foundations, the number and sizes of columns, the problem of raising the heavy architraves, but no word of the formal architectural solution; [72] and elsewhere he writes of the basilica of Paulus, with its admirable Phrygian Columns. [73] The emphasis is everywhere on technicalities, generally concerning the nature and properties of building materials.

He deals with building stones; masonry technique; cisterns - their construction and material; quick-lime; various kinds of sand, and the combination of sand and lime; defects in building generally, and in plastering; gypsum; pavements; terrace roofs; mosaics; and so on. [74]

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71. It has been said that when St. Augustine used the term 'cement', he developed metaphysical analogies, but when Pliny used it, he complained about the malpractices of the builders. The exact reference eludes me.

72. Pliny, op. cit. XXXVI: 21.

73. Ibid., XXXVI:24.

74. Ibid., XXXVI: 50, 51, 52, 53, 54, 55, 59, 60, 62, 64.

As we have seen in our discussion of Roman Science, Pliny's approach is empirical. He relies upon observation - even at second hand, and usually uncorroborated - rather than theory. Generally his philosophical approach is Stoicism, but in his reliance on observation rather than reflection there are tinges of Epicurean perception. Sandys says of him:

> As a scientific writer he fails because he is a compiler destitute of the critical faculty, and of the leisure required for independent investigation. His great work is nevertheless a comprehensive encyclopaedia of science and of art, so far as they are connected with Nature, or draw their materials from it. 75.

For architects his importance lies in his emphasis upon the materialist basis of architecture, upon the underlying fabric of materials and techniques. In this, he follows Vitruvius, as we shall now see.

Vitruvius presents a less one-sided picture. The term "Vitruvian" has overtones of rigid aesthetic dogma, and indeed it is for his formalist concepts that Vitruvius is best known. However, there is in the ten books a considerable amount of material which deals with practical,utilitarian (in fact, in a narrow sense, functional) criteria of design. He presents no coherent theory or philosophy of functionalism, for philosophic speculation of this sort is not his field, and his writings show no great depths of understanding. However, he seems to make a point of fundamental importance, in the understanding of functionalism, when he writes: "In architecture, as in all other arts, two considerations must be constantly kept in view; namely, the intention, and the matter used to express that intention: but the intention is founded on the conviction that the matter wrought will fully suit the purpose....." 75.

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75. In Sandy's, op. cit., p.674.

76. Vitruvius, Gwilt translation, op. cit., I:1.

The point which appears to emerge here [77] is the concept of an architecture whose material and form is expressive of its purpose. The tenet of "fitness of purpose" does not automatically produce functional architecture, because the purpose or intention may be an irrational or non-functional one. But, without this concept, functional architecture becomes impossible.

His second basic concept is his theory of economy in building. He writes:

> Economy consists in a due and proper application of the means afforded according to the ability of the employer and the situation chosen.... The other branch of economy consists in suiting the building to the use which is to be made of it, the money to be expended, and the elegance appropriate thereto; because, as one or other of these circumstances prevails, the design should be varied. [78]

Here the concept of the form of the building being dictated by its function, its cost and its character, is stated clearly, if one can free it of the ambiguity that arises by calling it a branch of economy - and yet, although the phrasing may be obscure, even that latter concept is of first importance, for it is none other than a plea for economy of means. [79]

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77. The crucial phrase "that the matter wrought will fully suit the purpose", appears only in the Gwilt translation. Morgan, op. cit., I:1:3, talks of "the thing signified, and that which gives it significance," and Granger, op. cit., I:1:3, of "that which signifies and that which is signified," both to differentiate between inherent and applied knowledge. Neither follow up with the important qualification which we find in Gwilt. In the Latin text as given by Granger, the phrase is as follows:

> "Cum in omnibus enim rebus, tum maxime etiam in architectura haec duo insunt, quod significatur et quod significat. Significatur proposita res, de qua dicitur; hanc autem significat demonstratio rationibus doctrinarum explicata."

78. Vitruvius, Gwilt translation, op. cit., I:2.

79. Morgan, op. cit., puts the matter thus: "Economy denotes the proper management of materials and of site, as well as a thrifty balancing of cost and common sense in the construction of works" (I:2:8)..... "A second stage in Economy is reached when we have to plan the different kinds of dwellings suitable for ordinary householders, for great wealth, or for the high position of the statesman." (I:2:9)

I have said that Vitruvius, in dealing with pure theory, is generally confusing and confused. [80] However, he displays more firmness when dealing with the practical aspects of design. In questions of planning and structure, he writes with greater conviction. He deals in authoritative tones with such problems as aspect and orientation, as when he writes:

> There will also be natural propriety in using an eastern light for bedrooms and libraries, a western light in winter for baths and winter apartments, and a northern light for picture galleries and other places in which a steady light is needed; for that quarter of the sky grows neither light nor dark with the course of the sun, but remains steady and unshifting all day long. [81]

He pays much attention to domestic planning, and analyses each room of the house in respect of its requirements of aspect and orientation. "We shall next explain how the special purposes of different rooms require different exposures, suited to convenience and to the quarter of the sky." In the light of this principle he discusses the orientation of the various rooms; notes the ill effect of sun and wind upon the books of the library, and the desirability of unchanging light in artists' studios, galleries, and embroiderer's work rooms. [82] He examines planning of houses in detail, [83] and extends his enquiry to country houses, where he makes such comment as: "Bathrooms, also, should adjoin the kitchen; for in this situation it will not take long to get ready a bath in the country." [84] He gives many facts of "time-saver standards" type- Folds for sheep and goats must be made large enough to allow each animal a space of not less than four and a half, nor more than six feet". [85] He also, in the same chapter, analyses lighting, and

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80. This is particularly evident in his definitions of order, arrangement, eurythmy, symmetry. propriety and economy. Morgan, op. cit., I:2. This confusion is partly semantic, but appears to go even deeper, and defies the efforts of all interpreters to reduce it to agreed coherency.

81. Vitruvius, op. cit., I:2:7.

82. Ibid., VI:4:1-2.

83. Loc. cit.

84. Ibid., VI:4:2.

85. Ibid., VI:7:4.

refers to 'clear sky factor' - "On the side from which the light should be obtained let a line be stretched from the top of the wall that seems to obstruct the light to the point at which it ought to be introduced, and if a considerable space of open sky can be seen when one looks up above that line, there will be no obstruction to the light in that situation." 86.

He analyses the functional requirements in theatre design, dealing with acoustics of theatres, sight lines - "the height of this platform must be not more than five feet, in order that those who sit in the orchestra may be able to see the performances of all the actors"; 87. comfortable seat sizes, and the raking of seating; 88. and ease of circulation - "the different entrances should be numerous and spacious, the upper not connected with the lower but built in a continuous straight line from all parts of the house, without turnings, so that the people may not be crowded together when let out from shows, but may have separate exits from all parts without obstructions." 89.

Elsewhere he deals with the effect of climate on buildings, writing that

> If our designs for private houses are to be correct, we must at the outset take note of the countries and climates in which they are built. One style of house seems appropriate to build in Egypt, another in Spain...."
>
> In the north, houses should be entirely roofed over and sheltered as much as possible, not in the open, though having a warm exposure. But on the other hand, where the force of the sun is great in the southern countries that suffer from heat, houses must be built more in the open and with a northern or north-eastern exposure. Thus may we amend by art what nature, if left to herself, would mar. 90.

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86. Ibid., VI:6:6.

87. Ibid., V:6:2.

88. Ibid., V:6:3.

89. Ibid., V:3:5.

90. Ibid., VI:1: 1-2.

In all these matters he displays a naive type of empirical functionalism. His dictates are based upon experience, hearsay, current practice, rather than upon a more scientific analysis and solution. However, he is dealing with architecture in a most practical way, and that is what, for our purposes is so important. It is most interesting to see, for instance, that when he analyses temple plan types his criteria are criteria of performance rather than appearance, that is to say, they are functional desiderata.

The arrangements of the Pycnostylos (space between columns 1½ diameters) and Systylos (2 diameters) are impractical because -

> when the matrons mount the steps for public prayer or thanksgiving, they cannot pass through the intercolumniations with their arms about one another, but must form single file; then again, the effect of the folding doors is thrust out of sight by the crowding of the columns, and likewise the statues are thrown into shadow; the narrow space interferes also with walks around the temple. And of the Diastylos -(three diametres): This arrangement involves the danger that the architraves may break on account of the great width of the intervals. 91.

What Vitruvius does for architecture in general, Columella does for the design of farmhouses; that is, he provides a framework of practical criteria for design.

He deals with orientation: "Winter bedrooms face the southeast, and the winter diningroom faces the west;" standards of accommodation: "Ox stalls should be ten feet wide, or nine at least - a size which will allow room for the animal to lie down and for the oxherd to move around in it when performing his duties;" zoning: "Cells for the herdsman and shepherds should be adjacent to their animals, so that they may conveniently run out to care for them. And yet all should be quartered as close as possible to one another".....(for the convenience of their supervisor, he says);.. .... and so on, in this vein. 92.

To sum up therefore, in Roman writings dealing with architecture, we find, apart from formal considerations, a considerable emphasis laid on practical matters. These include the

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91. Ibid., III: 2 3-4.

92. Columella, On Agriculture, I: vi-ix, cited by Lewis, op. cit.

establishment of one major principle, which, while not developed in depth, appears fairly explicitly as a self-evident truth, too obvious perhaps to require substantiation. This basic tenet is: The forms of architecture are expressive of its purpose; or, put more positively, that the form of the building is determined by its purpose, in terms of the satisfaction of the material and psychological functions of the building. The second head under which discussion of practical matters fall, is the aspect of sound planning, determined by such functional criteria as sight-lines, acoustics, ease of circulation, orientation and aspect, convenience, planning for climate, and so on. The third aspect is the study of the nature and properties of building materials.

.THE NATURE OF THE PROBLEM AS AN INCENTIVE TO THE PRACTICAL ATTITUDE.

In the age of Nero, says Rivoira "the Roman architects deliberately set themselves to work on the solution of new problems of construction and equilibrium, and also on the solution of new conceptions in plan and elevation." 93. The degree of originality and inventiveness shown by Roman architects in the fields of structure and planning is an index of the application of the practical attitude to architecture, and as such will be discussed in the next chapter. At this stage, however, we must note that there was inherent in the nature of the architectural problem in Roman times elements of great importance, the solution of which could only be attained by a practical approach; in other words, that in the nature of the Roman architectural problem there existed strong incentives to the formulation and development of a practical attitude.

The complexity of Imperial Roman civilization, far removed from the relatively simple community life of the Greek city-state both in scale and variety, confronted the architect with a host of new problems, and demanded from him an entire set of unprecedented building forms. The architect, faced with such problems as the sheltering of vast congregations on civil occasions, as in the basilica, or religious, as in the Pantheon; the handling of the mass circulation

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93. Rivoira, Roman Architecture, op. cit.

of tremendous crowds both horizontally and vertically, as in the Colosseum; the housing of a sophisticated Emperor of eclectic taste, as in Hadrian's Villa; the technical control of water reticulation and temperature adjustment of a tremendous range of bathing installations, as in the Thermae; the bridging of a deep valley, and the transportation of water over great distances, as in the aqueducts; or the provision of high-density housing, as in the flats at Ostia - faced with such problems as these, the Roman architect could not produce solutions merely by turning to the vocabulary of accepted Greek forms, but was forced by the novelty of the problem to seek a solution in the essence of the problem itself, and let its structural and planning complexities suggest its unprecedented architectural form. Thus in Rome, the exigencies of the problems suggested - even demanded - a practical approach to its solution: new unprecedented building types deriving from the increasing complexity of the Imperial cultural pattern were therefore an important contributory factor to the development of the practical attitude, calling as they did for originality in planning modes and structural thought. The fundamental problems were thus of a practical nature, calling for a practical attitude in their solution.

SUMMARY.

We have, in this section, analysed those elements in Roman times which were conducive to the growth of a practical attitude to architecture. We have seen that these elements are fourfold. The Roman cultural background is that of a materialist society; the cultural heritage contains aspects of Etruscan practicality and an inherited Hellenistic rationalism; the architectural literature of the times contains elements of a functional and practical nature; the type of architectural problem posed by complex patterns of Roman civilization was an incentive to the practical attitude. We must now consider in what forms the practical attitude develops, and in what ways it manifests itself in architecture.

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CHAPTER THREE.

PRACTICAL CHARACTERISTICS OF ROMAN ARCHITECTURE.

> Rome's most characteristic achievement consists in her practical work of social and legal organization, a work of slow accommodation and compromise, based on a sober sense of reality and immediate need, and related so intimately to the social expression of man that much of Rome's organization and way of thinking is wrought into the fibre of modern society. Roman art, on the other hand, like much of Roman letters, often seems to be something alien, something added to the main fabric of Roman life; and the most typical arts of Rome are perhaps indeed those practical arts that grew from the immediate necessities of the national life. Thus the roads and walls and bridges, the viaducts and aqueducts, the sewers and drains and military siege works, and the great public buildings of the Empire are on the whole more typical than the private houses, or even the temples; and Roman painting and sculpture are, except in a few significant respects, hardly Roman. [1.]

BUILDING MATERIALS.

Because it is basic to all building ventures, let us first consider the Roman attitude to building materials. The structural materials developed by cultures previous to Rome had included stone masonry, clay bricks, either burnt or sun-dried, and timber. [2.] All these materials, although worked by human hand before being utilizable in building, may be considered as natural building materials. The practical attitude of Romans,

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1. W.C. Greene, The Achievement of Rome, Harvard University Press, 1933, pp. 148-9.
   It is difficult to agree with the conclusion that Roman art is ar alien expression, and this matter will be argued later in this thesis. However, the extract from Greene is valid in the emphasis which it places upon the practical achievements of Rome, and in the consideration of the inherent practical element in Roman civilization.

2. For an authoritative account of Romar building materials, and particularly the traditional materials listed here, see the early chapters of M.E. Blake, Ancient Roman Construction in Italy from the Prehistoric Period to Augustus, Carnegie Institution of Washington, 1947.

when confronted by the limitations of these natural materials, led them to invent and develop an artificial material - that is, a compound material of a more complex nature than the natural building elements. This material, concrete, resulted from empirical researches and was utilized for its inherent structural potential. Aesthetically it was developed, not in order to achieve an architectural form a priori, but in order to free architecture from the shackles of formalism. By providing a flexible building material, structural developments on an unprecedented scale could take place, and out of this combination of new material and new structure, new architectural forms were developed, post facto. The important point for us is that these latter formal developments are necessarily preceded by the practical step in the field of technology, the invention of a new and plastic building material. As van Buren says:

> the true structural niche, roofed by a half-dome, would not have come into existence until a time when concrete was in use, i.e. not before the latter part of the second century B.C.; and its invention is to be sought in the area where the possibilities of this material were first methodically exploited i.e. Campania and Latium. [3]

The factor of fundamental importance in the manufacture of structura caementicia, or Roman Concrete, was the availability of a hydraulic cement. The beginning of the story of concrete, therefore, is the discovery of large deposits of trass, a porous volcanic rock, near Puteoli (the present Pozzuoli). This material, to which we give the name pozzolana, is also found in enormous quantities under Rome and the Campagna. It occurs in two strata, the upper, a light grey ash, being inferior, but the lower, a dark chocolate red, having great binding quality.

3. Van Buren, Ancient Rome as Revealed by Recent Discoveries, London, 1936, p.65.

This pozzolana, a coarse combination of volcanic clay and gravel, has the power, when added to line, of setting under water, or out of the presence of air: that is is to say, it is a hydraulic material, in the same sense as eminently hydraulic limes and portland cement. Gest [4] tells us that a mixture of pulvis Puteolanus (that is, volcanic ash or pozzolana) was used to lime the specus of the Aqua Marcia as early as 144 B.C., and that Cato (De Agricultura, 18,7) knew of this combination of materials to make cement. However, "it was not until the first century B.C. that experimentation had passed into established usage ..." Vitruvius also was familiar with the nature and quality of this hydraulic cement, writing that when it is used even piers constructed in the sea set hard under the water. [5].

Vacchelli, who had done comprehensive chemical analyses, reduces the ingredients of pozzolana to the following: Silica, 40-60%; alumina, 15-25%; chalk, 2-10%; Magnesia, 1-5%; alkali, 1-2%; iron oxide, 4-10% [6].

There is also to be found in Blake a summary of the laboratory investigations by Nicola Paravano into the hydraulicity of pozzolana. [7]. Paravano analyses the material into more or less crystalline substances, and an important component - quantitatively the greatest - of a vitreous material. He demonstrates that the hydraulicity comes from this vitreous material, which consists primarily of fused

4. Gest, op. cit., p.44.

5. Vitruvius, op. cit., II : 6 : 1.

6. Blake, op. cit., p.43.

7. Loc. cit. Blake cites Nicola Paravano, Riv. Roma, 17 : 1939, pp. 145-50.

silicates, molted in a volcanic process, and then cooled suddenly. "The vitreous substance in pozzolana owes its hydraulic property primarily to the fact that it is an aerogel formed of primitive magma in the act of eruption." In the course of time, we are told, substances such as the feldspars are changed into Kaolins, the fundamental ingredient of clays; and these Kaolins enhance the hydraulicity of the pozzolana.

The mixture of this pozzolana with sand and lime gave the Romans a workable mortar. According to Neuberger [8] the following mixture was used to obtain the necessary hydraulic mix: two parts by weight of pozzolana were added to one part by weight of 'ordinary' mortar. [9]. This ordinary mortar in turn consisted of a 3 : 1 mixture of pit sand and lime. Although, according to the Romans, [10] three kinds of sand were known - pit, river and sea sand - pit sand (arena fossita) was regarded as the purest, and an excellent variety of clean sharp sand of good colour was to be found on the Janiculum. [11]. The Roman preference for pit sand inhibited experimentation with river sand. They were sometimes forced to use river sand, and Van Doman [12] considers that it made an excellent mortar, which although not hydraulic, yet in

8. Neuberger, op. cit., pp.404-8.

9. This seems to infer a process of weight-batching of ingredients: a most interesting forerunner of modern techniques of concrete-making. The steelyard, or balance, had of course been used for centuries past, and there are excellent Roman models in existence today.

10. Vitruvius, op. cit., II : 4.

11. Gest, op. cit., p.44.

12. Cited by Blake, op. cit., p.42, n.2.

fact proved more durable than the early examples of pozzolana.

For structural work, that is, for foundations, walling and vaulting, this hydraulic mortar had to be mixed with a coarse aggregate. We have no information regarding the ratio of mortar to coarse aggregate, but, as we shall see, there was such a considerable range of aggregates used that it is obvious that ratios were varied according to circumstances, and were determined empirically. The concept of a cement paste, carefully determined in composition, which binds the aggregate together is of course in complete accord with present day concrete technology.

Middleton [13] analyses the various coarse aggregates in use. In Republican times, common ingredients were lumps of tufa or peperino, while, after Augustus, we get, in addition to these, the use of broken bricks, [14] broken travertine, or even broken marble. Special aggregates were used for specific purposes. For extra strength, for instance in the foundations under severe loading conditions, "the concrete was made with lumps of lava, the silex of Vitruvius and Pliny, taken from the great stream of lava which, issuing from the Alban Hills during the post-tertiary period, flowed in a great stream towards the future site of Rome" [15]. For lightness, particularly in the case of vaulting, pumice stone was used.

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13. Middleton, op. cit., 1:45.

14. By Imperial times bricks were no longer sundried but burnt to a hardness commensurate with the other ingredients of concrete. Indeed, we are told by Gest, op. cit., p.50, that Roman bricks found in Britain are so hard that they strike fire like a flint.

15. Middleton, loc. cit.

The ready availability of all these natural materials must have facilitated the Romans' task: the geological base to their architecture was rich and diverse, as Bagenal [16] has pointed out. Yet, we must not think that it is just the bounty of nature which made possible the development of concrete. In the colonies, Roman builders searched positively for alternative ingredients to enable them to build their monuments. Roman builders, according to Neuberger, "had an expert eye for discerning the kind of stone from which hydraulic mortar could be produced." [17]. Such stone was found in the trasses of the valley of the Eifel in Germany, the Moselle, the Nette and the Brohl, as well as in the Ries district near Nordlingen. Mortar produced from this type of trass went in to the great water-system of Cologne built by Trajan and Hadrian. Analyses carried out on the mortar of these canals show another interesting aspect of Roman ingenuity.

> At other points of the long aqueduct, which were too far for transporting the trass, a calcareous marl was used for preparing the hydraulic mortar; this marl contained silicon dioxide and argillaceous earth as water-resisting constituents, which entered into combination with limestone, forming a compound which, like the trass, hardened in water. [18].

It must be made clear that the Romans' 'expert eye' for discerning hydraulic materials come from experience, and not from an understanding of the physical and chemical principles involved. In the early republican period, for instance, the Roman builder imported from Puteoli the

16. Hope Bagenal, "The Geological Basis of Greek and Roman Forms," R.I.B.A. Journal, 40 : 1933.

17. Neuberger, op. cit., p.408.

18. Loc. cit.

substance from which he derived his hydraulic mortar. He ascribed its property of hydraulicity to "the effect of hot springs and the heat generated by volcanic flames upon the soil of the vicinity." 19. When he quarried the grey and red material of the Campagna, he failed to realize for some time that this was essentially the same pozzolana. Although he knew of its great strength, he did not anticipate that, being so far from Vesuvius, it could also have the property of hydraulicity. It is Mrs. Blake's contention that failing to recognize the hydraulic quality of the 'red' concrete of Rome, he perserverod with the use of squared-stone construction in aqueducts, bridges and sewers, and thus "delayed the development of great engineering works for about a century." 20.

The earliest use of concrete was as mass concrete. Gest claims that the podium of the temple of Concord (120 B.C.) is the first known use of concrete at Rome (102 p.44). Middleton would place the use of concrete much earlier, in fact, right back to the Regal period (106 V.1. p.141). However, in the examples he cites - the backing of the Servian Wall, and the foundation of the Porta Fontinalis - the dating of the concrete portions is not beyond dispute. Blake and Van Deman regard the development of concrete as taking place in the 3rd and 2nd centuries B.C. 21. The development preceding the use of concrete proper may be regarded in two stages: the use of roughly broken stones held together by mud, clay or pure lime; and the use of what Van Deman calls pseudo- or quasi-concrete, consisting of roughly broken stones held together by a weak mortar of sand and lime.

19. Blake, op. cit., p.42.

20. Ibid., p.349.

21. Ibid., p.324 et seq.

Pscudo-concrete, although it has the same ingredients as concrete proper, is a weak mechanical mixture rather than a homogeneous mass, and its ingredients are not premixed. [22] Once the important transition to a genuine concrete had been made, improvements took place slowly, as experience in the material mounted. Even at the close of the Augustan period "complete mastery of this atificial material had not yet been achieved," [23] and the use of concrete was relatively timid and inhibited by a lack of theoretic knowledge of its potentials under stress. Even when used as an inert filling, the full potential strength of the material was not at first realised. Just how great this strength was is indicated by the projecting staircase of the building on the Palatine
Fig. 1 hill, illustrated in Middleton, [24] where the landing appears to cantilever some twentyfour feet, a considerable feat when one considers that the concrete was not reinforced. Its strength lay in its homogeneity - it set hard as a monolithic structure of tremendous coherence and strength, as the broken overhanging vaults of the ruined Baths of Caracalla or the Basilica of Constantine testify.

The gradual revelation of the potential strength of concrete thus led to two developments which vitally affected the form of Roman architecture. The first was in the field of walling, where it facilitated the use of the compound wall, with a concrete core faced by brick, tufa or stone facings. The second development was in the field of vaulting. These aspects will be dealt with more fully in a later section, but in order at this stage to comprehend the extent of the effect of concrete upon building technique,

22. Ibid., pp.325-7.

23. Ibid., p.342.

24. Middleton, op. cit., V.1., fig. 10.

let us consider these words of Rivoira's:

> Roman concrete construction, being free from the rigidity, laborious execution, and costliness of Greek masonry, was easily handled, elastic, carried out with mortar of extreme durability, adaptable to every variety of plan and every form of roof, not to speak of its being inexpensive and capable of rapid execution. Combined with the arch and the vault which the architects of Rome had made supreme in their art, it led them step by step, aided by their own experience and that of other races, to the creation of the most elaborate, scientific, and original vaulted buildings of the ancient world. [25].

ROMAN WALLING.

The compound wall, which we have touched upon above, was an important element of vertical support in the Roman structural system, and has been dealt with as such in most descriptions of Roman architecture. However, it is in the field of reinforced walling - that is in the use of relieving arches to stiffen and strengthen the wall - that the Roman practical genius envinced itself most clearly. Although Mycenean, Sardinian and Estruscan precedent for the use of relieving arches (or triangular relieving spaces) may be demonstrated, yet it was the Romans who first systematically incorporated the relieving arch principle into their wall design. [26]. There is an instance of relieving arches over openings spanned by flat arches at the House of Germanicus on the Palatine; and similar arches may be found in the Tabularium (78 B.C.); the Forum of Caesar (54 B.C.); the Forum of Augustus (42-2 B.C.); and the theatre of Pompey (55 B.C.)

Perhaps the most spectacular, and the most extensive use of the relieving arch system is to be seen in the Pantheon, whose "organic framework ..... though based upon the principle of the relieving arch ..... is so original and

25. Rivoira, op. cit., (Rom. Arch.), p.82.

26. Ibid., pp.25-6.

advanced an application of that principle .... that it may be described as the work of a man of genius." [27]. The basic wall structure (we shall consider the structure of the dome separately) is composite brick-faced concrete walling.

Fig. 2

The effect of this ingenious walling system is to transfer the continuous ring load of the dome to a non-continuous system of massive point supports; because, as will be seen, the apparent continuity of the ring wall breaks down upon analysis into a system of separate but linked piers. Ashby [28] establishes the basic principles of the wall construction of the Pantheon when he agrees with Beltrami that the thickness of the wall of the rotunda can be divided radially into forty equal parts based upon a module of 3.44m, corresponding to the intercolumniation of the Corinthian columns which stand free in the six major recesses of the interior.

The wall is divided into three vertical zones, indicated externally by cornices. The uppermost zone is divided into forty equal parts by radial walls connecting the concentric inner and outer membranes of the rotunda wall. Twenty-four of these radial walls are cut through by chambers within the thickness of the wall, and sixteen pass right through the wall as buttresses. There are eight annular chambers in the wall, each coinciding vertically with one of the six recesses of the lowest zone (at floor level), plus the entrance and the large apsidal niche opposite; and there are eight smaller semicircular chambers, each occuring

27. Ibid., p.139. Rivoira actually refers to its "organic framework or skeleton", a most misleading appellation, because it implies the existence of a framing skeletal structure. In point of fact, the Pantheon must be considered as the prime example of a unitary structure, regarded as an organic whole.

