

Article

Urban Systems Between the Environment, Human Health and Society: An Overview [†]

Carlo Modonesi ^{1,*}, Stefano Serafini ²  and Alessandro Giuliani ³ 

¹ Department of Epidemiology and Data Science Fondazione IRCCS Istituto Nazionale dei Tumori, 20133 Milan, Italy

² International Society of Biourbanism, 00031 Rome, Italy; stefanonikolaevic@gmail.com

³ Department of Environment and Health Istituto Superiore di Sanità, 00161 Rome, Italy; alessandro.giuliani@iss.it

* Correspondence: carlo.modonesi@istitutotumori.mi.it

[†] Ecology must be applied to conditions determined by human activity. Both “natural” entities and anthropogenic derivatives must be analyzed in terms of the most appropriate concepts we can find. (Tansley, 1935, p. 304).

Abstract: This work underlines an analogy between urban and biological systems. The dialogic approach of systems biology showed us that parts constitute a whole and, in turn, the whole constitutes the parts. The development of a biological system such as an animal or a plant does not unfold by means of an autonomous internal program. Rather, it stems from the interaction of the organism’s internal response pattern and its external environment. The wide scientific literature on the genome–environment interaction confirms this. Nevertheless, the scientific community still tends to consider the environment as a mere external factor which simply modulates the organism’s program. On the contrary, the environment has a key role in development. For example, when a seed germinates after heavy rain, it does not simply react to an external signal indicating favorable conditions for germination. Rather, it interacts directly with rainwater, which becomes a developmental factor no less important than the seed coat proteins. Similar to what happens during the development of an organism, the interface between any complex system and its environment determines its structural and functional fate. We argue that large cities have blurred the interface with their natural environment and depend on delocalized global sources. They are like organisms kept alive by external devices. Hence, we propose to regenerate a vital interface between cities and their rural and natural environment as the main and promising path towards future urban civilization.

Keywords: ecosystems; urbanism; cities; public health; environmental risk; complexity; modernity



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1. Introduction

In recent years, new systemic challenges to the mechanistic approach have emerged in many science fields. These challenges are provoking a paradigm shift in the basis of the fundamental unity of scientific knowledge from “every entity is made of the same basic bricks” to “everything can be represented as a set of relations among its parts”. This systemic turn, anticipated by Robert Rosen’s work [1], had a quantitative formalization in the frame of non-equilibrium thermodynamics thanks to the work of Donald Mikulecky [2] in which the author makes a neat distinction between the “constitutive” and “network” principles governing systems’ behavior. The use of constitutive laws for the network elements is the way in which the physical character of each network element is represented

abstractly. It is a common feature of the material world. The topology or connected pattern of these elements in a network is an independent reality of the system [3]. This topological (network thermodynamics) approach has allowed us to recognize universal properties of the systems that made it possible to predict their behavior in terms of stability and phase changes with no reference to the material nature of their elements [4,5]. In this frame, another strictly related paradigm of use for a systemic approach to urban systems is the so-called “biodynamic interface” [6]. This paradigm stems from the consideration that two complex systems (in our case, a city and its surrounding environment) interact in a twilight zone (interface). This interaction happens in time, being dependent on the degree of the two systems’ mutual synchronization. The most evident examples of this kind of interface are biological membranes that, while assuring the neat distinction between internal and external compartments, allow for a finely regulated bidirectional exchange between these two phases [7]. The aim of our work is to suggest that, analogously to what happens in many human diseases like cancer [8] stemming from the disruption of a physiological interface between the tissues and their microenvironment, the progressive blurring of the interface between cities and the surrounding environment is the basis of many ecological, social and public health problems facing urban spaces.

The “universal” character of network thermodynamics principles reassures us of the possibility to apply the results coming from other research fields to the analysis of urban spaces, while the biological membrane paradigm is particularly suited for describing cities, as we will show in the following.

2. The City as a Complex Non-Linear System

The systemic paradigm implies that if randomness and instability belong to the domain of chance, order and negentropy must emerge almost as a necessity. Within this scenario, the arrow of time emerges. A direction exists that depends on the free energy model that applies to environmental systems [9]. In fact, perfect equilibrium may exist only in theoretical systems isolated from their environments. On the other hand, real ecological systems, such as lakes, savannas, forests, etc., are open and kept far from equilibrium by the flow of energy passing through them (mainly electromagnetic energy from the sun). In these cases, equilibrium is substituted by stationarity: the system is traversed by a stationary flux of energy, and a static minimum energy equilibrium point is substituted by a condition of minimum entropy production [9]. It is precisely here that complexity comes into play by activating processes leading to ordered structures; this self-organization is responsible for the dissipation of incoming energy flux with minimal entropy production [10].

