# The fundamental city

*In dilating my surface I increased the possibilities of contact between me and the outside of me that was so precious, but as the zones of my body soaked in marine solution were extended, my volume also increased at the same time, and a more and more voluminous region within me became unreachable by the elements outside, it became arid, dull and the weight of this dry and torpid thickness I carried within me was the only shadow on my happiness – so perhaps I could say that I'm better off now than I was then, now that the layers of our former surface, then stretched on the outside, have been turned inside out like a glove, now that all the outside has turned inward, and enters and pervades us through filiform ramifications...*
**(Italo Calvino, Blood, Sea)**

## Cities as things made of space

In the previous chapter it was suggested that the relation between human beings and space was, at a deep level, governed by two kinds of law: laws of spatial emergence, by which the larger-scale configurational properties of space followed as a necessary consequence from different kinds of local physical intervention; and laws of 'generic function', by which constraints were placed on space by the most generic aspects of human activity, such as the simple facts of occupying space and moving between spaces. In this chapter we argue that, to a significant extent, the spatial forms of cities are expressions of these laws, and that if we wish to understand them we must learn to see them as 'things made of space', governed by spatial laws whose effects but not whose nature can be guided by human agency. One implication of this argument will be that twentieth-century design (as dicussed in Chapter 5) has often used spatial concepts for urban and housing areas which fall outside the scope of these laws, creating space which lacks the elementary patterning which these laws have normally imposed, in some shape or form, in the past. If, as is argued here, such laws exist, then it will be necessary to revise current concepts of the well-ordered city back in the direction implied by these laws.

There are, however, obvious objections to the idea that urban forms evolve according to general laws. The most obvious is that cities are individuals, and that this is because the forms they take are influenced by factors which are quite specific to the time and place in which they grow – local topographical facts such as harbours, rivers and hills, particular historical events such as trading developments, population movements and conquests and by pre-existing contextual conditions, such as route intersections and the existence of exploitable resources. Each type of influence might be expected to have generically similar effects on urban form, but taken together it is highly unlikely that any two cities would repeat the same grouping or sequencing of influences. These factors, then, in spite of initially suggesting bases for comparison, tend make each city unique. And this, of course, is how we experience them.

A second objection is slightly less obvious, and a little contradictory to the first, since it is typological. The spatial and physical development of cities is – quite properly – held to be a reflection of the social and economic processes which provide the reasons for their existence. Differences in these processes are likely to give rise to differences in type between cities. We saw a clear instance of this in the typological contrast drawn in Chapter 6 between cities of production and cities of social reproduction. Differences in spatial and physical form were there shown to be reflections of differences in the essential functions of those cities. Similarly, differences in the physical and spatial form of cities, say, to the north and south of the Mediterranean, are manifestly connected in some way to the social and cultural idiosyncrasies of the European and Islamic traditions. It seems then to be specific social, economic and cultural processes, rather than generic spatial laws, that are the driving forces on urban form.

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Both objections seem well-founded. Seen in one way, cities are individuals; seen in another another, they seem to be types. How can these facts be reconciled to the idea that general spatial laws might play a role in their spatial evolution? In fact, there is no incompatibility. It is simply a matter of the level at which we are talking. The influence of spatial laws on cities operates not at the level of the individuality of the city, nor on the typology of the city, but at the deeper level of what all individual cities and types of city have in common, that is, what, spatially, makes a city a city. As settlements evolve under different social and topographical conditions, they tend to conserve, in spite of the influence of these differences, certain properties of spatial configuration 'nearly invariant'. By 'nearly invariant', we simply mean that the configurational properties we find fall within a very narrow band of combinatorial possibility. Without knowledge of these 'near invariants' we cannot easily understand what cities are in principle, before we consider them as types or as individuals.

What are these 'near invariants'? Let us begin by looking at a pair of illustrative axial maps: plate 2c-e, which is part of London as it is now, and plate 7, which is the central part of Shiraz, in Iran, as it was prior to twentieth-century modernisation. The grids have clear differences in character. Line structures are more complex in Shiraz, and are in fact much less integrated and intelligible. If we were to examine the relation of lines to convex elements, we would find that in London lines tend to pass through more convex spaces that in Shiraz. Looking at the integration core structures, we also find differences. Although at radius-n (not shown in the case of Shiraz), both have strongly centralised cores, linking centre towards edge, at radius-radius, London has a 'covering' core, linking centre to edge in the way characteristic of European cities, while in Shiraz the radius-radius core is markedly regionalised. These differences in grid structure are associated with well-known behavioural differences, for example, in the ways in which inhabitants relate to strangers and men to women in Islamic as compared to European cities. We can call these associations of urban forms and social behaviour 'spatial cultures', and note that one of the main tasks of a theory of urban form would be to explicate them.

However, as can be seen from the two plates, underlying the manifest spatial differences we also find much common ground in the urban grids. For example, in both cases, the spaces formed by the buildings tend to be improbably linearised in at least three senses. At the smallest scale, we find that buildings are placed next to and opposite each other to form spaces which stress linearity rather than, for example, enclosure. Second, at a slightly less local level, lines of sight and access through the spaces formed by buildings tend to become extended into other spaces to a degree that is unlikely to have occurred by chance. Third, we find that some, but only some, of the linear spaces are prioritised to form larger scale linear continuities in the urban grids, creating a more global movement potential. These properties are present in the two cases to different degrees, but they are nevertheless present in both cases. They will be found to be present in some degree in most settlements.

At a more global scale, we also find commonalities across the two cases, which are also 'near invariants' in settlements in general. Two of the most notable are that in both cases we will find a well formed local area structure of some kind coexisting with a strong global structure. Both levels of structure are different in the two cases, but each case does have both levels of structure, and this we will find is generally the case in cities. At the most general level of the overall shape of cities, we also find 'near invariants'. One of the most significant is that cities, as they grow, tend to fill out in all directions to form more or less compact shapes, even in cases where they are linear in the early stages. The 'deformed grid', with all the properties we have just described, seems to be the aptest term to summarise these, and other, 'near invariants' of cities, because, however much urban space is articulated and broken up, buildings are still in general aggregated into outwards facing islands to define intersecting rings of space, which then become improbably linearised to give rise to the local area and global structures that are found by configurational analysis.

These commonalities, it will be argued, arise from what spatial cultures have in common, that is, from what in the previous chapter was called generic function. This, it will be recalled, referred not to the different activities that people carry out in space, but to aspects of human occupancy of space that are prior to any of these: that to occupy space means to be aware of the relationships of a space to others, that to occupy a spatial complex means to move about in it, and to move about depends on being able to retain an intelligible picture of the complex.

Intelligibility and functionality, defined as formal properties of spatial complexes, are the keys to 'generic function'. In the case of settlements, generic function refers not to the specificities of different cultural, social and economic forms, but to what these forms have in common when seen from a spatial point of view. The deep invariant structure of urban grids is generated, it will be argued, from generic function creating emergent invariants, while the typological differences arise from cultural, social and economic differences, and individualities from topographical and historical specificities. In effect, it is proposed that there exists a fundamental settlement process, which is more or less invariant across cultures, and that spatial cultures are parameterisations of this process by, for example, creating different degrees and patterns of integration and intelligibility, and different degrees of local and global organisation to the overall form. Our task here is to show what this fundamental settlement process is and how it is a product of generic function and the laws of spatial emergence.

Before we embark on this, we must first be clear what exactly it is we are seeking to explain. It is clear that when settlements are small, they can take a great variety of forms. It is also clear that throughout history we find quite radical experiments in urban form, for example, the cities which we examined in Chapter 6. However, as cities become large, these peculiarities tend to be eliminated, and grids become much more like each other in certain ways. What we are seeking to identify here are the invariants in the processes by which large cities tend to grow – that is, to try to describe the main lines of urban evolution. 'Strange' cities exist, and for a while even grow quite large, but they are essentially dead ends in urban evolution.

Their principles of organisation do not support a large successor family of cases and types across the range of urban scales.

