Whatever happened to biological thinking in urban planning?

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Since 2007 the proclamation of the 'urban age' by the UN has been heralded as a critical moment in human society and history. The 'urban' has taken its place alongside the anthropocene as a new era for humanity. Its importance as a transformational moment has been underscored by scientific interest in cities. Anxiety about urbanisation was a motivator for early town planning activity in the 19th century. The tools developed by different disciplines to solve the crisis of 19th century urban development were designed around human welfare needs. With our cities forming both the origin and the solution to our planetary environmental crisis, a broader set of planning thoughts, languages and metaphors are needed that go beyond the mere human. Thinking biologically about *Homo Sapiens* in cities will be critical to our survival.

Planning history has a role to play in this project, drawing on the past to identify a biological lineage in urban planning and reveal what has and has not been successful. The aim of this paper is to start that identification. It forms part of a larger project to trace a lineage of biological thinking in urban planning history during the twentieth century. The paper analyses and reinterprets the use of science and biology by two influential planning visionaries: Sir Patrick Geddes (1854-1932) and Le Corbusier (Charles-Édouard Jeanneret, 1887-1965). Among the luminaries of his age, Geddes as a biologist turned sociologist was a unique figure. He attempted to grapple with the early 20th century urban age in biological terms. Le Corbusier, also used science and biology to argue for universal rules to guide urbanism and as an aesthetic. The paper describes the biological work of these canonical planning thinkers to consider why humanism became the hegemonic frame for urban planning in the twentieth century.

Keywords: Biological thinking, Le Corbusier, Patrick Geddes, urban metabolism, the urban age.

The age of biology meets the urban age

Since 2010 the leading journal *Nature* has featured a section on its website about cities[1]. The site profiles and promotes the 'special relationship' between scientists and the city aiming to understand how they can bring out the 'best in the other'. The hope is that scientists can assist cities in tackling their biggest problems. Included is an exemplar: a profile of the Nobel Chemistry Laureate Mario Molina who returned to Mexico City in 2005 to "tackle the messy world of public policy, urban planning and climate change"[2].

Molina is only one recent example of a scientist who has worked to apply science to city planning and management. Other important examples include the physicists Geoffrey West and Luis Bettencourt who have proposed a universal theory of cities[3] also in collaboration with numerous other scientists at the Santa Fe Institute[4]. West's ground-breaking and visionary transdisciplinary work is summarised in his popular science book '*Scale: The Universal Laws of Growth, Innovation, Sustainability, and the Pace of Life in Organisms, Cities, Economies, and Companies*.'[5] which proposes a 'Grand Unified Theory of Sustainability' (p. 411).

The interest of scientists and even physicists in cities has been a varying feature of urban planning for much of the twentieth century[6]. Much of this focus has been guided by an organic or biological conception of the city[7]. This continues a long tradition from Aristotle of likening the city to an organism, but throughout history the distinctions between the city, nature and landscape have remained fluid[8]. For Auguste Comte (1798-1857) for example, an organic metaphor of cities offered a way of understanding the construction of societies and the relationship between cities and hinterlands:

"The Fatherland establishes a relation between the soil and social order; and thus the organs of the Great Being can only be cities, the root of the word being the nucleus of the term civilisation. Cities are, in truth, themselves beings; so organically complete that, as each is capable of separate life, it instinctively aspires to become the centre of the vast organism of Humanity. In this tendency the Social organ differs radically from the organ in Biology, which has no separate completeness [...] The smallest city contains all the elements and tissues, required for the life of the Great Being, in the Families, and in the Classes or Castes, within it."[9]

In the history of planning, the use of metaphors and a language to describe cities in terms of biology has been a persistent theme[10]. Biological thinking about cities and planning strongly influenced Patrick Geddes, the prototypical biologist turned planner, and various key thinkers – Jane Jacobs, Lewis Mumford and Christopher Alexander. Yet, biological thinking has remained a secondary concern for planners for much of the twentieth century or has appeared as an environmental concern[11], which is humanistic in origin. If it becomes necessary for planners to think and consider the 'more than human'[12] developing and nurturing biological languages and metaphors for cities and for planning becomes necessary[13]. In other words, we should plan less for humans and more for *Homo sapiens* if we are to avoid widespread ecological destruction. Yet what further traces can we find of biological thinking in planning during the twentieth century and whatever happened to this? This paper contributes to this growing area of interest and points to some of the simple and fundamental reasons why biological thinking disappeared or was subsumed into a hegemonic humanistic discourse during the twentieth century.