28. T. Ashby, "Recent Criticisms of Roman Architecture", R.I.B.A. Journal, 37 : 1929, p.122.

Fig. 3

vertically over the solid piers between the recesses of the lowest zone. The annular recesses are divided into three by two radial walls, the semi-circular recesses into two by one radial wall. The central zone is similar to the uppermost zone, but only the eight pairs of radial walls which cut through the annular chambers are retained. 29. These, it will be noticed, coincide with the columns of the recesses below.

The system which emerges is one where the continuous thrust of the dome is dissipated over the forty radial walls and buttresses in the uppermost zone; that, with the reduction of the number of radial walls in the middle zone, the load is concentrated on fewer supports; and that in the lowest zone, the supports are reduced to eight massive hollow piers, and six subsidiary pairs of freestanding columns.

It is the function of the relieving arches to make this transition from the continuity of thrust of the dome to the isolated piers at the base. The pattern of alternating large and small relieving arches visible in the second and third (middle and uppermost) zones of the exterior, relates to the 3-module annular chamber and the 2-module hollow pier with its semi-circular chamber. In the lowest zone, by which time the load is safely discharged upon the piers, only the arches over the great recesses remain.

Because the inner membrane of the rotunda wall is not continuous, as is the outer, the pattern of relieving arches is more complex. They are so arranged, in superimposed combinations of small and large arches, that the

29. Rivoira, <u>op. cit.</u>, (Rom. Arch.), fig. 124, shows in the middle zone alternate annular and large semi-circular chambers, with radial walls, four pairs in all, traversing only the annular chambers. This has the effect of reducing the points of support at the lower levels even further. From a structural point of view, there is much to commend Ashby's contention.

small arches concentrate a small percentage of the load upon the relatively slender Corinthian columns, while the large arches transfer the greater portion of the thrust onto the massive supports adjoining.

The simplicity of concept of internal sp ce gives little or no hint of the complexity of the structural technique underlying it, nor does it express - in other than symbolic ways - the magnitude of the structural achievement. A hemispherical dome exerts a continuous thrust, and thus demands a continuous ring of support. As the thrust is both downward and outward, the thickness of this circular support is considerable. Yet, in the Pantheon, this ring wall is so cut into by niches, that it is in essence converted into a series of massive piers. The distribution of the load on to these separate piers, by the system of relieving arches and membrane walls, transfers the Pantheon into the realm of dynamic structure of the most progressive kind.

The Pantheon is not the only example of a continuous thrust being carried on what is virtually a discontinuous set of point supports. The reconstruction of the baths of Caracalla shows the dome of the calidarium to be carried on six giant supports, each of which in turn is penetrated, probably by a barrel vault, as in a triumphal arch. The little domed Temple of Venus, Baalbak is another interesting example. Here the wall pattern is similar to that of the Pantheon, but inverted. The niches which break the continuity of the wall, and reduce it to six basic piers, are on the outside of the curve, and not on the inside of the cella. The non-continuous nature of the support is accentuated both structurally and aesthetically by the columns of the peripteros, each column relating to the solid portion of the rotunda wall. When we come to consider the walls of rectangular buildings roofed by barrel vaults, a

similar situation is revealed. The rectangular Hadrianic temple of Venus and Rome exhibits the same breaking up of the wall into almost discontinuous supports as we have seen in the cirulcar Hadrianic temple, the Pantheon. The problem is commensurate, for the barrel vault of the temple of Venus and Rome exerts a continuous thrust, just as does the dome of its circular counterpart.

The apparent incompatability of continuous thrust and discontinuous support must be disposed of. Two assumptions suggest themselves. The first is that the nature of the vaulting is such that the loads are collected by means of ribs, and that these ribs then discharge their thrust upon their respective piers. We must defer the study of vaulting to a subsequent section, but at this stage must mention that while ribbed barrel vaults are found as early as the Colosseum [30] ribbed domes are not found until the third century. [31.]

The concentrated thrust of the rib therefore cannot be the answer in every case. We know that it is not in the earlier domes, and we cannot be sure that it is in the case of every barrel vault: although, as we shall see, the evidence points this way in many cases. We are forced to consider, therefore, the second supposition, namely that some means existed for distributing the continuous thrust of the vault to a given number of statically separate (though visually linked) supports.

The principle of separate but interconnected supports of deep section to withstand the thrust is clearly demonstrated by Giavannoni. [32.] He writes: "Frequently, the

30. Ibid., fig 97.

31. Ibid., p.128.

32. Giavannoni, in Bailey, op. cit., p.451.

outer walls in these buildings have projecting abutments, which are logically connected by arches on the horizontal, forming recesses (as in one wall of a villa near Frascati, and in a reservoir in the villa of the Gordiani on the Via Prænestina)". These examples make manifest what is hidden in the walls of the temples. In the Pantheon, we have seen that the distributing mechanism is the relieving arch. We have also seen the consistent use of the relieving arch in other contexts. However, we must not dismiss the possibility of the concrete itself, of great depth and strength, acting as a bridging lintol. We have seen earlier in this thesis, its capabilities as a structural material.

Just how effective the relieving arches were it is difficult to say. No structural test with modern measuring equipment has been made on the Pantheon, for instance, in order to trace the pattern of the transference of stresses. [33] Choisy put great stress upon their structural validity, [34] and Rivoira, while deviating from Choisy in some details, comes to much the same conclusions. He considered the

33. W. Macdonald, "Some Implications of Later Roman Construction", Journal of the Society of Architectural Historians, 17 : 1958, pp. 2 - 4, draws our attention to the statical analysis (force polygon system) prepared by Milani, and Biolchi's analytical axonometric drawing, both published in Vighi, The Pantheon, trans. by Ward Perkins, Rome, 1957. These would appear to be the latest scientific investigations of the dome, based upon analytic methods. Mr. R. Mills, Senior Lecturer, and Mr. I. Schwartz, Lecturer, both of the Civil Engineering Department of the University of the Witwatersrand, have expressed to me the opinion that a purely analytic approach would be inadequate, and that a measuring of actual stresses and their distribution would be necessary to predict the statical behaviour of the structure.

34. A. Choisy, L'Art de Batir chez les Romains, Paris, Ducheret et cie, 1873. See particularly plates XI, XIII, XV.

functional objective of the relieving arch to be "to bind the facing and the core together, to lighten from the top downwards the weight on the recesses at the bottom, to subdivide the walls into zones of adjustment so as to avoid serious cracks, and to discharge the weight of the mass on the side walls of the recesses. [35].

Middleton contests this view, and considers that Choisy gave too much importance to the structural value of the brick arch. [36]. He talks of "sham arches", and cites, as proof of his contention that these arches are decorative and not structural, two cases where they have been cut off before reaching their apex. [37]. Middleton's argument that the brick arch is only skin deep in relation to the bulk of concrete seems reasonable, and yet it does not seem possible that these arches, which relate to the structural pattern of the entire fabric, and which, we must remember, were covered up with stucco decoration, could have been purely decorative. [38].

We must distinguish carefully between two concepts: how the relieving arches actually functioned; and how the Romans believed them to function. Unfortunately we have no coherent account of Roman structural theory, and it is most likely that they had no consistent theory at all. In fact,

35. Rivoira, op. cit., (Rom. Arch.), p.111.

36. Middleton, op. cit., 1 : 67, n.1.

37. Ibid., V.1., fig. 6: Doorway to Caligula's Palace, and V.2., fig. 78: Peristyle, Baths of Caracalla.

38. The two minor examples cited as proof that the arches were not structural are far from convincing. As has been pointed out to the present writer, they may have resulted from a change in plans during the process of construction, a frequent occurrence in such large building projects. (This interpretation is based upon the views of Mr. M. Maltz, Senior Lecturer in Civil Engineering, University of the Witwatersrand).

historians of engineering such as Straub believe that the introduction of theories of statics based upon a scientific knowledge of the strength of materials, into the field of building construction, did not take place substantially until the eighteenth century, when such works as Parents' bending tests (1707) and Euler's buckling formula (1744) followed upon the basic work in physics of Galilei, Newton and Hooke. [39]. It is probably true that what Straub says of Renaissance architects and engineers applied at least with equal force to the Romans: "The practical builders were excellent structural designers with a highly developed sense for statics who were otherwise constrained to reply on a few empiric rules". [40].

I have put the question of the relieving arches to the exports in civil engineering. Their view, [41]. is that, while it is impossible to say just how the arches actually function, yet there is a prima facie case for believing that they did function in the way that Rivoira credits them. Moreover, given an empiric approach and an intuitive knowledge of statics based upon experience, such as the Romans had, it would have been entirely reasonable for Roman engineers to design the relieving arches as they did, and to credit them with performing useful statical functions. The fact that the Romans believed the relieving arches to be functionally valid is demonstrated in the Pantheon, where the porch is not bonded into the rotunda, in order to avoid cutting into the relieving arch at that point.

Fig. 4

39. H. Straub, A History of Civil Engineering, trans. by E. Rockwell, London, Leonard Hill Ltd., 1952, pp.105 et. seq.

40. Ibid., p.71.

41. As expressed to me by Mr. Maltz.

In view of the composite nature of the structure, being of brick and concrete, it is of course quite conceivable that the brick arches performed their supporting function only in the preliminary stages of the construction, and were supplanted by the concrete when it had developed full strength. Cozzo's extreme position, which Giavannoni tends to support, [42] that the relieving arches were built first, as a skeleton framework to be subsequently filled in, appears to have been satisfactorily disposed of by Ashby. [43] The latter maintains the traditional belief in the uniform erection of the structure, but maintains categorically that the function of the relieving arches must have ceased entirely upon the setting of the concrete. MacDonald also believes that "these arches were of use only during the construction of the building" [44]. This theory, that the arches performed a vital, but interim, supporting role, appears a promising one; for it seems to accept Middleton's criticism of the superficial nature of the brick arches while disposing of his untenable argument of a purely decorative purpose.

To recapitulate: the Roman dome and barrel vault imposed a continuous downward and outward thrust. To sustain these stresses a very thick continuous support was necessary. The Romans found that, while maintaining the thickness necessary for stability, the continuity could be broken down by cutting deep recesses and chambers into the supporting walls, thus dramatically reducing the weight of supporting material necessary. To accomplish this concentration of thrust upon what amounted in fact to a series of isolated

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42. Giavannoni, in Bailey, op. cit., p.460.

43. Ashby, op. cit., (Criticisms) p.117.

44. MacDonald, op. cit. p.5.

piers, two techniques were established. The first, the concentration of thrust within the vault itself by means of ribs, we will study in a later section. The second technique, which we have analyzed here, is the conversion of the wall from a static to a dynamic system of support by a highly ingenious combination of extremely strong concrete and a system of relieving arches. It is contended that this walling system, which incorporates the canalizing and controlled transference of thrusts, is a highly significant advance in the history of structures.

Walls, until the advent of the framed structure, traditionally performed two functions: support and enclosure. Let us conclude our study of the advanced technique of Roman walling by a brief reference to the wall as weather excluder. In normal circumstances, in view of its great thickness, the Roman wall was an adequate protection against the intrusion of the elements. In special instances, however, specific precautions had to be taken to meet unusual demands. The wall as radiant heating panel is a particularly advanced instance of the specialized wall, which will be dealt with in detail elsewhere. Variations of the techniques of hollow tile construction developed in the heating systems, however, were used to create an insulated barrier against the penetration of cold and damp. Middleton [45] discusses a ventilated cavity wall, following closely upon Vitruvius' specification, [46] which was used in the House of Livia to protect a wall painting from damp, and describes how similar precautions were taken in the tablinum of the Vestal's House, where the one wall, being particularly vulnerable to damp

45. Middleton, op. cit., 1 : 190.

46. Vitruvius, op. cit., VII : 4 : 2.

in its situation against the hillside, was heated by wall flues. [47].

Finally, in this brief discussion, we must make reference to the Library of Ephesus, where, to protect the valuable books from damage, the three inner walls of the
Fig. 5 chamber are double walls, so that the wall containing the niches for the books is not exposed at all to the infiltration of damp. [48]. It is apparent that the protective aspect of walls as enclosures was given the same practical consideration by the Romans as they devoted to its structural implications.

ROOF TRUSSES.

The covering of the spaces enclosed by these walls is our next field of investigation. Primarily we will be concerned with concrete construction, but before passing on to a discussion of Roman vaulting systems it is necessary to interpolate some comments on other roofing methods. These, while not as dramatic as the great vaulted structures, nevertheless reveal an insight into the practical Roman approach to structural problems.

Our first concern is with the development of the triangulated timber roof truss. This rather elementary feat in building techniques apparently eluded the Greeks, [49] and even in the late Hellenistic period wide spans were

47. Middleton, op. cit., 1 : 312. It is interesting to note that for the same reason the floors of the central room had an insulating layer of half-amphorae upon which the concrete floor was laid.

48. D.S. Robertson, A Handbook of Greek and Roman Architecture. Cambridge University Press, 2nd edition, 1954, p.291.

49. This may be argued from the small spans attempted, and the consistent use of internal columns. Moreover, the very terms used by the Greeks to describe their roofs, which Robertson, ibid., p.388, analyses, tend to suggest lean-to rather than trussed roofs.

beyond their technical and inventive resources.

The traditional Greek attitude, where the basic form once arrived at was never drastically altered, did not lead to major structural innovations: and at the peak of Greek ability, there was no incentive, in the functional problem of the temple, for the development of a clear span technique. In Rome, however, the practical need for halls of congregation by unimpeded internal columns, (which hindered such Greek buildings as the Bouleterion) drove the Roman architect to seek new structural systems. The resulting principle of the triangulated truss, and the new architectural forms it made possible was the direct outcome of the satisfaction of the practical need.

Owing to the perishable nature of the material, we have very little direct information about Roman timber construction. Our claim that the Romans developed a timber technology far in advance of the Greeks must rest rather on indirect evidence. This evidence may be grouped in three categories: our knowledge of Roman timber design in the field of bridge-building; our knowledge of late Roman examples of roof trusses, at the beginning of the Early Christian period; and our inferences from the nature of the roofing problem which confronted the Roman builder.

Caesar's bridge across the Rhine was novel and ingenious: and it gives us a picture of an early stage in timber structural technique. His own description of it gives a clear account of what must have been an impressive operation.

> He caused pairs of balks eighteen inches thick, sharpened a little way from the base and measured to suit the depth of the river, to be coupled together at an interval of two feet. These he lowered into the river by means of rafts, and set fast, and drove home by rammers, not, like piles, straight up and down, but leaning forward at a uniform slope, so that they inclined in the direction of the stream. Opposite to these, again, were planted two balks coupled in the same fashion, at a distance of forty feet from base

> to base of each pair, slanted against the force and onrush of the stream. These pairs of balks had two-foot transoms let into them atop, filling the interval at which they were coupled, and were kept apart by a pair of braces on the outer side at each end. So, as they were held apart and contrariwise clamped together, the stability of the structure was so great and its character such that, the greater the force and thrust of the water, the tighter were the balks held in lock. These trestles were interconnected by timber laid over at right angles, and floored with long poles and wattlework. And further, piles were driven in aslant on the side facing downstream, thrust out below like a buttress and close joined with the whole structure, so as to take the force of the stream ....[50].

Here we have the picture of an ingeniously improvised structure, but one which does not really establish new structural principles, for the supports are triangulated only in so far as the rigidity of the fixing of the balk and the raking shore permit. Given a rigid fixing here, however, balk, shore and ground line do form a triangle, which presumably give the structure its stability. The relative lightness of the structure, considering the width (40 feet at the base) and the distance between trestles (25 feet) is impressive.

On a far more ambitious scale was the bridge thrown across the Danube by Trajan in 106 A.D. Our knowledge of the structural principles of this bridge - but unfortunately not its details - is based on the relief representation on the column of Trajan; and as the designer of the column, Apollodorus of Damascus, was reputed also to be the engineer of the bridge, the representation is generally considered to be reliable.[51] Although the bridge was taken down by Hadrian, the stone piers were left standing; and Cassius Dio tells us the twenty piers were one hundred and fifty feet high, and one hundred and seventy feet apart. If these figures are true, then the span for a timber arched bridge seems

50. De Bello Gallico, IV, 16-19, Loeb Classical Library trans., cited by Neuberger, op. cit., p.464.

51. According to Gest, op. cit., p.161.

challenging in the extreme. We are given this account of its construction by Gest:

Fig. 6

> The arched members were composed of three parallel courses of timber, tied by braces or struts, which were continued upwards to the floor of the bridge and served as its support. The abutting ends of the arch timbers appear to have been quite insufficiently secured, and no provision seems to have been made to prevent the buckling of the long timbers ..... 52.

Gest continues by criticizing certain aspects of the structure, notably the lack of bracing and stiffening, but concludes that, for its time, it was an impressive undertaking. 53.

What is apparent from these descriptions is the courage and cleverness which marked these endeavours: what is also apparent, however, is the obvious lack of a clear insight into guiding structural principles. These bridges appear to be the empiric improvisations of bold practical men. Just when this empiric development led to the crystallization of the concept of triangulation we cannot determine. Briggs sees this as a development of the late Empire. "In some later and larger roofs," he says, "the important principle of trussing was introduced." 54. He cites old S. Peter's in Rome (4th century) and St. Pauls - without - the - walls (5th century) in support of [illegible]ntion. Choisy illustrates the truss of old St.

Fig. 7

Fo[illegible]d upon the 16th century drawing of Carlo Fontana. 55. The double truss is fully triangulated, and shows "iron

52. Loc. cit.

53. An idea of the nature of this bridge can be obtained by examining the model of the Roman timber arch bridge over the Rhine at Mainz, which is (or was, before the war) in the Mainz Museum of Antiquities, and which is illustrated in Neuberger, op. cit., fig. 637. A clear reconstruction of Trajan's bridge is given in Choisy, op. cit., fig. 95.

54. M.S. Briggs, "Building Construction," in Singer, op. cit., p.414.

55. Choisy, op. cit., fig. 90.

straps, pegs, or pins at all joints, a king-post common to the two trusses, and a scarfed tie-beam." 56. Another late building which helps us understand the daring of Roman timber construction is the Basilica at Trier (the Roman Augusta Treverorum on the Moselle). This building, which owes its fine state of preservation to its continued use, first as a palace during the Middle Ages, and subsequently as a church, has an internal span of about ninetyone feet covered by a timber roof - a considerable achievement, even by present-day standards. 57.

It is the creation of such large buildings as the basilicas, with clear floor areas (before the development of vaulting had reached a stage where it could provide the most adequate answer), that must have stimulated the progress of the trussed roof. There are many buildings of great clear span - viz. the basilica of Trajan, seventyfive feet, the basilica of Fano, sixty feet - which, by their plan shape and by the nature of the supports, could clearly not have been vaulted. Some may not have been roofed at all, other than over the aisles - as Robertson 58 thinks might have been the case of the basilica Julia. However, many were definitely roofed, as for example, the basilica at Timgad (2nd century A.D.), which was fiftytwo feet wide, had no internal columns, and had a wooden roof. 59.

The small theatre at Pompeii provides us with an interesting case in point. According to Bieber, this building

56. M.S. Briggs, A Short History of the Building Crafts. Oxford, the Clarendon Press, 1925, p.121.

57. According to Robertson, op. cit., p.270.

58. Loc. cit.

59. Loc. cit.

of about 75 B.C. was "a roofed theater for musical contests." 60. "The side wings of the rounded auditorium are cut short, because the whole building is rectangular in shape. Only thus could it be made to bear a solid roof covering both auditorium and stage building." 61. Not only does the plan thus clearly indicate that it was roofed, but there is an inscription which testifies to it. 62. The span of this theatre appears to be about ninety feet. The walls indicate no evidence of vaulting: and if course the early date would make a vaulted solution on this scale impossible. There is no indication of internal columns, such as in the Hellenistic Bouleterion at Miletus, and the problem is complicated by the fact that the roof was raised above the wall level, to let lighting into the theatre. 63. The roofing problem is thus severe: and the case is not an isolated one, for we are told of similar roofed structures, such as the Odeia at Taormina, Epidauros and Naples, which were roofed with wooden roofs. 64.

If vaulting is ruled out, there appears to be only one way of roofing these large structures; and that is by the timber truss. Moreover, the truss would have to be of more than elementary design to cope with the size of spans involved, because such spans would constitute a severe design problem in timber even with all the resources of the present day. Unfortunately, we cannot go further than this general proposition, and any reconstruction of the Roman roof truss would

60. Bieber, op. cit., p.328.

61. Ibid., p.331.

62. Robertson, op. cit., p.273.

63. Neuberger, op. cit., p.359; Robertson, op. cit., p.274.

64. Bieber, loc. cit.

be merely an enlightened guess.

We have such hypotheses in the case of another application of timber structure other than roofing. Roman concrete construction necessitated the provision of temporary casing and shuttering. We know that "wooden centering of immense size and strength must have been required for the vaults of the large halls; and great mechanical skill and ingenuity were, no doubt, displayed in the construction of these enormous timber framings." 65. Middleton's reconstruction of this formwork, based upon a knowledge of Roman techniques and materials, and the nature of the structural problem, inevitably incorporates the principle of triangulation. 66.

In view of the extreme span of some of these timber roofs, we might be prompted to ask if the Romans employed metalwork to assist, or even replace, the timber structure. We know that after the ancient religious prescriptions 67 inhibiting the use of iron had fallen away, metal cramps were used for joining timber in bridge-building. 68. We have already seen that in timber trusses, metal straps and pins have been found: and the use of metal cramps in masonry work is an established technique. Metal columns were made, the four large Corinthian columns of Roman times made of gilt bronze, and now in a chapel at the Lateran, being an ambitious example of the structural use of metal work. 69.

65. Middleton, op. cit., 1 : 67.

66. Ibid., V.1., figs. 11, 12.

67. Pliny, op. cit., XXXVI, 15, 23, 100.

68. Neuberger, op. cit., p.466.

69. Briggs, op. cit., (Short History) p.173.

Metal ceiling hangers are discussed by Vitruvius. We are also told, in Singer's History of Technology, that "classical writers mention roof-trusses of bronze, but it is uncertain whether they were of solid metal, or of timber cased with it." 70. Middleton tells us that in the Baths of Caracalla, large compound girders of iron, consisting of two T-pieces rivetted together, and then cased in bronze, were found. These he considered to have been the structural framework of the ceiling, the panels consisting of lightweight pumice concrete. He claims that "in the upper part of the wall deep sinkings to receive the ends of the great girders which supported the ceilings, are clearly visible." 71. This interpretation has not gone uncontested, in view of the great span, of over seventy feet, which was involved. 72. We have no conclusive proofs for these theories of the more extensive structural use of metalwork by the Romans; it remains a fascinating field for speculation. However, we have seen enough of their work to agree with Brigg's opinion that "the Romans apparently used structural ironwork on a scale never reached again until the nineteenth century." 73.

70. Briggs, in Singer, op. cit., p.417.

71. Middleton, op. cit., 2 : 163, 4.

72. Briggs, loc. cit., (Short History).

73. Loc. cit. In an attempt to carry Brigg's conclusions further, correspondence was entered into with the Joint Library of the Iron and Steel Institute and the Institute of Metals. The following is the burden of their comments.
"In general, the Romans did not make any striking advances in the field of metallurgy of base metals. They adopted and improved existing techniques and were considerable producers of copper, lead, and tin. They made great use of those materials, and bronze, in cast and worked forms. They also produced brass, by the 'cementation of copper with zinc ores, and treated it in similar fashion.
The Romans scarcely used iron as a structural material except in the form of nails, clamps and other small things. Without rolling mills, it was impossible for them to produce girders or angles from which to make roof trusses. Nor had they any cast iron from which to make columns .....

Two factors inhibited the full development of the timber truss. There was the chronic shortage of timber in Italy, and there was the knowledge of the vulnerability of timber particularly to fire. Both of these factors stimulu-lated research into non-timber forms of construction.

VAULTING.

The most important structural development of the Romans was in the field of vaulting. "In the last century of the Republic," writes Anderson, "we get complicated series of barrel vaulted substructions ..... and the stress already begins to be distributed from one vault to another. The pro-gress made in vaulting under the Empire was enormous ...." [74].

Even into the relatively simple form of the continu-ous barrel vaults, Roman structural ingenuity injected improve-ments. For instance in the Arcus Caelimontani (59 A.D.) periodic stiffeners or ribs are introduced. These consist of arches of two, sometimes three, rings of square tiles. The intrados consists of two outer archivolts, and the central band of tiles with a course of broken brick. The cavities between were filled with a rubble of tile, stone and tufa, set in a generous mortar mixture. According to Rivoira [75] this method of construction may be legitimately regarded as the forerunner - inasmuch as it establishes the principle of skeleton rib construction - of ribbed vaulting. These brick

Dr. S.B. Hamilton, M.I.C.E., in a paper to the New-comen Society on the 13th November, 1957 .... observed that the Romans used rivetted sections of bronze in the roof of the portico of the Pantheon."

74. W.S. Anderson and R.P. Spiers, The Architecture of Ancient Rome, revised and rewritten by Thomas Ashby, London, Batsford, 1927, p.31. Examples of these 'substructions' include the Tabularium, the sub-structure of the Temple of Hercules at Tivoli, and the great Temple of Fortune at Praeneste (Palestrina).

75. Rivoira, op. cit.,(Rom. Arch.), p.72.

vault ribs may also be seen in the barrel-vaulted galleries which ring the Colosseum.

By the introduction of brick arches into the mass concrete, the vaults were divided up into a load carrying framework and an inert filling. The ribs tended to concentrate the thrust of the vault in those portions which coincided with the location of the main piers which supported the superstructure.[76] In the barrel vault these ribs are formed as parallel rings down the length of the vault. They were also used in groin vaults, at the diagonals; and as meridian ribs in domes.

As with the relieving arch, the effectiveness of the brick rib is open to question. Choisy's emphasis upon their importance is today regarded as an exaggeration.[77] particularly when we regard the manner in which the concrete vault acted, as a rigid monolith. However, as with the arches, we can be sure that until the setting of the concrete, the rib acted in an important fashion as stiffener. This in turn had the effect of reducing to a marked degree the load upon the timber formwork.