Because they operate at a very deep level and govern the common structure of cities, it might be thought that the fundamental city is too generalised to be of real interest. This is not the case. The influence of spatial laws on cities is pervasive as well as deep. It effects the level at which we see and experience cities, as well as at the level of their deep structures. In order to understand individual cities and types of cities at any level we must first understand exactly what it is that these general laws have contributed to their form. If we think of cities as aggregates of cellular elements – buildings – linked by space, then in the language of the previous chapter, spatial laws are the ‘first filter’ between the boundless morphological possibility for such aggregates and the properties of the vanishingly small subset we call cities. Social and economic processes are then the second filter, guiding the basic paths of evolution this way or that to give rise to recognisable types. Specific local conditions in time and space are then the third filter through which the city acquires its eventual individuality.

Our task in understanding the fundamental city is then to answer two questions: how and why should these particular invariants emerge from a spatial process of generation? And what aspects of the social and functional processes that drive settlement formation guide growing cities along these pathways? The answer to both questions will be essentially those we have discussed in the previous chapter: laws of spatial implication from local physical moves to overall spatial pattern in cellular aggregates – for such cities are – these being driven by ‘generic function’, in conjunction, of course, with prevailing socio-economic and topographical factors.

**Two paradoxes**

How then and why should these ‘near invariants’ *emerge* in a process of successively placing built forms in a growing aggregate? First, we must be aware that aggregative processes are themselves subject to certain laws of ‘emergence’, which are not insignificant for urban growth. For example, a randomly growing aggregate will, if free from constraints, tend towards a circular form as it becomes large, simply because this is more probable than any other form.[1] This is relevant to urban growth because a circular shape is also the most integrating shape, and this means that to the extent that trips are from all ponts to all others, then mean trip length will be minimised in a circular form – that is, oddly, in the form that grows most randomly.

Such ‘laws of emergence’ are important to urban growth. But far more important is the fact that some of the most elementary laws of this kind affect urban growth not simply by being emergent properties of the growing system, but by imposing conflicting tensions on the system. The resolution of these then becomes the prime determinant of the pathway of the system. The laws of emergence operate, in effect, as paradoxes which must be resolved by the growth process. There are two such paradoxes. The first can be called the paradox of centrality, the second the paradox of visibility.

The paradox of centrality takes the following form. In a circular – that is, most probable – aggregate, integration runs from centre to edge, with the greatest integration in the centre, and the least at the edge. This prioritises the centre from the point of view of known effects of integration on the functioning of a spatial system. For example, more movement along shortest paths will pass through the central area than anywhere else, if movement is from all points to all other points, or if origins and destinations are randomised.

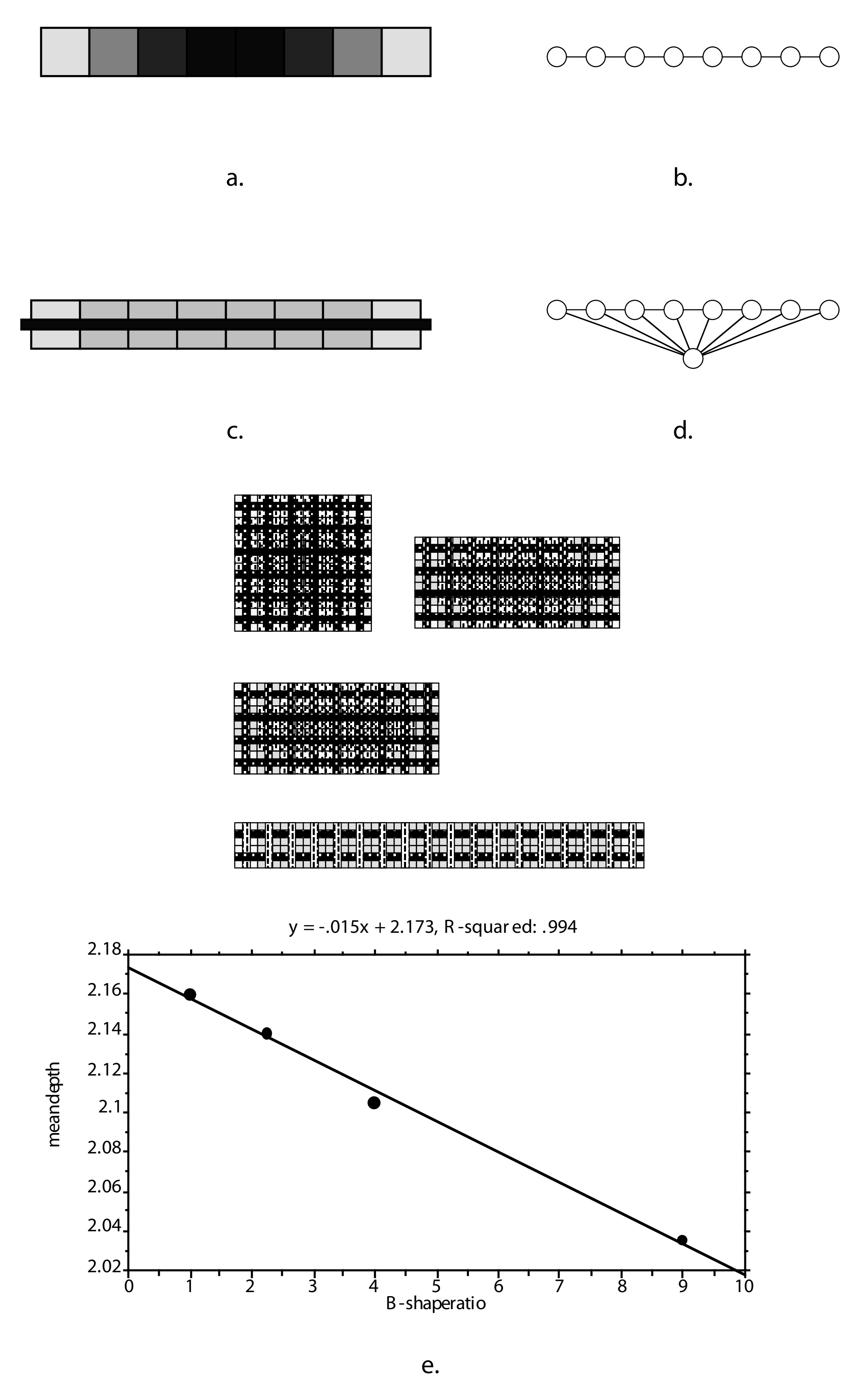
However, all this is only the case if we consider the urban system on its own, in terms of its interior relations. As soon as we consider its external relations, say to other settlements in the region, or even simply to the space outside the system, then the centre to edge distribution of integration no longer applies. In fact, the more integrating the form – that is the more it approximates the circular form – then the more its most integrated internal zone is maximally segregated from the external world, and, by definition, from any other aggregates that are to be found in the vicinity of the system. In other words, maximising internal integration also maximises external segregation. This is the 'paradox of centrality'.

Conversely, as we move from a circular form towards the most linear form, that is the single line of cells, or the least probable shape in a growing aggregate, then we find that the most linear form, which is the least integrated in itself, is the most integrated to the outside or to other systems in the region, since each of its constituent cells is by definition directly adjacent to the space outside the form. In short, the circular form is the least integrative with the space outside the form for the same reason that it is the most internally integrative: it has the least peripheral cells for the maximum interior cells. The converse is true for the maximally linear form which has the most peripheral cells against internal cells.

Growing urban systems must respond to the paradox of centrality, because it has the simple consequence that if you try to maximise internal integration then you lose external integration and vice versa, and urban forms seem to need both internal and external integration. The tension between internal and external integration leads settlements to evolve in ways which overcome the centrality paradox. For example, the tendency for a growing urban system to increase the length of certain edge-to-centre lines in proportion to the growth of the system is one response to this. Exactly why this should be the case leads directly to our second paradox, which we will call the paradox of visibility, although this does not quite express its complex nature, since it arises from differences between the metric and visible properties of space.

