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Le Corbusier and the creative use of mathematics

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> For the artist, mathematics does not consist of the various branches of mathematics. It is not necessarily a matter of calculation but rather of the presence of a sovereign power; a law of infinite resonance, consonance, organisation. Rigour is nothing other than that which truly results in a work of art, whether it be a Leonardo drawing, or the fearsome exactness of the Parthenon (comparable in the cutting of its marble even with that of machine-tools), or the implacable and impeccable play of construction in the cathedral, or the unity in a Cézanne, or the law which determines a tree, the unitary splendour of roots, trunk, branches, leaves, flowers, and fruit. Chance has no place in nature. Once one has understood what mathematics is – in the philosophical sense – thereafter one can discern it in all its works. Rigour, and exactness, are the means behind achieving solutions, the cause behind character, the rationale behind harmony.
>
> Le Corbusier, 1948[1]

Probably everyone reading this article has heard of Le Corbusier,[2] no doubt the most famous architect this century, but the images he will arouse in their minds may vary greatly. Some will blame him for those theories promoting standardized high rise construction, which have dominated town planning policy in post-war Europe. Others will admire his highly individual, sculptural buildings such as the church at Ronchamp (1950–55) (see Figure 1), the revolutionary public housing scheme of the Unité d'Habitation at Marseilles (1946–52) (Figure 2), its ground-level pillars (*pilotis*) and roof-level service stacks alike transformed into enigmatic statues, or his pre-war Purist villas in the Paris suburbs (1920s). His work displayed a wide variety of forms and spaces at any one time, and his career spanned almost sixty years, during which he was constantly questioning, and reformulating theories, and in consequence changing his formal language.

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1 'La mathématique n'est pas, pour l'artiste, les mathématiques. Il ne s'agit pas de calculs, forcément, mais de la présence d'une royauté; une loi d'infinie résonance, consonance, ordonnance. La rigueur n'est telle, que l'oeuvre d'art en résulte véritablement, qu'il s'agisse du dessin de Léonard, de l'effrayante exactitude du Parthénon, comparable, dans la taille de son marbre, à la taille même des machines-outils, de l'implacable et impeccable jeu constructif de la cathédrale, de l'unité que fait Cézanne, de la loi qui détermine l'arbre, la splendeur unitaire des racines, du tronc, des branches, des feuilles, des fleurs, des fruits. Il n'y a nul hasard dans la nature. Si l'on a compris ce qu'est la mathématique au sens philosophique, on la décèlera, désormais, en toutes ses oeuvres. La rigueur, l'exactitude sont le moyen de la solution, la cause du caractère, la raison de l'harmonie.' Le Corbusier, 'L'architecture et l'esprit mathématique', in *Les Grands Courants de la pensée mathématique*, Paris, 1948, 480–91, on 490; cited in Dario Matteoni, 'Modulor', in *Le Corbusier: Synthèse des arts. Aspekte des Spätwerks 1945–1965* (ed. A. Vorwinckel and T. Kesseler), Karlsruhe, 1986, 17–32, on 29.

2 Le Corbusier (1887–1965) was actually born Charles-Edouard Jeanneret. The name by which he is better known was invented to identify the new persona which he created for himself in the early 1920s, shortly after his definitive departure from his native Switzerland as part of the new identity he constructed for himself on his installation in Paris.

Figure 1. Le Corbusier, church of Notre-Dame du Haut, Ronchamp, near Belfort, France (1950–55) (author's photograph).

My interest here lies with how Le Corbusier, as an artist, used mathematics, and how such usage might contrast with how contemporary mathematicians seem to have thought mathematics ought to be used. This raises issues which are relevant to our own time, in which a comparable lack of mutual understanding prevails between artists and scientists. Despite our own expectations that an architect should straddle the arts–sciences divide, I think that we need to consider Le Corbusier as standing very firmly on the 'arts' side. There are several reasons for this: his architectural work is exceptionally sculptural, particularly in the post-war period. He had never really trained as an architect and had originally worked in Paris as a painter; indeed he continued to paint in a studio at home, quite separate from his office, on a virtually daily basis, until the end of his life. Moreover he also designed tapestries, enamels and sculptures. We should not be taken in by his verbal statements, with their claims for his technical competence, or commitment to industrialization. Whilst his interest in science was genuine, he lacked any formal training in the technical aspects of construction. The complaints voiced by several of his clients about the technical failure of the buildings he designed for them are undeniable.

Above all, Le Corbusier himself saw the modern architect as an artist rather than a scientist:

Figure 2. Le Corbusier, roof of Unité d'Habitation (housing block), Marseilles (1946–52) (author's photograph).

> I put today's architect in the artist's camp. By that I mean to indicate that, beyond the innumerable tasks of a practical nature which he has to accomplish, he is under an imperative necessity to make something that is graceful, that is in proportion.[3]

Le Corbusier invoked mathematics in different ways at different stages in his career. During his Purist period (1920s) he was obsessed with what he called *tracés régulateurs*. These are geometrical schemata believed, by certain people, to underlie works of art from all historical periods. The author Marius Cleyet-Michaud said in 1973:

3 'Je place l'architecte d'aujourd'hui dans le camp des artistes. J'entends exprimer par là qu'au delà des innombrables tâches de l'ordre pratique qu'il est obligé d'accomplir, s'inscrit comme une nécessité impérative celle de faire de la grâce, c'est à dire de la proportion' (cited in Matteoni, op. cit. (1), 27).

> We accordingly propose that for any given work we shall seek out a *geometrical schema* – a sort of fundamental schema – on which the composition is based. Schemata of this kind are often described as *regulating lines* (*tracés régulateurs*). We may be sure that in all periods many artists consciously based their compositions on geometrical armatures (combinations of geometrical figures), constructed exactly. This was possibly, for such artists, one way of freely imposing upon themselves those 'constraints' which Paul Valéry considers to be indispensable, even if they are arbitrary, which is to say meaningless.[4]

Essentially, this kind of theory – which is now very unfashionable – is an equivalent, for the theory of art, to the Platonic programme of not only seeking the mathematical structure underlying natural phenomena, of discovering the invariable laws governing the functioning of the universe, but also deducing physical truths from mathematical ones in an *a priori* manner. The above account is from a work addressed to a lay public, and was written in the 1970s, by which time such a style was no longer current in serious scientific circles. In the early part of the twentieth century, however, an essentially Platonizing programme had played an important part in certain areas of scientific enquiry, for instance in the explanation of the shapes of plants and marine animals.[5]

That Le Corbusier held similar views is shown by, for instance, his acceptance of an article about his work by Matila Ghyka, published in 1948, which included the following lines:

> The idea of proportion and the theory of proportions, established by the Pythagoreans, Plato, Eudoxus and Euclid, was built on the Pythagorean theory of the intervals of the diatonic scale. To these musical considerations are also correlated the Pythagorean and Platonic conception of the cosmos as a well-ordered and harmonious whole, the bulk of Platonic and Neo-Platonic aesthetics, as well as the planning technique of Greek and Gothic architecture, based on the principle of symphonic, that is harmonically modulated, composition.[6]

Moreover, Le Corbusier would retain such views to the end of his life, as is demonstrated by books which he bought and read in the 1950s.[7]

4 'On se propose, alors, s'agissant d'une œuvre donnée, de rechercher un *schéma géométrique* – une sorte de schéma de principe – sur lequel reposerait la composition. On désigne fréquemment les schémas de l'espèce par l'expression *tracés régulateurs*. … On peut tenir pour assuré qu' à toutes les époques, de nombreux artistes ont fondé consciemment leurs compositions sur des ossatures géométriques (combinaisons de figures géométriques) rigoureusement établies. C'était peut-être, pour de tels artistes, un moyen de s'imposer librement de ces *contraintes* dont Paul Valéry estime qu'elles sont indispensables, même si elles sont arbitraires, voire absurdes.' Marius Cleyet-Michaud, *Le Nombre d'or*, Paris, 1973 (5th edn, 1985), 111. The poet Paul Valéry, cited here as an expert on the theory of art, showed a considerable interest in the relationship between mathematics and art, perhaps demonstrated most famously in his article 'Introduction à la méthode de Léonard de Vinci' commissioned for the *Nouvelle Revue*, thanks to pressure exerted on the editor by Léon Daudet. Valéry wrote quite extensively on architecture, notably a dialogue 'Eupalinos ou l'architecte', published in *Architectures* (Paris, 1921). Indeed he corresponded with Le Corbusier, who sent Valéry a copy of his *L'Art décoratif d'aujourd'hui* (Paris, 1925); Valéry's response – agreeing with the arguments expressed in the book and praising it as 'admirable' – is reproduced in the English translation of the book: *The Decorative Art of Today* (tr. James Dunnett), London, 1987, p. xii.

5 See, for instance, D'Arcy Wentworth Thompson, *Growth and Form*, Cambridge, 1917, several later editions.

6 Matila Ghyka, 'Le Corbusier's Modulor and the concept of the Golden Mean', *Architectural Review* (February 1948), no. 614, 39–42, on 39. The Pythagorean consonances were indeed used in music, but Ghyka is mistaken in supposing they formed the basis of the diatonic scale.

7 Notably the collection of papers edited by Lancelot Law White, *Aspects of Form* (London, 1951), and Jacques Nicoll's *La Symmétrie dans la nature et les travaux des hommes* (Paris, 1955), the latter having been heavily annotated by Le Corbusier. Details concerning the contents of Le Corbusier's personal library are drawn throughout from the catalogue of it, in the Fondation Le Corbusier, Paris.

Although Le Corbusier's architectural work would change radically over the course of his long career, his fundamental desire to found it upon universal principles – thus ensuring that they would surpass the constraints of temporal and geographical specificities alike – remains constant. In this regard it is important to remember that, despite retaining a position in the vanguard of modern architecture even at the end of his life, in the 'swinging sixties' Le Corbusier was – both by birth and by general education – a product of the nineteenth century. For as we shall see, he was moulded above all by German idealism and the ideas prevalent in London, in the circle of Henry Cole, just after the Great Exhibition of 1851 (in the Crystal Palace).

During the years of the Second World War, Le Corbusier developed a dimensional system, which he called the 'Modulor', devised to bring together proportions which he believed to underlie both nature and the most enduring architecture of all time. This was intended as a standard for mass-produced dwellings – the preoccupation of government and architects alike in post-war France – and was first used in his own Unité d'Habitation at Marseilles; it was, in fact, applied in all his post-war projects. In 1959–61 a research project, funded by Renault, the French car manufacturer, enabled him to pursue further research into optimum dimensions for dwellings.[8] He also designed glazing units with proportions reflecting those found in musical harmony.[9] And he explored how rooflights must be sited in order to direct sunbeams (or moonbeams) onto symbolically significant spots on specific dates and times (the lectern in the Assembly at Chandigarh on Independence Day, the altar in St Pierre de Firminy at the Christmas Midnight Mass and the Easter Sunday High Mass).[10]

I shall focus on explaining Le Corbusier's work on the Modulor, because it is here that he actually came into contact with mathematicians, and indeed with serious, academic ones. But in order to understand what is going on there – why he is interested in using mathematics – we shall need to follow his development up to that point.

ORIGINS

Paul Turner, in his doctoral thesis on Le Corbusier's 'training',[11] has emphasized how far this young Swiss, born in 1887, fell under the influence of eighteenth-century Deism and German Idealism, for example through Friedrich Nietzsche's *Also sprach Zarathustra* (1883–92).[12] This predisposed him to become particularly susceptible to two books which

8 Judi Loach, 'Studio as laboratory', *Architectural Review* (January 1987), no. 1079, 77.

9 These *pans ondulatoires*, as they were called, were used most notably in the Dominican monastery of La Tourette, at Eveux, near Lyons, but were also used for the Palace of the Ministries at Chandigarh in India. For further details see Le Corbusier, *Modulor 2: La parole est aux usagers*, Boulogne-sur-Seine, 1955. All quotations will be cited from the English language translation: *Modulor 2: Let the User Speak* (tr. Peter de Francia and Anna Bostock), London, 1958, 321–30.

10 *Le Corbusier Sketchbooks*, annotated by Francine de Franclieu, 4 vols., Cambridge, MA, 1982, iv, No. 758 (sketch of 18 June 1961).

11 Paul V. Turner, *The Education of Le Corbusier: A Study of the Development of Le Corbusier's Thought 1900–20*, New York, 1977. All citations will be from the more widely available French language edition: *La Formation de Le Corbusier: Idéalisme et Mouvement Moderne*, Paris, 1987.