A clear answer was that the engagement between planning and science in general but specifically biology has been tainted by problematic associations during the twentieth century. For example, planners were strongly influenced by the Chicago School's Robert E. Park and Ernest Burgess's borrowing of competition and other concepts from nineteenth century social Darwinism[14]. Although influential, this was shown to be flawed[15]. In general, the aim of science to achieve universal laws and theories ignores the particular and diverse reality of cities. Furthermore, the history of planning is problematically linked to a colonial project of progress which is supported by universalism. A watershed moment for science and planning during the post-War period was the failure to translate a systems theory of planning into pragmatic action and the eloquent criticisms of planning by Jane Jacobs in *Death and Life of Great American Cities*[16] (1961).

The following selects two luminaries from planning history, illuminating their biological thinking and contributing to the path set by Batty and Marshall[17]. The selection is guided by their emphasis on science and their importance to the field. Sir Patrick Geddes' biological thinking in relation to cities, is examined by drawing on secondary sources and primary material at the National Library of Scotland and the Geddes Archives at the University of Strathclyde. Also examined is the work of the Swiss-French architect Le Corbusier. Le Corbusier is of course an icon of modernist planning and committed much of his career to insisting on the need for a scientific approach to planning[18]. The overall aim is to examine the thinking of these two figures and how they attempted to reconcile science, biology and the complex reality of cities.

Geddes' theory of biology and theory of life

Geddes, making a career transition from biology to social sciences in the late 1880s brought a particular set of ideas to urban history[19]. Firstly, borrowing from the German biologist Ernst Haekel, he considered cities to be ontogenetic. In other words, in the same way that a developing mammalian embryo will briefly transition through a set of vestigial stages in the uterus (eg. tail, gills), Geddes believed that all cities both contain similar elements that both remain in vestigial form as traces of their development. Similarly, cities had to go through these stages as part of their development. Geddes also recognised from his travels that a variety of urban possibilities existed and understood that at various periods in history cities had died. He envisioned how this cycle of life and death could be linked in an evolutionary cycle and that cities developed and changed as though on a branching phylogenetic tree. The phylogenetic metaphor for thinking about city evolution is shown in Figures 1 and 2. The idea of a historical progression and development from one city to the next as with species is shown in Figure 1, with Hellenic cities at the lowest branch spawning various city types that became extinct, before a successful evolutionary model led to a Hellenistic city and so on through to a modern European city. The interaction was implicit in the definition of stages of urban development in the "Ui Breasail" Cities and Town Planning Exhibition in Dublin 1911 for example (Figure 2).

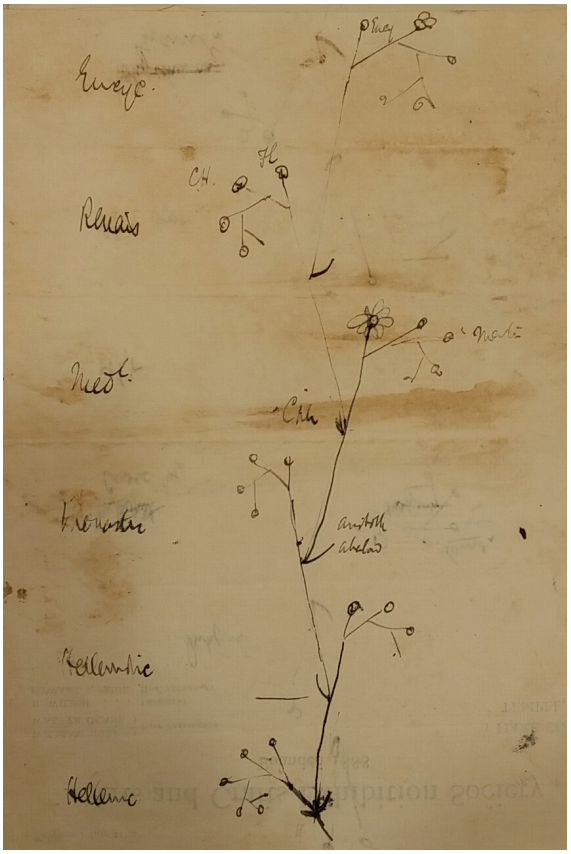

Figure 1: Phylogenetic classification of the history of cities (undated). Text on left reads: Hellenic, Hellenistic, Monastic (?), Med. (Medieval), Renaiss (Renaissance), Empire (Europe?). University of Strathclyde, Archives of Sir Patrick Geddes, T-GED/6/11. Compare with Figure 2.