The visibility paradox can be explained very simply. If we arrange elements in a single line, as in figure 9.1a and b (the corresponding graph), we maximise the metric or modular depth that those elements can have from each other in any contiguous arrangement. The more elements we so arrange, the greater the depth, and the worse the metric trip efficiency of the form if movement is to be from all points to all others. But if we are interested not in movement, but in visibility, then we find the contrary effect. Suppose, for example, we superimpose a line,

Figure 9.1


a.
b.
c.
d.
y = -.015x + 2.173, R-squared: .994
meandepth
B-shaperatio
2.18
2.16
2.14
2.12
2.1
2.08
2.06
2.04
2.02
0
1
2
3
4
5
6
7
8
9
10
e.

representing a line of sight, on our linear arrangement of elements, as in figure 9.1c and d. The visible (as opposed to metric) integration of the form is then maximised because all cells are covered by a single line. In the graph, this means all other elements are connected to the graph element representing the line. In other words, the arrangement of elements in which metric segregation is maximised, that is, the linear shape, is also the arrangement in which visual integration is maximised. For a linear shape without a line of visibility, mean depth increases with the number of cells, but with the superimposition of the line then, however long the line of cells, the maximum depth in the system will be 2, and in fact the mean depth of an expanding sequence must converge on a limit of 2.

In an important sense, then, the visual integration of a shape behaves in the opposite way to the metric integration. This will also apply to grids made up of elements and superimposed lines. Holding the number of elements steady at 36, and arranging them to be covered first by a 6×6 grid of lines, then 9×4, then 12×3 and finally 18×2, we find the mean depth of the system decreases with elongation. We can say then that visual integration increases with increase in the block shape ratio, that is, the ratio of the long to the short side, as in the figures and scattergram in figure 9.1e. This is the opposite of the effect of elongation on a shape on its own, without superimposed lines.

In other words, when considered as elements in a visibility field the primitive elements representing locations in the form have the contrary integration behaviour to the same elements considered as a system of metric distances. If lines are superimposed on grids of elements, then the more elongated the grid, the more integrating; the opposite of the case for arrangements without superimposed lines. The linear form, which from a metric point of view, and therefore from the point of view of movement considered as energy expenditure, is the least integrated form, is visually the most integrated form. The implication is obvious, but fundamental. If we arrange a series of, say, urban areas in a line we maximise the mean trip length at the same time as we maximise visibility. The same principle governs the progressive elongation of grids.

Urban form must then overcome two paradoxes. First, it must create external integration for the sake of relations to the outside world, as well as internal integration, for the sake of relations amongst locations within, even though these properties are theoretically opposed to each other. We may add that urban form must acheive this at whatever level the paradox might become problematic. That is likely to include at least a local and a global level. Second, it must pursue both compactness and linearity, the former for the sake of trip efficiency, the latter for the sake of visibility and intelligibility. The characteristic 'near invariants' of urban grids that we have noted are, it will be argued, essentially responses, at different levels, to these two paradoxes.

How then does urban form resolve these paradoxes? It is proposed here that two paradoxes set the questions to which the structured grid, whether 'deformed' or 'interrupted', give us the answer.[2] A structured grid is one in which integration and intelligibility are arranged in a pattern of some kind, which supports functionality and intelligibility. Essentially, lines and areas are prioritised for integration and intelligibility to varying degrees in order to create a system of differentiation, and it is this differentiation that we call structure in the system. This is why integration cores and area scatters are such fundamental functional properties in urban systems. They reflect the process of constructing a differentiated structure in the system. The distribution of integration in an urban system, together with its associated built form and land use patterns, is not a static picture of the current state of the system, but a kind of structural record of the historical evolution of the system. The 'structural inertia' imposed by this evolved structure is of course also the prime constraint on the future evolution of the system.

The task is then to show how urban form comes about in such a way as to resolve the two paradoxes, that is, to show how the structured urban grid is discoverable as an *emergent* pattern through the pursuit of more elementary properties of space arising from the disposition of buildings. This poses a methodological difficulty. All the spatial analyses we have made in this book so far are analyses of existing complex systems, that is, systems that have already evolved or already been constructed. The question we have posed about urban form is about the construction of systems, that is, how systems evolve and grow in what is initially a void. The spatial void seems to be structureless. How then can we conceptualise and analyse aggregative processes which are initiated and evolved in a spatial void?

The answer is simple, and will lead us into new theoretical territory. Space is not a structureless void. We only believe it is by using an implicit analogy with physical systems. What we call structure in a physical system, whether artificial or natural, has to be created by putting elements together in some way. Space is not like this. In its raw state, space already contains all spatial structures that could ever exist in that space. It is in this sense that space is the opposite of 'things'. Things only have their own properties. Space has all possible properties. When we intervene in a space by the placing of physical objects we do not create spatial structure, but eliminate it. To place an object in space means that certain lines of visibility and movement which were previously available are no longer available. When we talk of a structured grid in a city, brought about by the placing of built forms, this grid already existed, in co-existence with all other possible structures, within the 'substrate' space (that is, the space prior to our intervention in it) now occupied by the city, before the city came into existence. The spatial system we call the grid was not created by the placing of built forms. Others were eliminated. The grid was constructed in an important sense negatively. It was not assembled in itself. Its existence was drawn attention to and highlighted by the elimination of other '*virtual*' structures.

This view of space is as true practically as it is philosophically. A dance sketches out a possible structure of space within an infinite set of possibilities. The dance is an exploration – a celebration perhaps – of the infinite structurability of space. Any open space is a space in which no possibilities have yet been eliminated, and every open space is continually structured and restructured by the human activity that takes place in it. If we do not conceptualise space in this way we have no way of reconciling human freedom and the human structuring of space. Human activity is never actually structured by space. In structuring space by physical objects we suggest possibilities by eliminating others. But the spaces in the interstices of physical forms are still ‘open’. Within these limits, the infinite structurability of space still prevails. In our cells we may dance.

### All-line visibility maps

In order to understand how the placing of physical objects in a substrate space creates spatial structure by elimination, we must have a formal conception of the substrate space as containing all possibilities prior to our intervention in it. In view of the ‘unreasonable effectiveness’ of line-based analyses in understanding the space structure of cities, suppose then that we regard the substrate as a matrix of infinitely dense lines of arbitrary (or infinite) length in all directions, and call it the ‘line substrate’. An object placed in a ‘line substrate’ will block some lines and leave others intact, and this will have the effect of creating some degree of structure in the line substrate.

How can we identify and measure the structure in the line substrate produced by an object? Clearly, we cannot at this stage use the ‘axial maps’, which have proved so useful in analysing the structure of real cities, since we cannot yet draw them. A single object placed in a line substrate will have infinitely many lines incident to it, and also infinitely many lines tangent to it, as well as infinitely many other lines in its immediate vicinity. Such infinite line matrices do not at first seem to be usefully analysable.

However, there is a way we can proceed which seems to lead to a fundamental description of objects and sets of objects in terms of their structuring effect on the line substrate. Within the set of lines which pass in the region of an object – let us think of it as a simple building – there will be a subset which are as close as possible to the object but which are unaffected by it. These will be the lines that are tangent to the vertices of the object, including those that lie along any straight surfaces. A slightly smaller subset will be those that are tangent to exactly one vertex of an object. This will eliminate those that actually lie along a face, since such a line would necessarily be tangent to two vertices, one at each end of the face, but include those which are as close to the face as we wish – in practical computing terms, as close as a single pixel.

Defined this way, each vertex still has a infinite set of lines tangent to it, which we can think of as forming an open fan shape around that vertex. These line sets have the useful property of defining the limits of the object in the substrate – exactly if we use the larger subset, to within one pixel if we use the smaller subset – without making use either of the lines incident to the object or those in the region which are not tangent to a vertex. The tangent subset is, in a useful sense, a well-defined set of lines selected, and in that sense generated, by the presence of the object. We have at least simplified the situation a little.

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However, as soon as we add a second object in the vicinity of the first, we can define a new subset: that of the lines that are tangent to at least one vertex in each object. By finding each line tangent to a vertex on one object which is also tangent to a vertex of the other, then continuing that line till it is stopped by being incident either to a further object or to any boundary which we decide to place around the region, we define exactly the kind of line matrix that was demonstrated in Chapter 3. The set of lines is in effect made up of all lines drawn tangent to vertices that can 'see' each other, and therefore have a straight line drawn tangent to them. We may call this the 'all-line map' generated jointly by the vertices of the two objects that can see each other. Like any other connected line matrix, such 'all-line maps' can be subject to integration analysis. If we do so, we find that any set of objects will create some kind of structure.