12 Le Corbusier bought a French language edition (*Ainsi parlait Zarathoustra* (tr. Henri Albert), Paris: Société du Mercure de France, 1908) in 1908 (Turner, op. cit (11), 227 and 231).

he encountered as a young student, Henry Provensal's *Vers l'harmonie intégrale* (Towards universal harmony) subtitled *L'Art de demain* (The art of tomorrow, published in Paris in 1904)[13] and Edouard Schuré's *Les Grands Initiés* (The great initiates, first published in 1889).[14] Neither of these was ever prescribed to turn of the century art students as standard texts. Provensal was an otherwise wholly unknown architect, trained at the Ecole des Beaux Arts in Paris, and the appearance in print of his idiosyncratic, essentially metaphysical theory, synthesizing an eclectic mixture of sources, passed pretty well unnoticed in Paris. Schuré's text was not about the visual arts at all but, as his subtitle suggested – *Esquisse de l'histoire secrète des religions* (sketch for the secret history of religions) – overtly addressed his metaphysical concerns for the future of civilization, proclaiming the need for a spiritual renaissance and urging a rejection of the materialism and positivism which he saw as poisoning modern society; his argument concluded with case studies of Pythagoras, Plato and Jesus, all seen as exemplars of mystical prophets.

Provensal was preoccupied by 'the Absolute', which reveals itself in art, through divine laws, 'eternal laws of unity, number and harmony'. The purpose of art is to raise man to a spiritual realm, and to do this it must use generalized, 'universal' forms. The 'art of tomorrow' will be characterized by its union with science, and thus the union of reason with sensibility. Since beauty is defined as that which is 'eternal and general' the artist should turn to nature to discover 'essential forms'.

Such ideas would have come naturally to Le Corbusier because they are so close to those of Matthew Digby Wyatt and Owen Jones, whose *Grammar of Ornament* (1856) was virtually a set text in the municipal art school of his home town in the Swiss Jura, La Chaux-de-Fonds, where Le Corbusier trained, essentially in industrial design. The teachers at this art school financed by a town governed by industrialists were, like Henry Cole's circle in mid-nineteenth century industrialized Britain, aware of the value good design could add to their products; like their British counterparts they turned to nature as a more appropriate source of inspiration than historic style for ornament in this revolutionary age of the machine. Later Le Corbusier would fondly recall how students were sent one by one into the hushed library to 'explore' Owen Jones' *L'Histoire de l'ornement*, which he understood as depicting the products of 'l'homme de la nature', man directly inspired by nature, but nevertheless man trained in geometry ('avec sa formation géométrique').[15] Provensal, however, goes further than either the English or Swiss designers had dared, to repudiate decoration altogether; the new architecture should be pared down to forms and spaces which play with light and shadow.

Schuré's *Grands Initiès* seems to have been a gift from his art teacher, when his young protégé left for his visit to Greece in 1907. Schuré conceives of art in an idealist and spiritual way as did Provensal, but in a less neo-Platonic way. The new spirit is the scientific one. The important thing for us to note is how Schuré defines 'scientific', namely as the realm

13 Le Corbusier had bought his own copy of the 1904 edition (published by Perrin) in 1908 (Turner, op. cit. (11), 231), the year in which a second edition appeared.

14 Le Corbusier used the 1908 edition published by Perrin, which he appears to have bought that year (Turner, op. cit. (11), 231); originally published in 1889, the book would be reprinted several times, up to 1931.

15 Le Corbusier, op. cit. (4), 135; English translation, 133.

of abstract thought, with a fair amount of space dedicated to number mysticism, notably the sort of thing that is usually associated with the name of Pythagoras.

Le Corbusier seems to choose, and interpret, his other early reading in the light of these beliefs. He reads Maurice Denis' *Théories*, whose vision of art (also idealist and enduring) emphasizes the need to look beyond the material and individual, to find deeper, universal and spiritual truths ('the rules of life'), in order to accede to 'a new order' (the book is tellingly subtitled *Du symbolisme et de Gauguin vers un nouvel ordre classique*).[16] The role of art is to make manifest 'the order of the universe' ('l'ordre de l'univers'), by revealing 'numerical relationships' ('rapports numériques') and geometrical proportions.[17] Through Denis he absorbs Sérusier's belief in universal measures and in restricting the artist's vocabulary to straight lines, some arcs and a few angles in between.[18]

He underlines and annotates those passages in Auguste Choisy's standard architectural history which relate to formal laws.[19] He seems to have been particularly attracted to Choisy's explanation as to how the Egyptians used *tracés* (superimposed lines) derived from triangles, and how modular combinations can arouse a sense of order and thus of beauty. Perhaps the key passage for him was that to which he added the heading 'Laws' ('Lois') in the margin:

> Greater still – from the point of view of harmony of forms – is the importance of method. The idea of unity in works of art is that of a law controlling the whole: we feel that such a law exists even when we cannot formulate it… In architecture it hardly matters whether this law is geometrical or numerical: above all a law is needed.[20]

He reads Victor Cousin's *Du vrai, du beau et du bien*, 1836 (On the true, the beautiful and the good),[21] or rather just that part of it concerned with the Platonic *idea*.

We might also note a considerable interest in 'primitive' cultures: Arabic, Indian, Oriental and 'les premières civilisations', as well as palaeolithic caves and Roman catacombs.[22] His study of Owen Jones' *Grammar of Ornament* had actually concentrated

16 Maurice Denis, *Théories, 1890–1910*, Paris, 1912. Le Corbusier's inscription in the copy he owned indicates that he bought this in the year of its publication (Turner, op. cit. (11), 232).

17 Denis, op. cit. (16), 276–7.

18 Denis, op. cit. (16), 260. Maurice Denis would seem to be referring to the as yet unpublished ideas of Paul Sérusier, whose *ABC de la peinture* would not be published until 1921; the close relationship between these two painters is borne out by the fact the second (1942) edition of Sérusier's book was followed by 'a study of the life and work of Paul Sérusier, by Maurice Denis' ('suivi d'une étude sur la vie et l'oeuvre de Paul Sérusier, par Maurice Denis').

19 Auguste Choisy, *Histoire de l'architecture*, Paris: Gauthier-Villars, 1899; Le Corbusier had bought a later (undated), two volume edition around Christmas 1913 (Turner, op. cit. (11), 131 and 232). All subsequent references will be to the 1899 edition.

20 'Plus grande encore est l'importance de la méthode au point de vue de l'harmonie des formes. L'idée de l'unité dans une oeuvre d'art est celle d'une loi qui domine tout l'ensemble: nous sentons l'existence de cette loi alors même que nous en ignorons la formule… Que cette loi, en architecture, soit géométrique ou numérique, peu importe: avant tout il faut une loi' (Turner, op. cit. (11), 56).

21 Le Corbusier owned the Paris, 1904 edition (published by Perrin).

22 See Pierre Saddy, 'Les arts primitifs', in *Le Corbusier: Le passée à réaction poétique* (ed. Pierre Saddy), Paris, 1988, 128–78. In 1909 he had acquired a copy of Gustave le Bon, *Les Civilisations de l'Inde*, Paris, 1887 (Turner, op. cit. (11). 231); between 1912 and 1916 he acquired a copy of Théophile Roller, *Les Catacombes de Rome*, 2 vols., Paris, w.d., *c.* 1881 (Turner, op. cit. (11), 232). For a full list of relevant books acquired by Le Corbusier prior to 1921, see Turner, ibid., 224–9, plus a detailed chronology of his wider reading, 230–3.

upon the first two sections, concerning 'Ornament of savage tribes' (Melanesians) and the ancient Egyptians.[23] From 1907, when he first spent some time in the major European capitals, he sought out so-called primitive art (notably Mexican, Peruvian, Persian, Etruscan and, above all, black African art) in museums.[24] His crucial 'Voyage d'Orient', a journey principally around the Balkans which took up nearly a year (in 1911–12), was more concerned with vernacular architecture and culture than with high art or architecture.[25] The books acquired by him during his adolescence and student days included volumes covering palaeolithic cave paintings and ancient civilizations.[26] Such interests would endure throughout his life.[27]

THE NEW SPIRIT

In 1917 Le Corbusier moved definitively to Paris.[28] The evidence suggests that after his sojourns in the three foremost capitals of the Continent – Vienna, Berlin and Paris – he had found his relatively small home town suffocatingly provincial. Owing to Switzerland's neutrality he had not been liable to conscription and so was free to move. A few months later he watched Diaghilev's Ballets Russes dance *The Firebird* in the Châtelet Theatre. At

23 In around 1901–2 Le Corbusier copied the first five plates, probably as an exercise set in the art school. Parts of his copy of pl. I would find their way into his magazine *L'Esprit Nouveau*, and subsequently into his book *L'Art décoratif d'aujourd'hui* (op. cit. (4), 29; English translation, 29).

24 See *L'Esprit Nouveau*, 1924, reprinted in 'Confessions', in Le Corbusier, op. cit. (4), 201–4.

25 See Le Corbusier, *Le Voyage d'Orient*, Paris, 1965 (English translation, *Journey to the East* (tr. Ivan Zacnic), Cambridge, MA, 1987); the journey is summarized in Le Corbusier, op. cit. (4), 210 (English translation, 208–9). From Switzerland he travelled through Austria, Hungary, Yugoslavia, Romania, Bulgaria, Turkey, Greece and Italy. Throughout he shows greatest interest in vernacular pottery, furniture, costume, houses and villages; the buildings which most please him are those embodying 'simple geometric forms', such as Romanesque or Byzantine churches and Muslim mosques or sepulchres.

26 By 1920 Le Corbusier owned copies of the following: Frédéric Boissonas, *L'Epire, berceau des Grecs*, Geneva: F. Boissonas, 1915; Henri Breuil *et al.*, *Peintures et gravures murales des cavernes paléolithiques*, 2 vols., Monaco, 1910 and 1912); Gustave le Bon, *La Civilisation des Arabes*, Paris, 1884, and op. cit. (22), and *Les Premières Civilisations*, Paris, w.d., *c.* 1888; Louis Ménard, *Histoire des anciens peuples de l'Orient*, Paris, 1883; and Roller, op. cit. (22). (Turner, op. cit. (11), 224–9).

27 In 1927 Le Corbusier bought items from Drouot's sale of 'Art Primitif Africain et Océanien'. He collected the catalogues from the Exposition Coloniale held in Paris in 1931 and the Brussels Exposition Universelle of 1935. In July 1935 he mounted an exhibition of 'so-called primitive art in today's house' ('Les arts dits primitifs dans la Maison d'aujourd'hui') in his own flat; the exhibition included his own collection of African masks and statues, and of fragments of antique sculpture, together with a plaster cast of an archaic statue brightly painted by Le Corbusier in its supposedly original colours (following advice from a keeper at the Louvre), alongside recent paintings by himself and his friend, a more eminent modern painter, Fernand Léger. In 1937 his Pavillon de l'Esprit Nouveau was furnished with Berber and black African rugs. In his *Quand les cathédrales étaient blanches*, published the same year (Paris: Plon, 1937), he expressed his preference for archaic over classical Greek art, claiming that the latter bored him (p. 15). In 1957 he wrote a eulogistic preface to Dusan Granbridgan and Jura Neidhardt's *Architecktura bosne i put u savremeno* ('Architecture of Bosnia and the way to modernity') (Ljubljana, 1957), on the grounds that it linked international modernism with Yugoslav vernacular architecture. He continued to buy books and exhibition catalogues on primitive art throughout the rest of his life (for instance: Henri Clouzot and André Level, *L'Art du Congo Belge*, w.d., w.p. (Level also wrote on Picasso); Marquis de Wavrin, *Au Pays du Scalps* (Amazon), Paris, w.d.; Roger Courteville, *Fauves humaines de l'Amazonie*, Paris, 1932.

28 On marrying in 1930 he would take French nationality.

first sight his desire to see for himself this well-known avant-garde piece of theatre, whose score had specially been composed by Stravinsky, would seem like a deliberate rejection of the values represented by the cosy bourgeois world of La Chaux-de-Fonds, not least if one is aware that his mother was a conventional piano teacher there. It is worth bearing in mind the vogue for dance in Paris amongst the upper classes and in artistic circles during those years leading up to the First World War – witness not only the success enjoyed by Diaghilev's Ballets Russes but also the tango craze and a whole range of dance forms developed as much for figure-conscious amateurs as for professional performance, notably eurhythmics and Isadora Duncan's barefoot 'interpretative' dance.[29]

Yet in fact Le Corbusier may have been disappointed by what he saw, as his interest in modern theatre had been stimulated by an experience which would have left Bakst's violently coloured but otherwise by now (four years after the first performance of *The Rite of Spring*) conventional decors seem positively outmoded. For his brother Albert, a professional musician, had studied at the Institut Dalcroze in Hellerau, where the highly original Emile Jacques-Dalcroze (the founder of eurhythmics)[30] collaborated with the equally innovative artist Adolphe Appia to create a totally new kind of drama, called 'Espaces Rythmiques', which dropped melody and narrative in order to produce a universal work, in which pure rhythm was complemented by wholly abstract sets and costumes.[31] Presumably Le Corbusier would have been aware of this – and probably saw it for himself – when he visited his brother there over Christmas 1910.[32]

Indeed it seems that he was less profoundly influenced by the ballet itself than by the programme for it (which he bought), or at least by one essay in this, written by the leading Surrealist poet Guillaume Apollinaire (already recognized as a commentator on avant-garde art, and notably on Cubism);[33] describing Picasso's sets for the far more avant-garde, and cosmopolitan, ballet *Parade*,[34] which marked the Cubist painter's debut in stage

29 Lynn Garafola, *Diaghilev's Ballets Russes*, Oxford 1989, 295–6.

30 Dalcroze was born in Vienna in 1865. After gaining his diploma (in harmony) at the Geneva conservatory he studied in Vienna with Fuchs and Bruckner, and then in Paris with Délibes. In 1892 he returned to Geneva where, from 1905, he began elaborating his own musical theory. In 1910 he was invited to Hellerau, where he set up his institute and, in collaboration with Appia, its theatre. He died in 1950, but the system of musical education based on his theories is still quite widely practised (Luisa Martina Colli, 'Musique', in *Le Corbusier, une encyclopédie* (ed. Jacques Lucan), Paris: Centre Georges Pompidou, 1987, 268–71).