These ribs are often not of solid brickwork, but in the form of hollow tiles. An important effect of the rib was therefore to reduce the entire weight of the vault. This aspect of ribbed vaulting, however, we will discuss later.
The use of the coffer is somewhat related to the rib.
Where the coffers are relatively shallow, they merely serve to reduce to a degree the weight of the vault. Where their depth is considerable they provide the effective depth of the beams of what then becomes a beam and panel vault. For
Fig. 8 example, the coffers to the barrel vault of a room in Hadrian's

76. Giavannoni, in Bailey, op. cit., p.449.

77. Ibid., p.450.

Palatine Palace [78] 2' 10" square, are recessed to a depth of 2'4"; thus we have a series of beams of considerable depth at approximately 3'4" centres. The longitudinal beams would, in this system, appear to serve no structural function. The rhomboidal lacunae of the apse of the Temple of Venus and Rome was probably also merely decorative, but the interlacing ribs conceivably stiffened the structure, in the manner of a lamella truss.

Fig. 9 The fully-developed ribbed barrel vault is seen in the Throne Room of the Palace of Domitian at Rome, where the rib-and-panel vault, 118 feet long, spanned a distance of 97 feet. The relationship between the ribs of the vault, and the buttressed wall, with niches in between, and free-standing columns accentuating the axis of the supports, is clearly brought out in Bianchini's reconstruction. [79].

The development from barrel vaults to cloister vaults [80] soon followed. And from here to the groined vault proper there was for the Roman designer no unbridgable gap. Rivoira [81] considers the prototype of the groined vault to go back as far as the age of Nero, and illustrates his contention by citing the small cruciform chamber in the Domus Aurea, whose depressed cross-vault he regards "as the earliest developed cross vault with groins." Blake considers that although the

78. The dimensions are taken from Middleton, op. cit., V.1., fig. 13.

79. As illustrated in Rivoira, op. cit., (Rom. Arch.) fig. 115.

80. The term cloister vault is the translation of Rivoira's 'volta a padiglione', by which is meant a square dome "composed of four parts of equal barrel vaults," according to Sturgis's definition, cited by Rivoira, Ibid., p.9. n.2. It is sometimes called an ungroined quadripartite vault, because the internal angles are re-entrant.

81. Ibid., p.76. The Porta di San Lorenzo would antedate this example, but its date (41 B.C.) is not uncontested.

earliest existing example of the cross vault seems to be from the period of Nero, there were doubtless examples now lost as early as the Sullan period. [82] In the Colosseum, in the smaller corridor on the first floor, and on the second and third floors, continuous groined vaults, constructed in concrete with a tufa core, are to be found.

The subsequent step in the development of vaulting technique is also taken by the Romans. In the second century villa known as "Sette Bassi", near Rome, there is a room on the ground floor which, it has been claimed, was vaulted by a ribbed groin vault. Rivoira [83] considers that these ribs were developed from the ribs (or visible stiffening arches) of Roman barrel vaults, and claims that the ribbed vault of Sette Bassi is not only the earliest example of its kind but that it is the inspiration of later Lombardic vaulting, culminating in that of S. Ambrogio, in the eleventh century. The claims which Rivoira makes for Sette Bassi may be extravagent (although his chauvinistic enthusiasm for things Italian is usually tempered by sound scholarship), but it is indisputable that even if not as early as the second century, the ribbed vault was born and developed in Rome. [84] One other point must be made at this stage. As we have briefly mentioned it is generally considered [85] that the Roman vault functioned in a different manner from that of the Mediaeval vault; for whereas in the latter the stone ribs collected the thrust of

82. Blake, op. cit., p.346, n. 43.

83. Rivoira, op. cit., (Rom. Arch.), p.143.

84. Blake, op. cit., p.346, appears to confirm Rivoira's second century date, stating that cross vaults "were laid without any permanent ribs until the second century of the Christian era ...."

85. Vide Rivoira, Anderson, Viollet-le-Duc.

the web, and discharged this thrust on to the piers, yet in the former, the ribs performed this function only in the initial stages, and once the concrete had set, their usefulness, statically, was considerably diminished. Middleton points out that "it would have been impossible to vault their enormous spans if they had used vaulting of brick or masonry such as were built in Mediaeval times. The Roman concrete vault was quite devoid of lateral thrust and covered its space with the rigidity of a metal lid." 86. In assessing the Roman contribution to vaulting theory, as an index of their practical aptitude for building, we have considered the development of the Roman ribbed vault as the starting point of the entire Mediaeval vaulting tradition. In view of the variation in statical behaviour between concrete and masonry, however, a rider must be added, to the effect that there is only similarity, but not identity, in the structural principle involved. However, as far as the formal precedent goes identity is complete; and in so far as the Roman vault is an ingenious and practical solution to the problem of large scale spans, in terms of the building material available, it is a completely satisfactory solution on a functional basis; a solution which is, moreover, because of the larger spans which it permitted, in some respects in advance of subsequent Mediaeval vaulting development.

Ashby seems to consider that the Romans erred in relying too much upon the inertness of their vaults, and provided a massive system of buttresses to take the predominantly vertical

86. Middleton, op. cit., 1 : 66. MacDonald, op. cit., p.8, n. 21, referring in particular to the dome of the Pantheon says that this question of the absence of thrust in the vault has not been resolved. Although Middleton's concept of the metal lid has often been put forward, yet Milani's statical analysis based upon the force polygon system "would seem to argue against the monolithic concept."

load instead of, "modifying the structure of the vaults themselves." 87. It is difficult to follow this argument. If this is directed against the extravagance of the Roman supporting system there is some justification; but the whole system of Roman wall design is intended to achieve this lightening of the wall system and shows concern with the question of economy. If one measures the area vaulted in comparison with the area of supports, particularly in the multi-compartmented vaults, the achievement of the Romans as against their predecessors is incredible; and even in relation to the finest Mediaeval vaulting the Roman system stands comparison.

Fig.10 In the basilica of Maxentius, for instance, the groined vault, ambitiously employed, had important repercussions upon architecture both in its practical and formalist aspects. Practically, it enabled the roofing of large unimpeded internal spaces by fireproof means. Aesthetically, it produced an external expression of striking originality, and internally an entirely new concept of monumental space. The plan form, of central nave and side aisles in bays corresponding to the main vaults, is clearly the resultant of the structural system, and equally clearly the proto-genitor of the Mediaeval church plan insofar as it was expressive of its structure. The combination of high vaulted nave and lower side aisles made possible internally the use of clearstory lighting on the most dramatic scale; and externally, in association with the massive buttresses, new concepts of forms are developed native to Rome, and in no fashion dependent upon Greek aesthetic inspiration. "Here then is the complete principle of equilibrium as used in the Christian vaulted church," writes Giavannoni 88 "The Mediaeval church is simply more fragile and lighter, having all its masses

87. Ashby, op. cit., (Criticisms) p.116.

88. Giavannoni, in Bailey, op. cit., p.455.

cut up and pierced and even the transverse walls opened up by the arcades of the side aisles ..."

In one other respect Roman vaulting may be considered as a pioneering force, and that is in the field of supports. If in the ribbed vault the Roman established the principle of the concentration of loads, in a rudimentary, but ingenious way, he also began to establish the principle - to be later developed by the Lombards - of the compound pier. Already in the piers of the Tabularium we have a cruciform pier developed from which spring the vault arches: and this interesting system is developed further in the Basilica Julia, [89] where in the angles of the cross-shaped pier additional supports are provided, from which spring the diagonals of the vault. Thus we begin to get an articulated element in the supporting pier corresponding to each major arch of the supported vault.

The development of the dome, in the hands of Roman architects, is another chapter in our story of the effect of the practical attitude upon architecture. Perhaps, as Blake points out, early successful experiments were made with half-domes, before the more adventurous step was taken to erect the full domical roof. [90] One of the earliest forms of roofs to round buildings is the concrete roof for the circular peripteral temple, such as the temple of Vesta, Tivoli (1st century B.C.) Cloister vaults, that is, ungroined quadripartite vaults, [91] "gradually merging into a spherical cap, for polygonal rooms with walls either flat or recessed into niches" form the next step in dome development. Examples here are the

89. A note by Dr. Van Deman says: "The Basilica Julia affords the earliest example preserved, although an old design shows their use in the Porticus around the Theatre of Marcellus." Blake, op. cit., p.346, n. 45.

90. Ibid., p.345.

91. See note 80, supra.

Domus Aurea (Nero's Golden House) (64 - 68), and the Domus Augustana (81 - 96 A.D.) [92]. The next stage is the roofing of a rotunda by the continuation and extension of the drum into a hemispherical dome.

Here the most renowned example is the Pantheon, built in the time of Hadrian (117 - 138), the most ambitious dome successfully attempted up to that time, and one of the most satisfying aesthetically. The structure of the dome is not fully known. The famous examination of 1892 only extended for twentythree feet above the impost cornice of the dome. This examination revealed a structure of brick rings inclined inwards, with periodic courses of bonding tiles. The coffering is formed in these courses. The intrados of brick is covered with a lightweight concrete using volcanic scoriae (pumice stone) as its aggregate. Above this point the structural nature of the dome is conjectural, but Rivoira believes it to be a fair inference that the brick and concrete structure is continuous. Giavannoni is cautious, stating that "the real structure of the vaulting, from above the relieving arches in the attic-story, is not exactly known ...." [93], but Ashby, writing several years later, suggests that "recent investigations have shown that, as Beltrami suggested, the upper part of the dome is built in horizontal courses inclined inwards towards the interior, of pieces of stone some 20 cm. in length." [94]. MacDonald, summing up the work of the latest investigators, is however still forced to conclude that "there

92. This account of the early development of the dome follows Rivoira, op. cit., (Rom. Arch.) For the Pantheon, see in particular pp.126 et seq.

93. Giavannoni, in Bailey, op. cit., p.450.

94. Ashby, op. cit., (Criticisms) p.122.

are unsolved problems concerning the structure of the Pantheon". 95.

Even more controversial at one stage was the question of whether there was a ribbed structure to the dome. The tendency today is to regard the elaborate reinforcing system of ribs, as shown in the drawings of Piranesi as a work of imagination, and to consider the dome as a simple structure. 96.

One point which seems to the present writer to confirm the theory that there are no ribs is the pattern of the coffering. The coffers, if there is a ribbed structure, invariably constitute the ribs, at least in the vertical direction. Now the coffers of the Pantheon dome are relatively shallow; and, more important, the module of the coffers bears no relationship to the module upon which the wall-structure is based. We have seen that the uppermost zone of the rotunda wall is divided radially into forty equal parts. The vertical members between the coffers, however, number only twentyeight and there is therefore no coincidence between the two sets of units. Now, if the coffers were ribs collecting the load and directing it upon the walls, it would be reasonable to expect a correspondence between the radial walls and buttresses collecting the loads, and the ribs discharging them. 97. The failure of coffers and wall supports to coincide is thus a

See Fig. 3

95. MacDonald, op. cit., p.4.

96. Rivoira, op. cit., (Rom. Arch.), p.127; Giavannoni, loc. cit.; MacDonald, loc. cit.

97. As in the dome of Santa Sohpia, where the forty ribs discharge directly upon the forty piers of the drum. See the account of the structure in W. Emerson and R.L. Van Nice, "Haghia Sophia, Istanbul: Preliminary Report of a Recent Examination of the Structure," American Journal of Archaeology, XLVII : 1943, pp.423 et seq.

powerful indication that the coffers perform no purpose as structural ribs.

Very little comment has been made regarding the structural significance of the open eye of the dome, other than to make the rather obvious point that by leaving out so much material at this crucial point, the weight of the dome was considerably lightened. It may well be that the bronze ring around the eye of the dome had structural significance, in that it acted as a compression ring - at least until the concrete had set, and perhaps thereafter. It is noteworthy that this is the only part of the bronze metalwork which has not been stripped from the dome. At this stage this must be only speculation, but it is a suggestion which perhaps deserves expert investigation. Having successfully solved the problem of the dome as roof to the rotunda, the Romans tackled the more difficult problem of the dome on the non-circular plan. On the one hand there is a stream of development which leads to the dome with a continuous intrados, that is one where pendentives and dome belong to the same sphere; this development reaches its full stage with the fifth century Ravennato domes of Galla Placidia and the baptistery of Neon, by way of early examples, in a rather more indefinite form, in the times of Septimus Severus and Caracalla (193 - 217), such as the baths of Caracalla.

The other stream of development culminated in the dome on the fully developed spherical pendentive, which appeared for the first time on a large scale in the 6th century at S. Sophia. By comparison with that Byzantine achievement, Roman pendentives were primitive: but they were the essential preliminary steps which made the climax possible. In its most elementary form, we get the dome with the pendentives in the central room of the Domus Augustana, (C. 90 A.D.) which are described as "a very low pendentive dome starting from pointed bases or springers (a sort of rude triangular raccords or pendentives) which are

flat instead of bellying out like a sail with the wind, and pass imperceptibly into the dome itself." 98. For the first recognizable prototypes of the fully developed pendentive, as against the merging pendentive, we have the two tombs, one known as "Sedia del Diavolo", and the one near the "Casale dei Pazzi", on the Via Nomentana in Rome. Rivoira 99 considers them to be the earliest example of the true pendentive, although - because of their flat section - they are not perfected; and Swift says of the pendentives of the latter: "Indeed, were it not for their comparatively small scale, extravagant claims might well be advanced on their behalf." 100.

Although the origins of the dome on pendentives may thus be seen in embryo in Rome, the more significant fact is that, having the secret within their hands, the Romans did not proceed to develop it on any large scale. The critical factor is that, with the technical ability, and with the basic problem at least well on the way to solution, the Romans yet preferred not to persevere with the dome over the square compartment. Does this signify a vital and uncharacteristic failure of nerve? It is difficult to believe that this was so.

We must seek an answer to this enigma; and perhaps may find a clue in the sensitive writings of Hope Bagenal. Bagenal contends that the Romans knew and understood the principle of the pendentive, and had used it, as we have shown, in several small structures. However, they preferred as a logical support to the dome, the radial rather than the square plan. He goes

98. Rivoira, op. cit., (Rom. Arch.), p.108. See also fig. 122, for a photograph whose quality does not permit adequate reproduction here.

99. Ibid., p.273.

100. E.H. Swift, Roman Sources of Christian Art. New York, Columbia University Press, 1951, p.119.

on to claim: "The Romans alone distinguished clearly between the plan systems appropriate for dome and vault. When they wished to cover a radial space they used dome; when they wished to cover a rectangular space they used groin vault." 101.

This argument has an irresistable force of logic. The desire to set a dome upon a square plan is purely formalist in motivation. There is no practical reason for wishing to set the dome of the Pantheon on top of the Basilica of Maxentius, as was the formalist ambition of the builders of St. Peter's Although such a problem requires a high degree of imagination and technical skill for its solution, it embodies an irrational ambition. A practical man would say that the dome and the square were incompatible, and would seek to solve the problem by marrying the appropriate vault to the appropriate plan. The failure of the practical Romans to exploit the pendentive dome thus becomes completely explicable.

The technical problems which were associated with the construction of the dome itself, also received the Romans' attention. We have already discussed the nature of the Pantheon dome, where contrary to popular opinion there are no ribs as such. However, this form of construction, with its attendant advantages, was devised by the Roman builders, We find ribbed construction in the dome of the calidarium in the thermae of Agrippa (as rebuilt by Alexander Severus (222 - 235); [102] and later it plays an important part in the dome of the temple of the Minerva Medica built in the time of the Licinian Emperors (253 - 268).

This latter dome is most important in the history of dome construction, because it demonstrates an early use of the

101. Bagenal, op. cit., p.765.

102. According to Rivoira, op. cit., (Rom. Arch.), p.128, this was the first time that ribbed construction was used in a dome.

pendentive, [103] and also its drum is raised on a range of semi-circular recesses, [104] thus raising it above the level of the supporting structure, and initiating the chain of lofty domes, rising even higher, to culminate in the cupola of St. Peters. The first dome on a circular arcade, another step forward in structural technique, is achieved at the twilight of the Empire, for instance in the Mausoleum of S. Costanza, at the time of Constantine (324 - 326). [105].

In one other respect, Roman domes reveal a high degree of technical efficiency, and that is in the use of light weight construction, both in the use of light weight material (such as punice concrete, in the Pantheon) and in the use of terracotta amphorae. This latter system, the basis of the Ravenna domes, has Roman precedents. According to Rivoira, these are: a "rudimentary specimen" in the calidarium of the baths of Caracalla, and a developed and systematized use from the time of the Gordians(238 - 244) " which reveals a clear constructive and static intention, namely lessening the thrust of the vault where the curve is most pronounced ...." [106].

According to Giavannoni, these amphorae were sometimes inserted into the mass of concrete at random, as in the baths of Stabiae at Pompeii, and sometimes in a regular and systematized manner, especially at Pompeii and the provinces. [107].

Wheeler expands the reference to the provinces, by the examination of some important examples in Roman Britain. [108].

103. Anderson, op. cit., 32.

104. Rivoira, op. cit., (Rom. Arch.), p.273.

105. Ibid., p.273.

106. Ibid., p.178.

107. Giavannoni, in Bailey, op. cit., p.448.

108. R.E.M. Wheeler, "Notes on Building Construction in Roman Britain," The Journal of Roman Studies, 22 : 1932, pp.128-9.

Hollow box-tile ribs spanned the forty feet wide bath at Bath, and were covered by roof tiles; and similar box-tile voussoirs were found at many other Roman sites. Ribbed vaults of another sort were found at the bath building at Chesters, on the Hadrianic wall. According to Brewis [109] two rooms of these baths

> were probably spanned by arched ribs constructed by tufa voussoirs, the light weight of which had a proportionately light thrust. These ribs were spaced a foot or so apart, and the intermediate spaces were spanned by a double set of tiles carried by the ribs. Between the tiles was left a space of stagnant air, which had no thrust, and, like a hollow wall, was a poor conductor of heat.

ROMAN ENGINEERING.

> The Romans were the first of the nations of antiquity to cover the entire field of engineering works; others, the Assyrians, the Egyptians, the Phoenicians, the Carthaginians had before them directed their efforts to certain isolated branches of public utility; the Romans developed them all. [110].

In this section we will look at some of the Roman techniques of road making, bridge building and water supply as exemplifications of the Roman practical attitude, to show that these important fields of activity are stamped with the characteristics of a practical approach and, reciprocally, to learn something further from the monuments of the nature of that attitude. These are selected examples, and do not cover the whole field of Roman engineering.

Road building was an instrument of Empire: it was primarily a channel for facilitating administration, maintaining law and order, easing troop movements, and promoting commercial exchange. It was concerned with serious matters of efficient government, and the proper design, construction and maintenance of a ramified Imperial road-network received a commensurate degree of skill, thought, labour and money.

109. Archaeologia Aeliana, VIII, 1931, cited by Wheeler, Ibid., p.129.

110. A. Leger, Les Travaux Publics aux Temps des Romains, la Tradition Romaine jusqu'a nos Jours, Paris, 1875, cited by Gest, op. cit., p.202.

Vitruvius [111] shows the consolidation of a technique of 'floor making' in early Imperial days, and his description of the strata of the floors gives us a literal specification, of the Roman road. [112]. Pliny also discusses the topic, but without adding to our knowledge. [113]. Statius the poet gives us a graphic description of the building of a major highway in the time of Domitian (C. 90 A.D.):

> now the first stage of the work was to dig ditches and to run a trench in the soil between them. Then this empty ditch was filled up with the foundation courses and a watertight layer or binder and a foundation was prepared to carry the pavement. For the surface should not vibrate, otherwise the base is unreliable or the bed in which the stones are rammed is too loose. Finally the pavement should be fastened by pointed blocks and held at regular distances by wedges. Many hands work outside the road itself. Here trees are cut down and the slopes of hills are bared; there the pick levels the rock or creates a log from a tree; there clamps are driven into the rocks and walls are woven from slaked lime and grey tufa. Hand-driven pumps drain the pools formed by underground water and brooks are turned from their courses. [114].

Here we are not only given the specification in principle for the construction of the roadbed, but the wider picture is painted of the vast scope of all the auxilliary tasks. An impression is given of the organization required

111. Vitruvius, op. cit., VII : 1.

112. Ashby writes: "We have a description in Vitruvius of how a road-bed should theoretically be laid, and a section corresponding to this description has been found on the Via Appia. But in the vase majority of cases in the Roman Campagna the paving stones, massive polygonal blocks of lava (known as selce, and still used for paving in Rome), are laid almost direct on the volcanic soil or rock, and I have hardly ever seen what might be called the ideal or theoretical section in any Roman road."
T. Ashby, The Roman Campagna in Classical Times, London, Ernest Benn, Ltd., 1927, p.42.

113. Pliny, op. cit., XXXVI, 25.60. 184-6.

114. Forbes, op. cit., (Man the Maker), p.72. Much of the factual information in this section is derived from this source, and from Gest, op. cit. The inferences drawn are of course those of the present writer.

to co-ordinate the earth works necessary for the preparation of the site, the associated building tasks, and the considerable problem of drainage of surface and subsurface waters. Most important of all, we sense the mounting enthusiasm of the poet in the face of this splendid achievement. As in the documentary films of recent times, we are shown the power to move the poetic spirit which is contained in sagas of achievement: and how the mundane, practical tasks are invested with an aura of romance and excitement. Deep-rooted indeed is the practical spirit when the heroes of the poets include the highway engineer.

Gest gives us a description, based upon the ancient authorities and the work of Leger, Burr and others, of what might be called a typical road bed. [115] Upon a consolidated sub-grade a bed of sand four to six inches deep, or alternatively a mortar bed one inch thick, was laid. This layer, called the pavimentum, formed the foundation for four layers of masonry. These were - the statumen: squared stones laid in mortar or clay, usually one foot thick; the rudus: a concrete bed, with a coarse aggregate of small stones, consolidated to about ten inches in thickness; the nucleus: a concrete of much finer texture, one foot to eighteen inches in thickness, laid in successive layers and rolled hard; finally, the summum dorsum or summa crusta, a topping eight to twelve inches thick, varying in material according to locality. Generally, in Italy, this top layer was of silex (lava), or other hard stone, close jointed. Occasionally, concrete was used; on minor roads, gravel; in Britain, sometimes flint stones laid in cement on a gravel bed; near iron forges, cinders might be used - and many other instances of Roman adaptability to local conditions and variations in usage . Forbes [116] tells us of Roman roads

115. Gest, op. cit., pp.110 et seq.

116. Forbes, op. cit., (Man the Maker) p.74.

in Britain where, because of soft subsoil conditions, the roads were built on a pile foundation; and of roads in Italy carried through in a concrete trough, because of the corrosive action of volcanic waters in the subsoil of a particular region. With a total thickness of 3 to 5 feet, these Roman roads have rightly been called "walls on the flat." [117]. Such thickness may be considered excessive, and marked by that heaviness of construction, that massiveness, which is so characteristic of Roman building; but, under severe conditions of wear, we are told that they gave from 75 to 100 years usage, a life far in excess of modern roads carrying rubber-tired, rather than iron-tired, vehicles. [118].

In design as well as construction these roads were of technical interest. They were well cambered. They varied in width acc..ing to importance and situation. Narrow roads were common, but the 6 foot width of the Alpine Julier Pass must have been exceptionally restricted. [119]. We are told how, even in adverse circumstances, a road on the Danube "partly cut into the cliffs that rise sharply out of the river, and partly built on a wooden scaffolding built into the rock," maintained its normal width of 12 feet. [120]. Gest talks of main roads being usually 15 or 16 feet wide, [121] while Forbes says that

> in the Imperial period it was common to find main highways 80 feet wide, having a main road surface of 40 feet with two sidewalks of 20 feet each, separated from the middle

117. Ibid., p.73.

118. Loc. cit.

119. Gest, op. cit., p.112.

120. Forbes, op. cit., (Man the Maker), p.74.

121. Gest, loc. cit.

course by low stone walls or strips of grass. The sidewalks were used by pedestrians or horsemen, the latter finding the low walls and stepping stones a great convenience in mounting their steeds. Sometimes these sidewalks were used to enforce one-way traffic, while the middle of the road served for the movement of troops. 122.

The straightness of the Roman road is proverbial. When changes of direction had to be made - generally on high ground, or at stationes - short radius curves were used. These straight roads, because they neglected to adapt to the natural contours of the ground, imposed severe practical limitations, and gradients of 10 per cent were frequent, while even 15 or 20 per cent inclines were found. In view of the disadvantages arising out of the straight road, its use by the practical Romans - ever ready in other spheres to adapt to the exigencies of the occasion - raises interesting questions. An answer to these will be attempted in the later section dealing with Symbolism. The severity of gradients arising out of this lack of consideration of the lie of the land was aggravated by the consistent Roman refusal to excavate their roads, and so temper the rise. In Britain, this practice was taken to such lengths that roads were usually on embankments, even on the summit of a hill. 123. Two reasons for this practice have been suggested, both utilitarian. From a military point of view a raised road prevented a surprise attack on marching troops; and from a climatic point of view a road above the general grade was much less vulnerable to flooding, icing and blockage by snow. 124.

Although the Romans had some basis of existing roads, particularly in Persia, upon which to build, yet the extent of

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122. Forbes, op. cit., (Man the Maker), p.74-5.

123. Gest, op. cit., p.114.

124. This does not hold good for Italy, particularly in the vicinity of Rome. Consequently, on the roads of the Campagna, where neither snow nor the enemy is anticipated, we are told by Ashby, op. cit., (Rom. Camp.), p.43, that cuttings through the hills are frequently found.

their highway system cannot fail to impress. 125.

We are told by Stevenson of the great impression made upon his imagination

> when in a road-book of the Roman Empire he studied the lines followed by the great trunk roads which traversed it from end to end - the road from Milan to Boulogne by the Cottian Alps, and Rheims, or the road which ran from the same city to Alexandria by way of Aquileia, Sirmium, Constantinople Nicomedeia, and Antioch. 126.

The location of some of these roads imposed particular problems, especially in cases such as the Alpine passes, of which many were constructed. Some of these bear famous names today, such as the Little and Great St. Bernard passes, and the Brenner into Austria. A fine practical sense of location is shown in these roads, in relation to topography and meteorology. For instance, many mountain roads are built on the sunny side of the slope, to avoid disaster by avalanche, 127 and we are told that "the Roman road over the Bernardino is used in winter and spring in preference to the modern road, which is frequently blockaded by snow drifts which the Roman road avoided by its better location." 128.

Roads such as these in difficult terrain often necessitated considerable construction work. We have already seen how half the carriageway of the road along the Danube was carried on a projecting timber framework strutted off the cliff face. Often retaining walls were built, and sometimes the road was

125. Gest, op. cit., p.109, gives the total of three hundred and seventy-two highways, listed in the Itineraries of Antoninus, as approximately 50,000 English miles - and these are main roads only. Forbes, op. cit., p.76, has calculated that the total length of all paved roads in the Empire was the fantastic figure of 180,000 miles.