We can now use this as a general method for analysing the effects of objects placed in a line substrate, by finding all lines tangent to the vertices that can see each other for all objects in the substrate, then subjecting the resulting all-line map of those objects to integration analysis. To do this we must define a boundary to the system. To limit the effect of the boundary on the analysis we can allow the substrate to adapt its shape to form a more or less regular envelope around the group of objects. By proceeding in this way, a structure of integration is created in the line substrate which reflects the shapes and positions of the objects we have placed in the substrate with respect to each other. For example, in plate 3a, we have found the all-line map created by a number of objects and then its pattern of integration. It is reasonable to think of this as an analysis of the field of visibility created by the placed objects, since every line defines a limit of visibility created conjointly by a pair of vertices from a pair of objects.

These analysed visibility maps are quite remarkable entities, and appear to synthesise aspects of configurational analysis which had previously seemed to be quite independent of each other. For example, it is clear that, by definition, axial maps are subsets of the lines that make up the 'all-line' visibility map. Visibility maps, we may say, 'contain' axial maps. It follows that they will also contain some account of the global structure of a pattern of space in a configuration because axial maps do. We shall see shortly that this is the case.

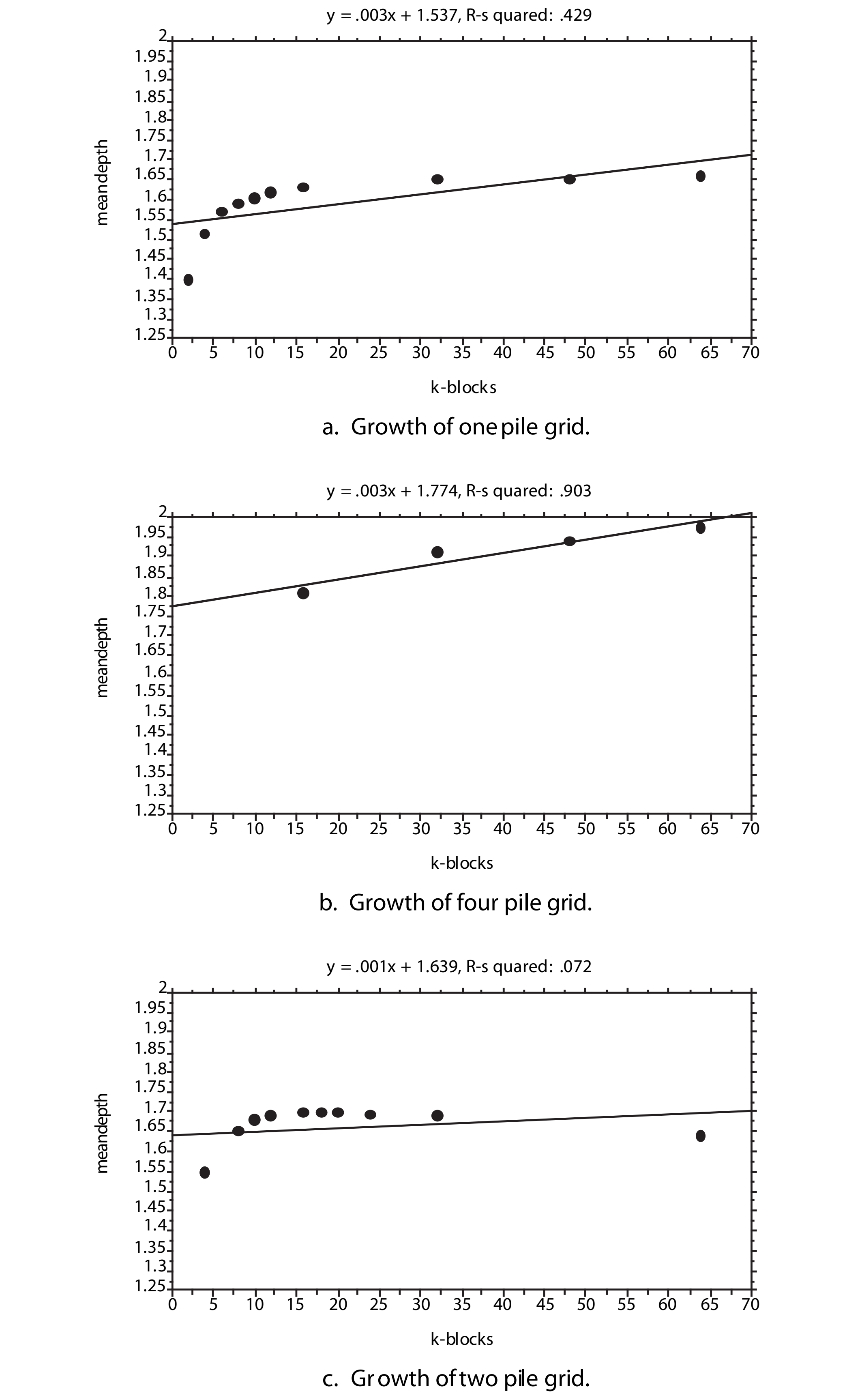
However, we also find that visibility maps reproduce some aspects of the analysis of shapes set out in Chapter 3. For example, if we construct a regular five-by-five grid of blocks, and carry out an all-line analysis, we find that whereas a simple axial map would give each line the same integration value (because all are equally connected to exactly half of the total) the integration structure in the all-line analysis distributes integration from edge to centre. This is shown in plate 3b. The central bias in the integration core arises because in addition to the global structure of lines, as would be found in the axial map of the grid, there are also everywhere a large number of lines of every length specified by pairs of vertices which can see each other, including a large number of lines only a little longer than the blocks of built form. This dense matrix of short lines acts as through it were a tessellation, and not only distributes integration from edge to centre in the short lines, but also necessarily transmits this bias to the longer lines. In other words, the all-line integration analysis reproduces both the global structure of the form through its long lines which are equivalent to the axial map, but also reflects the local structure of the shape as would be found in the tessellation.

All-line visibility maps also reproduce some of the conjoint effects of tessellations plus lines noted in figure 9.1. For example, if we take 36 blocks and arrange them 6×6, 9×4, 12×3 and 18×2 (calling the ratio of length to breadth the 'block shape ratio') and use each to generate all-line visibility analyses, we find that as the arrangement elongates mean depth diminishes. If we maintain the number of blocks constant, the mean depth in the all-line map is minimised by reducing the 'pile' (that is, the number of lines of blocks in the arrangement): a 2-pile arrangement of cells has less depth in the all-line map than a 3-pile arrangement, which has less depth than a 4-pile arrangement, and so on up to squareness. Greater elongation means greater integration.

On closer examination, the '2-pile' grid, as instanced in the 18x2 grid of figure 9.1, turns out to be even more interesting. If, instead of maintaining the number of blocks constant and rearranging them with different 'pile' (that is into the 4 pile 9×4, the 3 pile 12×3 and so on), we maintain pile constant and increase the number of blocks, then we find that mean depth increases with increasing numbers of blocks, but with different curves for different piles. For example, figure 9.2a and b show respectively the growth curves for mean depth in 1-pile and 4-pile arrangements with increasing numbers of blocks, and therefore increasing block shape ratio. Experimentation with larger systems so far suggests that mean depth continues to increase with 1-pile and 4-pile, at least up to the scales of a reasonable city system. Figure 9.2c, however, shows a quite different behaviour for 2-pile systems. In the early stages of growth, mean depth rises rapidly, and continues, slowing rapidly up to 18 blocks (2×9). With 20 (2×10) or more blocks, mean depth then begins to decrease, and continues to decrease as blocks are added, at least up to the normal limits of urban possibility. The reason why 2-pile systems, and only 2-pile systems, behave in this unique way is as simple as it is fundamental. Remembering that blocks which are aligned do not see each other through intervening blocks (because lines tangent to vertices do not include those that are tangent to two vertices on the same block, that is lines which lie flat on the face of a block are excluded), the 2-pile system is the only system in which all blocks see more than half of the other blocks. In all other cases, blocks which are not on the same alignment interfere with the mutual visibility of at least some of the blocks. As 2-pile systems grow, therefore, the privileged visibility over all other arrangements increases.