31 Colli, op, cit. (30), 269, and Pierre Saddy, 'Appia', in Saddy, op. cit. (22), 209–10. Appia, a native of Geneva, was well known in art circles throughout Europe before the First World War.

32 See Le Corbusier, op. cit. (25), 6 (English translation, 4).

33 He had published *Les Peintres Cubistes*, Paris: E. Figuière, in 1913.

34 Whilst the raw and exotic Slavic primitivism of *The Firebird* – in its narrative, music (by Stravinsky) and decors (by Bakst) – may have stunned a Parisian audience in the days before *The Rite of Spring* it must have seemed rather *passé* afterwards. *Parade* was at once more sophisticated and more cosmopolitan, being put together by leading members of the Parisian avant-garde – Jean Cocteau (1880–1963) for libretto, Eric Satie (1866–1925) for music and Pablo Picasso (1881–1973) for sets and costumes – and looking outside Europe as much West as East, for its storyline. Indeed, Cocteau's concept of ballet as total theatre went too far beyond Diaghilev's previous experience for him to be able to accept crucial parts of it – notably its spoken text and the score's 'acoustic illusions' (including typewriters, sirens and recordings of express trains); the net result was the final split between Cocteau and Diaghilev (Garafola, op. cit. (29): on *The Firebird*, 16, 64 and 386; on *Parade*, 99–107 and 407).

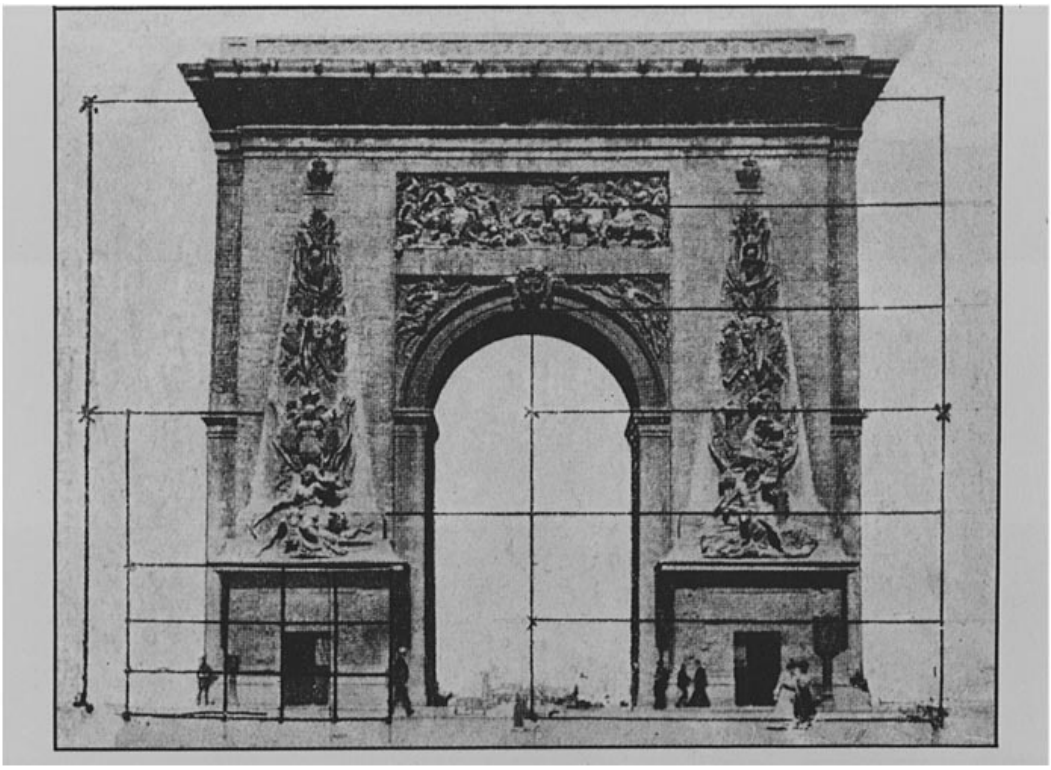

Figure 3. Photograph of Porte St-Denis, Paris (François Blondel, 1671–74) with *tracés régulateurs* drawn over by Le Corbusier. (Frontispiece to section on 'Les tracés régulateurs', in Le Corbusier, *Vers une architecture* (first published Paris, 1923); taken from Paris, 1977 edition, p. 49) (all rights reserved: Fondation Le Corbusier, Paris).

design, Apollinaire calls Cubism 'l'Esprit Nouveau', the term which Le Corbusier will shortly poach as the title for his own avant-garde magazine. It is unlikely that the young newcomer from a provincial town in Switzerland would have been on speaking terms with the great poet by this date, but it would not be long before he was, Apollinaire corresponding with him and sending him autographed copies of his works.[35]

Soon Le Corbusier comes under the wing of a fellow painter, Amédée Ozenfant, who is promoting Abstraction, precisely because of its timeless, classic qualities, which he compares with Assyrian, Greek, Chinese and black African art. In turning to such 'Primitive art' as a source of inspiration for contemporary painting Ozenfant is simply reflecting a trend which had dominated the avant-garde in France and Germany alike since the late nineteenth century. Gauguin, even before his sojourn in Tahiti, had extolled peasant culture – that of Brittany – resulting in the formation of the Synthetists (which included Paul Sérusier, whose ideas would prove attractive to the young Le Corbusier). In

35 Notably Guillaume Apollinaire, *Le Poète assassiné*, Paris, 1916, and his surrealist drama *Les Mamelles de Tirésias*, Paris, 1917.

the early years of the twentieth century African sculpture inspired Matisse and the Fauves in Paris at the same time as it did 'Die Brücke' ('The Bridge'), a group formed around Kirchner in Dresden. A few years later another German group, 'Der Blaue Reiter' ('The Blue Rider'), led by Franz Marc and Wassily Kandinsky, looked to African masks alongside pre-Columbian sculpture and textiles; for Kandinsky African art, together with oriental and European folk art, seems to have provided the stimulus which turned him towards abstraction. Most significant of all, however, was the role played by the sculpture of ancient and primitive peoples in general, and African sculpture in particular, in Picasso's invention of Cubism, such art offering examples as to how natural forms could be reduced to purely geometrical equivalents.

The following year Ozenfant and Le Corbusier published their manifesto for 'Purism', *Après le Cubisme*. This denounces Cubism as too decorative and superficial. To express 'the modern spirit', 'pure art' is needed, aimed at the intellect rather than the senses. The new age of science and industry is marked by the power and perfection achieved through mechanization; machines can serve to 'project' 'natural laws'. His interest lies not with real (dirty and noisy) machines but in the principles behind them. The new architecture must be rigorous, that is, apply laws and observe order and precision. Since reinforced concrete structures rely on rigorous calculation their exploitation will enable 'Number, the basis of all beauty, to express itself'. Art is seen as being like science, in that both depend upon laws, rigour, precision and purity. Again this is highly reminiscent of the Henry Cole circle in mid-nineteenth-century England, and particularly of Matthew Digby Wyatt's theory of form which, presupposing that nature has refined to perfection a series of model designs, posits laws of design deduced by objective observation of nature.[36] Le Corbusier's teacher, L'Eplattenier, who had set him Owen Jones' *Grammar of Ornament* to study, seems to have subscribed to Wyatt's theory, since he taught his students that nature was the only true source of inspiration for art, but that the artist must look beyond its appearance, studying instead its 'causes, forms and vital development'.[37]

In a chapter of the Purism manifesto called 'Laws', the role of the new art is defined as 'discovering… natural laws, the invariant beneath reality'. Thus art is like science, because both depend upon number. In fact the laws underlying nature are so rigorous that its products are marked by 'invariability'. Le Corbusier, although never himself an adherent of any formal religion, had been brought up in a Calvinist milieu, in the Swiss mountains, and in the world capital of watchmaking (Le Chaux-de-Fonds); trained in an art school and thus acutely aware of the tension between nature and industry, and dedicated to using art to resolve it, Le Corbusier seems here to be rephrasing its arguments, comparing nature with industry, as if both mass-produced identical products in a spirit of ineluctable

36 Matthew Digby Wyatt, 'An attempt to define the principles which should determine form in the decorative arts', in *Lectures Given after the Great Exhibition*, second series, London, 1852, 213–51.

37 Le Corbusier, op. cit. (4), 198 (English translation, 194). It is worth citing L'Eplattenier at greater length: 'Nature alone can inspire us, is true, and can support human works. But do not treat it like the landscape artists do, who only show its appearance. Discern its cause, its form, the development of its life, and produce a synthesis of this, through creating *ornaments*.' ('Seule la nature est inspiratrice, est vraie, et peut être le support de l'oeuvre humaine. Mais ne faites pas la nature à la manière des paysagistes qui n'en montrent que l'aspect. Scrutez-en la cause, la forme, le développement vital et faites-en la synthèse en créant des *ornements*.')

predestination. He even draws a direct parallel between nature and the machine: each builds up its products according to an underlying geometric grid (*trame géométrique*),[38] and according to mathematics. His reading of Schuré and Provensal is echoed in his claim that nature's 'invariability' is linked with (Pythagorean) 'number laws' and also 'laws of order and harmony'. The artist is the person who resonates with the order underlying nature, with numbers and proportions which, like those underwriting music, are sensible manifestations of a hidden ideal mathematics.

At first sight the conception of musical theory implied here seems old fashioned, and one might easily assume that the young architect, whilst avidly patronizing performances of Stravinsky's work (such as *The Firebird*), simply failed to appreciate the inherent discrepancy between his own theoretical position and that of the works he chose to listen to. One's interpretation changes, however, when one situates Le Corbusier within the context of his experience of Dalcroze and Appia's bare and abstract version of total theatre, which was certainly far more radical than anything Diaghilev ever dared to stage. It follows that Dalcroze's theories would therefore have seemed more modern than would those underpinning even the most progressive of his Parisian contemporaries.

Dalcroze's commitment to rhythm alone stemmed from his belief that it constituted the very essence of music, reduced to its simplest and most precise; moreover he saw it as the universal, and most primitive, language, predating that of any historic culture. Rhythm acquired a quasi-metaphysical status, owing to its capacity to establish order, harmony and clarity ('Le Rythme établit l'ordre, l'harmonie et la clarté'). It is relevant to note that by the time Le Corbusier published *Aprés le Cubisme* his brother had moved to Paris, where he taught 'Rythmique' at the Conservatoire Rameau; within three years he would open his own music school dedicated to spreading Dalcroze's system, thereby becoming the principal propagandist of these ideas in France. The two brothers saw their respective efforts in architecture and music as deriving from a single theoretical base, as becomes clearest in the article on Purism in music which Albert would write for *L'Esprit Nouveau*[39] in the very year he set up his new Dalcroze school. Within this context it is not surprising that Le Corbusier will eventually seek to develop his own artistic collaboration with such radical composers as Varèse and Xenakis, rather than with Stravinsky.

To return to Le Corbusier and Ozenfant's manifesto: the task of the artist, regardless of the medium through which he expresses himself, is to discover universal 'laws of harmony' and to use them to form works 'coherent with nature' and 'intelligible'. He can therefore be compared with Euclid, Pythagoras or Archimedes, the Egyptians who built the pyramids, the Greeks who built the Parthenon,[40] Persian dome builders,[41] the mediaeval

38 Le Corbusier, *Après le Cubisme*, Paris, 1918, 41–2.

39 Albert Jeanneret, 'L'Intelligence dans l'oeuvre musicale', *L'Esprit Nouveau* (1921), No. 7.

40 By this date Le Corbusier owned a copy of Maxime Collignon, *Le Parthénon* (Paris, w.d., *c.* 1912); the photographs are by Boissonas.