126. G.H. Stevenson, "Communications and Commerce," in Bailey, op. cit., p.141.

127. Forbes, op. cit., (Man the Maker), p.74.

128. Gest, op. cit., p.131.

carried on an arcaded causeway. [129]. On the Appian Way, "there is a levee over six hundred feet long and thirty-six feet high, with peperino side walls, pierced by three arched culverts." [130].

The most important structures associated with roadways were the bridges. We have already seen something of Roman daring in bridge building, when we examined Roman timber structure. However, the perishable nature of timber gave it a temporary character incompatible with the Roman search for enduring form: and it is in the more durable materials of stone and concrete that the Roman bridge establishes its claim to the admiration of posterity.

The two fundamental problems of bridge design are the span and the support. Within the limits of Roman technology it was possible to aim at larger spans with fewer supports, or small spans with multiple supports. Each solution had associated problems.

The large span, especially as it was built on the true arch system with stone voussoirs, exerted considerable lateral thrust on the abutments. Generally Roman engineers avoided this problem, and resorted to the multiple pier solution; but we do nevertheless have many notable large span examples. [131].

These great spans are tours de force of stone con-

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129. Ibid., p.112.

130. Ibid., p.113.

131. Gest, ibid., pp.163-5, tells us of a bridge over the River Tormes, at Salamanca, with 27 arches each of 66½ foot span, 160 feet high; of the bridge at Alcantara over the Tagus, constructed by Trajan about 109 A.D., with six close-jointed stone arches, the two largest spans being 111½ and 118 feet, with a total length of 600 feet, and a height above the river of 175 feet; of the fourth century Pons Salarius over the Anio, with a central arch span of 87½ feet; and of the great bridge at Narnia on the Flaminian Way, whose ruins indicate a centre span of 129 feet. The reconstructed drawing of this latter bridge in Choisy, op. cit., plate XXI, indicates a clear span between abutments of about 118 feet.

struction. The erection of the centering alone, at vast heights above water level, must have set the Romans incredible structural problems. Perhaps it is these problems of centering, which deterred them from using concrete as a primary means of construction. We do have examples, however, of composite construction. The bridge at El-Kantara constructed by the engineers of the Third Legion consisted of three double arches of masonry, the spaces between being filled in with concrete. 132. The bridge of St. Martin, in the Val d'Aosta, a single arch 105 feet across, is also composite. "A peculiar feature of this bridge is the construction of the vault which is built in parallel rings of stone masonry, built independently and some distance apart, with four intermediate rings of concrete." 133. Building in this way, it is possible to support one ring at a time, thus facilitating considerable economies in the centering for the stone arches: and when they were in place, they in turn would support the simple soffit shuttering of the concrete infilling, in all a most ingenious solution.

It is possible that it is this problem of centering which accounts for the extraordinary construction of the Pont du Gard at Nimes, where the arches of the lowest tier are in four parallel masonry rings, not bonded together in any way, 134 and the intermediate tier is in three such rings, with only the top tier of small arches being continuous throughout their width. The lower two tiers of arches have variable spans, ranging from 50 to 80 feet, and a separate system of centering was necessary for each span. By the system of independent parallel rings, however, it was possible to build one ring of each span size, then move the scaffolding across to the next ring, and so on,

132. Gest, op. cit. p.167.

133. Ibid., p.166.

134. Ibid., p.89.

thus reducing the centering by 75%. The uppermost tier however, consists of arches of uniform span, namely 11¾ feet, and here the homogeneous arch is completely logical, as it is possible to move the entire shutter from arch to arch. The design of this great structure is thus completely adjusted to the methods of construction.

An arch altogether of concrete, although it would have restricted the lateral thrust upon the abutments, would have involved considerably greater erection problems at these great heights above water, and it is presumably for this reason that concrete bridges were not developed to a degree commensurate with vaulting in building. We must remember, however, that bridge-building in stone was an established art in Republican times, before the development of concrete structure in buildings, and if we are surprised at the retention of masonry techniques, we are underestimating the tenacity of Roman traditions.

The alternative to the large span construction is the multiple small span bridge. This constitutes the normal type of Roman bridge. Although it avoids the dramatic structural problems of the large span, it raises new problems, the successful solution of which equally testifies to the practical skill of the Roman engineer. We must realize that the building of supports in a river is a difficult problem, one which had not been faced by earlier civilizations, which had resorted rather to the clumsy solution of diverting the river. The more supports a bridge has, the greater is the multiplication of this technical problem. Furthermore, these supports impede the flow of water; and to cope adequately with this problem necessitates a careful study of bridge heights and pier design.

The Romans were aware of the implications of these problems from an early time. One of the ways of sinking a pier was by the building of a coffer-dam. Vitruvius writes:

> Then, in the place previously determined, a cofferdam, with its sides formed of oaken stakes with ties between them, is to be driven down into the water and firmly propped there; then, the lower surface inside, under the water, must be levelled off and dredged, working from beams laid across; and finally, concrete from the mortar trough - the stuff having been mixed as prescribed above - must be heaped up until the empty space which was within the cofferdam is filled up by the wall. [135].

Gest considers that the possibilities inherent in the cofferdam could not fully be exploited by the Romans, because of their inadequate pumping facilities, [136] and claims that, observing that the pier was thus a potential source of failure, they compensated by enlarging both foundation and pier size. This of course aggravated the obstruction of the waterflow. To overcome this obstruction, bridges were made high above the water level, with steep a[illegible]es, to give adequate clearances; the piers were usually a[illegible]d to an acute angle, to facilitate the flow of water; and [illegible]s were frequently made in piers and abutments, to re[illegible]water pressure. In addition, we see in many of the bridges and aqueducts, that the sizes and spans were not equal, but increased towards midstream, where the force of the flow was the greatest.

Before leaving this question of pier construction, we must refer briefly to one other technique, namely the system of caisson foundations. Gest considers that the piers of Trajan's bridge over the Danube were made by sinking barges filled with concrete [137] and thus constitute a prototype in principle of the modern caisson. Giavannoni cites the ruins of the harbour of Civitavecchia, which show "the system of caisson-foundations, filled with concrete and sunk in the sea by means of rafts". [138].

135. Vitruvius, op. cit., V : 12 : 3.

136. Gest, op. cit., p.159.

137. Ibid., p.162.

138. Giavannoni, in Bailey, op. cit., p.463, n.2.

The Romans cannot be said to have solved all the problems of bridge building. However, they can claim to have advanced the art considerably, in comparison with earlier civilizations; and we can only agree with Giavannoni [139] that modern technology shows a direct line of development in bridge-building of the basic principles established by the Romans in centuries of vigorous building and courageous experimentation.

We have already mentioned the Pont du Gard. This 900 foot long, three-tiered bridge over the valley of the Cardon is a bridge for a purpose other than road communication. It was designed to carry the aqueduct of Nimes. This aqueduct is but one of the "indispensible structures carrying so many waters" of which Frontinus was so justifiably proud. From these aqueducts we learn about two aspects of Roman practical endeavour, for they are in part an exercise in structural skill, and also depend upon a commensurate level of hydraulic engineering ability.

Following upon our comments on Roman bridge building, we may expect those parts of the aqueducts which were carried above ground level to provide opportunities for an exhibition of Roman daring. Nor are our expectations disappointed, when we stand at the outskirts of Rome, and the splendid ruins of the Aqua Claudia evoke a picture of the great arcaded structure marching for six miles in noble rhythm across the Campagna. Equally impressive must have been the Ponte Lupo, which carried four aqueducts across the valley of Aqua Rossa. Extended at various times over three centuries, it eventually stood some 105 feet high and 46 feet wide - incorporating a bridle path and a wagon road - and was 508 feet long. [140].

If these great structures invite our admiration, we must remember they are but part of a vast system of water supply

139. Ibid., p.463.

140. Gest, op. cit., p.85.

which in its own way, a less spectacular way perhaps, is equally indicative of Roman achievement in practical matters. Sextus Julius Frontinus, curator aquarus, appointed as superintendent of Rome's water supply in 97 A.D., gives us in the introduction of his classic De Aquis Urbis Romae an indication of the vast scope of the problem of water supply to a great city. He writes:

> And that I may not by chance omit anything which is requisite for a comprehension of the whole subject, I shall discuss the names of the waters brought to the city, the persons who brought them and the dates, the sources of the aqueducts and their lengths, the underground channels, the masonry substructures, and the arches, the height of the aqueducts, the size and number of taps, the amount of water conveyed by each aqueduct, the delivery tanks and the distribution of the water within the city, the construction and maintenance of the aqueducts. [141]

This catalogue of aspects indicates the range of problems from source to utilization which confronted the Roman designer. It is not our intention to expand upon this list of attributes here - the worthy Frontinus has done that adequately enough. It is our object rather to discuss one or two specific problems in water supply, and to try and deduce from the way in which the Roman engineers handled them something further of the Roman attitude.

There are two principal means of conveying water from a high source to a lower point of consumption. The first way is to strike a direct line between the two points, giving the pipe line an even gradient. Where it encounters an obstacle such as a hillside, it tunnels through; where it strikes a valley or a gorge, it bridges over. This gravitational way is the way of the aqueduct, this way is, with certain exceptions,

141. Frontinus, De Aquis Urbis Romae, cited by Gest, ibid., p.66, Apart from Gest's useful summary, the fundamental work dealing with the aqueducts of Rome is: T. Ashby, The Aqueducts of Ancient Rome, ed. by I.A. Richmond. E.B. van Deman's sister volume is also reputed to be of great merit, but the present writer has not had the opportunity of inspecting the latter work.

the Roman way. The alternative method is to rely, not upon gravitation, but upon water pressure. It allows the pipe-line to follow the natural contours much more closely; at a river-gorge it drops in a pressure-pipe, and is forced up the other side. This is the system of the syphon.

We have already seen an early use of the syphonic principle at Pergamun, [142] where pressures of up to twenty atmospheres were encountered. A branch of the Aqua Claudia, extended by Domitian to the Palatine Hill, incorporated an inverted syphon, consisting of a twelve inch diameter lead pipe, under a head of 140 feet. "After this inverted siphon had been in service considerably over one hundred years," we are told, "the Emperor Septimius Severus had it replaced by an aqueduct bridge ...." [143]. Other examples of syphons include an inverted syphon across the Rhone, and one at Altari, reputed to have been subjected to a head of 340 feet. [144].

The most important example, however, was the Claudian aqueduct to Lyons, which had several aqueduct bridges.

> It is most notable, however, for having three sets of inverted siphons. The first, crossing the valley of the Garon, would have required, according to Leger, an aqueduct bridge about two hundred and fifteen feet high with four or five tiers of arches, the highest tier nearly fifteen hundred feet long. The inverted si-hon was composed of nine lines of lead pipe, eight and five-eighths inches in diameter and one and six-tenths inches in thickness of metal; the descending and ascending branches were carried on masonry on a slope of about forty-five degrees; at the middle of the slope the number of pipes was increased to eighteen and the size reduced to six and five-eighths inches to resist the increased pressure; the level portion of the siphon, or, as Vitruvius termed it, the venter, was carried across the valley on a masonry bridge of thirty arches about fifty feet high. [145].

142. See the discussion on the origins of the practical attitude in the previous chapter.

143. Gest, op. cit., p.82.

144. Ibid., p.92.

145. Ibid., pp.91-2.

Gest continues to describe a second syphon on this aqueduct designed on similar principles, and ooviating a bridge three hundred feet high; and yet a third, also on similar lines.

The advantages of a pressure system of hydraulics based upon inverted syphons are obvious. The saving in masonry, and consequently in labour, by replacing high and difficult-to-construct bridges with r[illegible]ly simple pipe systems seems decisive. The shortening o[illegible] water-line in comparis[illegible] o the frequent diversions of the gravity system, to avoid upgrades and unbridgeable or inpenetrable obstacles, must also be acknowledged an important factor. And yet, such systems are the exception in Roman aqueduct design. They are used where circumstances make it practically impossible to build a bridge; elsewhere they are generally avoided, because such pressure -ipes were expensive to build and repair. 146. Where it is possible to replace syphons by aqueducts, this is done, even at great cost. We have seen, for instance, that Septimius Severus replaced the syphon on the branch water-line to the Palatine; and we are told that the syphon of the Pergamun system was replaced in Roman times "by a system of aqueducts, which was more reliable." 147.

The preference for a gravitational system is thus partly based upon practical considerations. Stone conduits were inadequate to withstand high pressures: terracotta and wood, also pipe materials of those days 148 were hardly suitable for either the pressures or quantities involved, although they were used for moderate pressures. 149. Lead pipes were used, as we have seen at Lyons, but "the Romans had not the facilities for making lead

146. Forbes, "Hydraulic Engineering and Sanitation", in Singer op. cit., p.672.

147. Ibid., p.669.

148. Giavannoni, in Bailey, op. cit., p.467.

149. Gest, op. cit., p.96.

pipe of the large size required, and of sufficient strength and reliability, nor even in sufficient quantity, for so long a line ...." 150. It is true that the Roman method of pipe manufacture was laborious, in that it involved casting a sheet of lead, cutting strips from the sheet about four feet wide, bending these around a wooden former, and soldering the joints. 151. However, it is doubtful whether the quantity of pipes involved would have deterred the Romans, for there does not appear to have been a lead shortage. The quality of pipe, however, and particularly the skill required in making the joint, may have been a more potent deterrent. The dangers of lead poisoning were well known to the Romans, but this did not stop the widespread use of lead-pipes in local distributing systems. 152.

We know that bronze piping was used occasionally in the villas of the wealthy, and that bronze fittings were common. 153. We must therefore ask: could bronze not have been used for the syphon piping? Forbes disposes, perhaps too facilely, of this question, by stating: "Bronze pipes were too costly for common use." 154. Yet we know that Roman production of bronze was on a very large scale, and copper and bronze were items exported to all corners of the world, even as far as to India, by Rome. 155. We also know that bronze pipes had been successfully used in water supply before, in the pipeline from the mainland to the Phoenician island of Tyre. Finally, in the

150. Ibid., p.105.

151. Forbes, (Hydr. Eng.) in Singer op. cit., p.665.

152. Loc. cit.

153. Loc. cit.

154. Loc. cit.

155. Forbes, "Metallurgy", in Singer, op. cit., p.53.

question of cost we have to set off the cost of the lengths of piping involved against the cost of the multi-tiered aqueduct bridges: and on those grounds decide that cost alone could not have been the determining factor.

We may perhaps suggest that the reason why metal pipes were not developed into an adequate pressure-pipe system was due partly to the fact that the Romans were not advanced in the field of metallurgy, particularly in its theoretical aspects; [156] partly due to the lack of theoretical knowledge of hydraulics, which together with the cumbersome Roman arithmetic made it difficult for them to calculate pressures with accuracy; [157] and partly due to a preference for the visible aqueduct as a more imposing symbol of achievement - a point we shall discuss at greater length in a subsequent chapter.

In respect of hydraulic knowledge, it is interesting to see Gest's comments on the inaccuracy of Frontinus' calculations regarding the total water supply of Rome. [158] Although he concedes that Frontinus was not altogether unacquainted with the basic principles of hydraulics, yet in making his calculations and arriving at a daily consumption of 270 m. gallons, Frontinus makes assumptions that are fundamentally unsound. For instance, he

> assumed that the discharge of an acqueduct was equal to the total discharge of a large number of small pipes whose combined cross-sectional areas were equal to the cross-sectional area of the aqueduct, which is far from correct; and he also failed to take into account the effect of the velocity of the flowing stream on the rate of discharge .....

These points are not merely academic. They result, together with other factors not taken into account by Frontinus, in an error of over 300 per cent.

156. Ibid., p.41.

157. "Frontinus admits instances where the discharge differed considerably from predicted calculations." Gest, op. cit., p.466, n. 4.

158. Ibid., pp.97-9.

Empirical knowledge, in a field such as hydraulics, which requires precise calculation, and where tolerances of performance (in the nature of the materials used) are very small, is obviously not enough. Theoretical knowledge culminating in scientific precision is needed; and a bias towards theory is not, as we have seen, a Roman characteristic. Tolerances in design in stone, on the other hand, are comfortably large; and the Romans, who have a long tradition of masonry construction, be it in stone or concrete, turn instinctively to construction rather than to science or mechanics, to solve their problems. Even Giavannoni is forced to concede that, in the question of water supply, "the Romans showed themselves greater as builders than as experts in hydraulics." 159.

It must be made clear that the choice did not lie between a faulty and suspect syphonic system on the one hand, and a fool-proof gravitational aqueduct system on the other. The system of aqueducts normally adopted by the Romans had its own share of design and technical problems. Most of these problems were related to the difficulty of making the channel watertight. Both settlement movements of the supporting arches (stable enough in themselves) and expansion due to the exposure to fluctuating temperatures over tremendous lengths, caused cracking of the specus, and historians and inscriptions record a constant series of repairs and renovations at frequent intervals. 160.

Such was the force of the motivations for the aqueduct, and against the syphon, those motivations of attitude which we have discussed above, that, despite all these difficulties the Romans persevered for centuries with the structure of the great aqueducts. They were magnificent practical achievements, but

159. Giavannoni, in Bailey, op. cit., p.467.

160. See the comments of Gest, op. cit., pp. 101-3, and Giavannoni, in Bailey, op. cit., p.467, for validation of this point.

not a victory for science. They were the solutions of an empirical evolution, not of scientific investigation based upon theoretical knowledge. The Romans were faced with great practical difficulties in both systems of water-supply. Had they chosen, they might have conquered the problems of the hydraulic system; but they avoided the scientific and intellectual implications of that approach, and chose rather to follow the practical, empirical path of great construction. Seen in this light, their choice is not arbitrary but inevitable, the logical outcome in building of their whole attitude. We shall see evidences of this in other matters too.

SERVICES.

We have spent some time in a detailed consideration of the Roman practical attitudes exemplified in the primarily structural aspects of building and civil engineering. To carry our study of the utilitarian aspects of Roman architecture further, we must now consider the application of the practical attitude in what are known as technical services. These services include the reticulation of water to individual buildings; drainage; and heating. Because it is perhaps the most complex technical problem, let us take the heating of buildings as a case study.

The first important improvement upon the traditional hearth as a source of heating came with the development of the coal pan or brazier. Despite its obvious disadvantages - the escape of the waste-products into the room, and the danger of carbon monoxide poisoning if used in inadequately ventilated spaces - the brazier was used extensively in antiquity. 161. Although Krell's researches indicated that braziers were

161. Neuberger, op. cit., p.252.

comparatively effective in heating large spaces, [162] yet generally such an open system of heating must be regarded as inefficient.

It is interesting, therefore, to see the Romans developing a more controlled system of heating buildings. The brazier was an elaboration of, but not a departure in principle from, the earliest primitive system of heating. The hypocaust, which replaces it, is the beginning of a new era in heating techniques: in principle, it belongs to the modern age. The heating principles of the hypocaust system are explained by Thatcher in a most interesting paper. [163]. Hypocaust heating is a form of radiant heating, dependent upon a heating medium consisting of a mixture of smoke, combustion gases and excess air derived from an open fire. The hypocaust itself must be regarded as a chimney in a natural draught system, generally running horizontally under a hollow floor, with the hearth at one end and a vertical exhaust flue at the other.

> As this system developed from its beginnings in the first century before Christ, the number of vertical flues was increased until they lined the walls of many heated rooms. The walls, as well, then became heating surfaces and rooms of high temperature had both a warm floor and warm walls, while rooms of lower temperature continued to have unlined walls and only a warm floor. Moreover, there is evidence of a few installations where even the vaults were lined with flues, so that one was literally enveloped in a radiant cocoon .... [164].

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162. Krell writes: "The brazier found in the tepidarium of the baths in the forum of Pompeii, standing in the place where it was originally used, has a heating surface of 7 ft. 8 in. by 2 ft. 8 in. It is quite sufficient even at the lowest winter temperature to heat a large church with a seating accommodation for over two thousand people ...." This conclusion is cited by Neuberger, loc. cit., but, in the absence of supporting evidence, it is difficult to credit the claim made.

163. E.J. Thatcher, "Solar and Radiant Heating - Roman Style," A.I.A. Journal, 29 : 1958, p.121.

164. loc. cit.

The important point emerges that the hypocaust system is the most logical type of heating for the kind of room where it was most commonly used. The halls of the Roman thermae were generally high-ceilinged spaces, and the total volume was relatively very great in comparison with the floor area. To attempt to heat the enclosed air of the room to the required level of temperature would have been a formidable task. Instead, "the system applied itself most directly to the basic condition for human comfort - the inhibition of human heat loss - by providing warm surfaces that would inhibit this loss through its two broadest avenues - conduction and radiation." 165.

Fig.11 The construction of the hypocausts has been described fully by various authorities. 166. It is necessary here to emphasise only the basic principles, in order to underline the complexity of the concept, without investigating the innumerable variations and combinations of forms found in the actual buildings.

Fig.12 A pit, external to the heated chamber, opens on to the stoke hole of the firing chamber. From this firing point an inlet flue connects to the underfloor space of the chamber. This space consists of a lower concrete floor, and an upper floor, two to three feet above, supported generally upon a system of sleeper piers. 167. These piers were sometimes of stone, but more

165. Loc. cit.

166. See for example, Neuberger, op. cit., pp259 et seq., and Middleton, op. cit., 2 : 119 et seq.

167. Middleton, ibid., 2 : 122, writes: "In later times, when the Roman architects had grown bolder in their use of concrete, the pilae were frequently omitted, and the whole upper floor was supported only at its edges, as if it were one immense slab of stone." Middleton cites several examples of this in the Baths of the Palace of Severus on the Palatine, and elsewhere (1 : 317) he discusses a similar concrete floor, 14 inches thick, spanning 20 feet. This is an astonishing claim which, if substantiated, would testify to the amazing strength of unreinforced Roman concrete.

usually of brick or tile, often set in clay rather than cement. The upper floor, of concrete finished in marble, was about eighteen inches thick.

Where there was no wall heating system, the heat was extracted from the underfloor plenum by an exhaust flue, sometimes a single socket-jointed clay pipe of 10 - 12 inches in diameter, and sometimes by multiple flues. It is presumed that these were gathered at roof level into one chimney stack. Middleton tells us of a roof tile in the Museo delle Terme, with an 8 inch diameter clay pipe projecting from its upper surface, and considers this to be a chimney pot complete with flange. [168] He also refers to a now-lost mosaic of a fourth century Algerian villa, whose roof is pierced by a large number of chimneys, complete with chimney pots.

If the heating installation included a wall-heating system, then this provided the outlet, probably gathered into stacks in the same way. Basically, two different types of wall linings were used to create the heating channel; the tegulae mammatae, or tiles with bosses which kept them clear of the wall surface; and the tubuli, or hollow rectangular wall tiles. To facilitate the draught for the system, lateral openings were sometimes made in the inlet flue, or ventilation chambers connected with the plenum to increase and regulate the air supply.

It is doubtful whether the heating mixture of gas and air was allowed to enter directly into the chamber. As we have discussed above, this was not an efficient method of heating, besides having the disadvantage of introducing the rather unpleasant waste products of combustion into the room. However, Jacobi thinks that two of the pipes rising in the corners of the room at Saalburg "rise out slightly above the floor

168. Ibid., 2 : 123.

emitting the hot gases inside directly into the living room," 169 and Neuberger considers that the plate often found in the upper floor, generally thought to be an access panel to the hypocaust, was in fact used in similar fashion to let in the hot air when the flue was shut and the fires damped down. 170.

The effectiveness of this elaborate form of heating must be considered. Neuberger 171 voices some doubts. He considers the thickness of the upper floor to be such a barrier to the penetration of heat that the hypocaust system was probably only for drying the room, and not actually heating it. He was, however, probably unaware of the effectiveness of radiant floor heating. The present writer in a discussion with an authority on heating, 172 has come to the conclusion that Neuberger's fears were unfounded. Not only would the 18 inch thick floor transmit the heat, but it would need to be so thick in order to dissipate the heat, otherwise the floor would be too hot to walk on. That this was a problem which sometimes arose is evident from Thatcher's comments on the wooden clogs worn by bathers in the Thermae. 173. The present writer's own experience has shown that a floor heating system operating in the screed of a building of his design, at a temperature never exceeding 150° C, will heat the ceiling of the room below, through an 18 inch hollow slab (a much better insulator than a solid slab of equal thickness) to above blood heat. The temperature of the products of combustion of an open fire, however primitive the fuel, is of an order of magni-

169. Cited by Neuberger, op. cit., p.264.

170. Ibid., p.261.

171. Ibid., p.258.

172. Mr. N.P. Smit, Consulting Engineer to the University of the Witwatersrand.

173. See Thatcher, op. cit.

tude incomparably greater than 150° C, and one can thus expect a considerable build-up of heat on the floor above the hypocaust.

These conclusions, which validate the hypocaust's efficiency, are easily endorsed by calculation; and indeed, the whole question, as we shall see below, may be settled by imaginative reconstruction and scientific investigation. Neuberger himself cites (but does not give the reference) "the minute calculations of Krell, who worked out their efficiency on the basis of the theory of modern technical science," but queries the results because they are based upon special cases. [174]. However, he comes to the unexpected conclusion, in view of this scepticism, that they must have provided satisfactory heating, because they were in use for so long, and over such an extensive area of the Empire.

The most recent investigations into the effectiveness of the hypocaust system have been those of Thatcher. His general conclusions are remarkably close to Neuberger's. He concedes that there is no evidence whatsoever that the Romans understood the basic physiological principles of human heat loss and generation, "but there is no doubt that they realized the efficacy of using radiant surfaces for comfort, because the development of the hypocaust system that can be traced over a period of six hundred years, shows an increasing awareness of this efficacy." 175.

Thatcher, however, does not let his case rest upon this argument. Instead, he makes a thorough technical analysis of a Roman bath. Like Krell before him, he investigates a special case; but the example he selects, the Terme del Foro at Ostia, because of its untypical orientation, and its exceptionally large unglazed windows, represents an extreme test of the efficiency of the hypocaust system. If it will

174. Neuberger, op. cit., p.264.

175. Thatcher, op. cit., p.121.

work under adverse conditions such as these, the argument goes, it will work anywhere.

The object of Thatcher's test was to determine whether comfort conditions were created in the Hypocaust-heated thermae rooms. His procedure in this investigation was

> (1) establishment of probable heating surface temperatures;
> (2) derivation of air temperatures from these surface temperatures and from design conditions of wind and temperature;
> (3) determination of relative humidities from the derived air temperature and from design conditions of humidity;
> (4) establishment of surface temperatures under various conditions of solar radiation;
> (5) Calculation of the heat loss of a nude, normal adult in this environment [176].