2-pile systems therefore have a unique theoretical status among block arrangements as far as the degree of integration in the all-line map is concerned. We should not then be surprised that it corresponds to one of the primary spatial types – perhaps the primary type – that cities offer. Streets, avenues, alleys, boulevards, roads and so on are all variants on the fundamental 2-pile linear type. It is at least a

*Figure 9.2*


y = .003x + 1.537, R-s quared: .429
meandepth
k-blocks
a. Growth of one pile grid.
y = .003x + 1.774, R-s quared: .903
meandepth
k-blocks
b. Growth of four pile grid.
y = .001x + 1.639, R-s quared: .072
meandepth
k-blocks
c. Growth of two pile grid.

suggestive inference that these unique integration possibilities of the visibility fields created by 2-pile systems are the reason for this privileged typological status.

A related interpretation might be possible for that other dominant urban spatial type: the large open space known variously as the ‘piazza’, ‘place’ or – with inappropriate geometricity in English – ‘square’. If we create a square in a grid – say by eliminating the central four blocks in a 6x6 grid, as in plate 3c, the effect is to reduce the mean depth and thus increase the overall integration of the system. If we then move the square towards the corner, as in plate 3d, we find that the mean depth of the system is still reduced compared to the 6×6 grid, but to a lesser degree than with the central space. In other words, the effects are exactly what we would expect from the principles for the construction of integration set out in the last chapter. A centrally located larger space integrates more than one that is peripherally located. The effects of replacing the open spaces with equivalently shaped blocks, as in plate 3e and f, are also exactly what would be expected. A centrally placed block reduces integration more than a peripherally placed block. Replacing square spaces and blocks with linear spaces and blocks of equivalent area will also follow these principles.

In other words, all-line visibility maps reproduce the local to global effects by which the global configurational properties of spatial complexes were shown to arise from local physical moves. We may therefore pose interesting questions such as: what local physical moves give rise to the characteristic structures that are found in the various types of urban grids? For example, begining with the 6×6 grid, whose all-line mean depth is 1.931, in plate 3g a double sized block is created across the centre line near the ‘northern’ edge. The effect is to reduce the integration of the central line, previously (along with the central east-west line) the most integrating because of its central location. Also the overall mean depth of the system increases to 1.949. In plate 3h, the block is brought closer to the centre. The effect is to de-integrate the central north-south line even more, as can be seen from the deepening of the blue to the north and south of the block. There is a second effect. The east-west central lines are now less integrated than the north-south lines adjacent to the double block. This is because one of the crucial connections that gave them this value – the north-south central line – has been blocked. In fact this effect was also present in plate 3g, but less strongly, so that it did not reach the threshold at which the colour would be changed. In plate 3j the block is moved away from the central line and returned to the northern edge. Comparing with plate 3g, it can be seen that the segregative effect is less. In plate 3k, the block is moved away from the edge. The segregative effect is greater than for plate 3j, but less than for plate 3h.

It is clear that these effects follow from the principles set out in the previous chapter. The more centrally a block is placed, the greater the ‘depth gain’ or loss of integration. It should therefore be possible to explore how the deployment of blocks in general create differently structured grids. For example, if we place four double-sized blocks adjacent to the centre as in plate 3l, we immediately create a kind of ‘deformed wheel’ integration structure, with hub, spokes and a rim one block in from the edge.

This happens because the double-sized blocks all eliminate connection to the central lines, which are naturally prioritised by the form, and make the 'rim' lines, which are still maximally connected, relatively stronger in integration. The interstitial zones defined by the wheel are defined by the rather sharp segregation created behind the double blocks by cutting them off not only from the their lateral neighbour zones, but also from the central lines. This structure is therefore characterised by diffusing integration to create the wheel, and rather strongly segregated zones close to the centre of the form. In contrast, plate 3m, by placing the blocks away from the central lines, creates stronger integration in the central lines, but weaker in the rim lines. The four zones adjacent to the centre are still marked out by comparative segregation, but much less than before because in all cases direct links to both neighbour zones and the central lines are retained. The resulting form is overall more integrated than the previous case, with a stronger central structure, but a less strong zone structure and a less marked deformed wheel effect.

In each case, these effects are expressions of the principles for the creation of structure in spatial complexes set out in the previous chapter. They show that comparatively simple local changes in a spatial complex can have powerful structural effects on the configuration of the whole. Even on the basis of what we know, we can suggest generative processes which either minimise or maximise integration and, it will turn out, intelligibility (as defined in Chapter 3). In general, loss of integration and intelligibility results from placing blocks so that they bar lines generated by existing blocks at 90 degrees. The most general form of this would seem to be a process in which we locate rectangular blocks in non-contiguous T-shapes, as in plate 3n. The non-contiguous T has the effect that both lines parallel to the long faces of existing blocks are inevitably stopped by blocks placed in the vicinity, and lines along the surface of the block therefore change direction at 90 degrees. We can call this the 90-degree generator. As the scattergram shows, the aggregate form arising from the 90-degree generator has very poor intelligibility and it is clear that it will always do so if applied as the principal generator for the block placing. A similar 90-degree effect will arise in a square block process by similarly placing each next block so as to block the face line on at least one existing block. In order to make this process work in all directions, it is necessary to create slightly wider spaces near the corner of each block, as in plate 3p, in which the loss of integration and intelligibility is even greater than to the rectangular 90-degree process.

The 90-degree process depends on creating the 90-degree relation at the point where a new block is added to the system. Suppose then that we avoid such relations at least for one line parallel to a face in an existing block. In other words, suppose we add blocks so as to create at least one 'zero-degree' relation for the new block (i.e. continuing the line) and an existing block. Plate 3q is an example of a random process following only this rule. It will of course create 90-degree relations as well as zero-degree relations, simply as the result of the non-contiguous L-shape. The process creates a number of lacunas, and lines of all different lengths. But at this scale the outcome has a fairly strong edge-to-centre structure, and the degree of integration and intelligibility are high. We can then add to this process the 'extension' rule from the previous chapter and require the process always to conserve the zero-degree relation for the longest line available. One possible outcome of such a process is shown in plate 3r. The effect of introducing the 'extension' rule by which the longest line is conserved where each new block is added is to create not only a much stronger structure, but also a structure that is much more differentiated between high and low integration than before. Overall integration and intelligibility are also very high. We can now see that the pure orthogonal grid is a simple extension of this principle: line length is conserved in all directions by making all-line relations along faces zero-degree continuations.

However, there is no such thing in reality as a pure grid, if for no other reason than because certain lines will be spatially privileged at the expense of others by being continued outside the settlement into the routes that connect it with other settlements, while other lines will not. In practice we also find that geometrically ordered grids, such as those found in ancient Greece and Rome, ancient China and modern America, are not internally uniform. Sometimes lines in one direction are privileged at the expense of others by the overall shape of the settlement, but, more commonly, some lines are internally stopped at right angles by built forms, while others continue. This is why we call such grids 'interrupted grids', and note that they were just as structured as 'deformed' grids.

These simple cases illustrate the kind of thing we need to know: how spatial structure in a grid arises from local action on blocks. One whole class of grids – interrupted grids – is based almost entirely on what we have so far explored, that is grid shape and interruption. We can have the outline of a theory of interrupted grids on the basis of the methods we have so far set out. However, the commonest kind of grid is not interrupted but deformed. The difference between the two is easy to describe. In the interrupted grids we have so far considered all major lines – that is, the subset of the all-line map that constitutes the axial map – are either tangent to a vertex of a block or end on a block at close to ninety degrees. In practical terms this means that lines either continue with no change in direction, or compel a ninety-degree change in direction. We could call such grids zero-ninety grids, because all movements proceed with a zero-degree change in direction or a ninety-degree change in direction. Deformed grids are, quite simply, grids that use the whole range in between.