41 One of his sketchbooks dated 1915 (*Le Corbusier Sketchbooks*, op. cit. (10), i, No. 113) includes a diagram showing *tracés régulateurs* drawn over a section of an Achaemenian dome, supposedly taken from Marcel Dieulafoy's *L'Art antique de la Perse*, *Archéménides*, *Parthes*, *Sassanides* (5 vols., Paris, 1884–85); in fact it seems almost certain that Le Corbusier had only looked at this in a secondary source, Auguste Choisy's *L'Histoire de l'architecture*, which he owned by this date (see note 19), and in which an identical diagram appears, complete with *tracés* (Choisy, op. cit. (19), i, 137, fig. 6B).

master masons who built Gothic cathedrals,[42] and classical architects such as François Blondel, who designed the Porte St Denis in Paris (1671–72) (Figure 3). Therefore the primary aim of architecture is transcendent, the exploitation of abstract laws, through numerical and geometrical calculations. Although this manifesto had been delivered by two painters – Amédée Ozenfant and Le Corbusier – it turns out to deal with all the arts, with a total aesthetic.

TOWARDS AN ESSENTIAL ARCHITECTURE

This propaganda continued in Le Corbusier and Ozenfant's magazine *L'Esprit Nouveau*. In the Introduction to the first issue (published in October 1920) the editors expressed their desire to bring the methodology of experimental physiology to bear upon aesthetics. The Golden Section was therefore presented as offering a possible means of demonstrating the 'Esprit Nouveau'. They implicitly referred to Gustav Theodor Fechner's experimental work in 'psychophysics'[43] from the previous century, his conclusions that visual perception physiologically conditions aesthetic sensations justifying the role accorded to *tracés régulateurs*, as a virtually cultural, mechanistic means of determining human reactions to given buildings; in a broader perspective such an appropriation of widely accepted research, which applied scientific methodology to aesthetics, fitted what the editors saw as the principal feature of their poetic 'Esprit Nouveau', namely the quest for a scientific basis for artistic work.

In 1923 Le Corbusier published his articles from *L'Esprit Nouveau* as an architectural manifesto, entitled *Vers une architecture* (misleadingly translated as *Towards a New Architecture*).[44] This would become the most influential architectural treatise of the century, and its immediate impact can be gauged from the speed with which it was translated, into German in 1926 and into English the year after. In *Vers une architecture* architects are negatively compared with engineers who, led by calculation, put us in tune with the universe's laws. They attain 'harmony'. Architects are reminded that the beautiful forms are primary ones, because they are the most legible, the least ambiguous: look at Egyptian, Greek or Romanesque architecture. Again engineers are superior to architects, because of their use of calculation. Using 'primary elements', and then 'following the rules' in composing buildings from them, engineers make human artefacts which resonate with 'the universal order'.

42 By this date Le Corbusier owned a copy of Joris Karl Huysmans, *La Cathédrale*, Paris, 1908 (of which he acquired his own copy as early as 1909: Turner, op. cit. (11), 231), not to mention Eugène Viollet-le-Duc, *Dictionnaire raisonné de l'architecture française du XIe au XVIe siècles*, 10 vols., Paris, 1854–68 (which he acquired as early as 1908: Turner, op. cit. (11), 231). It is likely, however, that he had also read the relevant section in Choisy, op. cit. (19), ii, 123–48.

43 Fechner's 'psychophysics' had been brought to the attention of French audiences by Charles Lalo, in his *L'Esthétique expérimentale contemporaine*, Paris, 1908, 40–51. I suspect that Le Corbusier may have been directed towards these by Matila Ghyka, who would refer to them in his *Nombre d'or*, 2 vols., Paris, 1931 (vol. 1: *Les Rythmes*; vol. 2: *Les Rites*), ii, 155.

44 Le Corbusier, *Vers une architecture*, was first published by Crès et Cie. in Paris in 1923. The English version, *Towards a New Architecture*, translated by the Vorticist Frederick Etchells, was first published in London by John Rodker in 1927.

An entire chapter is devoted to 'Les tracés régulateurs'. Human (or Humanist, in the Renaissance sense of the word) architecture depends upon geometry – hence the *tracé régulateur*. But it also uses a module to ensure unity; this module, derived from the designer's own body – his foot, his finger, etc. – ensures that the building is of human scale. Once more Le Corbusier seems to be indebted here to the theories being propounded by his musician brother: in creating his 'Espaces Rythmiques' Dalcroze had insisted upon the need to relate everything to the scale of the human body, because of the body's universality, transcending historic periods and national boundaries. The human body thus provided a safe guide ('un guide sûr') for artists of all sorts, as the literal embodiment of measure. The importance of measure for Dalcroze can be ascertained from his definition of it as the law common to nature and reason.

As in their Purist manifesto, here again *tracés régulateurs* enable the underlying order to be made manifest; such primordial physical laws are simple and few, just like moral laws. The Greeks, Egyptians and Blondel provide examples as to how to use them well. Le Corbusier now offers several worked examples, applying this system of straight lines and arcs to line drawings or photographs of elevations, mainly choosing as cases those which he had already cited (albeit without such illustrations) in his earlier Purist manifesto: Blondel's Porte St-Denis, the Arsenal at Piraeus (taking the place previously given to the Parthenon), Achaemenian domes (hence his references to Persian dome builders), the cathedral of Notre-Dame in Paris (presumably standing as a specific example of the generic type, the Gothic cathedral, previously cited). With typical ingenuousness he presents all these geometric analyses bar one (the Persian dome, which he credits to Marcel Dieulafoy, a respected archaeologist)[45] as if they were his own work, when in fact they were all (including the analysis originally proposed by Dieulafoy) taken from Choisy's *L'Histoire de l'architecture*, of which he owned a copy.[46] But he now prefers a system composed wholly of straight lines and right angles, and uses 'classical architecture' to illustrate this, adding two new cases – Michelangelo's Capitol (that is the Campidoglio) in Rome and the Petit Trianon at Versailles – each presented with their *tracés régulateurs*.[47] He concludes

45 Dieulafoy, op. cit. (41). Dieulafoy had been an archaeologist supervising archaeological digs for the Louvre, and so citation of his work would have helped to lend academic credibility to Le Corbusier's more speculative considerations of such ancient monuments. Le Corbusier's diagram of Achaemenian cupolas is entitled 'Extract from a book by Dieulafoy' (*Towards a New Architecture*, op. cit. (44), 1946 edition, 72).

46 For Blondel's Porte St-Denis, Le Corbusier draws the *tracés régulateurs* over a photograph (*Vers une architecture*, op. cit. (44), 49); the *tracés régulateurs* are identical to those proposed by Choisy (op. cit. (19), ii, 746). The line drawing of the Arsenal at Piraeus together with the *tracés régulateurs* drawn over it (*Vers une architecture*, op. cit. (44), 57) appear to have been lifted directly from Choisy (op. cit. (19), i, 389); admittedly Le Corbusier changes the lettering of ths diagram! The line drawing of a section through an Achaemenian dome overlaid with *tracés régulateurs* (p. 58), credited to Dieulafoy (see note 41), is identical to that in Choisy (op. cit. (19), i, 137, fig. 6B), where it is similarly credited to Dieulafoy; Le Corbusier had copied this into his sketchbook back in 1915 (see note 41). For Notre-Dame (*Vers une architecture*, op. cit. (44), 59), as for the Porte St-Denis, Le Corbusier draws Choisy's *tracés régulateurs* (op. cit. (19), ii, 404) over a photograph of the façade. Eventually Le Corbusier tacitly acknowledged this debt to Choisy ('some pages in Auguste Choisy's book on the History of Architecture devoted to the *tracés régulateurs*'), Le Corbusier, *Le Modulor: Essai sur une mesure harmonique à l'échelle humaine applicable à l'architecture et à la mécanique*, Boulogne-sur-Seine: Architecture d'Aujourd'hui, Collection ASCORAL, 1950, 27. English translation by Peter de Francia and Anna Bostock, London, 1954; all references will be to the 1968 English language edition, Cambridge, MA.

47 Le Corbusier, *Vers une architecture*, op. cit. (44), 60 and 61 respectively.

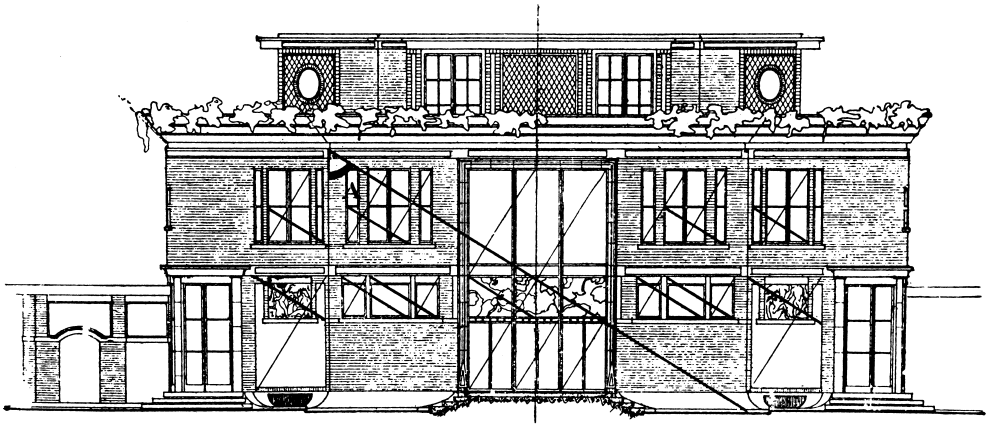

Figure 4. Front elevation of Le Corbusier, Villa Schwob, La Chaux-de-Fonds (1916–17), with *tracés régulateurs* drawn over by Le Corbusier (in Le Corbusier, *Vers une architecture* (first published Paris, 1923); taken from Paris, 1977 edition, p. 61) (all rights reserved: Fondation Le Corbusier, Paris).

– as architects often tend to – by using his own work to demonstrate how one should do it today, namely the Villa Schwob in his native town (1916–17)[48] (see Figure 4).

Later chapters compare buildings with cars – as icons of modernity. Each car is seen as the result of a kind of selection comparable to that of evolution in the natural world; in a contemporary treatise on applied arts Le Corbusier puts forward the same concept in order to justify according the status of classics to the standard products of peasant societies: 'The laws of physics subject these systems to an ineluctable process of development.'[49] Only the products of rational analysis will endure, and 'standards', or types, worthy of mass production. Housing needs to be industrially produced, in order that these 'types' can be sufficiently refined – through analysis and experiment.

For Le Corbusier, the 1920s – at least until the Wall Street crash of 1929 – were dominated by the design and construction of further Purist villas for wealthy individuals

48 Le Corbusier, *Vers une architecture*, op. cit. (44), 61–3 (illus. with *tracés régulateures* on 61 and 62).

49 'Les lois de la physique astreignent ces systèmes à des aventures rigoureusement fatales.' Le Corbusier, op. cit. (44), 180; the full argument runs: 'The inexplicability of causes. But everywhere, in nature as in life, we find the unfolding of causality. Going right back to the limits of our awareness, we can find reasons. The further back we go, the more we are satisfied in this respect. On consideration one finds that everything is ordered according to principles consistent with the generality of things, and that every organism marks a certain stage along the line of variables on the axis which joins two poles, variables which, obeying the law of a single function, set up a series: a coherent system varies according to innumerable modalities of combinations. The world is thus summed up in a few species. The laws of physics subject these systems to experiences that are rigorously determinate. (L'inexplicable des causes. Mais partout, dans la nature comme dans l'événement, se trouve l'explication de l'enchaînement. Remontant jusque-là où s'arrête notre prise de conscience, nous pouvons trouver les raisons. Plus nous remontons haut, plus nous sommes satisfaits. L'on mesure que tout s'ordonne selon des principes conformes au général et que tout organisme est un certain point d'étape de la ligne des variantes autour de l'axe qui relie deux pôles, variantes qui, obéissant à une fonction, établissent une série: un système cohérent varie avec les innombrables modalités des combinaisons. Le monde alors se résume en quelques espèces. Les lois de la physique astreignent ces systèmes à des aventures rigoureusement fatales.)' ibid., 177–80.