Environmental research achievements include the understanding of the biophysical processes of ecological systems in conditions of thermodynamic non-equilibrium, in compliance with physical laws [11]. Imagine a forest described by a point identified by its coordinates in a large geometric space spanned by different axes (for example, temperature, humidity, organic substances, etc.). Overall, the space covered by the above variables corresponds to the so-called “phase space”. Some areas of the phase space are called attractors because the system tends to stabilize in them and therefore reside there for a relatively long time. Each attractor has its own “basin” corresponding to its area of “influence”: if the trajectory in time of the system passes by a given basin of attraction, the system is pushed toward the corresponding attractor state. Despite being in non-equilibrium, the system continues to function and is stable or, to be more precise, resides in a stationary state, even if more or less large fluctuations occur around an attractor. In other terms, the systemic model prevails because it maximizes the probability of seeing or predicting what actually happens even if with relatively coarse detail [12]. The same happens in the case of cities where self-organization arises on the basis of a continuous flow of both information and

matter among its parts [13]. In this respect, it is worth noting the real-world quantitative analysis of self-organization within urban space reported in [14].

Many authoritative scientists believe that, from the specific point of view of scientific ecology, cities should be equated with (or seen as very similar to) natural ecosystems. They do not consider this statement as a simple parallelism but interpret it literally, arguing that urbanized environments are often ecological mosaics made up of interconnected “grey” and “green” structures and infrastructures. In other words, instead of considering “topological principles”, these scientists are driven by “constitutive laws” and thus define an ecosystem as something made of plants and animal species. In addition to the human component, urban environments also host a certain biodiversity, which is part of a context of biophysical processes and energy flows, as in natural ecosystems [15]. Other authors underline the artificial nature of cities, defining them as “products of purposes, intentions, plans, design and engineering” [16]. In other cases, the dual identity of urban systems has been resolved by defining cities as “hybrid ecosystems” [17] not without some ambiguity. Urban planning, including its unintended effects, makes the urban environment more like a social machine than an ecosystem, so it is often argued that the concept of ecosystems is not relevant to the design of more “natural” cities [18]. Among scholars and environmental agencies, however, the idea that cities should be managed as if they were “natural” ecosystems is rather widespread, this being a fundamental prerequisite for their resilience [19]. This idea in itself is not wrong; in fact, increasingly extreme climate events weaken the already-poor resistance and resilience of many cities, significantly increasing the vulnerability of urban structures and human communities, causing deaths, injuries and displacements that bring local economies to their knees. However, we believe that the uncritical use of the term “natural” could generate misunderstanding. It lacks a clear definition, and this ambiguity derives from the clear fault line that modernity has introduced between man and the natural world. This work outlines a model of the city as a “cultural organism” (a singular case of a complex system not to be confounded with the usual definition of the “*homo sapiens*” species) interacting with the surrounding environment in a way consistent with the paradigm of the biodynamic interface [6]. According to this paradigm, the trajectory of cities emerges as a consequence of the continuous interaction between the organism (the city) and its milieu. As we stressed before, complex systems cannot interact directly but require a shared even if partially autonomous “interface” with a peculiar dynamic character [20]. In the case of the city, this interface corresponds to the boundary between high-building-density urban areas and the surrounding countryside. The blurring of this boundary (with the consequent uncertainty of the location of such an interface) is a crucial issue of modernity.

3. City Boundaries as Dynamic Interfaces

A 14th-century fresco in Siena city palace, painted by Ambrogio Lorenzetti and not by chance entitled the “*Allegory of Good Government*” (*Allegoria del Buon Governo*), illustrates a dynamic interface between the city and its rural surroundings (<https://www.wga.hu/support/viewer/z.html>, URL accessed on 10 May 2025). The realism of the rural landscape clarifies the basis of such a relationship [21]: the “urban” and the “rural” are clearly distinct, but they are dynamically linked. Analogously to a cell membrane, the walls allow for a neat separation between urban and rural spaces, while the gates allow for a dynamic in/out regulated flux that “transfers” the rationality of urban planning to the rural space in terms of geometrically organized plantations while at the same time allowing the sustainment of citizens by rural production. It is evident that the organization of a central Italian medieval town cannot be proposed as such in modern times, but we can find the same style of

thinking in actual urban planning debate, emphasizing the need for an efficient multiscale interaction between all the urban functions and the different social classes [1,16,18,19].