This investigation was based upon a reconstruction of the rooms concerned derived in the main from the extensive and well-preserved remains, and shaped by a knowledge of the principles of Roman architecture.

The result of this investigation showed that, with the exception of one room where special factors operated, all other rooms, if their doors were shut [177] and the adjustable dome ventilators or oculae were closed, [178] achieved comfort conditions without the aid of solar radiation. Thatcher sums up the effectiveness of the heating system thus: "Under cloudy skies and the most extreme conditions of winter wind and temperature, they were able to maintain the comfort of the bathers." [179]. The results of this stringent examinate seem to vindicate the hypocaust heating system conclusively.

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176. Ibid., p.172.

177. Perhaps these doors were shut automatically. Briggs, in Singer, op. cit., p.415, tells us that "the doors of the baths at Pompeii had inclined doorposts, so that the doors closed automatically to exclude cold draughts and prevent the escape of warm air."

178. These are the bronze valves described by Vitruvius, op. cit., V : 10 : 5, which, when operated by pulleys and chains, regulated the air flow through the aperture of the eye of the dome.

179. Thatcher, op. cit., p.123.

The point must be made, in conclusion, that this elaborate and effective central heating system was not restricted only to the baths. Neuberger writes that such hypocausts were to be found in the better sort of dwelling-houses and the villas of the rich. 180. Forbes states that heating of houses developed especially when the Romans were subjected to the more severe climates of Gaul, Germany and Britain, 181 and, to quote Middleton, "in both of Pliny the Younger's country villas hypocausts were used, not only for the baths, but also to warm his bedroom. In the Laurentian Villa, near Ostia, there was some arrangement by which the admission of heat to the bedroom could be regulated by a door or valve ...." 182.

If Roman heating systems developed as up-to-date a concept as solar radiant heating, then Roman cooling systems can be regarded as developing an embryonic system of evaporative cooling. Let us end our discussion of heating by a few words on temperature control at the other end of the scale: for we must not forget that Roman temperatures in the summer months soar to uncomfortable levels. For this reason we have the long and spectacular history of the velarium or awning, the invention of which Pliny 183 ascribes to Catulus in about 80 B.C. But, magnificent example of catenary structure as the awning was, it was supplemented by even more sophisticated cooling systems. Gray, discussing the Roman theatre, says: "The theatre was first cooled with water by Pompey; later, there were sprays ... and saffron (crocus) was sprinkled to cool and perfume the house." 184.

180. Neuberger, op. cit., p.264.

181. Forbes, op. cit., (Man the Maker), p.80.

182. Middleton, op. cit., 2 : 125.

183. Pliny, op. cit., XIX : 23.

184. J.H. Gray, "The Roman Theatre," in Sandys, op. cit., p.518.

Middleton also mentions cooling by water in this luxurious fashion: "It appears to have been the custom, under the Empire, for all theatres and other places of amusement to be provided with perfumed fountains and concealed jets for cooling the air with a fine spray of scented water; Lipsius, De Amphi. can. xvi., gives a number of classical references to this custom." 185. This appears to be the height of sensuality and sophistication in temperature control by mechanical means.

TECHNICAL ACHIEVEMENTS.

One could continue to examine the Roman technical achievement in a never-ending list of accomplishments. One could talk of details, such as the development of taps and valves, or of locks; or perhaps discuss more dramatic accomplishments in the field of harbour design and lighthouse building; or look with interest at the multitude of surveying instruments by which the Roman architect or engineer governed his operations; or appreciate the fact that Roman plumbing and drainage was more advanced than anywhere in Europe up till the time of Napoleon; or marvel, as Seneca did so many centuries ago, at the mechanical ingenuity of Nero's Golden House - machinationes tectorum supra tecta surgentium et urbium urbes prementium .... 186. But there is no need to gild the lily. We feel our case is established.

The achievements which have been analysed in some detail here, form impressive evidence of the result in architectural terms of an attitude to architecture inspired by a practical vision, an attitude to architecture which is characteristically materialist and rational. The development of building techniques in such fields as vaulting has here been traced, not only to enable us more readily to evaluate the measure of the Roman contribution to structural science, - and the contribution is of course

185. Middleton, op. cit., 2 : 86, n. 2.

186. Seneca, Epistles, XIV, 2, cited by J. Ward Perkins, "Nero's Golden House," Antiquity, 30 : 1956, p.211.

considerable - but, perhaps more important, to give us an insight into the process, the way in which this development took place. Our analysis reveals not flashes of poetic visions of form, for the creation of which new techniques had to be found, complete and in the instant, but rather the striving, step by step, to improve existing techniques, in the effort to expand the possibilities of construction in face of the practical challenge of programme. This process of structural development, inspired as it was by the flashes of inventive genius, is nevertheless and more characteristically stamped by its empirical nature. It is a process not based upon the fulfilment in practice of scientific theories, but rather upon what Straub has called "the instinctive assessment of statical conditions." 187. It is a cyclic process of appreciation of the short-comings of an existing system, an imaginative and intuitive concept of an improvement, the testing of the improvement, and, if successful, its incorporation in the system. What is impressive about Roman structural developments is not only that in monuments such as the Pantheon and the Thermae, they achieved remarkable results, but that all along the line, in every aspect of the structural field, and all through their history, steady and constant progress is made in improving building techniques. The occasional brilliant solution to a structural problem is the work of a genius, and may occur in any period. However, the steady, if unspectacular, advance of the frontiers of knowledge in the field of construction can only be the work of a whole corpus of architects: and only of a corpus motivated by an attitude to architecture with a practical bias.

PLANNING.

If on the one hand a practical attitude to architecture expresses itself in a concern with the mechanics of construction, it is, on the other hand, equally evident in the establishment of

187. Straub, op. cit., p.xvi.

planning methods based upon functional criteria. We have seen that, in theory, the validity of many planning practices in Rome were tested by the manner in which they complied with the dictates of use and purpose. If theory is carried over into practice, we can expect buildings where the plan elements are disposed with reference to functional requirements.

Although our analysis of the functional validity of Roman planning is impeded by the somewhat limited information available about the usage of rooms in certain Roman buildings, yet it is still possible to make general comments about Roman functional planning, particularly in relation to such broad aspects as circulation, zoning, service areas, etc. It would perhaps be permissible to categorise Roman planning as functional (even though, as we shall see, there is a strong formalist trend), for it may be demonstrated that considerations of purpose often determined, or conditioned, the Roman's approach to his architectural problem.

Perhaps the practical approach affected the plan shape in no way more obviously than in planning for movement, and for the circulation of large crowds. Prime examples which come to mind are the Thermae and the Amphitheatres. The Thermae, for instance, accommodating vast crowds [188] posed problems of mass circulation which were admirably solved by the carefully disposed entrances, lobbies and anterooms, and by the great distributing central hall, or cella media which not only served as the architectural climax, formally speaking, of the whole complex, but was the pivot of the circulation scheme. In the theatres and amphitheatres, the circulation problem became even more acute. Not only were the total numbers to be dealt with

188. According to R. Lanciani, Ancient Rome, London, MacMillan and Co., 1894, p.89, the huge Thermae of Diocletian had facilities for some 3,600 people.

of a much greater magnitude,[189] but vertical, as well as horizontal, circulations were involved.

An analysis of the Colosseum, for instance, requires
Fig.13 the study of both plan and section to elucidate the circulation pattern: and the actual solution arrived at, was an outstanding step forward in the rational solving of a severe practical problem. In fact, with little precedent to go on, and on a basis of pure ingenuity, a surprisingly mature and fully worked out solution was achieved. It is, in fact, extremely difficult to trace intermediate steps in the development of this system. A
Fig.14 hint of it is given in the Hellenistic Theatre of Assos, which was built in the first half of the third century B.C. Here we have two vaulted entrances, one on each side, passing under the upper tiers of seats, and discharging through vomitories on to the crossover aisle. From this tentative essay to the fully developed system, there seems to be no intermediate stage. The earliest example of which we have definite knowledge, the Theatre of Marcellus,[190] finished in 11 B.C. by Augustus,
Fig.15 exhibits all the characteristics of the fully matured type. Bieber describes it thus:

> A carefully planned system of radial and concentric walls, stairs, roofed corridors, vaulted passages, ambulacories and doors (vomitoria) served as means of entry and exit for the many thousands of Roman theatregoers, thus

189. According to W.S. Anderson and R.P. Spiers, The Architecture of Ancient Rome, revised and rewritten by T. Ashby, London, Batsford, 1927, p.4, the Colosseum held about 45,000 spectators, although there are estimates as high as 80,000, as in Banister Fletcher, A History of Architecture on the Comparative Method, London, Batsford, 1931, Roman theatres were generally smaller, that at Orange seating about 7,000, according to Fletcher. Anderson, op. cit., p.89, mentions the wooden theatre of M. Scaurus, reputed to seat 70,000 spectators.

190. Pompey's theatre, the first permanent theatre in Rome (55 B.C.), may have anticipated the Marcellus system of crowd control. The reconstructed plan shown in Bieber, op. cit., fig. 450, seems to indicate a vomitory system, but this does not appear on the plan of the theatre as indicated on the Severan map of Rome, ibid., fig. 449.

> enabling them to reach their seats without crowding, by separate and uninterrupted approaches leading to each section in each tier. 191.

It is inconceivable that this full-blown solution was arrived at without a progressive series of experiments; and yet, of these, we have no evidence. The answer to the enigma lies perhaps in the series of wooden theatres, with a history in Rome of over 200 years before the Theatre of Marcellus. These temporary structures, continually being demolished, were an ideal medium for experimentation. Timber is a flexible and facile constructive medium, and it is more than likely that in the series of timber theatres, now lost except for vague literary descriptions, we have the missing steps in the development of the mature Roman circulatory system. If it appears an obvious system today, it is because contemporary planning procedure has departed little from the principles laid down in the Theatre of Marcellus and the Colosseum. The Roman handling of staircases, aisles and cross-aisles, vomitories feeding out and back to upper levels, shows a facility which is most impressive; and the dispersal of the vast crowd through the many exits 192 must have been rapid and efficient.

See Fig.13

Equally efficient was the handling of audio-visual problems, and in the theatres and amphitheatres, acoustics and sightlines are generally carefully considered.

191. Ibid., p.349.

192. Eighty entrances were provided, including two for the Emperor and his suite, two for the gladiatorial processions, and seventy-six numbered entrances giving access to all parts of the cavea. Anderson, op. cit., p.93.

The Greek classical theatre, from which the Roman was partly derived, was considered to have reasonably good acoustics. We must now consider whether the modifications which the Romans made to theatre design in any way affected the acoustics, either favourably or adversely. If the changes are favourable, we must then endeavour to see if they were made with understanding, or were fortuitous.

Before entering upon a discussion of these topics, we must record the confirmation which recent scientific investigations have given to the generally held notion that the acoustics of the Roman theatre were in fact excellent. Dr. Canac has reported on tests conducted on the Roman theatres at Orange and Vaison.[193] These tests included intelligibility tests at various points in the auditorium; ripple tank tests; and analysis of the reflection of aerial waves upon small scale models. Canac comes to the following conclusions:

Fig.16

> The excellent acoustics of the theatres at Orange and Vaison, considered as the result of a centuries' long progress in theatre architecture, are due to the following reasons: (i) Protection against exterior noises, by means of the stage wall and peristyle; (ii) Absence of echo, and scattering of the sound by the stage wall (recesses, columns, niches and statues); (iii) Absence of echo, and scattering of the sound by the continuous pulpitum niches; (iv) Absorption of sound on the sides, owing to the broad openings of the *parascenia* and *paradoi*; (v) Equalization of sound intensity on the seating owing to the stage floor; (vi) Absence of standing waves along the seating owing to their circular form; the audience is homogeneous.[194]

Now, apart from the circular shape of the seating, which accounts for the last item - and also for the relatively good acoustics in Greek theatres - all the factors involved are essentially Roman. The highly ornamented stage wall or *scaenae frons*; the peristyle, that is the roofed portico at the top of the seating, where the *cavea* ends in the girdle wall; the *pulpitum* with its continuous row of niches; the openings at the side of the

193. F. Canac, "On the Acoustics of Grecian and Roman Theatres," R.I.B.A. Journal, 56 : 1949, pp.412 et seq.

194. *Ibid.*, p.414.

stage; and the stage itself; are just those aspects where the Roman theatre differs from the Greek. It is thus highly significant that in each case, the change has had an important consequence in the improvement of acoustics. There is one further matter, upon which Canac does not comment, probably because it is no longer in existence in any of the theatres investigated, and that is the timber roof over the stage. This structure was designed primarily as a protection to the rich ornamentation of the scaenae frons; however, "this stage roof, slanting upwards towards the spectators, was at the same time, together with the roof of the colonnade, a kind of sounding board ...." 195.

We cannot say with certainty that the Romans adopted these particular forms because of their acoustic efficiency. As we shall see in a later section, when we deal with the design of the scaenae frons, there are many overlapping motives for the adoption of a specific form - motives that are historical, practical, symbolic. However, it is too much of a coincidence to consider that all these Roman innovations should just by chance be the critical accustic factors. At least we must consider that the Romans were aware of their effectiveness. As Bieber reminds us, Vitruvius was very much concerned with acoustics. He recognised the value of the stage roof as sounding board; 196 and that the portico at the uppermost rim of the cavea improved acoustics in that "the voice thereby resounds evenly throughout the theatre." 197. We can see, in the various Greek theatres altered by the Romans, the emphasis which is placed upon such elements as the decorated scaenae frons, or upon the width of the side openings, as in the case of the theatre built under Lycurgus, where the Romans increased the openings of the

195. Bieber, op. cit., p.355.

196. Loc. cit.

197. Vitruvius, op. cit., V : 6 : 4.

paradoi by over 5 feet. [198].

The weight of this evidence, considered in the light of our knowledge of the Roman point of view, leads us to the conclusion that the Romans must have been aware, through experience, of the acoustic value of the architectural forms they developed in their theatre architecture; and that this utilitarian advantage must doubtless have been a factor in the retention and development of these forms over the centuries. For a theatre to function adequately, the chief factors of performance are visual and auditory. These factors were adequately met in Roman design.

Similarly, the service aspect of the great Roman buildings was provided for on a comprehensive basis. In fact, the sound planning of auxiliaries, and the importance which the Romans attached to the design of service facilities, is an index of the practical attitude they brought to bear upon their architectural problems. For example, the triple service corridor, 58 feet wide, which ran under the Thermae of Caracalla, toplit and well ventilated; the branch corridors for access and storage; and the ramified vaulted store rooms; have led Anderson to conclude that "in fact, the planning of the subterranean portion is no less admirable than that of the superstructure." [199]. The substructures below the arenas of the amphitheatres are indicative of the complexity of planning of these service areas, and the thought and ingenuity which went into the detailed design. Provision was made for the storage of scenery, and the housing of wild beasts in large numbers. Ingenious facilities for the introduction of both scenery and animals into the arena, with due dramatic effect, existed in many amphitheatres. The Colosseum, for instance, shows evidence of an inclined plane up which cages were hauled by windlasses, the bronze pivots of which still

198. Canac, loc. cit.

199. Anderson, op. cit., p.106.

remain.[200] The power for these might have been human labour, such as was used in the treadmill which operated Roman building cranes.[201] Similar ramps are found at Pozzuoli.[202] Elaborate scenic machinery, for the most part in timber, was known to
Fig.17 have existed at the Colosseum,[203] Pozzuoli,[204] Treves,[205] and elsewhere. With this machinery was associated a series of trapdoors in the arena floor for the sudden and dramatic entry of the protagonists of the displays, and probably some form of lifting device. The most elaborate of these would appear to be the lifts[206] which Middleton believes were installed in the fifth or possibly the sixth century, complete with pulleys and counterweights. Even the cages for wild animals, as illustrated by
Fig.18 Middleton[207] show careful consideration of access, feeding facilities etc.

In planning, consideration was given to aspect and orientation. In the Thermae of Caracalla, for instance, "there were only four doorways on the north-east side which was exposed to cold winds: but large columned openings to the gardens were a feature of the south-west side."[208] The baths of Diocletian

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200. Middleton, op. cit., 2 : 105.

201. See for instance the crane depicted in a relief in the Lateran Museum, illustrated in Bailey, op. cit., fig. 23.

202. H.S. Jones, Companion to Roman History, Oxford, Clarendon Press, 1912, p.133.

203. Middleton, op. cit., 2 : 105.

204. Jones, loc. cit.

205. Neuberger, op. cit., fig. 494.

206. Middleton, loc. cit.

207. Ibid., fig. 62.

208. Fletcher, op. cit., p.167.

are similarly planned, and both Thermae have the Frigidaria on the cold side. The emperor's box in the Colosseum is similarly orientated to avoid the cold winds.

One of the most interesting examples of planning in relation to use and orientation is found at Ostia. We have previously, in discussing Roman heating systems, mentioned Thatcher's investigation of the problem of the 'open rooms' of the Terme del Foro. This investigation throws much light upon the question of Roman planning.

Thatcher [209] describes the unique plan form of the baths. The northern half, like so many of the thermae, is symmetrical about the frigidarium; the southern half, however, departs radically from symmetry, in a most untypical fashion. There are seven main chambers, each with its own individual shape and form, in an apparently arbitrary stepped pattern. These southern rooms have walls almost entirely consisting of large windows: and these windows, according to the archaeological evidence, were certainly unglazed. This in itself is surprising, for Roman glasswork, which "attained an extraordinary high degree of excellence," [210] was certainly known and used extensively at the time, bronze window frames glazed in panes of 21 inches by 28 inches being testified to by both Neuberger [211] and Briggs [212]. Thatcher comments: "Since Rooms 1 to 5 were the principle heated rooms of the establishment it is apparent that their open windows are unique, to say the least, for they present a problem in both heating and orientation that we are only lately equipped to deal with ourselves." [213].

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209. Thatcher, op. cit., pp.116 et seq.

210. Neuberger, op. cit., p.158.

211. Loc. cit.

212. Briggs, in Singer, op. cit., p.416.

213. Thatcher, op. cit., p.117.

The following, according to Thatcher's numeration, were the principle rooms of the baths, in the section under discussion.

Fig.19 1. Sun room; 2. Laconicum (dry heat); 3, 4. Sweating rooms; 5. Caldarium, with three hot pools; 6. Sweating room; 7. Service area, containing water heaters.

> The skillful disposition of these rooms gave the bather a variety of choices .... The six rooms seem to have been purposely arranged in two groups .... The first group might be said to emphasize dry heat and the other to emphasize wet heat, but they were so arranged that the bather could enjoy the subtle variety of either, or both. 214.

The siting of the baths gives rise to particular problems. The space is irregular, and awkwardly orientated. As a result of the site, the minor axis of the Forum Baths is 30° East of South, that is 75° out of position, if we regard Vitruvius's injunction that the hot rooms of baths should face southwest, to benefit from the afternoon sun in winter, and if we regard the prevailing orientation of most other baths, including those of Caracalla and Diocletian. In the light of this forced deviation from the optimum orientation, the stepped plan is seen to be not arbitrary, as first thought, but an ingenious solution to the problem.

> The architect was gaining as much sunlight as possible and at the same time providing protection against north-easterly weather. The projection of the rooms, particularly those of Rooms 4 and 5, not only achieve the latter purpose, but also furnished reflection surfaces and, thereby, considerable diffuse solar radiation .... 215.

With the exception of Room 1, which we shall consider as a special case, Thatcher shows that all rooms, with doors and dome ventilators closed, were adequately heated, despite the open windows, by the hypocaust system. What then was the purpose of the open windows? The negative answer is that, with the heating system, and with the considerable assistance given by solar radiation, [illegible]ing was not necessary; and the practical Romans there-

214. Ibid., p.119.

215. Ibid., p.121.

fore left in out. The positive answer is that there is a sophistication of effect, in a room which combines an open character with a high level of heating, which must have been particularly gratifying to the highly sensuous Romans: they must have delighted in the unique combination of fresh air and a heated atmosphere. Moreover, there is something of a demonstration of the Roman faith in technical achievement, in harnessing the sun's rays to demonstrate the power of man over nature - but, as Thatcher says, "the great unglazed windows were not a tour de force, but an honest attempt to open up the wall as much as possible for a legitimate purpose." 216.

The importance of the unglazed windows is best demonstrated in Room 1. This room, because it only had floor heating, was particularly dependent upon the assistance of solar heating. Its use has been established: it was a sunbathing room or heliocaminus. Thatcher's research into sun penetration at various times of the day, and various days of the year, indicated that this room received almost constant sunshine, and that the solar radiation it received in winter was appropriately much greater than that in summer. During the winter days of November to March, where there is an average of 68% of days with any sunshine at all, it was usable for 67% of the time. That is to say that, owing to almost ideal orientation and fenestration, it was 98% efficient. Glazing would have increased this efficiency by only 2%, but thereby "would have nullified its evident function as a sunbathing room. For glass, and especially the rather opaque glass, would have shut out the sun's 'tanning' rays." 217.

Fig.20

Fig.21

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216. Loc. cit.

217. Ibid. p.128. Briggs, in Singer, op. cit., p.430, writes of one example of opaque glass, found in a bath house, which was 40 by 28 inches, 1¼ inches thick. It was frosted on one side, probably with a sand abrasive.

The success of these rooms depended partly on their insulation on the north side from the colder rooms of the building, and the plan was cleverly arranged to have buffer zones of rooms of intermediate temperature. Thus, Room 2 was shielded by the small heated vestibule adjacent to it and Room 1, as well as by Room 12. [218]. External planning, however, of the baths in relation to the forum, was equally important in the proper functioning of the Terme. "The final elements of the plan that assured its success," Thatcher concludes, "were the buildings surrounding the palaestra. The two-storied buildings to the southeast and southwest were tall enough to act as windbreaks, yet low enough to let in the winter sun; the higher building to the northeast gave maximum protection against the worst weather." [219].

We have looked at the planning of the Terme del Foro at some length, since it is perhaps the only example of a major Roman building which has had its planning subjected to a scientific functional analysis. For the purposes of investigating the Roman planning attitude it is an invaluable study. For endorsement of the lessons learnt, we must turn to a smaller building, a Roman villa.

In two letters (Epistles ii. 17 and v.6) Pliny the Younger describes his principal country villas, at Laurentun and in Tuscany. [220]. His Laurentine villa in particular was was very fully described, and although Church and Broadribb [221] regard it as misguided "to attempt anything like the construction of an actual plan of the houses described," numerous reconstructions have been set up, from Castells' in 1728 to Pember's of

218. Thatcher, op. cit., p.128.

219. Ibid., p.129.

220. Epistles ii : 17 and v : 6, in A.V. Church and W.J. Broadribb, Select Letters of Pliny the Younger, London, Longmans, Green & Co., 1871.

221. Ibid., p.117.

1947. From Penber's reconstruction, which is the joint effort of an architect and a classical scholar and which takes few liberties with Plin,'s description, we get a picture of the care taken to plan for privacy, aspect and orientation. Let us focus our attention on Pliny's private suite.

> These private rooms provided complete isolation. A small central hall, which was doubtless used for the reception of more favoured guests, gave access to other chambers of the suite. To the left of one entering the crypto-porticus, an arched opening led into the semi-circular sun-room where, sheltered by the projecting eaves, one might rest in shaded coolness, looking out on the sunlit panorama of the western sea. To the left, a window presented a clear view of the sea-front terrace running along beside the covered way and terminating in the portico of the great swimming pool attached to the house and the baths beyond. 222.

This picture of comfortable and sensible planning for good living is expanded by many references in Pliny's letters. Thus he talks of a room which gets both morning and afternoon sun, and retains the warmth after the sun has set; and tells how "the angle formed by the projection of this chamber with the 'triclinium' before mentioned, retains the warmth of the sun at its height, and intensifies it." 223. Here we have a clear endorsement, in Pliny's own words, of Thatcher's interpretation of the significance of the projecting rooms at Ostia.

Pliny shows himself to be as concerned with artificial as with solar heating. Thus apart from the heated chambers of the baths, he refers in a passage dealing with the suspended (i.e. elevated) corridor, to the pipes or tubuli by which it was heated. 224. He is fundamentally interested in planning mechanisms which achieve peace and quiet, and notes of his bedroom, so satisfactory in this respect, that "the cause of this profound tranquillity is that a passage between the two separates the

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222. O. Penber, "The Country House of a Roman Man of Letters: the lost villa of the Younger Pliny," the Illustrated London News, Aug. 23, 1947, p.220.

223. Church and Broadribb, op. cit., p.234, n. 7.

224. Ibid., p.235, n. 9.

chamber from the garden, and thus drowns all sound by the intervening vacancy." 225.

If in the planning of the large private villa of the wealthy Roman a high degree of functional success was achieved, in an environment which combined the practical conforts with a quota of sophisticated living: then, in a much more modest fashion, the design of the multiple dwelling for the lower income groups at Ostia demonstrated a similar facility for practical planning. 226. In these flats we find common-sense design, untrammelled by formalistic preconceptions, which satisfied both structural and economic necessity, and in so doing, created a new architectural type of no small aesthetic merit.

> The substantial brick-faced walls of these Ostia tenement houses were well adapted to support the burden which was to be placed upon them; there was rational disposition of the various elements, with due regard to light, air and accessibility, and there was intelligent adaptation of means to ends. In Calza's words, 'a problem of architecture was solved, a social need was met: twofold solution, practical and artistic, in which is to be recognised a distinctly Roman characteristic.' 227.

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225. Ibid., p.238, n. 22.

226. For an account of the origins of the Ostia-type of taberna house, see Axel Boëthius, "Remarks on the Development of Domestic Architecture in Rome," American Journal of Archaeology, 38, 1934, pp.158-70. Ward Perkins, in a review of Boëthius, "Roman and Greek Town Architecture," Journal of Roman Studies, 39, 1949, pp.175-7, makes the point that the tenement house is specifically Italian, with little or no evidence of its use in the Roman provinces.

227. A.W. Van Buren, "News Items from Rome," American Journal of Archaeology, 45 : 1941, p.457.

CHAPTER FOUR.

THE ROMAN FORMALIST ATTITUDE.

FORMALISM AND ORDER.

The formalist attitude is manifest in a society which believes in systematization and classification. In Roman times it is most evident in the search for apparent order. The climate of ideas in Rome tended to reduce diversity and variety to conformity and uniformity: upon the superficial chaos of the ancient world it imposed regularity and order.