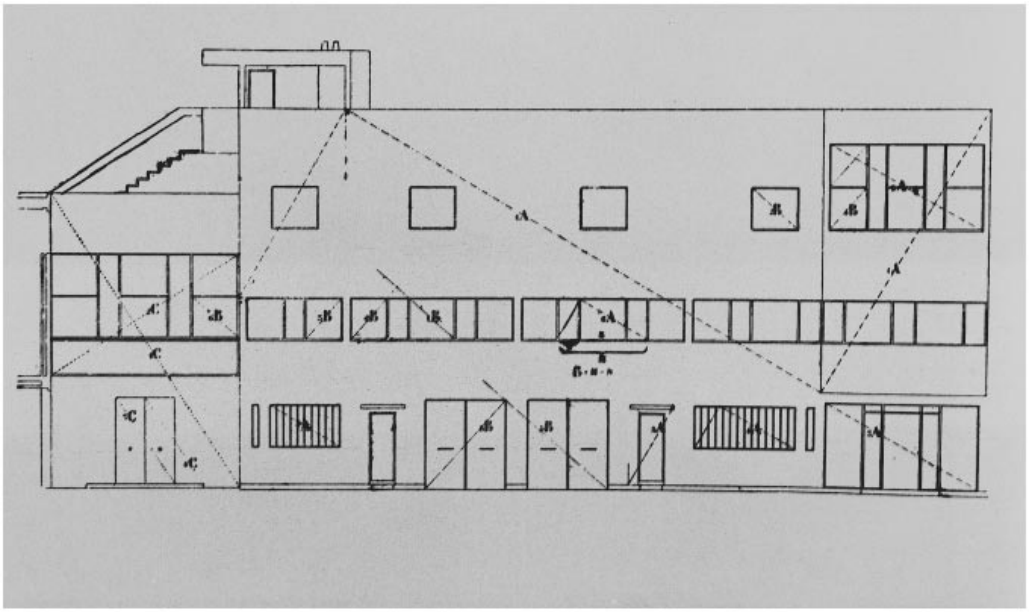

Figure 5. Front elevation of Le Corbusier and Pierre Jeanneret, Villa La Roche-Jeanneret, Auteuil, Paris (1923–25), with *tracés régulateurs* drawn over by Le Corbusier (in Le Corbusier, *Vers une architecture* (first published Paris, 1923); taken from Paris, 1977 edition, p. 64) (all rights reserved: Fondation Le Corbusier, Paris).

– like that done for Raoul La Roche (see Figure 5). They provided the opportunity to develop the application of *tracés régulateurs*, whilst serving as built exemplars to complement the published manifesto of *Vers une architecture*. The same principles were also applied in larger buildings, such as that commissioned by the Salvation Army (1929–33) and the Swiss Pavilion in the Cité Universitaire (1930–32), both in Paris, but it was probably the Villa Savoie (1929), at Poissy, just outside the capital, which caught most attention.

THE MODULOR[50]

Owing to the Depression and then the war, the 1930s and early 1940s offered few opportunities for building. Le Corbusier therefore returned to theorizing, this time primarily in the realm of town planning. From 1942, however, he returned to the issue of proportion and dimension, this time determined to invent a system, eventually to be called the Modulor, which would combine abstract numerical laws underlying nature with contemporary anthropometrics and ergonomics, thus reconciling the universal with the particular, and the timeless – both in the senses of ahistoric and eternal – with the present.

50 For details of Le Corbusier's development of the Modulor, see Le Corbusier, op. cit. (46), ch. 2 'Chronological review', 23–68 (his own account); cf. Matteoni, op. cit. (1), for an account based largely upon archival material (notably developmental drawings and sketches).

This desire to link abstract harmony with human dimensions had been stimulated by Matila Ghyka's books *Esthétique des proportions dans la nature et dans les arts* (Paris, 1927), and *Le Nombre d'or* (Paris, 1931), which Le Corbusier owned and heavily annotated;[51] indeed he even drafted a review for the 1934 edition of Ghyka's *Esthétique des proportions*.[52] He suggested that he had read both books as they appeared, '[grasping] the meaning of the figures' in them but – significantly – without being able to follow their mathematical arguments.[53] Through them he had become aware of the work of the nineteenth-century German Adolf Zeising on anthropometrics[54] and of the American Jay Hambidge; the latter's concern to 'rediscover principles of Greek design' and comparable 'design principles' in nature (such as the logarithmic spiral, an expression of the Fibonacci series) had led him to propose his theory of 'dynamic symmetry' – geometrical ordering systems based on irrational numbers, notably as found in the Golden Section (and presumed to have been used in the Parthenon) – for application in modern art and architecture.[55]

Together Ghyka's two works provided a detailed review of research, from the mid-nineteenth century onwards, interpreting Western architecture from antiquity to the Middle Ages as being dependent upon proportional systems, and thus embodying abstract mathematics, so as to demonstrate the central role played by the Golden Section in Western culture; he not only examined *tracés géométriques* in architecture of the past, but also the mathematical structures inherent in natural forms, in order to support his contention that such architecture enjoyed an organic relationship with the natural world, or rather that both manifested the same essential principles of the universe:

51 Matila Ghyka, *Esthétique des proportions dans la nature et dans les arts*, Paris, 1927, and op. cit. (43). Le Corbusier admitted having read these before beginning this project (Le Corbusier, op. cit. (46), 29). He was probably also influenced by Ghyka's later work, *Essais sur le rythme*, Paris, 1938.

52 Two typewritten sheets headed 'Tracés régulateurs' and dated 24 February 1934 (Archives de la Fondation Le Corbusier, cited in Matteoni, op. cit. (1), 26). Le Corbusier owned (and annotated) a copy of the 1934 edition (Dario Matteoni, 'L'idea del Modulor: Le Corbusier e la tradizione della sezione aurea', in *Le Corbusier: La ricerca paziente* (ed. S. Pagnamenta and B. Rachlin) Lugano, 1980, 103–23, especially 104).

53 Le Corbusier, op. cit. (46), 29.

54 Adolf Zeising, *Neue Lehre von den Proportionen des menschlichen Körpers, aus einem bisher unerkannt gebliebenen, die ganze Natur und Kunst durchdringen morphologischen Grundgesetze entwickelt und mit einer vollständig historischen Übersicht der bisherigen Systeme begleitet*, Leipzig, 1854; in this Zeising considered anthropometrics together with the use of the Golden Section in order better to understand the relationship between micro- and macrocosm (see Matteoni, op. cit. (1), 26). Zeising, who was best known for his work on the relationship between religion and science, also published a book on the Golden Section, *Der goldene Schnitt*, Halle, 1884.

55 Jay Hambidge, *Dynamic Symmetry. The Greek Vase*, New Haven, 1920; republished 1930 and 1931, and *The Parthenon and other Greek Temples*, New Haven, 1924. Hambidge first published his theory of dynamic symmetry in the monthly magazine, *Diagonal*, which he edited from November 1919 to October 1920 (published by Yale University); this magazine was entirely devoted to explaining the 'rediscovered principles of Greek design, their appearance in nature, and their application to the needs of modern art'. A key feature of his theories was the division between static forms (based on rational numbers) as opposed to dynamic forms (based on irrational numbers, including those inherent in the Golden Section and the Fibonacci series). After publishing *The Greek Vase* in 1920 and then three years later *Dynamic Symmetry in Composition as Used by the Artists* (New York, 1923, 1926, 1927, 1948), the remaining articles from *Diagonal* were published under the title *The Elements of Dynamic Symmetry* (New Haven, 1926, 1948). This was in turn followed by *Practical Applications of Dynamic Symmetry* (New Haven, 1932, 1942).

> An architectural composition cannot be anything other than geometry of Life, of Growth; it ought to be a conscious design, not merely a simple network of lines.[56]

Certainly Le Corbusier was a long-time admirer of Ghyka, at least since publishing an article by him on *tracés régulateurs* in *L'Esprit Nouveau* in 1921.[57] Now he virtually quotes Ghyka's ideas in his design work, as well as in his theoretical writings; for instance, a sketch made for the Modulor project in late 1945 labels a Golden Rectangle 'the element which brings forth life or movement'.[58] Moreover he seems to have realized that by allying his own work with Ghyka's he could be assured of precisely the kind of intellectual authority which he, as one standing outside the recognized academic system, needed. After all, they shared the same theoretical basis, as is evident from Le Corbusier's unpublished review of Ghyka's *Esthétique des proportions*:

> Proportion endows the numerous organs of any structure with the principle of unity. This unity can go right from the most immediate perception – the façade – through to the most profound ones – provided by plan and section. The past has left us some examples of such a profound and splendid unity. The effects of proportion may reach infinitely far, because here, as in all spheres of art, it is a matter of the precision of the game, of the richness of the game set up, of the intellect brought to fixing the rules of the game.[59]

Le Corbusier's Modulor system was conceived as playing a comparable role as a framework within which to design 'standards', types or models, so as to ensure a high level of refinement in the product to be mass-produced. French architects – whether working for Vichy or inside the Resistance – were preoccupied by the looming housing crisis, as it was agreed that over four million dwellings would be urgently required after the war. In 1940 the Vichy government set up AFNOR – the Association Française de Normalisation (the French Association for Standardization) – to prevent the key problems expected as a result of the industrialization of the construction industry, now accepted as inevitable in order to alleviate the imminent housing crisis.[60] The eminent architects, engineers and other technical experts appointed to serve with industrialists on this committee were sufficiently flattered at being directly consulted by politicians – in marked contrast to their pre-war experience – that they failed to appreciate the implications of their collaboration in such an inherently anti-democratic undertaking. Although Le Corbusier (along with the famous engineer Auguste Perret) would eventually be included amongst those very few individuals lacking an academic diploma in architecture whom the regime would admit into its Ordre

56 'Une composition architecturale ne peut être que géométrique de la Vie, de la Croissance, doit être une conception consciente, non un simple réseau de lignes', Ghyka, op. cit. (43), i, 34. Ghyka absorbed Hambidge's ideas on dynamic and static symmetry here, claiming that the structure of inorganic matter consists of hexagonal geometries, whilst that of organic matter consists of pentagonal geometries, such as can be linked with the Golden Section; thus the geometry of the living world was the same as that discovered to underpin all great works of art. For further information see Dario Matteoni, 'Tracés régulateurs', in Lucan op. cit. (30), 409–14.

57 Ghyka remained in touch with Le Corbusier and would write a positive article on the Modulor (Ghyka, op. cit. (6), 39–42).

58 'L'élément qui engendre la vie ou le mouvement', annotation on a sketch of 9 December 1945, cited in Matteoni, op. cit. (52), 105.

59 Matteoni, op. cit. (1), 27.

60 Le Corbusier, op. cit. (9), 27.

des Architectes,[61] thus permitting him to practise as an architect, he was clearly not considered a member of the establishment, and therefore was not invited to join the committee.[62] Confident of his superior claims to advise the government on these issues he appealed to be appointed, detailing his continuous professional concern with these issues from the publication of his first articles in *L'Esprit Nouveau*, in 1920, onwards; these included his controversial, and well-known, article on mass-produced housing, in which he had coined his definition of the modern house as a machine for living in ('une machine à habiter'), and another on standardization, in which he had extolled Henry Ford's conveyor belts as a model for the construction industry, and the Parthenon as an exemplar of standardization and precision engineering.[63] Nevertheless an invitation to join the Vichy administration misled Le Corbusier into believing that his ideas would be taken into account in formulating government policy, and to this end he moved to Vichy in January 1941. Eighteen months later, however, realizing that the aesthetic preferences of the Pétain regime were as reactionary as their political ones, he withdrew to his studio in Paris.

Later that year Le Corbusier set up an architectural research group, ASCORAL (Association des Constructeurs pour la Rénovation Architecturale), which brought together architects and engineers,[64] a great innovation for any Research and Development team in France at that time; it has been reasonably suggested that Le Corbusier founded this association, which was at least in part identical with his own architectural practice, as a direct response to his realization that he would never gain any position within AFNOR.[65] The group worked in eleven specialist sections (probably in part for reasons of security), one of which studied 'The science of Housing', in terms of equipment, the effects of standardization on construction, and industrialization.

It was within this context that a young British assistant, Gerald Hanning (who had been in Le Corbusier's office since 1938),[66] took on the project of devising a series of standards, implicitly superior to those being developed by AFNOR; this proportional system was to derive its superiority over others from its incorporation of universal laws of harmony inherent in nature, thereby 'reconciling human stature' with the dimensions to be prescribed for the construction industry. Hanning was therefore told to elaborate this system through *geometrical* constructions, derived from the Golden Section, and yet whose finite dimensions would be determined by the height of an ideal man.[67] Le Corbusier

61 Le Corbusier, op. cit. (46), 42.

62 This may have been as well for Le Corbusier's later reputation, but one should remember that, at the time, the Vichy regime had some apparent claims to legitimacy.

63 Le Corbusier, op. cit. (9), 127ff. The appeal to AFNOR was made in 1948.

64 The first AGM took place on 26 March 1943, but Le Corbusier dates its inception to the previous year (Le Corbusier, op. cit. (46). For further details on ASCORAL see Patrice Noviant, 'ASCORAL', in Lucan, op. cit. (30), 50–1.

65 Matteoni, op. cit. (52), 107, and op. cit. (1), 20. On Le Corbusier's activities during the Vichy period see Danielle Pauly, 'Sul cantiere di Marsiglia', *Rassegna* (1980), **2**, 3, 72–8, and Giuliano Gresleri and Dario Matteoni, 'Introduzione a Le Corbusier', in *Proposte di urbanistica*, Bologna, 1980, 7–24.