In large modern cities, “nature” is represented above all by designed insertions of parks and green elements within the urban fabric [18,19]; “countryside” and “city” are no more connected by a dynamic interface. “Green areas” are surrogates of nature or symbols meant to preserve the memory of an irremediably lost natural landscape. The borders between the urban and the rural have become fuzzy: the countryside suffers a metastatic invasion by the city that runs parallel to the inner destruction of middle scales and geometrical links in urban design [16]. As cities expand into rural areas, large tracts of land are exploited according to a “leapfrog” model, i.e., at low density [22]. The different uses of extra-urban spaces, such as homes, shopping centers, recreational facilities, or public parks, are kept separate from each other due to constraints imposed by local administrative institutions and zoning rules. In these cases, it is necessary to build new infrastructures for the suburban inhabitants. As a result, a large part of mobility—including basic necessity supply—is based on cars [22]. Newly built suburbs are always rather squalid and homogeneous compared to the diversity found in traditional cities, where the urban landscape is decidedly more hospitable. Furthermore, most suburbs are penalized by the scarcity and/or low quality of services.

4. False Cities and False Citizens

Contemporary cities no longer have control of their own destiny because their resources and the decisions that govern their processes come from distant places. Indeed, the functions of urban life have “exploded” outside the previous urban boundaries into a dematerialized landscape called the “global world”. Nowadays, cities import food, matter, energy and services from their surroundings only in a very limited amount. This is due to the rapid decay of the surrounding countryside’s agricultural productivity and rapid urbanization. Rather, they heavily depend on extraneous sources located far away [23]. The link between the city and its environment is thus broken and transformed into a mere spatial relationship devoid of any particular meaning other than recreational use. The dwellers of ancient cities cared about the health of their agricultural soils (and consequently of the city–environment interface) for the very cogent reason of food supply. The need (and the related work) for taking care of city–environment relations was sustained by the embedding of citizens since their birth into mutual assistance organizations (e.g., Siena “Contrade”, still present today). Thus, even if at odds with modern (and full of merits) voluntary participation in various forms of “active citizenship”, the system supported a truly “civic” engagement of inhabitants [23,24].

The inhabitants of current global cities should be called “urbanites”. Their relationship with the “urban system” is, at least in the great majority of cases, merely consumerist and aesthetic, hence the rhetoric of politicians on the care of “beauty” as a tourist resource. In essence, the swarms of large-urban-center inhabitants experience an abstract and consumerist global dimension, which, for historical and cultural reasons, cannot be universally defined as “the city”.

We increasingly live in fragmented urban areas, marked by poverty, instability and social conflict. The results of this state of affairs are indelibly engraved in the spatial forms of our cemented and hyper-technological cities, kept separate from any connection with the natural environment and increasingly organized into fortified fragments, gated communities and privatized public spaces: in other words, cities subjected to constant surveillance by cameras, barriers and restricted-access zones. In many countries, cities are crumbling aesthetically and socially. At the same time, physically and socially separated areas are being created, fueling the worrying sensation of many independent “microstates” [25].