Roman hegemony over a large portion of the civilized world is an expression in political terms of this concept, and in "the idea of an ordered empire, with a fully articulated system both of central and local administration", we find the epitome of the Roman ideal of systematization. [1]

Most characteristically this tendency showed itself in the stratification of Roman society, in the rigid definition and compartmentalization of its hieratic classes which, by the time of Constantine, culminated in a "new social order based on hereditary status." [2] Again, it is evident in the detailed systematization

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1. H.S Jones, "Administration," in Bailey, op. cit., p.92. Jones makes the interesting and highly significant point that Roman orderliness, as expressed in their political organs, did not approximate the Greek. The various components of Artistotle's Constitution, for instance, "fall into their places as parts of a coherent and rigidly logical scheme to which the Roman state can show no parallel." (loc. cit.). The Greek system is pure theory, the Roman a sense of order tempered by experience.

2. Ibid., p.137.

   According to Jones, loc. cit., ".... the enactments included in the Theodosian Code show that all services of importance to the State are rendered by hereditary corporations."

of the Roman army, where even warfare is pressed into a recognizable, and therefore, predictable, form. [3] In the legal code, we find again the reduction of a wealth of precedent and custom to a systematic pattern of practice.

A minor, but far from insignificant example of the Roman passion for order is cited by Barrow. [4] He describes the numerous 'clubs' which were to be found in Rome, generally organized by slaves, freedmen and the poorer free man.

> These clubs, which might include men of each status, combined a religious cult with the amenities of a social or 'dining' club, and often made provision for the funerals of members - church, social club, craft-guild and funeral society. Again, the Romans' genius for 'order' asserts itself, as the rules and minutes which we possess abundantly show. Officers are elected who on appointment take the oath and on resignation render up accounts; new members are advised to read the rules and expected to pay their subscriptions. The rules, which are couched in the language of Roman law, lay down conditions about entrance fee, subscriptions, funeral benefits, expenses of those who attend the funeral, about the kind of fare and wine to be provided at 'club' dinners, about complaints and about the standard of behaviour expected.

The elaborate framework of regulations testifies, as Barrow points out, to the innate Roman sense of order. But this feeling for order is evident in an even wider sense. For the slave and ex-slave, for the Roman citizen of the lowest income group, these clubs indicated an attempt to create stability out of social and econonic insecurity; to cut out an orderly social existence from an otherwise precarious world; to impose a system of order upon chaos.

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3. "From the time of Marius onwards the cohort of three maniples appears as the tactical unit in all descriptions of battles; and from the writings of Caesar and his officers it appears that the usual battle formation was the triplex acies, in which there were four cohorts in the first line and three in the second and third ..... The depth of the cohort was normally eight file; Pompey's cohorts at Pharsalus were drawn up ten deep, but this was unusual (sic!) .... The rule under the Republic was that the legions occupied the centre of the line, the 'auxiliaries' the 'wings' - " and so forth. Jones, op. cit., (Comp. to Rom. Hist.), p.200.

4. Barrow, op. cit., pp.103-4.

A bronze tablet found in Portugal sets down with similar precision the meticulous regulations governing a government mining village.

> The local shopkeepers worked, it seems, under contract with the State. The keeper of the public baths has to supply hot water every day, clean his boilers once a month, admit women from daybreak till one p.m. and men from two till eight, and exclude soldiers, children, and the freedmen and slaves employed by the Imperial procurator. The shoemaker must provide footwear of all kinds and sell hob-nails 'according to the regulations of the iron-works.' The licenced barber has a monopoly, except that private slaves may shave their masters or fellows. 5.

The urge to compress the multiform aspects of life into a predictable pattern is here apparent.

It must be noted that this formalist attitude on the part of the Romans is largely the obverse side of their practical nature. We have already seen that the Roman social order was the expression of a practical ability to govern: that the Roman army was the tool which, in a most practical manner, implemented and enforced the Imperial will: and that the legal system (in so far as it was concerned with, not the abstract concepts of idealized justice, but the practical aspect of the instrument with which [illegible]hion a smoothly-working society) was in essence the expression of a practical attitude to life.

One of the most interesting illustrations of this dual nature of the search for order is the rectangularity of the "castrum" type of Roman town. The orderliness of this type of plan layout is rigidly formalistic as a pattern imposed upon, rather than developing from, organic life. It is also formalist in the sense that "with the Romans the founding of a city was a religious act and performed with well-defined ceremony." 6. The augur takes up his position at the proposed centre of the town and, facing east, lays out the two intersecting main roads of the town, the kardo running N.S. and the decumanus running E.W.

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5. Jones, in Bailey, op. cit., p.129.

6. Gest, op. cit., p.172.

Taking these two main roads, intersecting at right angles, as the two main axes, secondary sets of roads parallel to the axes are then laid out, which divide the area of the town into a rigidly demarcated grid-iron. The resultant plan is thus highly formalist in pattern. [7.] According to Polybius, the camp was laid out in a regular pattern within the boundaries of a perfect square. [8.] Simple proportional relationships were to be observed, such as a 3 : 2 ratio between pars postica and pars antica. The entire camp was based upon a decimal system of measurement, and was planned upon a modular grid of 50 feet (10 paces or 1 vorsus). Again, in the camp described by Hyginus, the formal geometry is evident, this time based upon a duodecimal system, with a module of 60 feet (12 paces). At the same time, however, there is a convenience and an ease in laying out such a town, which, seen from the surveyor's point of view, was practical in the extreme. [9.]

Thus we have a direct example of a form of order perpetuated because of practical considerations, which eventually hardens into a purely formalistic patterning. Considered in this light, the Roman attitude to formalism can been seen as an index of the Roman practical attitude. Formalism becomes, not an intellectual concept, but the convenient means of achieving greater practical efficiency. Like the executive's filing system, Roman formalism is a by-product of the urge to greater

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7. The facts concerning the Roman camp are derived from Jones, op. cit., (Comp. to Rom. Hist.), pp.226 et seq.

8. The camp at Novaesium was a rectangle with sides approximately 3 : 4. Hyginus advocates a 2 : 3 rectangle. The proportions advocated are generally commensurate. See Jones, ibid., p.234.

9. Gest, op. cit., p.173, writes that "by naming the region and the number belonging to any kardo or decumanus, any point in the city could be designated." Hence, the practicality of the formal town planning extended to the easing of communications: and indeed today the simplicity of direction-finding remains one of the few positive attributes of the grid-iron plan.

practical effectiveness. This formalism of convenience is a superficial formalism, in that it is primarily concerned with apparent order, with surface patterning, as it were. It is concerned with tidying up the filing cabinet of the mind, as a prerequisite for action.

There is of course, a formalism on an altogether more elevated plane. This formalism derives from tendencies towards innate order, that is, order intrinsic in the systematization of the universe. It is concerned with the fundamental order of the macrocosm, and the application of the principles of unity in the microcosm. Activity in this realm of order takes the form of investigations into and the establishment of philosophical principles rather than concrete action. Such ventures into speculation and metaphysical deduction were not the Roman forte, and where in Roman theory, reference is made to such fundamental concepts, the source is Greek rather than Roman. The Romans added nothing to the Greek philosophy of unity, but that philosophy was adopted and incorporated into the Roman pattern and modified within the matrix of the Roman attitude. We have seen that Stoicism "came to be the characteristic philosophy of the Roman empire," [10] and we have (in Chapter two) analyzed its practical content. Rex Warner equates the rise of Stoicism to favour with the growing systematisation of the Empire, and the growing pressure of political and moral controls on the range of free-thinking indulged in by the Romans. He writes:

> After the defeat of Antony at Actium in 31 B.C., the government of the first emperor, Augustus, brought to the world a condition of comparative order and stability such as had been unknown for many decades before. Almost at once the tone of Roman life became stronger, but also more constrained. There was indeed a new enthusiasm for public affairs, a general readiness to labor for the new and beneficent regime; but with this there went a constant pressure of official propaganda, moralistic, traditionally religious, rather

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10. Rex Warner, The Greek Philosophers, New York, Mentor Books, 1958. p.215.

stiffly self-righteous. [11].

The climate in which Stoicism flourished was thus compounded out of conservatism, a regard for traditional values, and an acceptance of authoritarian discipline which exceeded the passive, in that it recognized authority as a means to social order. "One universal society, one state of the whole world; one law of nature, with which all its members must live in conformity - these are the two great tenets of Stoicism." [12]. The Stoic conception of the whole universe as a 'single intelligible unity' in Barker's phrase, is thus seen as fundamental in the formalist attitude towards order.

We have seen, in our analysis of the formalist attitude (Chapter One) that conformism is an essential characteristic. Conformism stems from two sources: a regard for the enduring values of tradition, and a respect for authority. These two characteristics are, as we have seen, inherent in the Roman philosophical system. Hugh Last, in discussing the virtues of Roman home life, which, even more than religion, dictated the forms of Roman morality, draws attention to the three kinds of excellence extolled by Cicero: gravitas, pietas and simplicitas. [13]. Gravitas is defined as a sense of earnestness and responsibility, which emphasizes mature reflection and inhibits spontaneous and perhaps short-lived enthusiasms. Pietas, is the natural corollary to this - "the attitude of proper submission which gravitas creates to all established institutions." [14]. In its acceptance of authority, both human and divine, pietas is an expression of Roman submission with good grace to imposed systems of discipline. (The

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11. Ibid., p.216.
12. Barker, in Bailey, op. cit., p.51.
13. Hugh Last, 'Family and Social Life," in Bailey, ibid., p.211.
14. Loc. Cit.

third characteristic, simplicitas, is that sense of the reality of things, which we have seen as fundamental to the practical attitude).

Thus, within the family, conservatism and obedience are ingrained. To a large extent, these traits resulted from the patria potestas, the undisputed power of the father - more judge, however, than tyrant - which, exercised wisely and with restraint, "above all was responsible for the discipline which made the Roman people". 15. The family presents in microcosm the essential picture of Roman society. Obedience is extended from the home to the state, and the emperor, semi-divine, stands in locus parenti to Roman Society, as a whole. The spirit of discipline to authority and respect for tradition is basic both to the concept of the Roman state, and to Roman religion.

We have seen earlier that Roman religion was eminently practical: it was also essentially formalist.

> From the beginning their relations with the divine powers were strictly business-like; and as they elaborated in their system of civil law a code which defined with admirable fairness the obligations of man to man, so they set up, in the ius sacrum, a parallel code laying down the obligations of man to God. The name religio signifies obligation, and to go beyond this - in other words, devotion - was superstitio. Thus, while the Romans had no mythology, they had a minute and elaborate ritual. 16.

This formalism of religion is indicated by the insistence upon the scrupulous observance of Roman rites; and by the systematization of public and private worship by the Roman calendar, with its formally balanced and rhythmically repeated cycles of events. It is true that all great world religions today are similarly calendar-based, and the established church or synagogue becomes increasingly bound up with formal ritualism. The question is one of emphasis, however, Underlying the formalism of Christianity and Judaism is the solid rock of fundamental belief. Roman religion, on the other hand, fails to penetrate beneath the

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15. Ibid., p.215.

16. Jones, op. cit., (Comp. to Rom. Hist.) p.267.

superficial patterns and apparent order of a ritualistic approach.

The Roman adherence to the outward aspects of formalism rather than the inward content, can best be demonstrated by the maintenance of the traditional forms and institutions, after their functions had changed beyond recognition. For instance, the concept of patria potestas was adhered to formally (that is, in form only, not in substance) even though contradicted and denied by the realities of later situations. The institution of the Senate, to cite another example, remained virtually intact in outward form for centuries while its constitution and powers were fluctuating violently. Indeed, Barker regards it as "proof of the legal genius of the Romans and their instinctive respect for precedent and constitutional tradition, that even the deified Caesars, masters of all the legions, should have respected for centuries the impotent majesty of republican forms." 17.

There is in Roman history at all stages a tacit agreement to respect traditional forms, and somehow to insinuate new contents into familiar packages without disturbing the wrappings. The conventions must be observed, even if they have become devoid of significance: and conventionalism is one of the main-springs of the formalist attitude. In Roman constitutional development we have many such instances of formal procedure lacking inner meaning, such as the case cited below.

> A remarkable example of the Roman unwillingness to break formally and completely with the past is afforded by the fact that throughout the Republican period, magistrates... did not receive their authority to act from the assembly which elected them. That authority was dependent on the passing of a resolution by the oldest assembly, the comitia curiata. The lex curiata de imperio was annually enacted, and rapidly became a mere formality. 18.

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17. Barker, in Bailey, op. cit., p.70.

18. Reid, in Sandys, op. cit., p.254.

Roman conservatism was a powerful factor in their tenacious retention of form - traditional form - while the Roman attitude to practicality, being a progressive force, simultaneously stimulated change. This is one of the roots of the conflict which we shall examine later in this thesis.

THE LITERATURE OF FORMALISM.

Having touched upon some basic aspects of a general nature which affect the Roman formalist attitude, we must now give more detailed consideration to formalism in relation to architecture.

When we seek in Roman literature, and particularly Roman architectural literature, an explicit theory of formalism, we find some profound principles rather summarily stated. Our chief and most typical sources, whose generality we have demonstrated in an earlier chapter, are Pliny and Vitruvius: and from these sources certain leit-motifs appear, not as principles argued out and developed, but rather as *a priori* statements which explain the facts of the system, and from which the principles may be deduced.

The primary themes deal the the Orders as standardized building elements; and Proportion as the guiding principle of architectural form. Let us deal with these aspects in some greater detail.

Vitruvius catalogues and defines the three Greek Orders, and adds to them, in parenthesis, the Composite. He discusses the origins of the orders in mythological terms, and considers their symbolism anthropomorphically. He then describes the standard prototype of each order, stipulating in great detail the proportional relationships between all the constituent parts, in terms of a unit based upon the lower diameter of the column. His detailed specification covers all aspects of the Orders from base of column to entablature, and the extracts cited below must be regarded as typical of an extensive system.

Vitruvius deals here with the details of the Ionic base:

> But if Ionic bases are to be built, their proportions shall be so determined that the base may be each way equal in breadth to the thickness of a column plus three eighths of the thickness; its height that of the Attic base, and so too its plinth; excluding the plinth, let the rest, which will be a third part of the thickness of a column, be divided into seven parts. Three of these parts constitute the torus at the top, and the other four are to be divided equally, one part constituting the upper trochilus with its astragals and overhang, the other left for the lower trochilus. But the lower will seem to be larger, because it will project to the edge of the plinth. The astragals must be one eighth of the trochilus. The projection of the base will be three sixteenths of the thickness of a column. [19].

Here the details of the column are related to the unit of the lower diameter. The height of the column is similarly regulated.

> In aerostyle temples, the columns should be constructed so that their thickness is one eighth part of their height. In the diastyle, the height of a column should be measured off into eight and a half parts, and the thickness of the column fixed at one of these parts. In the systyle, let the height be divided into nine and a half parts, and one of these given to the thickness of the column. In the pycnostyle, the height should be divided into ten parts, and one of these used for the thickness of the column. In the eustyle temple, let the height of a column be divided, as in the systyle, into nine and a half parts, and let one part be taken for the thickness at the bottom of the shaft. With these dimensions we shall be taking into account the proportions of the inter-columniations. [20].

For a given diameter, we now have fixed the detailed subdivisions of the Order, and its height. It then becomes necessary to determine the spacing of the columns. The various terms 'aerostyle', 'diastyle', 'systyle', etc., mentioned in the paragraph above, refer to a series of systems codified by Vitruvius, [21] and each defined rigidly in terms of inter-columniations expressed in diameters. Hence: "The construction will be diastyle when we can insert the thickness of three columns in an intercolumniation, as in the case of the temple of

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19. Vitruvius, op. cit., III : 5 : 3.
20. Ibid., III : 3 : 10.
21. Ibid., III : 3 : 2-7.

Apollo and Diana." 22.

There is, in Pliny, wedged into the chapters on Materials, one short chapter which is typical of this kind of modular analysis. He writes:

> There are four different kinds of pillars. Those of which the diameter at the foot is one-sixth part of the height, are called Doric. When the diameter is one-ninth, they are Ionic: and when it is one-seventh, Tuscan. The proportions in the Corinthian are the same as those in the Ionic; but they differ in the circumstance that the Corinthian capitals are of the same height as the diameter at the foot, a thing that gives them a more slender appearance; whereas in the Ionic column, the height of the capital is only one-third of the diameter at the foot. In ancient times the rule was, that the columns should be one-third of the breadth of the temple in height. 23.

In these chapters on the Orders Vitruvius and Pliny codify both the vocabulary and grammar of architecture, in that they establish the nature of the forms to be used, and the manner of their relationship. Thus the formal qualities of architecture become dependent upon a fixed repertoire of elements related to each other according to a fixed proportional system. When the architect has exercised his creative choice in respect of the type of column he is going to use (e.g. Doric); the system of spacing he desires (e.g. systyle); and the number and actual diameter of the columns: then, this choice having been made, he finds that he has determined the exact length and height of the facade, and has moreover determined each division and moulding. Thus, through the system adumbrated by Vitruvius and Pliny, every detail is related in a fixed proportional system to the other.

Certain comments must be made here. Firstly, an assumption as to the possible number of column types is here made deriving from past practice as developed in Greece, but an arbitrary limitation when considered in terms of another culture and other times. Secondly, these possible columns, the major inherited structural and decorative elements, are rigidly

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22. Ibid., III : 3 : 4.

23. Pliny, op. cit., XXXVI : 58.

defined and circumscribed. The relative proportions of the Orders, in terms of the unit of the diameter, are closely defined. The important point which emerges is that, by the time of Vitruvius and Pliny, the Romans have accepted, in theory, certain standardized building elements, and have agreed upon the principle that rules govern the employment of these elements: in other words, the Romans have accepted a vocabulary and a grammar (not of their own invention, but modified and varied by them) of architecture. The acceptance of a code of aesthetic rules leads to an established pattern of architectural treatment, that is, to Formalism, if it is carried over from theory into practice.

The acceptance of the Orders, and their definition in terms of proportions, leads to the wider question of Proportion as a general proposition. When Pliny correlates the height of a column with the breadth of a temple, he is extending the proportion of the constituent part to the whole.

Vitruvius formulates this concept as a general principle: "Proportion is that agreeable harmony between the several parts of a building, which is the result of a just and regular agreement of them with each other; the height to the width, this to the length, and each of these to the whole." 24. And elsewhere he states: "Proportion is a correspondence among the measures of the members of an entire work, and of the whole to a certain part selected as standard." 25.

The corollary to this general proposition, which is implied in the theory of the Orders, is that, not only does beauty lie in the determinate relationship of sizes, but that certain ratios are more beautiful than others. That Vitruvius

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24. Vitruvius, op. cit., (Gwilt trans.), I:2:4. It is typical of the semantic confusion that Morgan, op. cit., I:2:4, gives this definition as one, not of Proportion, but of Symmetry. According to the Latin text of the Loeb edition, op. cit., the word is symmetria.

25. Vitruvius, op. cit., (Morgan trans.), 111 : 1 : 1.

believed in the validity of this corollary is implicit in his rules for the proportions of the curia, "If the building is square, let its height be fixed at one and one half times its breadth; but if it is to be oblong, add together its length and breadth and, having got the total, let half of it be devoted to the height up to the coffered ceiling." [26.] / consider also his statement: "Dining rooms ought to be twice as long as they are wide. The height of all oblong rooms should be calculated by adding together their measured length and width, taking one half of this total, and using the result for the height. But in the case of exedrae or square oeci, let the height be brought up to one and one half times the width." [27.] Vitruvius clearly believes that proportions under certain conditions are fixed and static: that these proportions, originally empirically determined, have become unchanging relationships, which can be learned and applied. [28.]

The implications of this theory of proportions upon design are far-reaching. Criteria of design are established which determine dimensioning in terms of aesthetic a priori decisions, without reference to the demands of function, purpose and structure. [29.] This is, of course, the essence of formalism. The point

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26. Ibid., V : 2 : 2.

27. Ibid., VI : 3 : 8.

28. Ibid., (Gwilt trans.), II:1:7. "Thus by experience and observation the knowledge of certain proportions was attained, which in the beginning were fluctuating and uncertain." Morgan, op. cit., translates it thus: "Next, observation and application led them from fluctuating and indefinite conceptions to definite rules of symmetry."

29. It must be borne in mind, however, that, in the initial formulation of these rules, considerations of function and structure may well have been taken into account. This is evident in Vitruvius's description of the eustyle system of intercolumniation, in Morgan, ibid., III:3:6. "An account must now be given of the eustyle, which is the most approved class, and is arranged on principles developed with a view to convenience, beauty and strength. The intervals should be made as wide as the thickness of two columns and a quarter, but the middle intercolumniations, one in front and the other in the rear, should be of the thickness of three columns. Thus built, the effect

which we have here established is that there is a coherent and fully developed principle of Formalism implicit in the writings of Roman architectural theorists.

ORIGINS OF FORMALIST THEORY.

As this theory appears fully-blown in the pages of Vitruvius, (and to an extent in Pliny) without a hint of its development, we must next examine the sources and origins of the theory. We have already quoted the acknowledged Greek and Roman sources of Vitruvius. It is significant that the extent of his Greek 'bibliography' far outshadows his meagre Roman list: it is also significant that his source-list deals primarily with formal topics. There is Silenus on the symmetry of Doric buildings, Philo on the symmetry of temples, Argelius on the proportions of the Corinthian order, and at least ten lesser known Greek authors, dealing with proportion. [30]. The Ionic order, incidentally, was codified by Hermogenes of Priene, an author whose works must be reckoned an important influence of Vitruvius. [31].

There is therefore, no lack of evidence to sustain the contention that Roman theories of Formalism stem directly from the Greek. We can also demonstrate the important fact that the basic principle of the theory of Formalism, namely the principle of the relationship of part to whole and whole to part, is a Greek principle. Bosanquet sums up the Greek position as follows:

> The synthesis of the one and the many was, as we all know, the central problem and the central achievement of Greek philosophy. The conception of unity in variety is the indispensable basis of that idea of system or totality of interdependent parts, which was destined to be the structure erected by modern speculation upon the definite foundation

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of the design will be beautiful, there will be no obstruction at the entrance, and the walk round the cella will be dignified."
Vitruvius, as a practical man, is prepared to temper his formalistic conceptions with practical considerations.

30. Ibid., VII : introduction.

31. According to W.B. Dinsmoor, The Architecture of Ancient Greece, London, Batsford, 1950, p.273.

> laid by the Greek thinkers. The relation of whole to part - a slightly more concrete expression for unity in variety - has never been more perfectly elucidated and more justly appreciated than by Plato and Aristotle." 32.

Fig.22

The mathematical concept of the harmonic relationships of the universe is Pythagorean, and Timaeus, the Pythagorean, expresses this concept most lucidly. [33.] Also the concept of the very structure and relationships of the basic elements of the universe in the Platonic cosmology is proportional - "as that fire is to air as air is to water, and as air is to water, water is to earth." This Platonic concept of universal proportion based upon the relationships of part and whole, this Greek philosophy of formalism then, runs right through Roman architectural theory in its formal aspects. Vitruvian aesthetic law depends on it: and in the neo-Platonists it is recapitulated and reinforced. [34.]

FORMALISM AND STANDARDIZATION.

We have seen that Roman formalist aesthetic theory had two primary components: It was based upon the Orders - that is, upon a standardized architectural grammar of relationships, and its process was that of the relationship of parts to form a whole. We have also analysed the origins of both these components, and have found them in general principle to be Greek. These inherited

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32. Bosanquet, op. cit., p.32.

33. It is not possible for two things to be fairly united without a third, for they need a bond between them, which shall join them both. The best of bonds is that which makes itself and those which it binds as complete a unity as possible, and the nature of proportion is to accomplish this most perfectly; for when of any three numbers one is the mean term so that the first is to the middle is to the last, and conversely, as the last is to the middle so is the middle to the first, then, since the middle becomes first and last, and the last and first become the middle, thus of necessity all will come to be the same, and being the same with one another all will be unity." Plato, Timaeus, cited by Richter, Rhythmic Form in Art, London, John Lane the Bodley Head, 1932, p.17.

34. As in Plotinus - "What is it that impresses you when you look at something, attracts you, captivates you, and fills you with joy. We are agreed, I may say, that it is the inter-relation of parts towards one another and towards the whole ....."
Ennead 1:6:1, cited by Richter, ibid., p.3.

Greek attitudes were adopted and significantly modified by the Romans. Without venturing too far into the field of socio-psychological analysis, it can be fairly assumed, both from the literature, with which we have been here concerned, and from the artefacts, which we shall examine, that the Romans suffered from an unsureness of aesthetic judgement which led both to their plagiarization of Greek architectural forms, and to a willingness to rely upon authoritarian standards inherent in the adopted grammar of architecture. Standardization, can, of course, have practical motivations; it can derive from questions of utility, or functional efficiency, or economy. There is, moreover, a particularly valid function of standardization in a widespread empire, for the establishment of standards helped to attain a more-or-less uniform architectural environment - modified of course by regional differences - which was consistent with the unified concept of Empire itself. In addition, such standardization facilitated the interchange, not only of ideas, but of the artists and architects to carry them out. With the Romans, however, it is clear that the motivation is to a large extent formal, and standards are used as a crutch to bolster up an inherently insecure attitude to aesthetics. The question of formalism in relation to standardization and authoritarian rules is a complex but fascinating one, to which we will return again later in this study. Certain comments, however, are germane now.

The relationship of part to whole in the Roman theory, based as it is upon a standard unit (the lower diameter of the column) is fundamentally a modular theory. This theory comes, as we have seen, from the Greek, but with slight variations which are, however, of considerable import. It would seem from our analysis of the Greek Philosophers - all of the post-golden age - that they bear out this modular theory. When we examine 5th Century Greek buildings, however, we fail to find this theory exemplified. Plommer draws attention to Dinsmoor's researches in

this matter.

> As the table in Dinsmoor makes clear, no easy ratio existed in Greek Doric or Ionic between the interaxial distance and the lower diameter. Vitruvius in the third chapter of his fourth book divides the stylobate of a hexastyle Doric temple into forty-four modules, allots twelve to the six columns and thus leaves six each for four of the spaces and eight for the centre. Not only his numbering but his actual system here lacks all classical Greek precedent, and we had better omit all references to modules in Greek Doric. [35].

The difference is significant. In Greek building, at least of the Periclean age, the shapes and forms of the parts are modulated and adapted in their relationship to the whole. The process is one of organic synthesis, and, as Lethaby points out,

> these modifications may be used to bring about unity. If, for instance, the eight columns of a portico incline towards the axis and there is some adjustment in the spacing, you do not have one factor repeated eight times, but together they make up one whole thing - a portico. [36].