66 Like many Britons working in Paris, Hanning seems not to have anticipated the occupation, which was quite sudden, and therefore found himself unable to leave. As might be expected, the Germans treated British nationals in occupied France in pretty much the same way as they treated French ones.

67 Le Corbusier, op. cit. (46), 36–7. For the Renaissance connections of this idea see below.

apparently derived the height of this ideal man from Ghyka's analysis of the male body in works of art (which had been published in his *Nombre d'or*, 1931); as Le Corbusier noted on a sketch made in January 1943, relating the Modulor to the human body, Ghyka asserted that the Golden Section was a dominant principle throughout the proportioning of the human body.[68]

Having broken with Vichy Le Corbusier needed to persuade the Resistance of their need for his services; as the pre-war leader of the French branch of CIAM (the Congrès International de l'Architecture Moderne) he had established himself as a theoretician of international standing – and indeed the leading French one – on modern workers' housing; its initial manifesto (the La Sarraz declaration, of 1928), signed (and probably largely drafted) by Le Corbusier, emphasized the need to exploit rationalization and standardization in the building industry, not in order to increase commercial profit but to improve the living conditions of the working classes; and two of CIAM's earliest conferences (1928 and 1930) had been dedicated to minimum dwelling standards and the rational use of land and construction materials in the building of housing estates. ASCORAL may therefore be seen as a vehicle through which Le Corbusier would work out the agenda for modern (and primarily working class) housing, not only as set out in his own earlier manifestos (notably *Vers une architecture*) but also in those of CIAM, in other words the European vanguard of modern architecture.

The political context of the Modulor's origins – Le Corbusier's attempt to be accepted by the Resistance – explains why the book promoting it[69] presented it specifically as an instrument for use on the building sites of the post-war reconstruction, where its use would banish confusion and introduce order into the construction industry.[70] Indeed, the Modulor, 'a new Human(istic) Measure', was to serve as the tool to enable co-ordination at every level, from town planning to furniture.

Le Corbusier's ambitions for the Modulor outstripped those of AFNOR which, as its name implies, intended to set up a nationwide framework for standardization. For the implicit aim of the Modulor project was to set up a universal system, one which – by tapping into a proportional system inherent in nature, and in the greatest works of art of *all* times and cultures – would be applicable worldwide.[71] At one level, this system would effectively reconcile metric with imperial measurements, and thereby continental with British and American building products;[72] here again one suspects that the participation of the Briton, Hanning, in the initial development of this French-based project was particularly significant.[73]

68 Matteoni, op. cit. (1), 23. The first sketch of the Modulor man (dated 28 December 1943), which would become the hallmark of the project, includes references both to Ghyka's *Esthétique des proportions* (op. cit. (51), 47) and to Zeising's work (Matteoni op. cit. (52), 105, and op. cit (1), 22). Ghyka had in fact taken Zeising's assertion that the umbilicus marked the division of the human body by the Golden Ratio as his starting point, but then taken this idea further (Matteoni op. cit. (52), 105).

69 Le Corbusier, op. cit. (46). Its final text was written in August to November 1948, but it was first published only in 1950. It is worth noting that publication would be under the auspices of ASCORAL.

70 Dario Matteoni, 'Modulor: un système de mesures', in Lucan, op. cit. (30), 260.

71 Matteoni, op. cit. (1), 28.

72 Le Corbusier, op. cit. (46), 57.

73 I owe this idea to Tim Benton (conversation, July 1996).

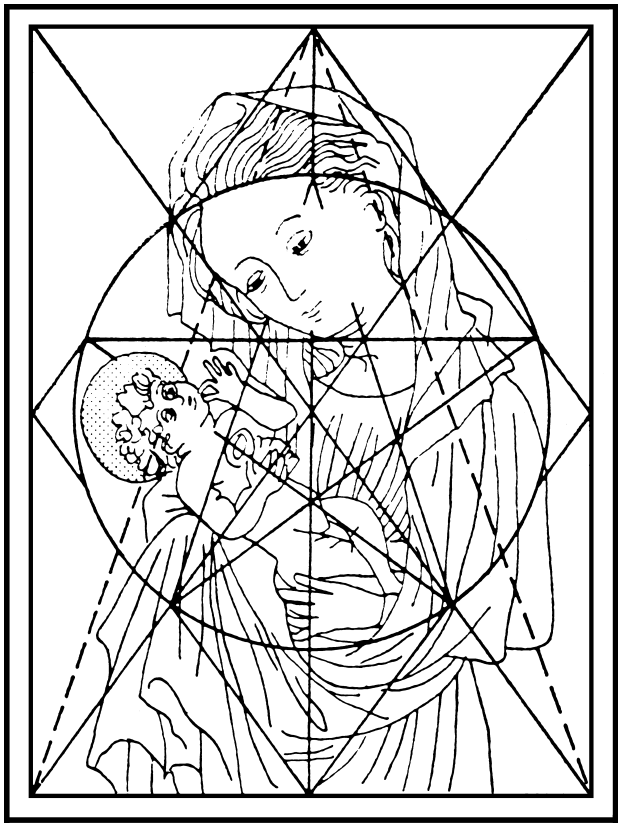

Figure 6. Elisa Maillard, geometrical analysis of *Vierge à l'enfant* (anon., N. France, *c.* 1425) (in Marius Cleyet-Michaud, *Le Nombre d'or*, Paris, 1973: taken from 5th edition, 1985, p. 117).

At another, more profound, level, the Modulor was intended to incorporate a metaphysical dimension into measures themselves; consequently every block of flats, and even every flat built according to the Modulor scale would be raised to the status of a temple.[74] By exploiting number and geometry in this way architects would inevitably 'produce works of the utmost morality'. The principal aims of the Modulor were stated as being Efficiency and Harmony: Efficiency, in terms of the construction industry, was defined as the rational organization of production; this tacitly meant standardization, and

74 This is clearest in the article written by Danielle Janin (an assistant in Le Corbusier's office), 'La Maison Radieuse' for the special edition of *Homme et architecture*, supervised directly by Le Corbusier (Paris, numéro spécial 11–12–13–14, 1947, 68–73), which constituted the first monograph on the Unité d'Habitation at Marseilles. The illustrations to this article included, on its opening page, a photograph of the *pilotis* in a model of the (as yet unbuilt) Unité, with an Egyptian statue in their midst, so as to make them read as the columns of an ancient Egyptian temple (p. 68). Directly above and opposite this photograph were comparable ones of the Basilica at Paestum and the courtyard of Rameses II in the Temple of Amon at Luxor (pp. 68–9). Later on (p. 71) Janin recounts a fictitious visit by some traveller in the future, who arrives at the Unité after visiting many cities, some new and others in ruins; on encountering the *pilotis* he asks aloud, 'Well, well, a new religion in a new temple?' ('Tiens, tiens, une nouvelle religion dans un nouveau temple?').

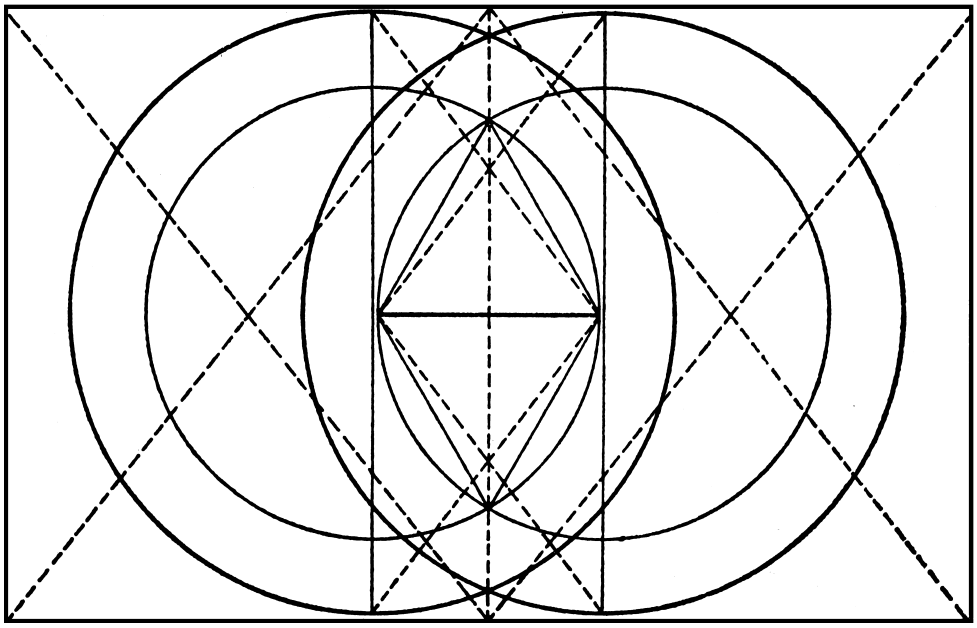

Figure 7. Elisa Maillard, geometrical analysis of Botticelli, *The Birth of Venus* (Uffizi, Florence) (in Marius Cleyet-Michaud, *Le Nombre d'or*, Paris, 1973: taken from 5th edition, 1985, p. 119).

could therefore be seen as depending upon a universally agreed system of dimensions. Harmony was defined as that almost unlimited range of combinations of such measurements, derived from certain ideal numbers, in fact those derived from geometrical constructions based on the Golden Section.[75]

As has been noted, Le Corbusier had already been struck by Matila Ghyka's works on the Golden Number and on rhythms, with their presuppositions that nature is ruled by mathematics and that all the greatest works of art resonate with these mathematical laws of nature. He was not alone in his interest, and a circle of scientists, art historians and practising artists had informally established itself, to study the Golden Number. Early in 1943, when an opportunity arose for Hanning (as a British national) to leave Paris, Le Corbusier brought an art historian from that circle, Elisa Maillard, into the Modulor project; she was a young curator from the Musée de Cluny, who would publish a small book on the Golden Section in architecture that same year (Figures 6–8).[76] From mid-1943 through to the end of the war Hanning and Maillard pursued their research in parallel, the former in isolation in Savoie, the latter with Le Corbusier in Paris.[77] Hanning's role in the

75 Matteoni, op. cit. (1), 28.

76 Elisa Maillard, *Du nombre d'or*, Paris, 1943; Le Corbusier praises this work in *Le Modulor*, op. cit. (46), 38. Her other publications include: *Les Cahiers du nombre d'or*, 5 vols., Paris: vol. 1, *Albert Dürer*, 1960; vol. 2, *Eglises byzantines*, 1962; vol. 3, *Eglises des douzième au quinzième siècles*, 1964; vol. 4, *Botticelli*, 1964; vol. 5, *Le Parthénon*, 1968. The special issue of *Revue d'esthétique* (vol. 14, parts 3 and 4) on 'Arts et mathématiques' (Paris, 1961) includes Elisa Maillard, 'Les proportions du nombre d'or dans les œuvres à deux dimensions'.

77 Le Corbusier, op. cit. (46), 37–42.

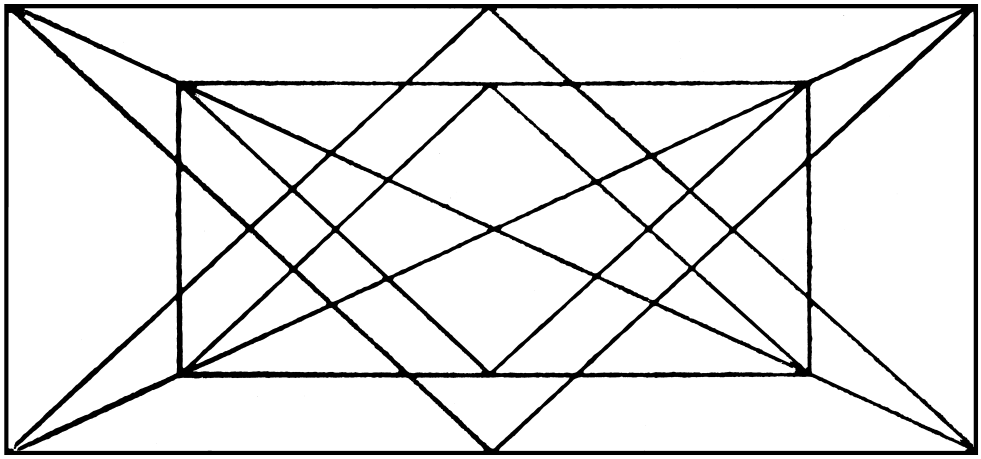

Figure 8. Elisa Maillard, geometrical analysis of plan of the Parthenon (Acropolis, Athens) (in Marius Cleyet-Michaud, *Le Nombre d'or*, Paris, 1973: taken from 5th edition, 1985, p. 120).

initial development of the Modulor was crucial, far more than Le Corbusier would be prepared to admit later on;[78] this reluctance may be due to the fact that since Hanning was working independently his conclusions sometimes conflicted with Maillard's, whose work was under the direct control of Le Corbusier to such a degree that he might consider it at least partly his own.