5. Urbanization Explosion and Metastatic Cities

The crisis of the modern urban environment is seriously exacerbated by the fact that most human beings live in cities and megacities or in their suburbs. In the 18th century, cities boomed with the advent and spur of industrialization [26]. However, the most recent urban transition represents a milestone that perhaps no one would have imagined just a century ago. This urban growth has undergone a sudden acceleration in the last half-century due to massive migrations from many countries. For example, from the 1970s to today, large numbers of humans have moved from depressed regions of the developing world to industrialized cities in search of new lives and job opportunities. The continental urban areas of the developed world (especially Europe and North America) have long been the destination of important mass migrations from countries where necessity, political instability, wars, climate, food scarcity and ethnic conflicts push people to leave their places of origin [27]. Currently, more than 50% of the world's 8 billion people live in highly urbanized areas: a percentage that is expected to rise to 70% by the middle of this century. It is worth noting that, overall, the urbanized surface of the planet corresponds to 3% of the total land surface [28]. This means that a huge mass of people occupies an extremely limited part of the globe, with all the consequences that this entails. Such an impressive concentration of human beings entails critical management and organization issues, as well as an unpredictable number of energy, social and public health problems. For example, raw materials, such as fossil fuels, foodstuffs and a myriad of different materials, undergo industrial transformation, producing impressive quantities of by-products and toxic waste that must be managed with the utmost care so as not to increase the load of chemicals that contaminate environmental matrices (water, air, soil). Each phase of these processes always involves a combination of social, ecological and health impacts that are closely related to each other. While there is a wealth of scientific papers (especially in the frame of the so-called "One Health" approach [29]) focused on the multitude of problems arising from the urbanization explosion (see for example [30,31]), in the great majority of cases, these studies are driven by the examination of the ecological or public health consequences of urbanization (see also the next chapter). This is certainly a very important task to pursue, but in the great majority of cases, these studies lack a truly systemic attitude. In addition, some of the proposed solutions for "more sustainable" cities still perpetuate the model of "inserting" pieces of nature into cities without any consideration for an autonomous urban–rural environment connected by an interface [32,33]. The city/surrounding interface is not systematically explored; the attention focuses on general, delocalized problems like climate change [34,35]. Little attention is paid to the local processes that take place in cities and large urban conglomerates on which global problems depend [36]. Clearly, there are some notable exceptions, and the paper by Prof. Warren Hern represents one of these [37]. This work is totally consonant with our proposal (see below) and has the merit of carrying forward a metaphorical approach, giving a proof of concept of the equivalence between the fractal dimension of modern cities and the fractal dimension of metastatic cells. In this respect, it is worth noting that the fractal dimension (a signature of the complexity of the studied system) of cell membranes is a crucial signature of malignancy [38]. Thus, the loss of a functional interface between the city and its rural environment has a direct counterpart in the loss of the constraints that limit cancer proliferation by the alteration of the relationship of cancer cells with their microenvironment. Oncology has recently adopted a very different paradigm with respect to the classic gene-centric one, shifting to the consideration of cancer as an "organization disease", altering the relation between the tissue (the city) and stroma (the supporting structure of the tissue, corresponding to the rural environment). A thorough explanation of this shift is reported in [8], together with a clear description of the role of complex system science in this paradigm change.

6. Public Health and Cities

Urbanization clearly demonstrates the human ability to alter the environment, disfigure the landscape and hinder social coexistence. Large cities present a multitude of challenges related to the management of unwanted impacts, such as the uncontrolled development of territorial boundaries (urban expansion) and the constant decline in quality of life [39,40]. Of course, modern cities in developed countries continue to be perceived as fundamental places where art, science, culture, technological progress and human well-being traditionally develop. However, these places can feed extremely negative aspects, such as social hardship, inequalities, pollution, overcrowding, marginalization, poverty and, ultimately, many and very serious health problems [41]. The urban living environment has been associated with poor levels of public health, which can often manifest as acute reactions due to extreme events, such as heat waves causing excessive deaths in the elderly population [42]. In other cases, health problems arise from long-term human exposure to risk factors induced by various conditions, as in the case of air, water and soil pollution. For example, airborne contamination from particulate matter and other toxic agents is implicated in the increasing incidence of chronic and degenerative diseases, such as cancer, asthma, chronic obstructive pulmonary disease (COPD), heart attacks, blood pressure issues and stroke, especially in congested urban areas [43]. It should be noted, however, that the health of a community is sensitive not only to chemical alterations in environmental matrices but also to the degree of urbanization and the demographic structure of the population, as well as to income, which obviously reflects the socioeconomic status of the people and, at the same time, their health condition. A new emerging transdisciplinary field examines phenomena that occur at the interface between urbanization and health to clarify the impact of cities on community quality of life from a socio-ecological perspective [44,45]. A study by Wallace and Wallace [46] is an interesting example. These authors investigated the dynamics taking place within the socially and physically degraded urban neighborhoods of large U.S. cities, with particular attention given to the Bronx in New York City. Unfortunately, the results of this study led to some rather worrying conclusions. The disappearance of the link between social and environmental factors (defined as “urban desertification”) produced dramatic results in terms of social fabric disintegration and the worsening of public health. The study highlighted a marked increase in communicable and non-communicable diseases, as well as an escalation in crimes and episodes of violence. The authors noted the degenerative potential fueled by mutually reinforcing phenomena, which turned entire neighborhoods into unlivable places [46]. Where the degradation of the physical and social environment characterizes people’s daily lives, community disorganization affects the frequency of organic and behavioral pathologies. These, in turn, further aggravate the condition of the living environment, triggering dangerous feedback that is difficult to control. Marginalization can undermine health by reducing access to medical care and even basic commodities such as healthy food and clean water. It also disrupts social relationships, generates depression and excessive alcohol consumption and often leads to a reduction in funds for buying food and for home heating. In these contexts, the tipping point is very close. The mistakes of decision makers, public institutions and socioeconomic agencies can reverberate in highly stressed human communities to the point of expelling people from the social system [47]. This is particularly true where a human community has long been subjected to the strong pressures of poverty and marginalization. The lack of social cohesion and equity produces serious effects on human health and well-being, especially in large urban centers where cancer represents one of the most common serious diseases. In 2008, more than 350,000 lung cancer deaths occurred in the European region of the World Health Organization alone. This means 42 cases per 100,000 people among men and 10 cases per 100,000 people among women (standardized rates) [48]. Lung