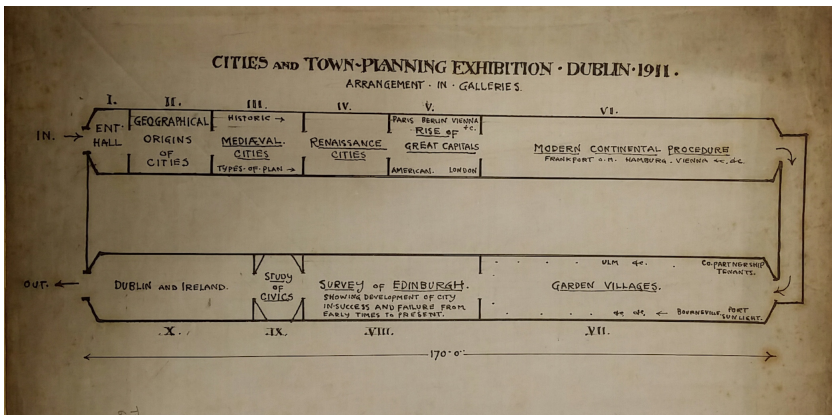

Figure 2: Layout of the Cities and Town Planning Exhibition Dublin 1911. T-GED/6/11/2.

Yet, for Geddes, city evolution, as well as being a question of genetic transfer was one of memetic or cultural transfer. In other words, the city occupied the role of a nucleus within a cell passing on the cultural inheritance of a regional civilization from one generation to the next[20]. Permanent and travelling exhibitions represented a means of facilitating this transition[21], as did Geddes' frequent travelling, the summer schools he organised and even the Masques or theatrical performances[22].

As Helen Meller notes, Geddes was spatial thinker and for that reason he employed geometry to express his ideas rather than algebra. The two dimensions required for a flat piece of paper meant that his ideas would be limited by this medium could only be far more restricted than is needed for the increasing number of concepts he found essential use" p. 37.[23] Yet, at the same time, this limited typology forced him to bring together ideas and terms that would not normally be associated.

While Geddes' contribution is often considered in isolation his work was subsequently important to modernism in two important ways. Firstly, his enthusiasm for libraries and education through museums[24] found its voice through support for the 'universalism' of Paul Otlet[25]. Secondly, through the work of the Anglo-Greek architect Jaqueline Tyrwhitt his work was translated into the post-War work of CIAM[26].

Le Corbusier – from the cell to the City

Geddes started his career as a scientist and then largely eschewed scientific theory and empirical testing when he applied his focus to town planning. Le Corbusier on the other hand had no formal training in science but had a firm belief in the power of science to revolutionise urbanism. As Von Moos (2009) points out[27], Le Corbusier's early artistic and design education in the 'Cours Supérieur d'Art et de Decoration' under Charles L'Eplattenier was embedded in the aim of creating a decorative style that was embedded in appreciating and abstracting the nature around the Jura region. Le Corbusier was motivated by a romantic engagement with nature following in the footsteps of John Ruskin. The magazine *l'Esprit Nouveau* that he co-founded and ran from 1920-1925 regularly included articles on science. In some cases, there were articles by scientist themselves, in other cases latest advances were subject to interpretation by one of the editorial team, they represent a means of illustrating the ideas of science that underpinned Le Corbusier's ideas. For example volume 9 includes an article by the engineer Paul Recht on 'Pré-adaptation' a review of the book '*Chimie et la vie'* by the biologist Georges Bohn (1868-1948). The article questions the extent to which Darwinian natural selection can be brought down to the molecular or chemical level. A key concern for Le Corbusier and his colleagues as Lopez-Duran notes[28], was that mechanical advances in science had made much faster progress than biological advances. Thus, the article by Recht already points to a molecular-mechanical interaction and would have been selected to show how biology was catching up with mechanics.

A major influence on the biological thinking of Le Corbusier however, was Dr Pierre Winter who wrote articles for the magazine on sport and the human body. In one article entitled "Le Corps Nouveau"[29] Winter describes the potential of the healthy and hygienic human body to bring about a societal revolution. After three pages of ecstatic language he describes the human body as a clean and minimal element as part of a new society: "*Le corps va réapparaître nu sous le soleil, douché, musclé, souple."* (The body will reappear naked under the sun, showered, muscular, supple). Geddes was strongly influenced by the English philosopher and founder of eugenics Herbert Spencer (1820-1903) but never expressed or connected town planning with eugenics. While Geddes attempted to develop the theory of biology alongside town planning into a theory of life, for Le Corbusier, another means by which biology and the city came together as a eugenic project was to 'improve' man. As Lopez-Duran notes in her history of translantic Eugenics. [30]

Yet Le Corbusier's biological perspective gave him an ability to see the urbanism as a problem to be tackled with the human body at the centre, although the strength of his assertion gave an impression that he alone had solved or reduced this complexity to its essentials. A clear definition of Le Corbusier's view of science comes through an analysis of his description of the functional city during the CIAM congress aboard the *SS Patris* in 1933 as Mumford notes (p. 79).[31] Unknowingly celebrating the Anthropocene, the plans by CIAM represented no less than a 'biology of the world'. In CIAM Le Corbusier asserted that the role of the planner was to develop 'honest means of expression' to prescribe to authorities. 'Through bodily movement the three dimensions imply the notion of time, and our lives are regulated by the "solar regime" of twenty-four hours and the year, which "commands distances and heights"' (p. 79).[32].