By the time of the Liberation they had still not resolved the mathematical calculations. Early in 1945 Maillard took Le Corbusier to meet a mathematician friend, Paul Montel, a member of the Académie des Sciences and Dean of the Faculty of Sciences at the Sorbonne;[79] he also seems to have been associated with the Golden Number circle.[80] Montel seems to have clarified the nature of the mathematical problem facing Le Corbusier, rather than solved it for him.[81] The team pursuing the Modulor project now seems to have expanded, as not only Hanning but also some other pre-war assistants – notably André Wogensky and Roger Aujame – returned to the office.[82]

78 Matteoni, op. cit. (1), 21.

79 Le Corbusier has recorded that a meeting of all three regarding the Modulor took place on 7 February 1945 (Le Corbusier, op. cit. (46), 43).

80 Conversation with Rene Taton, July 1995. See also Paul Montel's essay 'La mathématique du nombre d'or', *Revue d'esthetique*, op. cit. (76).

81 Le Corbusier, op. cit. (46), 43.

82 Le Corbusier, op. cit. (46), 43; Le Corbusier's own list of those entering his office, compiled for his exhibition at the Musée de l'Art Moderne, Paris, in 1962–63, runs as follows for the period concerned here: 1944, Aujame and de Looze; 1945, Soltan; 1946, Bodiansky, Janin, Candilis, Gardien, Zalewsky, Dubois. This list is contradicted by Soltan's account, in which he and Hanning were working alone in the office from summer, but the number of inaccuracies in his version – Maillard being a mathematician instead of an art historian, Ghyka being Greek instead of Hungarian, Hanning being French, etc. – suggest that his memory had faded by the time he wrote it, more than forty years after the event (Jerzy Soltan, 'Working with Le Corbusier' in *The Le Corbusier Archive*, vol. 17: *Unité d'Habitation, Marseille-Michelet*, vol. 2 (ed. H. Allen Brooks), New York: Garland, and Paris: Fondation Le Corbusier, 1983, pp. ix–xxiv, especially p. xviii.

A crucial breakthrough occurred later that year with the arrival of a new assistant, the young Pole Jerzy Soltan.[83] He evidently brought a breath of fresh air into the project, casting a critical gaze on it. He would later observe that 'Corbu was not strong in mathematics, but … was very much under its spell.' He recalled how Le Corbusier worked on the Modulor in the late afternoon, seemingly under the influence of the music of Bach and Handel from the church organ next door. It seemed to him that any objective approach to the project was rapidly being displaced, as Le Corbusier progressively placed more emphasis on 'the mythical aspects of the golden section, Pythagoras, the Fibonacci series'; Le Corbusier was relying increasingly upon Ghyka, for whom Soltan evidently had little respect, referring to his writings about 'the golden mean' as 'an interesting mixture of objective information and poetic fuzziness' (and adding that 'it was clear that Ghyka took particular delight in this fuzziness'!).[84] Le Corbusier observed that very soon Soltan 'had a strong reaction against the whole thing', and pointed out that the system being developed was essentially a linear one, and should therefore be expressed as such, instead of as a grid of regulating lines.[85]

Work continued, and Le Corbusier profited from a crossing of the Atlantic by ship over Christmas 1946 finally to complete the Modulor. He took advantage of the boredom and enthusiasm of a teenage boy on board to measure steps and doors on the ship for him, to check the anthropometrics.[86] Meanwhile he discussed this work each night with his cabin-mate, a master cabinet-maker turned teacher at the Ecole des Beaux Arts, Claudius-Petit, now Minister of Reconstruction; in this role he would in due course oversee the completion of the Marseilles Unité, and later, as Mayor of Firminy, he would commission another Unité, together with three public buildings (a stadium, a cultural centre and a church), all built to the Modulor.

Whilst in the United States, Le Corbusier showed his finished work to Albert Einstein. In his subsequent publication of the Modulor Le Corbusier would invoke this scientific icon to lend authority to his new invention, claiming that the scientist had written him a rhapsodic letter the same evening: 'It is a scale of proportions which makes the bad difficult and the good easy … This weapon shoots straight: in the matter of dimensioning, i.e. of proportions, it makes your task more certain.'[87] Whilst in the United States, Le Corbusier also looked for a company to produce a tape-measure printed with his two new Modulor scales.[88] In other words, by now Le Corbusier was conceiving of the Modulor simultaneously in terms of an abstract system of measurements and as its material embodiment in a tape-measure.

83 Soltan, an officer in the Polish army, came directly from several years in a Prisoner of War camp in Switzerland, from which he had written to Le Corbusier asking for work in his office. Multilingual and highly cultivated, Soltan had translated some of Le Corbusier's works into Polish before the war.

84 Soltan, op. cit. (81), p. xviii.

85 Le Corbusier, op. cit. (46), 43.

86 Author's interview with Alain Tavès, summer 1986. Tavès had been the 'boy' concerned; little over a decade later Tavès would enter Le Corbusier's office as a draughtsman, on graduating from architectural school in Paris (interviews with author, summer 1986).

87 Le Corbusier, op. cit. (46), 58.

88 Matteoni, op. cit. (1), 25. On returning to France Le Corbusier left John Dale (chairman of Charles Hardie Inc.) searching for an industrialist to manufacture the Modulor rule (Le Corbusier, op. cit. (46), 46–8).

From notes on a sketch Le Corbusier made in 1944 for the development of the Modulor it is evident that he not only connected his own scale with the geometries employed by builders in Antiquity or the Middle Ages but that he also envisaged it as being used in like manner, namely by being drawn on a wall on the building site, for continual hands-on reference during the construction process.[89] On his return, in 1947, Le Corbusier took out a *brevet* (the French version of a patent) on his Modulor, now understood at once as an abstract system and a tape-measure (*ruban*) printed with both Modulor sequences; by thus giving his system material form Le Corbusier hoped to maximize its adoption by architects, through getting the measure accepted as an essential piece of drawing office equipment.[90] The same year saw the publication of a special issue of the magazine *L'Homme et l'architecture*, dedicated to the (as yet unbuilt) Marseilles Unité d'Habitation, the first building designed to the Modulor scale.

AN ARTIST AND A MATHEMATICIAN

Nevertheless the final calculations for the Modulor were not yet entirely resolved. Le Corbusier went back to Montel, to ask for further help. The great mathematician pleaded lack of time, but promised to find another mathematician in his place. No doubt Montel was busy, but also perhaps reluctant to spend any spare time he might have on such a project. He may well have realized that involvement at this late stage was liable to get his name attached to this academically questionable project, in the now looming publication of it. Montel suggested an ex-student of his own, now completing his thesis on the history of geometry, René Taton (who subsequently became one of the best respected historians of mathematics in France). He felt that Taton's work on perspective, and therefore on the relations between architecture and geometry, equipped him ideally for the task. Taton's reflections on this collaboration – which did indeed lead to him being credited in the 1950 publication of *The Modulor*[91] – reveal the hitherto undocumented side of this story, namely the mathematician's account of events.

Today Taton is very reticent – and diplomatic – about his involvement in the Modulor: 'I just did a few basic calculations for him.' In fact these filled less than two pages. Le Corbusier reproduced them in full in the eponymous book, both in facsimile and in transcription. They are thus exploited as an authority. Although Taton persistently reiterates that his memory is now vague, owing to the passing of time (nearly half a century), it actually turns out to be quite clear if a little painful: 'I never understood why he didn't just get his *Bureau d'Etudes* to do those calculations' (in France architects usually rely upon *bureaux d'études* – separate offices of technical draughtsmen – to take care of all their detailed drawings and calculations for them). Surely it was because Le Corbusier wanted to be able to invoke a mathematician's authority? Taton hints that he did not feel

89 Matteoni, op. cit. (52), 104, and op. cit. (1), 22–3.

90 The publicity for the tape-measure promoted it as 'The instrument to put on the table beside compasses' ('Outil à placer sur la table à dessin à côté du compas'), letter from John Dale to Le Corbusier, 9 December 1946 (Archives de la Fondation Le Corbusier, cited in Matteoni, op. cit. (1), 25); it was relatively small (2.16 m), and thus designed for office rather than site use. It was available in fabric and metal versions.

91 Letters to author 1994–95; conversation with author, June 1995.

that mathematics was being used as it should. He cites an example of Le Corbusier glossing over a difference of 1/2000, a lack of precision which Taton found unacceptable. He knew Le Corbusier was the most famous architect in France, if not the world, so believed that the Modulor project must be of some importance. But he could not understand it because, as he said, 'I'd had nothing to do with this world of architecture before'; and he now seems embarrassed at having ventured into this foreign territory.

The intellectual roots of the disagreement between Le Corbusier and René Taton as to the nature of mathematics, and the role it should therefore play in architectural design, can be elucidated by further study of this incident. Le Corbusier admits that Taton had pointed out what seemed to him, as a mathematician, a fundamental problem in the generation of the Modulor grid: Le Corbusier interprets Taton's calculations as confirming his original hypothesis, that posited in 1942, namely: 'Take two equal and contiguous squares and set a third square, equal to the others, inside the two initial squares, at the place known as "the place of the right angle".' Taton, however, noted that in the diagram Le Corbusier had given him to work on, 'the two initial squares' were not really squares at all, as one of their sides was larger than the other three by 6/2000. Le Corbusier appears not to have fully appreciated the basis of Taton's objection, as he blithely dismissed it:

> In everyday practice, six thousandths of a value are what is called a negligible quantity, a quantity which does not enter into account; it is not seen with the eye.
>
> But in philosophy (and I have no key to that austere science, I suspect that these six thousandths of a value have an infinitely precious importance: the thing is not open and shut, it is not sealed; there is a chink to let in the air; life is there, awakened by the recurrence of a fateful equality which is not exactly, not strictly equal... And that is what creates movement.[92]

For Taton, as a mathematician, the essential character of mathematics requires that it be consistent within itself. Mathematics, in the sense of the scientific discipline, has no obligation to be applicable to the external world; therefore external values – in this case metaphysical ones – cannot validly be deduced from it. Furthermore, Le Corbusier's 'misuse' of mathematics is compounded here – as he even admits himself – by taking mathematical approximations as the basis for such metaphysical pronouncements.

So was this encounter a one-sided relationship, the artist grabbing authority from the mathematician? Not quite. Taton becomes quietly enthusiastic as he recalls the party he and his wife threw, with Le Corbusier as star attraction: 'All the top scientists came – Montel, of course, but also Jean Rostand the biologist... and all of them.' Evidently the young mathematician acquired prestige within the learned community through his public association with such a famous figure from the artistic avant-garde.

CONCLUSION

> We have two ways of positing the outside world.
> 1. Numbers. Through their effect there is plurality of individuals: sympathy, order, harmony, beauty, etc.... in short, everything that is of mind.
> 2. Space. This gives us objects 'having extension'. In the spatial world the images of the numerical world are projected, first by nature itself, then by men and above all by artists. It can be said that our duty on earth and during the whole of our life consists precisely in this projection of forms

92 Le Corbusier, op. cit. (46), 234–5.

> issued forth from numbers, and that you, the artists, fulfil that moral law to the highest degree. Not only is it possible to appeal simultaneously to geometry and to numbers, but to do so is the true purpose of our life.
>
> Andreas Speiser, cited by Le Corbusier as the preface to the final chapter of *Modulor 2*[93]

It is worth recalling the contemporary intellectual context of the 1940s and 1950s in the humanities. The most academically respectable art historians were beginning to display a new interest in the role played by proportion and harmony in mediaeval and Renaissance architecture, actually writing up and publishing the results of their research at exactly the same time as Le Corbusier was pursuing his studies for the Modulor. A series of articles published in London during the Second World War set out the research by the *émigré* Viennese art historian Rudolph Wittkower into the philosophical significance of the geometry and proportional systems underlying Renaissance theory and practice in architecture.[94] 1949 saw the publication of both James Ackermann's seminal article on the geometry of Milan cathedral, in the States, and Rudolph Wittkower's highly influential book, *Architectural Principles in the Age of Humanism* (basically a collection of his wartime articles), in Britain.[95] Wittkower at least was not unaware of the parallel interests of practitioners, noting in the preface to his book that 'the subject is very much alive in the minds of young architects today'.[96] Indeed, as he had predicted to his scholarly publishers, who had believed his book would only attract a strictly academic audience, such large numbers of architects bought it that a reprinting was needed shortly after publication.[97] This text would in turn exert a significant influence upon the subsequent architecture of the Modern Movement.[98]

Within such a climate it is hardly surprising that in 1951 the ninth Milan Triennale devoted its first ever International Meeting (Primo Convegno Internazionale sulle

93 Le Corbusier, op. cit. (9) 205. Le Corbusier fails to give any detailed reference.

94 Rudolph Wittkower, 'Alberti's approach to antiquity in architecture', *Journal of the Warburg and Courtauld Institutes* (1940–1), **4**, 1–18; 'Principles of Palladio's architecture', part I in ibid. (1944), **7**, 102–22, and part II in ibid. (1945), **8**, 68–106.