cancer mortality is expected to vary according to urbanization, as shown by the differences recorded in the urban and rural areas of a number of countries. For instance, a study carried out in the UK between 2002 and 2004 found significantly higher mortality risks from lung cancer in urban areas compared to in rural ones [49]. A Dutch investigation in the period from 1989 to 1991 verified that by stratifying the population by gender, the level of urbanization influenced the patterns of malignant diseases, producing an excess of incident cases in the female population [50]. Another study conducted in seven Italian regions between 1980 and 1994 highlighted an excess of mortality from lung adenocarcinoma in urban environments [51]. In the United States, an investigation covering the entire period from 1950 to 2007 revealed rural–urban differences in lung cancer mortality, showing that men and women living in metropolitan areas in the 1950s had markedly higher lung cancer mortality rates than their non-urban counterparts [52]. Some other studies are reported below that can give an idea of the problem [53–55].

The environmental degradation that characterizes many cities in the Western world often imposes high healthcare costs on citizens. As often denounced by environmental justice movements, this especially affects those who bear no responsibility for environmental degradation. Increased exposure to dangerous and/or carcinogenic agents at home, at work or during urban travel increases the burden of disease in more vulnerable populations. The fight against cancer and other degenerative diseases cannot be delegated only to the therapeutic field. National and regional governments have a duty to combat diseases through public health measures based on primary prevention. Furthermore, urban policies can help reduce the socioeconomic gap between citizens and reject choices that place market pressures before public health and social equity. Urban planning should take these challenges into consideration, integrating theoretical and pragmatic perspectives from systems theory, ecology, geography, biology, philosophy and the social sciences. As researchers, we should focus on the totality of the object of investigation and on the networks of causes that intersect different ways of observing the world. This approach requires overcoming old and useless dichotomies such as <urban/rural>, <social/biological>, <cultural/natural>, <body/mind>, <internal/external>, <organic/psychological> and so on. In fact, these dichotomies have fragmented our understanding of the world, comparing half-truths with other half-truths.

We are actively interested in a range of scientific and political issues that go beyond the common, modernist notion of the city and its role in today's civilization. The chronicles remind us almost daily as to how vulnerable and dangerous cities are today for their inhabitants. Global warming hits more and more intensely in all seasons, and the effects of extreme events, both on human populations and the economy, are severe. In 2020 alone, urban disasters attributed to natural phenomena caused about 16,000 deaths, affected about 100 million people and produced USD 190 billion of economic losses globally [56]. Recent epidemiological data show that the direct effects of urbanization on human health and mortality do not just depend on the violence of extreme events. The increasing density of buildings caused by land urbanization increases the risk of the spread of serious infectious diseases, which add to the aforementioned non-communicable ailments [56].

The world is experiencing another historic wave of urbanization. Although cities collectively occupy a very small area of the Earth's total surface [28], they are primarily responsible for the consumption and deterioration of global natural resources, such as energy, soil, air, water and biodiversity. The problem is that large modern cities depend on external and distant territories for their survival. The ecological crisis, together with many other crises of our time (economic, social, geopolitical, etc.), has forced cities to face unexpected problems that they themselves have contributed to generating. This stems from the impressive pressure exerted by that 3% of urbanized territory on most of the

planet's ecosystems, as documented by the enormous amount of data on the state of the Earth collected and analyzed by approximately 1400 scientists from all over the world [57].