What the two types of grid have in common is that, whatever the technique for creating angles of incidence between lines, the outcome is variation in the lengths of lines. These variations are one of the means by which structure is created in the urban grid. In both deformed and interrupted grids, this structure most commonly arises from the application of the 'extension' principle: longer lines tend to be conserved by zero- or low-degree line relations, allowing ninety- or high-degree line relations to occur away from the longer lines. This is why in deformed grids we typically find the dominant structure is made of sequences of longer lines whose intersections are low degree, and shorter, more localised, lines whose intersections are high degree. In Chapter 4, for example, we found that in the City of London, there was a pervasive tendency for longer lines to be incident to others at open angles while the more localised shorter lines tend to be incident at, or close to, right angles. In spite of other differences, similar observations can be made about many Arab towns, though the lines that intersect at open angles tend to be less long, and less differentiated in length from some of the more localised lines. This is an example of a parametric difference expressing cultural variation in the fundamental settlement process. We should also note of course that this relation was exactly inverted in the 'strange towns' of Chapter 6. It was the longest lines that ended in ninety-degree relations by being incident to major public buildings.

In fact, the situation is slightly more subtle. If we consider the structure of the grid from the point of view of how its local sub-areas are fitted into the larger-scale grid in both western and Arab cities, we find that in both cases this relation is most often formed by using a ninety-degree relation to join the internal streets of the local area to the larger-scale grid. However, the sub-area line that links to the main grid at ninety degrees will itself then tend to avoid ninety-degree relations as it moves into the heart of the sub-area, and continue out in another direction. In other words, the lines that form the dominant structure in sub-areas follow the same type of logic as the line of the main grid, though at a smaller scale. Linearity is being used to create an integration core linking edge to centre for the sub-areas in much the same way as the larger-scale grid is creating it for the town as a whole.

The pattern of angles of incidence of lines created by different ways of placing blocks of built form, and particularly the variation between low- and high-degree angles of incidence in deformed grids, and zero- and ninety-degree angles of incidence in interrupted grids, therefore seem critical to our understanding of how real urban structures are put together as spatial systems. Since most large cities are deformed grids, and there is reason for believing that the structure of deformed grids is in some senses more complex and subtle than interrupted grids, we must now explore the implication of what we have learned for deformed grids.

### How emergence overcomes indeterminacy to create local order

If we are to begin without the assumption of an underlying grid, to guide the placing of blocks, then we must first show how *local* order arises in a growing agregate in the first place. By local order, we mean constant relations between one block and its neighbours. This excursion will lead us to a conclusion of as much theoretical as practical importance. The reason we find urban systems invariably display local as well as global order, is that without local order there is indeterminacy in the emergent structure. Very small changes in the positioning and shape of objects can lead to a radical difference in the structure of integration in the all-line map created by those objects. For this reason, large-scale layouts cannot be constructed on the basis of local indeterminacy, and this is why we invariably find local as well as global order in urban systems. The role of local rule following is to make the emergence of local structure predictable. These local 'emergences' then stabilise the situation enough to permit the emergence of more global order 'on their back', as it were. This is why we find, at smallest urban scale, 'near invariants' in the form of continuous definition of local external spaces by building entrances, and the local linearisation of built forms. Local order in this sense will be seen to be the necessary foundation of global urban form. Without it, the local system cannot be stabilised sufficiently to allow global patterns to be constructed.

We must begin by considering the most elementary relations in a system, beginning with one object in the vicinity of another. Plate 4a, b and c shows a series of possible cases which are then subjected to all-line analysis. As we can see, in each case the precise pattern of integration is different, depending on the shapes of the objects and their positions with respect to each other. But there is also an invariant effect. Regardless of the shape or relative locations of the cells, all the pairs of objects create a focus of integration between them in the all-line map. Further experiment would show, and reflection confirm, that given any pair of objects in a substrate then, other things being equal, integration will tend to be drawn to the region jointly defined between them. This means also that each object is adjacent to a shared set of integrating lines, and therefore potentially permeable to it, in the direction of the other object. This is an instance of what we mean by an invariant. It is a structural condition that is always the case even under considerable and geometric variation. It is also an emergent effect, in that it was not defined in the initial rule which placed the second object, but emerged from this placing wherever it occurred. In this particular case, the invariant emergent effect gives a meaning to the spatial concept of 'betweenness'.

As soon as we begin to consider systems with more than two objects, however, we lose this invariance in the emergent outcome and instead discover a profound problem which seems initially completely incompatible with the idea of a local order: that of indeterminacy in the emergent outcome. As soon as we have a third object, we find that structures emergent from analysis of the all-line maps arising from those objects are highly unpredictable and subject to great variation in outcomes with very small changes in the shape and positioning of any of the objects. Fortunately, it is in finding the answer to this problem that we will be able to set the foundations for a full theoretical understanding of settlement space. Only by placing and orienting objects in certain ways in relation to each other can local indeterminacy be overcome and local order created in the evolving system.

Suppose then we add a third object to the pairs we have already considered, as in plate 4d and e. It seems there is no reliably emergent pattern. On the contrary, the structure changes from 4d to e following very minor changes in the locations of the blocks. Plate 4f and g show the same effect in a much more complex system. The only difference between the two is a change in the size – but not the shape or position – of one of the objects, yet the outcome in the all-line map is quite different. Further experimentation will show that this is always the case. There is of course a local determinism operating. But it is so dependent on very small changes in the shape and positioning of objects that it is virtually impossible to predict without this very detailed knowledge.

# The fundamental city

Now everything that has been learned about real spatial systems in the earlier chapters of this book suggests that structural indeterminacy in spatial patterns is the last thing we expect to find. On the contrary, we have found that spatial systems of all kinds and at all levels tend to organise themselves according to certain genotypes, that is, common patterns that often cross seemingly quite different cases. It is clear that such systems are not indeterminate. Nor are they altered in their structure by minor changes. On the contrary, their structures are highly robust, and can usually absorb quite significant modifications without undergoing great changes in structure. In this sense, we can say that real systems have a great deal of redundancy. This redundancy, and the consequent robustness in the structural outcome, can only arise from consistencies of some kind in the way that objects are placed, that is from a local rule following behaviour in the placing of objects. Since we have seen that real systems seem to follow rules about local linearity of built forms, and the relation of lines to entrances, we should first consider the structural effects of these.

Suppose then that we align a series of blocks, as in plate 4h. Now there is an emergent invariant. Integration in the all-line map will align itself one side or other of the alignment of cells. On reflection, it is evident that this must always be so. Integration must always be dominated by the outer vertices that can see each other. However, which side is selected is still highly indeterminate. It depends on quite minor differences in the nature of the cell surfaces, and the inter-relations of these differences on either side of the alignment. Plate 4i, for example, shows a slight realignment of the same blocks as in h, in that the positions of the three internal blocks are rearranged. The effect is that the dominant lines of integration shift from one face of the alignment to the other. The reasons for these differences can always be traced, but they are often quite hard to find. In this case it depends on the relative length of the longest alignments along the face, and this depends on very small differences in the degree to which blocks protrude. The all-line integration analysis of the system is therefore not yet robust. We have solved half the problem. We know we will find a linear pattern of integration in the all-line map. But we do not yet know where it will be.

One way of making the outcome determinate will of course be to align the objects perfectly and standardise their shape. If we do this, then integration will distribute itself equally on both sides of the alignment. However, there is a second factor that can bring redundancy into the alignment, one which does not require us to attain geometrical perfection, and that is the relation of external space to building entrances. If we model even a single cell not simply as a convex object, but as a building-like entity with an interior and an entrance (and creating a finite substrate mirroring the shape of the built form) then we find that this on its own will have the immediate – and on reflection obvious – effect of bringing integration onto lines passing the entrance, as in plate 5a. In other words, the effect on the all-line map of considering internal as well as external space, as related through the entrance, is to integrate the area outside the entrance to the building in a direction orthogonal to the orientation of the entrance. It would not stretch things too far to suggest that the effect of even one such building with entrance is to create a local spatial pattern which is already street-like. It is easy to see that this is a necessary emergent effect. Other things being equal, the relation to the interior of the 'building' will always create an extra degree of integration in the local all-line map, and in the absence of other influences, this relation will dominate the structure of integration.

Now it is clear that if we both align cells with interiors and face their entrances more or less in the same direction, then integration in the resultant all-line map will powerfully and reliably follow the line orthogonal to (and therefore linking) the alignment of entrances, as in plate 5b. We are in effect using the alignment and the entrance effect to reinforce each other, and so create redundancy in the resulting structure. This effect will be lost if we face a pair of cells in opposite directions, as in plate 5c, or place one behind the other, as in plate 5d. Stabilisation requires alignment and entrances to coincide in creating the same effect.