Such deviations from mechanistic rigidity in Greek architecture are doubtless the result of the realization that "a strict application of the laws of proportion to architecture produced a total deadness." [37]. This sensibility is not reiterated in Roman architecture, and while we have cited several instances where Vitruvius indicates a willingness to modify his rather dogmatic theories in terms of practical requirements, yet we cannot find a similar willingness to temper rigid doctrines to achieve a humanization of design in aesthetic terms. In Roman design, however, (as in later Greek works), [38] the parts are standardized,

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35. E. Plommer, Ancient and Classical Architecture, Simpson's History of Architectural Development, London, Longmore, Green and Co., 1956, 1:

36. W.R. Lethaby, Architecture, London, Oxford University Press, 1955, p.71.

37. E. Read, Icon and Idea, London, Faber and Faber Limited, 1955, p.85.

38. According to Read, ibid., p.86, Hellenistic art, where it is not wilful and arbitrary, loses all vitality by mechanically reproducing standardized types according to academic rules.

and are unaffected by their incorporation into the whole. This is a process of mechanical addition, where a knowledge of the parts will make possible the prediction of the whole. This attitude is carried over into later Roman theory, and Plotinus puts forward the un-Greek proposition that a beautiful whole must have parts that are beautiful separately as well as in combination. [39].

Scholfield's analysis [40] of Vitruvian proportion is highly pertinent to this concept of proportion as seen in actual Roman building. He defines Vitruvius' system as analytic, commensurate and arithmetic; valid only from a single viewpoint; and more concerned with relationships of part to part than of part to whole; that is, dealing with multiples (modules) rather than submultiples. The use of commensurate dimensions is significant, for they clearly facilitate an additive system. Moreover, as Scholfield points out, commensurate dimensions have greater utility than incommensurate ones, for they are easier to manipulate and apply.

Once again, we are led to the conclusion that Roman formalist concepts have a powerful practical component. The utility of standardization referred to by Scholfield is underlined by other writers. For instance, Ogden emphasizes the the practical base of the modular system, writing: "With the development of tools for mensuration, it was natural, and inevitable, that the canons of ancient art should be translated into "modules" of definite linear proportion in which incommensurable numbers no longer appear." [41]. The crystallisation of empirical practice into rigid formalist theory may

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39. According to Bosanquet, op. cit., p.116.

40. Scholfield, op. cit., pp.26-8.

41. R.M. Ogden, The Psychology of Art, New York, Charles Scribner's Sons, 1938, p.190.

thus in part be ascribed to a systematization of building technique. The reduction of the creative process to an automatic application of a formula is the essence of the formalist attitude: and yet, practical advantages are also apparent. Thus Brown, et. al., in a rather prosaic commentary on the orders, claims that "the very process of reducing the Orders to a "rule," with its inevitable loss of artistic expression, yet caused them to attain an average that made their use possible - with a certainty of not going far wrong - by individuals of indifferent genius or architectural training." [42].

Brown implies that the establishment of a universally accepted architectural idiom facilitated the creation of a general body of architecture on a wide scale, to a uniform minimum standard of acceptance. This is a particularly important factor in a widespread empire. A standardized architecture resulted in a uniform urban environment throughout the empire; that is to say, a uniform environmental system or matrix results, within which local and regional variations will of course occur. It constituted the visual link between colony and mother-city, and in symbolic language proclaimed the hegemony of Rome. Moreover, standardization facilitated the interchange of architects and artisans from one part of the empire to another, an interchange fundamental to establishing an expanding conception of the Roman Way.

To recapitulate: we have postulated some of the practical connotations of an essentially formalist theory stressing the standardization of the part, and the mechanical relationship to whole/ to whole. This mechanistic concept of the relationship of part to whole implies the possibility of the re-analysis of the whole into its components. As Ogden puts it:

> When the plan of a building, including its facade, doors, windows, and other details of structure, can be reduced to recognizable units, the result is static and enumerative. An appreciation of this order rests upon a naive estimation

42. F.C. Brown, F.A. Bourne, J.R. Coolidge, Study of the Orders, Chicago, American Technical Society, 1948, p.251.

> of the number of times a given unit is contained in the whole. [43]

The components retain their original identity within the whole, and of necessity must be articulated and separable. The necessity for articulation immediately produces architecture of a certain type. A wall surface, for instance, is non-articulated and continuous; in fact not unified, but a unity, that is, one indivisible whole. A perforated wall, although it is punctuated, remains essentially non-articul[illegible]ese perforations become round-headed, we have an arcade [illegible]rried on piers, where the basic wall character is retained. An arcade carried on columns, however, breaks away from the continuous nature of the wall, and brings us into the sphere of articulation, but not in an altogether unambiguous way. [44] A system of architecture based upon clear-cut vertical and horizontal divisions is much more effective in realizing the compartmentalization or articulation of the facade. The inherited system of the Greek orders, with their precise definition of parts, was just such a system: an excellent means for defining and isolating component parts of the whole. The architectural role of the Orders, particularly in a non-structural context, and the consequences of the need for articulation, are subjects to which we shall return in the next chapter.

SYMBOLISM.

One of the most powerful motivations in architecture is symbolism: and, as it is often subconscious, or when conscious, not overt, it is one of the most difficult motives to isolate and analyse. Furthermore, it has been stressed that concepts of symbolism in building do not come easily to the modern mind, and that consequently it is difficult to recapitulate convincingly the symbolic intent of another age. "This means that architectural

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43. Ogden, op. cit., p.185.

44. For a penetrating study of this problem, with particular reference to the work of Alberti, see Wittkower, op. cit., (Arch. Princ.).

symbolism will continue to seem artificial as long as ... it is assumed that the motivating factors of architectural creation were always, as they are today, only structural necessity, utility, decorative desire, and a particular kind of taste." 45. It is doubtful however, whether this assumption of the absence of present-day symbolism is altogether justified: and the contention remains unconvincing while house-builders continue to express their desire for a "homely" house, bank-directorates demand "dignified" banks, and coffee bars evoke the "romance" of far away places. Such demands for specific essences in building are perhaps unwitting, but not for that the less powerful, symbolic motivations of modern architectural forms.

We must therefore concede that even in materialist modern times architectural forms are modified by symbolic intentions. In less scientific, more superstitious, more ignorant or more spiritual ages, we must regard as a powerful incentive to formalism in architecture the concept of architecture as a symbol. Where, for instance, a society believes that a column represents in material form the spiritual qualities of a deity, then religious buildings erected to such a deity will be columnar architecture. The symbolic and functional attributes of the column may coincide, as in the Greek temple, but this is not necessarily so, and even when functionally redundant the column will be retained for its symbolic connotations.

It is argued therefore, that when forms are used for their metaphysical associations, and are not derived from practical considerations, it may fairly be said that the forms are derived *a priori*, and are the result of an approach with a formalist bias. This argument needs further analysis, because the term 'functionally redundant' may in some circumstances be misleading. Symbolism may serve the practical desideratum of

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45. Smith, *op. cit.*, p.3.

purpose, even if the purpose is a metaphysical or magical one. By the same token symbolic forms are not necessarily arbitrary, but may be inherent in the problem. When symbolism is deeply felt and purposeful, it is a legitimate generator of architectural forms. However, a stage is reached when symbolism as a live issue ceases to operate, and becomes mere habit. Thus, when we follow in Smith's analysis the transmission of the arcaded gallery from pagan palaces of deified emperors to the Royal House of Christ, until we see it at its climax in the arcaded fronts of Lombardic and Tuscan churches, we speculate with him, "and wonder to what extent the traditional palace symbolism had begun to fade into a decorative aesthetic by the end of the Romanesque period ..." 46. Thus it is not living symbolism, but 'frozen' symbolism - when symbolic forms are transmuted to traditional forms - which generates formalism in architecture.

Through tradition, by constant repetitive associations, certain symbolic forms become perpetuated. Conversely, certain forms become, in perpetuity, regarded as symbolic of certain attributes. The association may be anthropomorphic - the Doric order is characterized as masculine, the Ionic as feminine: or it may be a mood association - this colonnade is grave or dignified, that scroll is gay. Certain forms are regarded as symbolic of power, others of luxury. These attributes of symbolism are common to all eras of architectural endeavour; and in so far as they give appropriate concrete form to abstract concepts of character, or make articulate the purposes and motivation of man, they are proper and valuable means to legitimate architectural ends. They must, however, be recognized as formalist disciplines, which, to the extent that they are regarded as sacrosant and unchangeable, must be disciplines inherently capable of frustrating practical ends and purposes.

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46. Ibid., p.37.

In Roman Imperial times such types of associative, tradition-bound symbolism were widely evident. Roman symbolism derives partly from Hellenistic sources, as Baldwin Smith [47] has been at such pains to demonstrate, partly from native traditions, [48] partly from the character of the people, and partly from the needs of the ruling class.

As has been pointed out elsewhere, [49] symbolism of the ruling class in Rome was manifest in buildings for propaganda purposes. In the case of monumental architecture, it is certainly the case that he who pays the piper calls the tune. For the creation of great buildings, the control of land, capital, labour and material is an essential prerequisite. Architecture subserves the motives of the man or group who has the power to cause its creations. Its symbolic forms underline his purposes; it is propaganda in concrete form for his aims; it attempts to facilitate the perpetuation of his ideals.

Symbolism in Rome is therefore concentrated specifically in two directions: propaganda on behalf of the State, and propaganda on behalf of the Emperor as personification of the State. Thus the strength, dignity, stability and grandeur of the State are impressed upon the peoples of the Empire by the identical characteristics of the architecture built under the patronage of the State. We have a state which is "cultivating by every means

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47. Ibid., passim.

48. "The Romans had their own symbolic traditions long before they learned from the Hellenistic East the value of impressive architectural forms as a means of conveying ideas and strengthening popular beliefs. It was only after the solemn deliberation of the Senate that Caesar was granted the honour of having a gabled roof (fastigium) on his dwelling." Ibid., p.5. The gabled roof, by traditional association with the temple, had acquired spiritual connotations, and Caesar, in being permitted the use of the gable, derived therefrom an aspect of divinity.

49. The present writer has discussed this point extensively in Herbert and Furmanovsky, Architecture and Society, unpublished thesis, University of the Witwatersrand, 1946.

at its command a kind of monumental propaganda to impress the masses throughout the provinces ...." 50. The symbolism of buildings reinforced the symbolism of ritual and tradition. This we shall see in a later section, when we look at the symbolic implications of the monumental arch, or the Imperial palace. At this stage however the operative principle must be noted.

> The Romans desired to make their public buildings and monuments throughout the Empire an impressive manifestation of the enduring supremacy of the State. This meant that the architecture associated with the ruler was intended to be seen in relation to the ceremonies as an expression of the divine and cosmic nature of the emperor who was the embodiment and personification of the State. 51.

Certain important architectural consequences follow. Firstly, certain architectural forms and motifs become associated with certain ceremonies, 52 and these are perpetuated for their symbolic connotations. These we shall study in the later section, where we deal with the characteristics of symbolism as it affects Roman architecture. Secondly, the entire character of Roman architecture may be affected by these symbolic implications. The detailed consequences of this we shall also defer for later study, but the general statement must be amplified here.

It must be recognised that architectural symbolism cannot afford the nuances and subtleties of the spoken or written word. It must be obvious and direct, and to be effective must be broadly-based, upon the most popular level of appeal. It is intuitive and emotional rather than intellectual. Imposed by the rulers upon the ruled, ".. its forms, which transcended anything within the attainment of the ordinary man, were the most memorable means by which the people could visualize the grandeur,

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50. Smith, op. cit., p.4.

51. Ibid., p.74.

52. As in the case of the gabled roof discussed in note 48.

power, and superhuman authority of their earthly and spiritual lords." 53.

The characteristic qualities of such an architecture must be monumentality of scale, grandeur of ornamentation, luxuriance of materials. We cannot expect subtlety, restraint, modesty, refinement; we must not be surprised at blatant vigour, and an accompanying coarseness of detail. In a sense, architecture deriving from these concepts of power symbolism must be architecture of immediate and overwhelming effect, not architecture for contemplative appreciation.

Moreover, the language which such symbolic architecture speaks must be traditional. It must reiterate that which is familiar and customary, if it is to be understood on a broad basis. Symbolism is therefore a tremendous force for conservatism, for it perpetuates traditional forms. We have many examples in contemporary history, notably in Soviet Russia, Fascist Italy, and Nazi Germany, to demonstrate how architecture for propaganda is inevitably reminiscent in form, recalling nostalgically and emotionally the echoes of a heroic past. Roman demagogues were equally facile in showing their descent from a lineage of traditional heroes, and in bolstering their status by the prestige of the past. This approach, is essentially a romantic one.

Geoffrey Scott 54 has argued that romanticism conceives style as a stereotyped language, and stimulates an architecture unduly stylistic and unduly antiquarian. At first glance it may seem paradoxical to talk of the Romans as romantics. This hardy, stern, practical race epitomizes the virtues of levelheadedness and a realistic outlook. Yet, as Edith Hamilton has so perceptively realized, "What we today call realism ... always

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53. Smith, op. cit., p.5.

54. Scott, op. cit., p.54

has romance for a companion." 55. Where realism reveals the ugliness and harsh brutalities of life, there is always a romantic reaction.

> The Greeks, who would have nothing to do with extremes, knew neither the one nor the other. They were realists to whom the real was beautiful and the direct expression of that spirit is classic art. But the Romans, to whom the real was the reverse of beautiful, ended inevitably by turning away from it to romance. 56.

We shall see in the next section an analysis of the architecture stimulated by these concepts. Here the point must be made that the Roman way of life, with its strongly conservative and traditional component, has a propensity for associative and symbolic form. This propensity may be seen in the many a-functional, purely symbolic structures, such as triumphal arches, commemorative columns, etc. developed by the Romans: and in turn these structures stimulated a purely formal approach to their design, and consequently to design in other fields.

We must recognize the ambivalence of symbolism. We have in Roman times certain structures (e.g. the aqueducts) which are derived from practical considerations of purpose and structure, but which, by the nature of the forms derived, are symbolic of the power of the Empire; we also have structures (e.g. the triumphal arches) which are symbolic in purpose (and may even utilize the same elements of majesty as the aqueducts), and whose forms are determined only by their relevance as symbols. It is clear that although the final forms may be similar, the motivations are different, as are the relationships of form to context.

There are two aspects of symbolism in its relationship to formalism. The one aspect is, as we have seen, romantic. The other aspect of symbolism is discussed by Bosanquet apropos of Plotinus's concept of symbolism, where art is no longer considered imitative, that is, governed by ordinary perception,

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55. Hamilton, op. cit., p.118.

56. Ibid., p.119.

but becomes charged with symbolic associative content. The consequences of this re-orientation are most important.

> As we should anticipate, the identification of beauty with mere symmetry, or unity in variety - the limitation which makes aesthetic purely formal - is broken down when the beauty of art ceases to be subordinated to the standards of ordinary reality. [57]

Symbolism, considered in this aspect, is simply expressionism. This expressionism is, as Bosanquet sees it, antagonistic to formalism in its narrow, geometric sense: but it is productive of formalism in terms of the wider definition which we have adopted throughout this thesis. Considering as we do that formalism is the attitude to architecture where the forms of the building stem from considerations of neither structure nor purpose - that is, Bosanquet's "Standards of ordinary reality" - but from non-functional, non-structural (that is, in terms of our definition, non-intrinsic), disciplines; then we must interpret the type of architecture whose forms are determined by association and symbolism as being formalist architecture.

SYMMETRY.

The type of monumentality demanded by Roman symbolism was most readily achieved by symmetry. Monumentality represents achievement rather than striving, being rather than becoming. It is the summation of an accomplishment rather than the process. Thus monumentality is usually concerned with the stable rather than with instability. Perfect balance is the balance of identical, rather than merely equivalent, forces: and this perfect balance of identical forces about a central axis, constitutes a definition of symmetry as we use the term today. In the Vitruvian [58] usage of the word, however, symmetry is used

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57. Bosanquet, op. cit., p.114.

58. "The design of temples depends on symmetry, the rules of which architects should be most careful to observe. Symmetry arises from proportion, which is a due adjustment of the size of different parts to each other and to the whole; on this proper adjustment symmetry depends." Vitruvius, op. cit., (Gwilt translation) III:1. See also note 2 above.

loosely as synonomous with good proportion, or the just relationship of part to the whole. [59]. This connotation of the term has not been lost, and the dictionary definition of "symmetry" still speaks of proportional relationships rather than of balance and identity of the parts. [60]. In the Vitruvian sense, as in the primary dictionary sense, there is always the implication of the value judgements, the "due" or "right" proportions, and the "pleasing whole", and the resultant "beauty". It is interesting to note that for those trained upon classical precepts, these two meanings are perhaps one. For the classical architect, the beauty of symmetry is achieved only by the rigid application of the "mathematical" symmetry of identically disposed parts. In classical times, there was therefore no dualism in the concept of symmetry. Today, of course, we are somewhat divorced from the classical vision, and we can conceive a 'symmetrical' architecture (i.e. an architecture where due proportion of the parts results in a pleasing whole) which is, in the mathematical sense, not symmetrical. Such dualistic concepts do not find expression in Roman architecture: rather does that architecture make concrete the concept that beauty lies in the rigid application of the principle of identical (or pseudo-identical) balance.

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59. Vidâ Scholfield, op. cit., pp.19, 20, for an analysis of the meanings of proportion and symmetry. Scholfield considers that the Vitruvian term "symmetria" connotes relationships of the parts in terms of a smaller part or module; "proportiones" are relationships of the parts to the size of the whole. He admits the Vitruvian usage of words to be confused, and sees the difficulty of translating Greek words, such as that for proportion, ("which is used in many different senses by Greek writers, including 'commensurability', 'symmetry', 'proportion', 'suitable relation' and 'convenient size'") into Latin.

60. The Consolidated Webster Dictionary defines symmetry as "a due proportion in size and form of the parts of a body or structure to each other: such harmony of parts as produces a pleasing whole." Only in the botanical and mathematical usages of the word does it suggest the sense in which we use it today. The Oxford Pocket Dictionary gives as its first meaning "Right proportion of parts, beauty resulting from it....." and only as its second meaning the definition which we understand today: "Divisibility into two or more parts each of the same shape and size as the other (s) and similarly placed with regard to the dividing point (s) or plane (s) or line (s)."

There are precedents for this rigid attitude, wherein symmetry is regarded simultaneously as a means and as an end in the problem of achieving significant architectural form. There is the inexorable axiality of the Egyptian Temple, and the symmetrical balance of the Doric Temple (although this symmetry is confined to the actual building, and not to the building-site relationship). There is, closer at hand, the axiality of Etruscan design. In Rome, however, we find the principle of axial planning carried to its ultimate - perhaps not to be equalled until the seventeenth century. The axialities of the fora; the symmetry - in the compartments, but not in the totality - of the Palatine hill; the plan disposition of the thermae; all these exemplify the principle of symmetry. The monumental column and the triumphal arch are the paraphernalia of an axial planning system culminating in selected vistas. The circular plan - to which the Roman architects demonstrated a marked affinity, as in the Vestal Temples, the Pantheon, the Mausoleums of Augustus and Hadrian, and the domed halls of the Thermae - is the ultimate product, short of the omni-symmetrical sphere, cube and dodecahedrons, in the search for symmetry, in that is is symmetrical from all horizontal points of view.

The concept of symmetry gives the Roman architect a preconception of form. It arises from the psycho-philosophical disciplines, and reflects the formalist attitude to architecture. It implies all sorts of limitations to the effectiveness of the design from the functional, materialist, practical point of view. It dictates plan shapes and dispositions, fenestration and orientation, according to criteria other than, and often in conflict with, the functional requirements. In extreme cases, it leads to redundancy and duplication. Inevitably, as we shall see, it must come into conflict with the practical attitude to architecture, as exemplified in the "architects handbook" chapters of Vitruvius to which we referred earlier. Of pseudo-symmetry, or the attempt to reconcile this conflict, we will have more to say later.

CHAPTER FIVE

FORMALIST CHARACTERISTICS OF ROMAN ARCHITECTURE

MONUMENTALITY.

If one were to seek a single epithet which would evoke in our minds a faithful image of the character of Roman architecture, that word would be "monumental". The monumentality of Roman architecture, although it derives partly from the practical attributes of material structure and purpose, is an expression symbolic of Roman power, and formally derives from the symbolic concept. The architectural components of this symbolism of power are s[illegible].e. magnitude of physical dimension), scale (i.e., the [illegible]act of size upon the human observer) and dignity (i[illegible]acter commensurate with the inherent seriousness o[illegible] symbolic purpose; this ranges from grandeur to pomposity). Sheer physical size is epitomised in the Colosseum, the Thermae of Diocletian and Caracalla, the Maxentian basilica, the Circus Maximus, or Hadrian's Villa. Monumental scale is achieved in all these structures, but particularly in the Thermae and the basilica; in addition, the engineering structures - the bridges and aqueducts - are marked by a noble sense of scale. Spatially, the Pantheon must rank with the great exponents of the monumental scale. The rhythm of these Roman buildings is slow and broad. Their essential rhythm is Wagnerian - slow, majestic - and the resultant character is grave. This gravity of character, this inherent seriousness, arises partly from the monumental scale of the buildings, and partly from the structural elements. Where the structure (or the apparent structure) is trabeated, it carries with it a sense of inevitability and balance inherent in the contra-poising of horizontal and vertical. The round arch, too, is by nature static rather than

dynamic, suggesting a complete resolution of the forces involved, and so again producing an architecture of composed balance and gravity. The frequent combination of both trabeated and arcuated systems which, as we shall see, so characterised Roman architecture, united the static balance of the first with the weighty gravity of the second, and the resultant was an architecture of the highest monumental content. Roman architecture is often heavy, often pompous, often lacking in profundity - but its concept of basic structure and space is always monumental, never frivolous or merely charming. There is an underlying formal consistency in Roman architecture, which stems directly from the conscious fulfilment of symbolic function, and from the p -petuation of symbolic forms. The formal relationship between the Pantheon and the Maxentian basilica is of the first sort. Although the plan shape and the structural system of these two buildings are very different, yet they are one in the atmosphere of grave dignity and monumental spaciousness which derives from a single vision and a common symbolism. On the other hand, despite the formal similarities, there is the world of difference in character between the aqueducts and the triumphal arches. Here the similarity is not that of motivation, but of a perpetuated grammar of forms. Perhaps this latter type of secondhand formalism is best demonstrated by comparing the Theseion at Athens and the Maison Carree at Nimes. The vocabulary - rectangular plan form, trabeated system of construction, classical orders, pitched and gabled roof - is identical: but in character the final products bear no resemblance to each other.

SYMBOLIC FORMS

In our comments on the importance of Symbolism to the Roman building, we referred two points forward

for further discussion. These were the architectural forms and motifs which were perpetuated deliberately for their symbolic connotations; and the monumental character of building which was exploited as a symbol of Roman power.

In the discussion on particular symbolic motifs I shall follow in the main the argument of Professor Baldwin Smith,[1] whose studies in the field of Imperial symbolism are valuable not only for the light they throw upon Roman architecture, but for the thread of continuity which they establish from the Hellenistic palace through Rome to the Romanaque church. He states his thesis as follows:

> The exact intent of this imperial symbolism is difficult to interpret because the separate architectural features, when removed from the beliefs and public ceremonies which gave them their content, look to our rational and unimaginative age like mere conventions of design. Nevertheless, when such elements as the city-gate, towered facade, castrum, cupola, orbis, royal ciborium, and domical vestibule are seen as forms of palace symbolism and are reviewed as historical ideas from their inception down to their adaptation by the Christian Church, they reveal a consistent use and a persistent expressive intent.[2]

In order to highlight this contention, let us look briefly at two examples only: the triumphal arch, and the domed hall. Of these two building types we have ample evidence and our discussion is thus firmly based upon fact.

The triumphal arch, deriving probably from timber antecedents as a temporary structure[3] commemorated the victory of a Roman general - which meant, under the Empire, the glorification of the Emperor himself, as

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1. Smith, op. cit., passim.

2. Ibid., p.5. The simultaneous origin of art and ritual is discussed by Herbert Read, op. cit., (Icon and Idea), p.57, in a passage where he rejects the concept of the priority of the rite.

3. Smith, op. cit., p.24; Talbot Hamlin, "Triumphal Arch", Encyclopaedia Britannica, 22:487.

commander-in-chief under whose auspices the general served. Attired like the Capitoline Jupiter in robes of purple and gold, with a laurel branch in his right hand, an ivory sceptre surmounted by an eagle in his left, the Emperor rode in triumphant procession from the Campus Martius through the city to the Capital.[4] The arch was thus part of a ceremony of great richness, with strong religious connotations. "The Roman Triumph, especially as it influenced popular ruler - concepts and gateway symbolism, had much in common with the Hellenistic Epiphany and Imperial Adventus. All were ceremonies of welcome whose rites of deification gave a celestial content to the arcuated portal."[5] The religious symbolism of the triumphal arch in Imperial times becomes intimately tied up with the cult of divi imperatores, which, after Augustus, became a religious and political force throughout the Empire.[6] The symbolism of the archway is therefore two pronged, emphasising not only the temporal power of the Emperor, but his potential divinity, if we might put it that way. The archway becomes a symbol of heaven.

> There is an intimation of why the Roman public associated the archway with heaven in the fact that the Porta Triumphalis became known as the Arcus Divorum. This kind of imagery, however, was merely the continuation of much earlier ideas.... As Cooke has pointed out, man visualized the arch as a sky image because they were accustomed to think of the figure of a triumphant general on his arcus as the embodiment of the supreme sky-god on the arch of heaven. During the Empire this habit was further strengthened, when the Triumph and Adventus had become a form of Emperor-worship and the passage through the arch was celebrated as the apotheosis of a divine Augustus."[7]

With this religious connotation, it is not surprising

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4. "Triumph," Encyclopaedia Brittanica, 22.487.
5. Smith, op. cit., pp. 21-2.
6. According to Sandy's, op. cit., p.293.
7. Smith, op. cit., pp. 30-1.

that the triumphal arch is taken over in the Early Christian Church, where although its context is so different, its essential symbolism is unchanged.

The transference of the symbolism of semi-divine power from the Porta Triumphalis to the arcade crowning Imperial gateways, and thence to the façade of Imperial palaces, can be traced step by step.[8] Eventually the arcaded gallery becomes a symbol of Imperium Romanorum, of Imperial power. It becomes an established phrase in symbolic language, and can eventually be recognized in various diagrammatic forms and mutations.