7. Conclusions

One of the most promising ways to overcome current local and global urban challenges should be inspired by an effective connection of cities to the rural and natural environment. This proposal is quite simple and is consistent with the need to put what is important for people at the center of urban planning. We must satisfy primary human needs without distorting the environmental and social contexts in which communities live. In our opinion, an essential requirement to work on is the recovery of a “vision” of the territory based on the meaning of “urban space”. It is necessary to free this concept from the hegemony of overbuilding, private speculation against the common interest, the centrality of cars and, more generally, the idea that a strong and virtuous reciprocal bond cannot exist between the city and the natural environment. These are, in short, smaller cities with clear boundaries, a related landscape that produces sufficient food and energy for its inhabitants and a population size that allows for deliberative democracy. Such cities are in control of their own destiny because their vital functions (“organs”) are not external [23]: they have a real and local economy, and their citizens can develop an eco-civic language based on agriculture and related professions, including services. A common language develops in terms of civic activity, politics, economics and architecture, as demonstrated not only by 2000 years of Mediterranean urbanism [58] but also by the patterns emerging from squats and slums around the world [59]. The failure of such a language produces disasters at the urban, social and ecological levels. An eco-civic language is the first quality of a true and lively bio-urban city [60].

The basic novelty of this work is the focus on the similarity between urban and living organism growth with a particular emphasis on the disruption of a well-defined biodynamic interface typical of both cancer development and modern cities' uncontrolled growth. Cancer development implies a loss of the constraints shaping the relations between the cells constituting a tissue and their microenvironment, causing the “invasiveness” of cancer. This makes the tissue (city) lose its typical morphology by means of the invasion of the neighboring space. This is much more of a metaphor: In his 2008 paper [37], the author demonstrates the identity of the fractal dimension of urban space of some paradigm cities like Baltimore, London and Berlin and the fractal dimension of different cancer types (malignant melanoma, pulmonary adenocarcinoma), allowing, at least in principle, action against this kind of malignant growth by corrective actions. Prof. Hern explicitly affirms the following: “From the point of view of a physician, the expanding, invasive, colonizing urban form with highly irregular borders resembles a malignant lesion. Malignant neoplasms have at least four major characteristics: rapid, uncontrolled growth; invasion and destruction of adjacent normal tissues (ecosystems); metastasis (distant colonization); and de-differentiation. Many urban forms are almost identical in general appearance, a characteristic that would qualify as de-differentiation.”

In addition the author states: “Large urban settlements display rapid uncontrolled growth expanding in population and area occupied at rates of from 5 to 13% per year. We propose a null hypothesis that there is no similarity or correlation in the fractal dimension of urban forms and malignant neoplasms”. This null hypothesis was falsified highlighting a cancer-like growth of cities [37].

Figure 1 depicts the growth of London from 1800 to 1955, clearly demonstrating the progressive invasion of the surrounding rural environment by the city, reaching a fractal dimension of around 1.26, typical of malignancies.

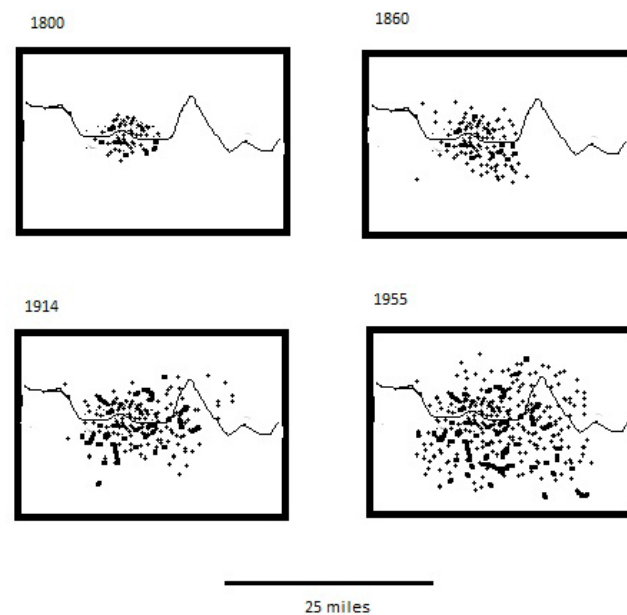


Figure 1. This figure (modified from [37]) reports the growth of the city of London from 1800 to 1955 and highlights the progressive loss of a definite shape of the urban space. The thin line traversing the graph corresponds to river Thames, the bold lines framing the maps correspond to approximately 25 and 15 miles in horizontal and vertical directions.