We now see that these two most localised invariants in urban form, the relation of space to entrances and the local alignment of forms, together reliably create exactly the emergent local structure in the substrate that we have observed to be the case. Cell alignment 'means' the creation of a linear integration structure along the surfaces of aligned cells; entrance orientation specifies on which side this is to occur. In the absence of one or other we will not find the invariant pattern we have noted. The two together have the effect of eliminating local indeterminacy in the form, and creating a robust emergent pattern of integration in the aggregate.

There is, moreover, a second way in which an emergent pattern of integration can be stabilised in a small aggregate: by creating a second alignment of cells more or less parallel to an existing alignment. This second alignment does not have to be complete, but the more complete it is the more it will eliminate indeterminacy in the resulting pattern of integration in the all-line analysis. In the two cases in plate 5e and 5f, for example, quite minor changes in the shape and alignment of cells – the lower left cell in f has been moved slightly to the left of its position in e – is enough to realign the dominant line of integration from left right to diagonally top down. However, if, as in plate 5g, we add a third cell on the second line, it is very hard to find an arrangement of the cells or shape change which does not lead to the main axes of integration running left to right between the two alignments. The pattern of integration has again become robust. It is not likely to change under small variations in the shape and position of cells.

There are then three ways in which the local indeterminacy of integration patterns can be overcome in small cellular aggregates. One is alignment of the cells. The second is alignment of entrances. The third is parallel alignments. What we find in real settlements is that all three are used to reinforce each other. It seems an unavoidable inference that, at this localised level, settlements pursue integration in the emergent structure by using all three ways of achieving it to reinforce each other. In other words, even at the most localised level we find that settlements exploit emegent laws of space. We can then be quite precise as to the respective roles of human agency and objective laws. The human agency is in the physical shaping, locating and orientation of built forms. The laws are in the emergent spatial effects consequent on those physical decisions. Built forms, we may say, are shaped, located and oriented by human agency, but in the light of laws which control their effects.

**The laws of growth**

If this is so at the most localised level, what of the higher levels of area and global structure? Here we must remind ourselves of the contrary influences of two underlying principles: linearity integrates the visibility field, compactness integrates the movement field. Urban form, we proposed, reconciled these two imperatives of growing systems through 'deformed' or 'interrupted' grids, both of which tend to maximise linearity without losing compactness. We shall see now that this principle can be seen to operate at every level of the evolution of urban form, right down to the level of certain very small settlements whose layout seems to contain the very seeds of urban form.

In *The Social Logic of Space*[3] it was shown that the basic topological forms of certain small and apparently haphazard settlement forms, in which irregular ring streets with occasional larger spaces like beads on a string – hence the 'beady ring' – could be generated by 'restricted random' cell growth processes in which cells with entrance and spaces outside the entrance were aggregated randomly, subject only to the rules that each cell joined its open space onto the open space of a cell already in the complex, and that joining cells by their vertices was forbidden (since joining buildings at the corner is never found in practice). Plate 6a shows an example.

It was also suggested that many settlements which began with this type of process progressively introduced 'globalising' rules as they grew larger. These globalising rules took the form of longer axial lines in some parts of the complex, and larger convex spaces, usually with some well-defined relation between the two. The effect of globalising rules was that certain key properties, such as the axial depth from the outside to the heart of the settlement, tended to remain fairly constant. Such contents tended to create a structure more or less on the scale of the settlement as it grew. Analysis then showed[4] that the effect of these rules was to maintain both the intelligibility and the functionality of the settlement, to maintain a strong relation between the different parts of the settlement and between the settlement and the outside world.

In these 'beady ring' forms, two key local spatial characteristics were noted, which then tended to be conserved under expansion. First, virtually all local 'convex' spaces, however small or narrow were 'constituted' by entrances. Second, these convex elements tended to be linked by lines of sight and access. Since we knew that both of these arise as emergents from the conservation of integration in the form, it seems reasonable to believe that we now have a theory for these local aspects of the form. But what of the globalising processes?

We should note that beady rings already resemble urban systems in ways which are significant for urban structures. First, the distribution of integration in the open space is not undifferentiated, but biased strongly towards certain lines and certain locations. Second, the lines that are prioritised tend to be among those that link the settlement to its exterior. Theoretically, of course, this is likely to be the case, because in any small collection of objects, the lines which are wholly internal (in that both ends stop on built forms), are likely to be shorter than lines which connect the interior to the exterior. This is particularly significant, since it seems to contain the seeds of a key aspect of urban structures: that is the tendency for the integration core to link at least some key internal areas to the periphery of the settlement.

To explore how this becomes a key factor in settlement growth, we must bring into place the 'four principles' set out in the previous chapter, and reinterpret them for the aggregative process in which built forms progressively construct patterns of open space. The reader will recall that the four principles were *centrality:* blocks placed more centrally on a line create more depth gain – that is reduce integration – than peripherally placed blocks, and vice versa for the creation of open space by block removal; *extension:* the longer the line on which we define centrality, the greater the depth gain from the block, and vice versa for space; *contiguity:* contiguous blocks create more depth gain than non-contiguous blocks, and vice versa for space; and *linearity:* linearly arranged contiguous blocks create more depth gain than coiled or partially coiled blocks.

Seen from the point of view of the line structures that are created by block aggregation processes, the four principles begin to look much simpler. The centrality principle and the extension principle can be expressed as a single principle: maximise the length of the longest available line. If there is a choice about placing a building to block a longer or shorter line, block the shorter line. This does not quite work in a void, since too many lines are infinite, but it would be progressively more and more possible to make such discriminations as an aggregate becomes more complex. The effect of this rule would be always to conserve the longest existing lines in the growing aggregate and gradually evolve these lines into yet longer lines. A similar simplification is possible for the principles of contiguity and linearity when considered from the point of view of line creation. Both imply the minimisation of deflection from linearity. Placing objects contiguously will clearly increase deflection, and so will the linear placing of objects, rather than in a 'coiled up' form.

We might then transcribe the four principles into a simpler form which runs something like: select longest lines for maximum linearity, and on others (where maximum linearity is by definition not being conserved) keep deflection to the minimum. We can easily see how such a rule, operating in the context of the need to resolve the paradox between compact metric integration and linear visual integration would lead naturally to the structural bias we find in the beady-ring form. Is is less obvious, but nonetheless the case, that it can also lead to the much more complex structural biases in larger urban grids that we identify as 'integration cores'. In due course, we will also see that it can in itself lead naturally to the commonest kinds of local area structure that we find in larger cities.

How then and why do these global properties of urban systems arise? Considering the earliest stages of growth in deformed grids, beginning with the

the hypothetical 'beady-ring' settlement of plate 6b, with its all-line analysis and intelligibility scattergram below. The integration core links edge to centre and the scattergram shows that the intelligibility is high (from which we may be sure that the correlation of local and global interaction will be even higher). Now we know that in any such system the longest available lines are unlikely to be those that make interior connections, since these by definition stop on buildings at each end, but will be among those that link interior to exterior. Suppose then that we simply follow the rule of placing new blocks so as to extend longest lines. A possible outcome after a while would be as in plate 6c.

This is a fairly common form of development, but as a principle to guide the evolution of larger systems it is insufficient, since the effect is to create lacunas in the form and make it non-compact. We also find, on analysis, that the core becomes focused very strongly in the centre, with edges that become very weak. This is what we would expect, since it is the lack of compact development in all directions that led to the lack of structure at the edges. We also find intelligibility, as shown in the scattergram, beginning to break down in the more integrated areas, reflecting the independence of growth along different alignments. In fact we find this type of development is quite common in small-scale settlements, but is rarely found in larger ones. Morphologically, there seem to be sound reasons for this limitation. None of the properties we have come to expect in growing systems are conserved beyond a certain stage in this type of development.