> When Diocletian, the living Jove, constructed his palace overlooking the Adriatic the arcade was already so traditionally identified with the heavenly abode of a divine ruler that he had it sculpturally translated into a decorative arched corbel-table above the Porta Aurea as the ceremonial entrance, and had statues of the gods and perhaps of the royal family set into the openings of the arcade. The fact that it was an established mark of Imperium, with all the celestial implications customarily associated with a sacrum palatium, is proved by the importance which is given to the motif on the "Palace of the Exarchate" at Ravenna."[9]

Fig.23

In a later section, we shall look at the development of the arcaded gallery from another point of view, as the resultant of the transmutation of structural into decorative forms. In making this analysis, we must bear in mind the implications of symbolism which this motif embodied.

As a further example of the development of architectural forms with specific symbolic associations, let us examine that most Roman of architectural forms, the dome. The relationship of the form of the dome and its decoration to sky-symbolism has been extensively dealt with by many writers.[10] It is not our intention

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8. For this development see ibid., pp. 31 et seq.

9. Ibid., p.34.

10. Notably by Smith, ibid., and also in The Dome, Princeton University Press, 1950. K. Lehmann, "The Dome of Heaven", Art Bulletin, XXXVII, 1945, pp. 1-27; and Herbert Read, op. cit., (Icon and Idea), pp. 67 et seq.

here to recapitulate the entire argument, but only to relate it to the appearance of the dome as an important factor in Roman architecture. Dome symbolism is partly related to the cosmic significance invested in curved and spherical surfaces, vestiges of which we have seen already in the arcuated portal, and partly to the shape and decoration of the Sacral Tent, such as was used by divine rulers of practically every ancient culture, and is exemplified by Alexander's "Tent of Heaven".[11] This celestial tent is part of the royal ritual of those quasi-divine rulers of the Hellenistic period and of Egypt from which the Roman Imperial cult drew so much inspiration, and the symbolism of the sky-tent is transferred in shape and decoration to the vaults and domes of Rome.

This is all straightforward, a logical transference of ideas and forms. The particular importance of Smith's thesis in the understanding of this development, is the emphasis he places upon the dome in relation to the Imperial palace. The dome is not just a symbol of divinity, it is a symbol of imperial divinity; it is associated not only with the ritual of worship, but particularly with the ritual of emperor-worship. It is thus to be found not only in the temple of the gods, but in the palace of the emperor; and particularly in the vestibule of the palace, which was the focal point of palace ritual and ceremony.

In our discussion of Roman constructive principles, we referred to the domed vestibules of the palaces of Augustus and Nero, and the villas of Hadrian at Tivoli. These domes were discussed as illustrations of the Roman practical attitude, as examples of

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11. Smith, op. cit., pp. 115 and 145.

Roman technical mastery. The motivation for the development of the dome, it was inferred, was partly in the challenge of the problem itself, the creation of a large space unimpeded by internal supports. We must now consider whether, while this statement is true, it is indeed the whole truth.

The physical challenge of the conquest of space is evident in the dome of the Pantheon, spanning 142 feet, or in the domed calidarium of the Baths of Caracalla, of almost similar magnitude (about 120 feet). On the other hand, the domed rooms of the palaces are relatively small: the vestibules of the large Palace of Hadrian, the small Palace of Hadrian, and the Palace of Diocletian are all in the neighbourhood of 40 feet, while the domed vestibule of the Imperial Palace at Constantinople is the smallest room in the whole suite. It is obvious that the motivation for the use of the dome in these cases cannot be structural, and the evidence for the symbolic derivation becomes more compelling. We must acknowledge that, even if the domes of the Domus Augustana and Nero's Golden House are limited by technical immaturity at that early date, and that they represent the maximum spans achievable by domes at that time, yet there were other forms of roofing available, and that the choice of the dome cannot be impelled by structural considerations. Furthermore, the 140 foot Pantheon dome and the 40 foot dome of Hadrian's Villa are both representative of the same Imperial epoch.

The small domes represent the perpetuation of an architectural form because of its symbolic connotations. The great domes of Imperial Rome, however, must be regarded as exhibiting two forms of symbolism, for if, on the one hand, the form evokes a religious response through associations of the sort we have been

examining here, then, on the other hand, there is, in the physical achievement of vaulting the great span, an evocation of pride in the power of man himself. A dome such as that of the Pantheon is symbolic simultaneously of both spiritual and materialistic essences. There is the symbolism imminent in the form itself, and there is the symbolism of the achievement of the form.

We must first consider the inherent associative, symbolism of the Pantheon dome. In an eloquent passage, James Lees - Milne, writes

> The be-all and end-all of the Pantheon was of course the dome; and there can be no doubt that it was purposely made symbolical. Whereas the Gothic cathedrals of the Christian builders were aspirant - their pointed pinnacles and spires reaching to the highest heaven in joyous praise of a beneficent Almighty - the Pantheon was meant to be propitiatory. Instead of striving to epitomize in stone the supreme attribute of a single celestial god, the architect of the pagan shrine endeavoured to devise a wordly habitat which the elusive Roman deities might condescend to visit from time to time. In other words the dome was meant to be a microcosm of that limited universe which the Roman civilization understood... The concave dome, "seemingly suspended in the air," as John Evelyn saw it, was the finite sky and the central circular opening the sun, the only source of light and life ....[12]

The concept expressed by Evelyn, of a dome suspended in the air, is the critical factor in our discussion. In any consideration of the dome as microcosmic symbol of the universe, the separation of dome and the realities of support - and thereby the connection with the earth - becomes imperative. The dome must be read as an entity unrelated to the more tangible presence of the support. In the Pantheon, this separation of dome and support is achieved in several ways, of quite remarkable subtlety.

The most obvious of these techniques of separation is the use of the boldly-projecting upper cornice,

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12. J.Lees-Milne, Roman Mornings, London, Allan Wingate, 1956, p.19.

which sweeps round the interior unbroken to provide a strong visual delimitation of drum and dome, an effective cut-off between the two spaces. This isolation of dome and drum is accentuated by the failure to correlate the ribs of the coffered dome with the module of the columns in the drum. We have drawn attention to this lack of correlation in our structural analysis of the dome. It may now be tentatively suggested that the misalignment is not accidental, but a deliberate subtlety by which the division of dome and support may be accentuated. The columns in the niches are the only visible forms of structural support; they are separated from the load of the dome, however, by the structurally neutral attic storey. The most telling factor of all, perhaps, is the ratio 1:1 which exists between the height of the drum to the cornice, and the radius of the dome. This vertical duality effectively separates the cylinder and the hemisphere into two visually independent elements.[13]

This emphasis upon the independence of the dome from all structural support is perhaps a factor in the Roman avoidance of the pendentive dome.[14] Otto Demus, discussing the dome on pendentives, writes: "Byzantine architecture is essentially a 'hanging' architecture; its vaults depend from above without any weight of their own. The columns are conceived aesthetically, not as supporting elements, but as descending tentacles or hanging roots."[15] The pendentive forms a bridge between heaven and earth, a link between the dome and the ground.

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13. This separation of elements, so necessary to the concept of the dome, is contained within the over-riding unity of the space, arising out of the correlation of the total height of the structure with its diameter.

14. See the discussion of this problem in Chapter Three.

15. Cited by Read, op. cit., (Icon and Idea), p.70.

It is an element of continuity, not separation. As such, it is incompatible with the Roman symbolic intention. There is, in this Roman creation of a microcosmic universe, a reflection of the Roman search for order. The sky-symbolism of the dome is significant, for, as Bevan has pointed out, the sky, in

> its higher regions above the clouds, is a world of order. While the terrestial world offered primitive man a region in which regular law seemed to prevail only in particular strands (fire always burnt, and so on) amongst promiscuous irregularity, the movements of the shining bodies seen in the world overhead repeated themselves with invariable regularity.[16]

The acceptance of this symbolic vision is in a sense a Roman flight from disordered reality to the ideal world of order: and as such it is yet another manifestation of underlying strata of romanticism in the Roman character. This romanticism is especially evident in the symbolism of the large dome. Size - sheer dimensional magnitude - becomes an important factor. If the dome is to represent the universe, perhaps it should also represent the infinity of the universe. The sublimity of the sky lies in the limitless expansion of its space: and, in Roman dome design, the suggestion of infinite space becomes of great importance. Great size, and the suggestion of even greater dimension, become the means of achieving the ultimate goal of limitless space.

Dome symbolism derives not only from the sky-tent concept, but from the essential sublimity of height and space. Herbert Read[17] discusses this point in relation to Edwyn Bevan's concept of height "as a quality whose apprehension led to feelings of reverence and sublimity," and while regarding height merely as a function of space,

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16. E. Bevan, Symbolism and Belief, cited by Read, ibid., p.146, n.27.

17. Read, op. cit., pp. 146, notes 27.

concedes that, as an expression of infinite spatial consciousness, height "enters into man's transcendental imagination". He also cites Morey's view that "the first great structure that displays the change (in spatial expression, G.H.) is the Hadrianic Pantheon in Rome, built at a time when the transcendental element was fast transforming Mediterranean belief..."[18]

Space, and the suggestion of space: upon both of these factors rests the Pantheon's intimations of infinity. The actual physical dimensions are, even by present-day standards, most impressive, and in the eyes of Hadrian's contemporaries, the size must have appeared overwhelming. The architect of the Pantheon did not let the matter rest there however. He very cleverly subdued the effect of the dome externally, by burying it partially within the mass of the rotunda wall; and by reducing its apparent height externally, he, by virtue of the subsequent surprise and contrast, accentuated dramatically its apparent size internally. This exaggeration of size is amplified, moreover, by the diminishing perspective of the coffering, which leads the eye compellingly upwards, to culminate in the hypaethral opening at the apex, where the aura of light causes an elision between suggested and actual infinity of space.

The vaulting of this great space is in itself an achievement symbolic of Roman power and material invincibility. Structures such as the Pantheon, and others of similar magnitude, must be regarded as monumental symbols of Roman materialist achievement. Let us low look more closely at this, the second aspect of symbolism.

Baldwin Brown, in his sensitive analysis of

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18. Ibid., p. 147, n.30.

the aesthetics of the Pont du Gard, writes: "Utilitarian in intent as the structure may be, it is yet ideal in its expression of Roman Imperial majesty. The Romans discerned a practical utility in display, and there underlies the massiveness and grandeur of the great engineering structures a real though perhaps unconscious effort after aesthetic expression."[19]

We have seen, at the beginning of this chapter, that the characteristic expression of Roman architecture is monumentality. It may well be that this monumentality stems from the vast nature of the projects concerned, and the bold techniques of building. However, the resultant character, the monumental nature of the architecture, carries with it an undeniable expression of power and grandeur. It is natural to transfer the character expressed by the building to the builder of it; and we regard bold and dignified structure as speaking for the courage and dignity of the man who caused it to be raised. This transference of attributes between builder and that which is built is symbolism of the most potent sort, for it relies not upon any intellectual understanding of the archtypal forms, but upon an emotional einfuhling or empathy. However, we would be doing the Roman architect less than justice if we regarded the symbolic expressionism of his work as fortuitous, the accidental bye-product of choices made in the field of structure and purpose or historical style. It is unthinkable that the Roman was unaware of the impact of his work upon the observer. Even though it may be thought that the monumental nature of Roman work was an inevitable result of the

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19. G. Baldwin Brown, "Roman Engineering Works and their Aesthetic Character," The Journal of Roman Studies, 22:1932, p.49.

Roman character, it is not necessary to assume that it was an unconscious process, taking place without the volition of the architect. We believe, with Brown, that the Romans "discerned a practical utility in display," and contend that much of the architecture of display was consciously designed for a given symbolic purpose. This conscious fulfilment of symbolic function has given rise to some of the greatest of the Roman monuments. It is significant and characteristic that these are not usually the formal monuments, but rather the monumental utilitarian structures.

We have, in our discussion of Roman engineering achievements, referred in some detail to the Roman hydraulic systems. It may be recalled that we discussed the Roman preference for a gravity - feed aqueduct system over the syphonic pressure system: and came to the conclusion that, on practical grounds alone, it would not have been altogether explicable for the Romans to have persevered with the more clumsy and less scientific aqueducts. We suggested, finally, that in addition to the deterrent to the pressure system provided by an inadequate theory and technology of metallurgy, and an inadequate theory of hydraulics, we should nevertheless seek for a positive motivation for the choice of the visible aqueduct. This positive motivation, we now suggest, may be sought in the concept of symbolism.

Gest draws our attention to the opinion of historians and engineers upon this important topic.

> Duruy, in his History of Rome, ascribes the building of the high aqueducts to the fondness of the Romans for display, saying that 'rather than hide their aqueducts underground they caused them to traverse the Roman Campagna upon majestic arches,' and even Leger declares that they were constructed 'in great part to satisfy their amour-propre', and 'without great necessity'.[20]

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20. Gest, op. cit., p.104.

Of course, the phrase 'without necessity' is misleading, as Gest is quick to point out. It is, as we have tried to indicate in our weighing up of the problem, a question of emphasis. The choice is not between a functional and a non-functional solution; it is rather a choice between two valid solutions, each with practical advantages and disadvantages. The point at issue is: What determines the Roman's choice. Why does he choose the aqueduct, and not the syphon? The answer which we have elicited from this debate is: he chooses for many reasons, most of them severely practical; but one of his reasons is that the aqueduct solution is visually the more daring and the more impressive, and is therefore a more efficient symbol of the Roman virtues which he delights to extol.

We may see the same attitude in another field of Roman endeavour. The Roman highway engineer laid out his roads as straight as possible. As we have seen, the consequence of this refusal to adapt the road to the contours of the land, and to modify its course in the face of nature's obstacles, had a two-fold result. Firstly, the difficulty of the engineer's task was markedly increased, as he was forced to tunnel through, or bridge over, the obstacles he encountered. Secondly, because for practical reasons such as military security and invulnerability to snow and flood, he could not resort to cutting, the gradients of the road were often unreasonably steep. Gradients commonly encountered - and not in particularly adverse country either - were as steep as ten and twelve percent.

Why did the Romans choose to build straight roads, with all their attendant disadvantages? They were eminently practical men, and surely realized the foolishness of driving a road straight through at

all costs. There can be only one answer to this question, if our reading of the Roman character is correct. We have seen that a utilitarian approach, which is the normal approach, is only abandoned if the alternative, nominally non-utilitarian or anti-functional, has a utility of an altogether higher level. The preservation of the prestige of the state may be considered the epitome of utilitarianism to the Roman: and therefore practical utility must be sacrificed to the greater utility of symbolism. There is, in the creation of a straight road, an arrogance of man in the teeth of nature, an assertion of 'man the maker' as the greatest force. The straight road, we have said, is an instrument of Empire. We see now that this is not only because it facilitated communications. By far its more important role is its symbolic function. Wherever the road rides straight, up the hillside, through tunnels in the hearts of mountains, across mighty bridges over deep gorges and tumultuous waters, the road says to the subject peoples of the Empire: "I am the road of Rome. Nothing can stop me, nothing can deflect my path." We have no more effective example of power symbolism.

SYMMETRY.

We have seen earlier that symmetry is an instrument of Roman monumentality: and that in Rome the principle of axiality is carried to its ultimate expression, in the planning of baths, temples, fora, palaces. "What connects all these undertakings, from the rather modest Forum of Caesar to the enormous Bath of Caracalla..... is obviously axial symmetry and frontality," writes von Blanckenhagen.[21] If rigid symmetry is the main

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21. P.H. Von Blanckenhagen, "The Imperial Fora", Journal of the Society of Architectural Historians, V.XIII, No.4, 1954, p. 23.

characteristic of monumental Roman planning, we are confronted with two questions: how did it come about, and for what objectives? Von Blanckenhagen traces the derivation of the axial forum from two principal sources, the Hellenistic Sanctuary and the Roman Republican town square (with the Hellenistic agora as an influence which, while not obvious, cannot be excluded entirely.[22] Boëthius considers a tendency towards axial planning to be a distinctively Italic element in Roman design.[23] Ward Perkins denies that early Italian towns were regular in plan, but concedes that

> it is true that there developed, in late Republican and Imperial Roman times, a tendency to reduce planning to ready-made formulae, with a predisposition towards axial symmetry: at best, this may be taken to indicate a standardized, authoritarian approach to the problems of architecture; at worst, it argues a lack of sensibility to the finer possibilities of siting and layout.[24]

He draws attention to the Hippodamian influence, and to the possibility that in the rigid axiality of the castrum "military planning led the way" to the formality in the Roman town plan. As we have seen, in the previous chapter, the castrum constitutes a particularly pure example of a completely formal layout embodying the principle of rational proportions and axial symmetry. As for the meaning of symmetry and axiality, Von Blanckenhagen writes: "I think we must conclude that it is merely the pattern of the blueprint, a love of regularity for its own sake, a dealing with architecture in an almost abstract way."[25] This concern with the poche of the plan, with its pattern as a formal idealization, is the architectural embodiment of the Roman

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22. Ibid., pp. 23-4.

23. J.B. Ward Perkins, op. cit. (review of "Roman and Greek Town Architecture"), p. 175.

24. Ibid., p. 177.

25. Von Blanckenhagen, op. cit., p. 24.

preoccupation with systematization and order, which we have considered a mainspring of the formal attitude. The axiality goes beyond the single vision, beyond what is

Fig.24 immediately apprehensible. The Imperial Fora provide us with a striking example of axiality carried beyond the range of vision. In the progressive development of the fora, from the initial Forum of Caesar, through those of Augustus, Nerva, Vespasian and Trajan, Von Blanckenhagen's restored plan clearly shows how axes were maintained and alignments striven for, which could never have been apparent on the actual site, but only

Fig.25 in the plan pattern. He analyses the plan in these terms:

> One straight line can be drawn through the NE wall of the court of Trajan's Forum and the NE wall of Vespasian's Forum. On this line lie also the NE corners of both apses of the Augustan Forum. Another straight line runs through the back of the rectangular niches of the two NE apses of the Forum of Trajan (that of the court and that of the basilica) and also through the straight rear wall of the Forum of Augustus behind the temple. Since these two lines constitute, respectively, the enclosure of the two fora and the extreme limits of another pair of fora, I cannot believe that the regularity was not planned. This means that the architect of the Forum of Trajan designed the ground plan in accordance with the already existing complex, that is to say, the correspondences between his forum and Caesar's are to be understood as a part of a very well thought-out plan. It seems to me, though, that the architect of the Forum of Vespasian had already followed similar notions; the back of the SE colonnade of the Forum of Augustus and the back of the NE niches of the Forum of Vespasian, lie on a line which if extended to the NW runs through the front of the two small apses behind the NE wall of the Forum of Trajan.... the existing reconstructions now show the axis of the Forum of Trajan almost coinciding with the axis of the Forum of Vespasian ..... For me there can be no doubt that Apollodorus, the architect of the Forum of Trajan, conceived of his Forum as the final unifying element of the entire complex.[26]

The formality of the Imperial Fora is a sophisticated development of the orderliness which stamped the Roman castrum. But whereas, in the castrum,

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26. Ibid., pp. 25-6.

the necessity for order was partly based upon the ease and practicality of a simple layout, and the utility of a systematic control system, in the Fora the motivation for the symmetrical layout appears to be purely formalist.[27] It is perhaps an oversimplification merely to state that the Romans loved regularity for its own sake. This regularity, as we have seen, evoked the essence of monumentality: and that monumental essence was the architectural symbol of Imperial power and dignity. The Roman architect was doing more than creating a tidy plan in which the regulating boundaries and axes lined up; he was deliberately creating an architectural environment which would evoke the grandeur of the Empire.

We must bear in mind that although these relationships were not immediately apparent, they must have been sensed as one traversed from forum to forum. The memory retains impressions whose correlation to subsequent impressions is as sure and certain as it is unconscious. Memory also sets up, as its opposite pole, anticipation: and the satisfaction of anticipation is one of the prime functions of a unified work of art. There is a relationship of part to part, in the Imperial Fora, which is the substratum of all systems of unity and proportion.

PROPORTION.

We have seen, in our consideration of the theory of proportion, the emergence of two different aspects. The first is relatively simple being con-

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27. Although the axiality of the forum was purely formalist, the origin of the forum itself may have been practical. Lanciani, for instance, clearly thought so. He regarded the Forum of Trajan as a major scheme of civic improvement, whose prime aim - apart from the creation of a huge new open space - was the improvement of communications. The ridge which previously linked the Capital and the Quirinal - presenting traffic with an insuperable barrier, was removed (amounting to some

cerned with overall dimensional relationships. It is merely the relationship of the co-ordinates of a space in a simple and satisfying ratio. When we look at the monuments, we see that Vitruvius's dicta are not always rigidly adhered to.

It is of course possible to find very close approximations to Vitruvius's specified ratios, as Morgan has illustrated for us.[28] Thus, where we find in Vitruvius the recommendation that, for a peripteral temple exceeding forty feet in width, the length should be twice the width; we then have as an actual example the Corinthian Temple at Labranda, 45 feet 9 inches wide, where the length is just under twice the width. A temple <u>in antis</u>, we are told, should have a 3:5 ratio of porch: naos, and a 2:1 ratio of length: width; the Temple of Themis at Rhamnis complies almost exactly with these requirements. We must take these correspondences demonstrated by Morgan, and see if their generality can validly be expanded, both with respect of the number of examples, and with respect of the time range beyond the age of Vitruvius.

Let us first consider the ratio of length, width and height. As we have seen earlier, Vitruvius advocated for rectangular rooms a formula of height equals half the combined length and width. Although the Cellae of the temple of Fortuna Virilis and Maison Carree approximate closely to this formula, it is apparent that the rooms are too high, and as the rooms get larger, lower relative ceiling heights are favoured. However, the new ratios remain generally simple commensurate figures. The temple of Antoninus and Faustina, the temple of Saturn, and the 'nave'

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27. (continued) 24 million cu. ft. of earth and rock) and pressure on the whole traffic system in the vicinity was eased. R. Lanciani, <u>op. cit.</u>, pp. 86,7

28. Vitruvius, <u>op. cit.</u>, (Morgan trans.) p.115.

of the Maxentian basilica, are in the ratio of height equals one third the combined length and width; and in the basilica of Trajan the height equals one quarter of this sum. Other simple dimensional relationships also are found: the width of the barrel-vaulted temple of Venus and Rome is equal to the height, and in the Pantheon the height is equal to the diameter.

"....careful mark how far in hidden art the noble plan extends," wrote John Dyer in the eighteenth century,[29] paying tribute to the inner consonances of the Pantheon arising out of its fundamental proportional relationships. Sebastiano Serlio, two centuries before, had also responded to the Pantheon's aura of unity. "Among all the ancient buildings to be seen in Rome," he wrote, "I am of the opinion that the Pantheon (for one piece of work alone) is the fairest, wholest and best to be understood; and is so much the more wonderful than the rest because it hath so many members, which are all so correspondent one to the other...."[30]

When we consider plan proportions, we find again the simple dimensional ratios.[31] The ratio of 2:1, which Vitruvius advocated for rectangular triclinia, appears to govern the length - width relationships of many structures. Several peripteral, or pseudo-peripteral temples, including Fortuna Virilis, Saturn, Maison Carrée, are twice as long as they are wide. So, too, is the interior of the basilica of Trajan, the frigidarium of the Thermae of Diocletian, and also its two large peristylar courts. The Thermae

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29. Cited by Lees-Milne, op. cit., p. 21.

30. Ibid., p.1.

31. The figures from which these ratios are calculated have been obtained by scaling reconstructions of the plans and sections. They are necessarily approximate, but as the ratios are derived from dimensions of a high order of magnitude, the percentage error is unlikely to affect the validity of the general deductions.

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of Caracalla, in its overall dimensions, also has a 2:1 ratio of length to width.

However, where the dimensions are not the summation of inter-columnar spaces, this rationality of dimensioning is not so consistently found. Hence the interior dimensions of temple cellae, the interiors of the basilicas, or the tepidaria (or cellae mediae) of the Thermae, display more irrational and arbitrary relationships. Also, except in the columnar architecture, the ratios are approximate and not exact, indicating that they resulted rather from desired aesthetic effect than from the rigid application of aesthetic theory. For an understanding of these problems, we must consider the second, and perhaps more complex, aspect of proportional relationships.

The second aspect of Proportion, deals with the relationship of part to whole, and the determination of the proportions of the whole by reference to the part as standard.

This aspect of proportional relationship may be studied in two different, but related, manifestations. The first is where the unit which establishes the module occurs perhaps only once, as a major element, from which the dimensions of other important element derive. An example of this type of proportional relationship is the theatre, where the module is the diameter of the orchestra. The second type of modular proportional relationship is where the module derives from a standard part used repetitively in combinations which make up the whole. The prime example of this type of proportional facade is the columnar facade deriving from the Greek orders.

Vitruvius prescribes the ideal proportions

for Greek and Roman theatres.[32] This prescription is in the form of a geometrical diagram, based upon the ground circle corresponding to the line of the lowest row of seats. From this circle, an inscribed square, tangents to the circle, and various radials, all combining in a star-shaped figure, the principal elements of the theatre, such as the skene wall, the pulpitum, the stage, and the circle of seats, are derived. The theoretical diagrams of Vitruvius have been checked against actuality in two ways, namely as a geometrical check, in the studies of Margarete Bieber[33] and others, and as an arithmetical check, in the analysis of Madame Lepic[34]. It is of interest to comment upon some of the correspondences and deviations found.

The stage, according to Bieber[35], should range from 10 to 12 feet high. The theatres of Assos, Sikyon, Tyndaris, Eretria and Epidaurus, conform to those measurements, but exceptionally small theatres, such Priene, and exceptionally large theatres, such as Athens, deviate.

> Naturally, with the growth of the orchestra and the wider distance of the tiers of the seats, the height of the stage increases proportionally. The depth of the stage also depends upon the ground circle, since it must occupy about three-tenths of the radius of the orchestra. This is the case in Priene and Delos. The individual parts of the Greek proskenion theatre are organically and harmoniously correlated in their proportions. They must certainly have made a harmonious impression. Since, however, even in its latest forms the high shallow stage was not very practical, it was replaced even on

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32. Vitruvius, op. cit., V:6:1,2; V:7:1,2.

33. Bieber, op. cit., passim.

34. Wilhelmina Lepic, Mathematical Planning of Ancient Theatres as revealed in the Works of Vitruvius and detected in Ancient Monuments, Travaux de la Societe des Science et des Lettres de Wroclaw, Seria A. Nr. 22, Wroclaw, 1949. As there is no available translation from the Polish, I am dependent upon the review by Stillwell in American Journal of Archaelogy, 55:1951.

35. Bieber, op. cit., p.255.

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