95 James Ackermann, 'Gothic theory of architecture at Milan Cathedral', *Art Bulletin* (1949), **31**, 84ff, Rudolph Wittkower, *Architectural Principles in the Age of Humanism*, Studies of the Warburg Institute, 19, London, 1949. The only major differences consisted of the inclusion in the book of an extra chapter (ch. 1), 'The centrally planned church in the Renaissance', and the section on Palladio's optical and psychological effects at Il Redentore, in the chapter on Palladio (Alina Payne, 'Rudolph Wittkower and architectural principles in the age of modernism', *Journal of the Society of Architectural Historians* (1994), **53**, 322–42, on 325 n14).

96 Wittkower, op. cit. (95), Preface. On Rudolph and Margot Wittkower's considerable awareness of modern architecture and the current interests of its practitioners see Payne, op. cit. (95), 338 n106: From 1925 onwards he wrote on modern architecture; they both read 'all' the modern architectural writers, including Le Corbusier; and they claimed to have been the only art historians to have visited the Weissenhof Siedlung in 1927.

97 Margot Wittkower informed Henry Millon that the publishers had only wanted to print 500 copies, for Renaissance scholars, but the Wittkowers advised them to print an extra 100 copies as 'some architects will want to read the book'; it sold out within three months (Henry Millon, 'Rudolph Wittkower, *Architectural Principles in the Age of Humanism*: its influence on the development and interpretation of modern architecture', *Journal of the Society of Architectural Historians* (1972), **31**, 83–91, on 89 n33). A second edition was brought out by Tiranti (London) in 1952 and a third in 1962 (ibid., 83 n2).

98 For further details see Millon, op. cit. (97); Payne, op. cit. (95); Eva-Marie Neumann, 'Architectural proportion in Britain 1945–1957', *Architectural History* (1996), **39**, 197–221.

Proporzioni nelle Arte) to proportions in art, under the heading 'De Divina Proportione', with Ghyka, Ackermann, Wittkower and Le Corbusier all amongst the principal speakers.[99] The fact that academics and practitioners were no longer merely pursuing their interest in this subject in parallel but rather in tandem is borne out by the considerable presence of other leading members of the Modern Movement, alongside Le Corbusier, amongst the speakers: Siegfried Giedion, the General Secretary of the Congrès International de l'Architecture Moderne (CIAM); Luigi Nervi, the prime engineer responsible for enabling cutting-edge architecture in post-war Italy; Ernesto Rogers, founding editor of the main magazine produced by the Italian Modern Movement, *Casabella*, and senior partner in Milan's most influential post-war architectural practice, BBPR (Banfi, Belgiojoso, Peressutti and Rogers).[100] The associated exhibition of books[101] included works by relevant practitioners and theorists from the past (beginning with Villard d'Honnecourt in the thirteenth century and most of the major Renaissance theorists) set out beside those of twentieth-century historians and theorists such as Ghyka and Wittkower, culminating in the presentation of Le Corbusier's *Modulor*.[102] Thus congress and exhibition alike assimilated Le Corbusier into the international academic community and his work into an academically defined and validated canon of treatises and studies, thereby according him precisely the kind of acceptance and recognition which he had craved for so long.

Two years later Wittkower contributed the introductory essay to the 1953 *Architects Yearbook*,[103] presenting a summary of studies on antique, mediaeval and Renaissance use of proportions in architecture but warning against depending on such abstract systems in the modern era, now that such systems, inherently with 'their bases … outside the material facts of the human body', were no longer counterbalanced by anthropometric measures, 'the foot, the palm, the cubit, *etc*.'. Wittkower acknowledged the contemporary revival of interest in systems of proportion, and then asked how artists might appropriately apply them within today's understanding of the universe, radically transformed by relativity theory into one based on non-Euclidean geometry; in other words, what effect would 'the replacing of absolute measures of space and time by the new dynamic space-time relationship' have upon proportion in the arts? He concluded by offering Le Corbusier's Modulor as 'a preliminary answer' to the issues he had raised:

99 James Ackermann later recalled that the congress received so much attention that it seemed more like a glamorous film opening, with Wittkower and Le Corbusier in the role of the two stars (Payne, op. cit. (95), 339 n109).

100 The lectures they gave were on the following themes: Wittkower, 'Some aspects of proportion in the Middle Ages and the Renaissance'; Ghyka, 'Pentagonal symmetry and the Golden Section in the morphology of living organisms'; Ackermann, 'Gothic architectural proportions, Milan 1400; Giedion, The parts and the whole in contemporary art and architecture; Nervi, 'Proportions in technology' (static equilibria which determine architectural proportions); Rogers, 'Measure and greatness'; Le Corbusier, 'The Modulor'; Bill, 'The idea of space', The artists Severini and Vantongerloo also delivered papers. A summary of the conference is given by Le Corbusier (op. cit. (9), 141–5); abstracts of the papers were published in *Atti e Rassegna Technica della Società degli Ingegneri e degli Architetti in Torino* (1952), No. 6, 119–35.

101 The catalogue was published as *Nova Triennale di Milano*, *Studi sulle proporzioni*, Milan, 1951.

102 Le Corbusier, op. cit. (46), 2nd edn, Introduction.

103 Rudolph Wittkower, 'Systems of proportion', in *Architects Yearbook*, No. 5 (ed. Trevor Dannatt), London, 1954, 9–18, on 18.

> In the light of history it appears as a fascinating attempt to co-ordinate tradition with our non-Euclidean world. First, by taking, instead of universals, man in his environment as his starting point, Le Corbusier has accepted the shift from absolute to relative standards. But on this level he attempts a new consolidation. The older systems of proportion were what I might call one-track systems, in so far as they were coherent developments of basic geometrical or numerical concepts. Not so Le Corbusier's Modulor. Its elements are extremely simple: square, double square and divisions into extreme and mean ratios. These elements are blended into a system of geometrical and numerical ratios: the basic principle of symmetry is combined with two divergent series of irrational numbers derived from the Golden Section. Whatever one may think of it, this is certainly the most consistent synthesis since the breakdown of the older systems, reflecting our own civilisation into the bargain. At the same time it testifies to the coherence of our cultural tradition. Like the proportions of plane geometry used in the Middle Ages, like the arithmetical proportions of the Renaissance, Le Corbusier's dual system of irrational magnitudes is still dependent on the conceptions which Pythagorean–Platonic thought opened up for western mankind.[104]

I see the Modulor project as a paradigm of Le Corbusier's *œuvre* as a whole, and perhaps even as its supreme resolution of his intellectual and pragmatic intentions. Regardless of his international status (attained well before the post-war era) Le Corbusier's feelings of insecurity and doubts as to his success would haunt him to the end of his life. The 'architect of the century' lacked any formal academic or indeed architectural qualifications, having trained in decorative art at a provincial Swiss art school. Thus he had always sought to capitalize on any accreditation of his work by recognized academics, and especially by scientists. An early example of this (noted in passing above) was his reference to Dieulafoy, an eminent nineteenth-century archaeologist attached to the Louvre, in order to justify his assertions that all great architecture which we revere from past ages has been designed according to geometric proportioning systems. The Modulor opened up greater opportunities than ever before to associate himself, and his work, with individuals and institutions respected by society on academic grounds. Hence the fact that the vast majority of work in developing the Modulor was undertaken by his assistants is perhaps given lesser acknowledgement than it might deserve, in order to highlight the (in actual fact relatively minor) role played by recognized intellectuals, so as to raise the profile of his own project.

In this regard one should recall the role he accorded to Elisa Maillard (presented here as keeper from a major national museum), Paul Montel (explicitly referred to as Dean of the Faculty of Sciences at the Sorbonne) and René Taton ('a mathematician').[105] He made particular capital out of Einstein's positive reception of the Modulor,[106] citing this no less than four times in *Modulor 2*.[107] Indeed a large part of *Modulor 2* is framed as a justification of his work, specifically on the grounds of its acceptance by those whom he saw as commanding respect in intellectual circles: the numerous references to Andreas Speiser, professor of mathematics at the University of Basle;[108] Siegfried Giedion, referred to here specifically as professor at Zurich and Harvard, rather than as founding secretary of CIAM;[109] Konrad Wachsmann, head of the research unit specializing in industrialization

104 Le Corbusier, op. cit. (9), 191–3.
105 Le Corbusier, op. cit. (46), 231.
106 Le Corbusier, op. cit. (46), 58.
107 Le Corbusier, op. cit. (9), 84, 131, 201, 289.
108 Le Corbusier, op. cit. (9), 20, 76–9, 205, 207.
109 Le Corbusier, op. cit. (9), 74.

of the construction industry at the Illinois Institute of Technology;[110] directors of prestigious or powerful institutions, including the production director at the National Commercial Department of Electricité de France, the director of the Institute of Physico-Chemical Biology in Paris (Pierre Girard), the overall director of national museums (Germain Bazin), and the director for construction at the Ministry of Reconstruction and Town Planning.[111] Similarly he uses to full advantage this opportunity to publicize major international conferences to which he has been invited (notably that at the 1951 Milan Triennale)[112] and official honours he has received (such as the RIBA Gold Medal).[113] Furthermore, seeing that he was not alone but that artists in general faced a progressively declining status within an increasingly technological world, he had adopted a strategy rather akin to that of his Renaissance forebears; just as they had grasped the necessity of theorizing upon architecture and the fine arts in order to raise them from the level of the *ars* of the guild-based crafts into the *scientia* of the university-based liberal arts, so Le Corbusier had concerned himself with theorizing as much as design, and then taken advantage of every occasion to try and insinuate those theories into the academically respectable milieus of scholarly art history or science. Dario Matteoni has, I believe rightly, interpreted Le Corbusier as envisaging his Modulor as offering artists (and notably architects) a solid foundation from which to develop their daily work, by providing them with a mathematical rule related both to the scale of the human body and to human perceptions.[114] Yet, as we have seen, Le Corbusier's prime interest in mathematics, above all other sciences, stemmed from his almost religious belief in it as the sole means of revealing to man the most essential laws of the universe, those transcending the particularities of any given place or time. Likewise his preoccupation with harmony derived from the possibility which it offered of material incorporation into architecture – through mathematically calculated proportional systems – thereby constituting the most reliable means of taking architecture beyond the present, not merely in order to create architecture which would be truly modern (that is, of its own time) but rather would stand outside time, and thereby endure in the same way as had such architectural classics as the Parthenon.

Le Corbusier's relationship with, and approach towards, mathematics was thus one of a respectful believer, and devotee; for him mathematics was primarily conceived as a constituent part of philosophy, even of metaphysics, 'the presence of a sovereign power' no less.[115] Hence he empathized with designers of monuments which have come down to us from Antiquity, the Middle Ages and the Renaissance, since he believed that they had shared such a view of mathematics. Equally obviously, such a conception of mathematics opened up a chasm between him and modern scientists, for whom his ideas would have seemed not only unfashionable but probably bizarre. Nevertheless, Le Corbusier's Modulor project whilst dependent upon, and exploiting, mathematical techniques (of

110 Le Corbusier, op. cit. (9), 163. Wachsmann was in fact an ex-associate from Le Corbusier's office, a fact which he fails to mention.

111 Le Corbusier, op. cit. (9), 21, 22, 131.

112 Le Corbusier, op. cit. (9), 141, 170–3.

113 Le Corbusier, op. cit. (9), 133.

114 Matteoni, op. cit. (1), 29.

115 Le Corbusier, op. cit. (1).

geometry, algebra and arithmetic) to achieve its goal, firmly considers these to be no more than means to an end; it is fundamentally posited upon a conception of mathematics as a metaphysical entity, as nothing less than a means of acceding to a higher plane of consciousness or being.

When mathematics is accorded respect by artists this may be for reasons very different from those which scientists usually invoke, since for artists its authority may derive from its fulfilment of a philosophical, even metaphysical, role within the universe, including today's world. Architects and other artists therefore often use mathematics – and indeed other sciences – in a way so different from that of scientists that their very claims to using science, let alone their pretensions to being 'scientific', can shock and pain 'real' scientists. But can scientists claim exclusive rights over this 'property'? After all, have they the right to confine mathematics to the domain of science, thereby excluding it from that of philosophy, and thence from the humanities? Should we not accept that it might usefully serve at once as an art (perhaps in the ancient sense, of *scientia*, a body of abstract knowledge of fundamental consequence and universal relevance), as well as a science in the current sense in which mathematics is popularly understood, a body of techniques (which, confusingly, would equate with the *ars* of earlier times). In my view, we need to acknowledge that artists can profitably draw inspiration from science even when – within the terms of modern science – they 'misunderstand' it, or use it 'creatively'. In other words, if the ultimate test of the artists' appropriation of mathematics is to be made within the terms set by the artist, it must be made on the grounds of the artistic success of the work created using mathematics, rather than the correctness of the work's usage of mathematics.