Let us then experiment by expanding the hypothetical settlement compactly. We will explore two possibilities. In the first, we pursue our dual rule of optimising the linear extension of existing longest lines, and avoiding undue linear deflection in the remainder of the system. In the second, we reverse the first principle, and block longest lines at ninety degrees with blocks that also cause substantial deflection of lines elsewhere in the system. Plate 6d shows two possible outcomes after a further ring of growth complete with all-line analyses and intelligibility scattergrams. In the first outcome, the integration core continues to link centre to edge, and maintain overall integration and intelligibility in the system. In the second, chicanes on all lines from centre to edge mean that these lines become hard to differentiate from other lines. The result is a much more centralised core, which no longer covers the diameter of the system. The overall degree of integration and intelligibility are accordingly substantially less than in the first case. If we then continue the same pair processes as in plate 6e and f, we find similar outcomes, though with the additional effect that the integration core in 6f has now split into two. The levels of both integration and intelligibility are significantly lower in 6f than 6e.

These are of course considerable simplifications of real urban growth processes, but they serve to illustrate a fundamental principle: that given that we follow the rules of local alignment of built forms and entrances to stabilise integration in the local system, then simply following the rule of selecting the longest lines for extending linearity, and keeping deflection to a reasonably low level in the rest of the system, will in itself tend to create an integration core that links centre to periphery in several directions. This not only tends to solve the paradox of linearity and compactness, by creating spaces that link centre to edge, but also creates a system which is internally integrated, and intelligible. Thus the paradox of centrality is overcome, at least from the point of view of visibility and intelligibility. All this happens because the integration core structures the settlement in such a way as both to integrate the settlement internally while at the same time integrating it to its exterior. In other words, the combined 'centrality' and 'extension' principles – simply by being applied in a growing system – have the effect of overcoming the centrality paradox by exploiting the visibility paradox. In this sense at least we can say that some of the key invariants of global order in the fundamental settlement process are simply products of generic function applied to growing systems in the light of the paradoxes of growth in such systems.

One question then remains. How do local area structures arise? Let us then pick up the story of the expanding deformed grid that we left at plate 6e. We know that systems can evolve a centre-to-edge integration core which will guarantee certain key system properties under growth. However, as the system grows farther, it will generate more and more the structural problem we saw in Plate 6c: as the lines that form the integration core drive outwards, they tend to become farther and farther apart creating larger and larger lacunas in the system. As the system grows, this problem must become more acute. The scale of the lacunas means that it cannot be solved by simply avoiding overly deflecting lines. There must be structure within the lacunas just as previously there was a need for structure in the main settlement as it grew. The structure, we might say, that resolves the centrality paradox at the level of the whole settlement recreates it as a more localised problem, by partly enclosing areas that must by filled in with built forms if the compactness rule is to be retained. It follows that structure must evolve to overcome this problem.

All we need to specify is the continuation of the process we have already described for the growing centre into the lacunas between the radials. Since built forms will already exist at the edge, the process must begin there. A process of placing blocks in order to maximise the longest lines created by the built forms will first tend to create a linear space penetrating the lacuna laterally, so that in spite of the fact that the process has begun at the edges of the lacuna, a structure will be created which is dominated by edge-to-centre lines in at least two and possibly more directions. The interstices will then be filled with blocks that avoid overly deflecting linearity, and these will then form the less integrated zones within the sub-area. Because initially the conditions of this local process are structured from the periphery, the conditions for radial growth do not exist here. On the contrary, the initial moves in the system under these more structured conditions necessarily begin to sketch a more orthogonal grid. Accordingly, we tend to find a greater tendency towards orthogonal order in these interstitial areas than in the initial urban form. It is literally suggested by the process itself.

In cases where this process subsumes an earlier settlement – say an existing village – then this may initially be the natural magnet for the lines penetrating the lacuna from the edge. This will tend to form a local deformation of the grid evolving in the lacuna. It is exactly such a process that gave rise to London's 'urban villages'. These are invariably the foci of the integration core of local deformed grids which, like other London areas, take the form of a 'deformed wheel' (that is, an integration core with a hub, spokes and a rim, with quiet areas in the interstitial zones) in which the periphery, instead of being the space outside the settlement, is formed by the radials of the larger-scale urban process. It is this process that gives rise to the fact that in cities like London the 'deformed wheel' structure is repeated twice, once at the level of the whole city and once at the level of the local area. It is also this that gives rise to the geometry of the local and larger-scale organisation of the city that we noted earlier in this chapter, in which length of line and angle of incidence were the key variables.

Not all cities, of course, have this kind of local area structure. But this is the difficult case. London embodies the continuation of the operation of generic function, and the spatial processes to which it gives rise, into the local area structure of the growing city. It is this that makes London, in spite of initial appearances, such a paradigmatic case of the well-structured city. Perhaps because throughout its history planning intervention was of the most parsimonious kind, the greatest latitude was created for the fundamental settlement process to evolve in one of its purest forms.

It is this that gives London its unique theoretical interest. Other cities have very different ways of constructing their local area structures, but they are *more* structured, that is, they are a product more of cultural parametrisation of the fundamental process than of the fundamental process itself. In Shiraz, for example, local area structures are much more axially broken up than London, but they are also smaller and less complex as areas. Most local areas in Shiraz are made up of sequences of right-angle lines connecting in one, two, three or four places to the dominant structure of the integration core. Their relation is predominantly to the outside, and that relation is constructed by simple, but deep, sequences of lines. We do not therefore find that the correlation of radius-3 and radius-n integration gives the structure of the local area. We do find, however (as shown by Kayvan Karimi, a doctoral student at UCL), that the the correlation of radius-6 and radius -n integration does capture this structure, as shown in the two cases picked out in plate 7. We also find a geometric correlation to these properties: each line that forms part of a local area belongs entirely to that area. No line which is internal to an area also crosses a core line and becomes part also of another local area. Local areas in Shiraz are, we might say, linearly discrete. This was much less the case in London where at least some lines which were part of local areas also continued into neighbouring areas. As we have found before, configuration of properties are constructed eventually out of the line geometry constructed by blocks of built form.

Shiraz is a fairly extreme case, where local structures are small, segregated and highly dependent on the global structure of the settlement. At the opposite extreme we find cities like Chicago, where the high mean average length of line and the fact that some cross the entire system mean that integration is very high. There is then, in the settlement as a whole, a high correlation between connectivity and integration, and *a fortiori* a high correlation between local and global integration. In Chicago there is very little tendency for whole lines to be confined to any plausible sub-area in the city. On the contrary, a major characteristic of the structure of the city is that all areas are made up of lines that include many that are global lines in the system. But this does not mean that there is no local area structure. On the contrary, if we select for areas all lines within that area and those which pass through the area, we find reproduced at the local level even stronger correlation between connectivity and integration than prevails for the system as a whole. In other words, the local area structure of the city is characterised in the case of Chicago by the correlation between connectivity (that is, radius-1 integration) and radius-n integration, in London by the correlation between radius-3 and radius-n integration and in Shiraz by the correlation of radius-6 and radius-n integration. This then is a parameter by which each city adapts the fundamental settlement process to its own structural needs.

However, all of the invariants that were specified in the original description of cities hold in all three of these cases. Not only do we find these deep structures in common, but also a common geometrical language of line length and angles of incidence through which not only these structures, but also the parameterisations through which cultures identify themselves in spatial form, are realised. It is the existence of this common geometric language which permits both invariants and cultural parameterisations to proceed side by side. At the deepest level of what all cultures share – that is, of what is common spatially to humankind –is the geometric language that we all speak.

**Notes**

1 This was explored in the early seventies by Daniel Richardson in ‘Random growth in a tessellation’, *Journal of the Cambridge Philosophical Society*, 74, 1973, pp. 515–28.

2 The difference between a ‘deformed’ and ‘interrupted’ grid is that the controlled irregularity of the former comes about essentially through geometric deformation of the line structure, in the manner of European cities, while that of the latter comes about by placing buildings and other facilities to ‘interrupt’ some lines rather than others, in the manner of Graeco-Roman or American grids. Both usually achieve the result of a well-defined pattern of integration in the axial map of the city. For a further discussion, see below.

3 See B. Hillier & J. Hanson, *The Social Logic of Space*, Cambridge University Press, 1984, Chapter 2.

4 B. Hillier et al. ‘Creating life: or, does architecture determine anything?’, *Architecture & Behaviour*, vol. 3, no. 3, Special Issue on Space Syntax research, Editions de la Tour, 1987.