It is worth noting that the topological dimension of a point is 0, the topological dimension of a continuous line is 1, and the topological dimension of a surface is 2. The topological dimension of the edge of an irregular, fragmented object (such as cancer or a city) is a fraction somewhere between 1 and 2. It is a “fractal pattern”; this fractal pattern is independent of the scale and is generated from the slope of the line (in logarithm scale) of the relation between the unit length of a ruler and the number of units necessary to cover the object. When in the presence of a fractal object, the length of the edge does not reach a finite limit (expressed in terms of the number N of units of the ruler) but negatively scales with the ruler unit because the smaller the unit length, the higher the number of the “turns” and, thus, the higher the perimeter value [61]. Figure 2 reports an example of fractal scaling.

The x axis reports the unit length of the ruler (r), while the y axis corresponds to the number of units needed to cover the studied profile; both axes are reported in logarithm scale. In this case, the fractal dimension is equal to 1.45.

The “malignant” growth makes all modern cities almost identical: the fractal dimension of London is very similar to the outlines of Berlin or Houston [62]. On the contrary, the walled cities of medieval Europe had characteristic patterns that reflected both the local culture and the environmental features of the territories; this is a signature of de-differentiation that modern cities share with cancer.

All in all, what emerges from our analysis is the necessity of putting urban planning into a wider frame that leverages the consilience between General System Theory and the recent developments in complex system sciences. This task can be faced by importing methodological tools and results from fields like biochemistry and material science to the study of urban systems (hopefully to find solutions to emerging societal and health problems). The universality of both methodologies and results stems from the dramatic shift of the unity of different sciences from the statement “all entities are made of the same basic units” to the consideration that “all entities can be described in terms of the relational structure among their parts”. This last consideration, stating the possibility of studying systems in a way largely independent from the nature of their constitutive elements, is the

implicit raison d'être of system science [62] and holds promise in the cross-fertilization of different sciences, recomposing the actual fragmentation of knowledge.

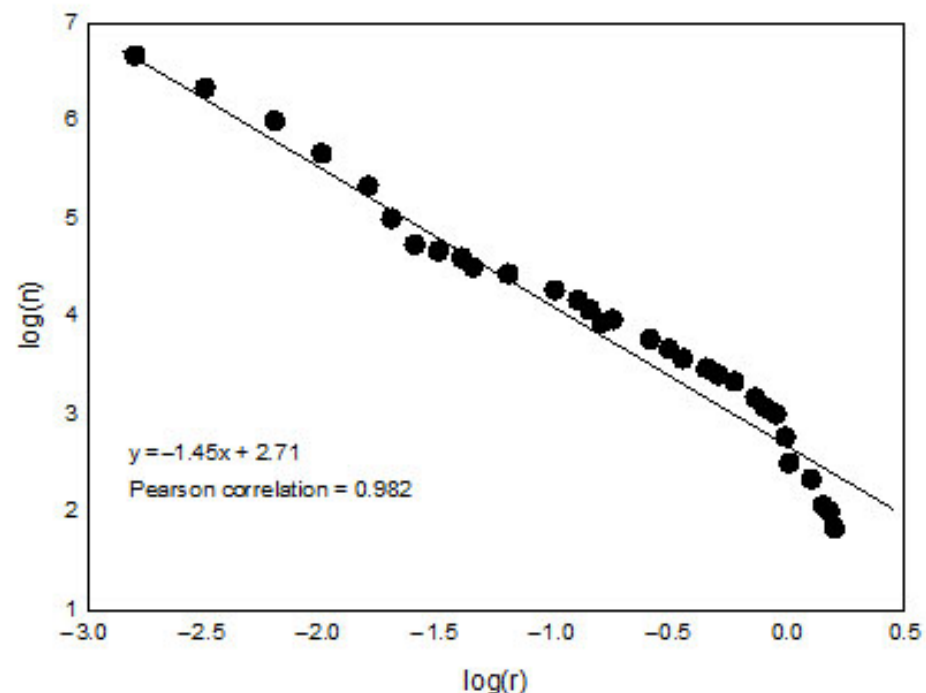


Figure 2. Fractal scaling (simulated data): the x axis reports the logarithm of the unit length of the ruler; the y axis shows the units needed to follow the perimeter. The fractal dimension corresponds to the absolute value of the slope of the regression line between these two variables and in this case is equal to 1.45.

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