Conclusion: if the twentieth century's planning was Euclidean, the twenty first century's will be Fractal

In 1961 Jane Jacobs famously criticised planning as a 'pseudo-science' comparing it to bloodletting and labelling its 'plethora of subtle and complicated dogma' as a foundation of nonsense (p.13).[33] Since that time, planning has embraced a range of non-scientific ways of understanding. These theories are not those that would be recognisable to a physicist like Geoffrey West. In other words, a way of modelling or seeing the world that is based on first principles and has some predictive power which can be empirically tested. Instead theorising in planning is meant in part to guide practice and is in part a phenomenological project.

For both Geddes and Le Corbusier scientific understandings of cities were of course flawed from a number of perspectives. For Le Corbusier, science, rationality and standardisation were avowedly tools for prediction and analysis to derive a deeper or more fundamental understanding of cities but were also part of a suite of propaganda tools to further his own projects. For Geddes on the other hand, city planning was a spoke on a wheel in which the hub was an open-ended quest for a theory of life. Biology, geography and sociology all comprised other spokes of the wheel. His ability to jump from one spoke to another and to think laterally about a problem of city planning, particularly in a colonial context[34] make his ideas seem almost post-modern and contemporary.

For both, the role of science and in particular biology in city planning was an inspiration and a source of metaphor. Yet, it was not just a question of not embracing or understanding science but also that science itself wasn't up to

the task of understanding the city. Both were limited by the constraints of their Euclidean geometry. In 1967 the French mathematician Benoit Mandelbrot published a landmark study examining why the apparent length of the British coastline increases the more accurately it is mapped[35]. This seemingly simple question gave rise to a new paradigm in mathematics and a deep understanding of fractals and their dimensions. It is the basis of the work of Michael Batty and others who work in complexity[36] but it also provides a way of explaining the efficiency of life forms such as trees, mammals and cities[37].

Table 1 is an initial and simple binary approach to the different periods during the twentieth century of thinking about the application of biology in planning. There are many further periods to detail this initial layout as part of this ongoing project.

Table 1: A binary approach to biological thinking in cities and planning

Geometric	**Systems**	**Organic**	**Environmental**	**Ecological**
Euclidean	Closed	Society as a human body	Sanitary	Location theory and social organization
Fractal	Open	City as a natural system	Sustainability	Ecological expansion and segmental growth
References				
Batty[38]	Berry[39]	Harvey[40]	Daniels[41]	Morgan Grove et al[42]

Both Geddes and Le Corbusier while seeking to point to explanations about the city that were linear or Euclidean, had an instinctive or even artistic understanding of the relationship between fractal objects in nature and cities. In his book *Cities in Evolution* (p. 25) Geddes described a view of London that would have been unfamiliar to many at the time[43]. He imagined looking from above on the large smoking city as though looking down on a coral reef. On his so-called `man-reef' the buildings were the hard structures that had steadily been accreted upon over the centuries. The polyps were the humans and other life forms that existed on these.

Le Corbusier frequently used biological and fractal imagery in his designs toying with them. It can be easy to see these as providing a stark contrast with the flat and angular surfaces of some of his designs, but his writing reveals a deeper more instinctive understanding of nature. Figure 3 shows the tree growing in the middle of the patio on the Pavilion de l'Esprit Nouveau (1924). It clearly illustrates Le Corbusier's focus on light as a source of life. But there it also show the geometric contrasts of the two forms. Whereas the geometry for describing the built form was well understood that of nature was yet to be formulated. Figure 4 shows the interior of the later Pavilion Suisse 1930. A majority of the natural forms on photographs on the wall refer to the idea of natural habitation, such as animal and plant cells and honeycombs. While Le Corbusier would have been doing this to playfully and aesthetically allude to his ideas as an extension of nature the idea of bringing human and natural habitation in line with one another is a first and necessary step in thinking biologically in the city.

For contemporary planners these reflections on the historical role of science in planning should provide a way of better understanding how to embrace biological thinking in planning. The use of biology, however incompletely understood, and even as a metaphor can provide a powerful narrative to describe a vision for a new city or development. At the same time, the biology that is being advocated by West and colleagues describes a helicopter perspective on cities that seeks to propose universal rules. Yet, necessarily there are large cities and areas of the world where the data for corroborating these conclusions do not exist. A feature of the urban age is that we have very large cities, which do not reliably fall inside the ambit of reliable data gathering, let alone reliable planning control. We may never know the extent to which Bettancourt and West's laws about the city apply simply because as economies develop data gathering improves along with public welfare and cities change to resemble those of developed country cities.

For Le Corbusier a recurring theme was the human body and the idea of the city as a problem to be tackled at the human scale. While a helicopter view can offer general insights that can guide interventions about the city, science has a great deal to offer at the human scale by considering the problem of human beings as Sapiens.

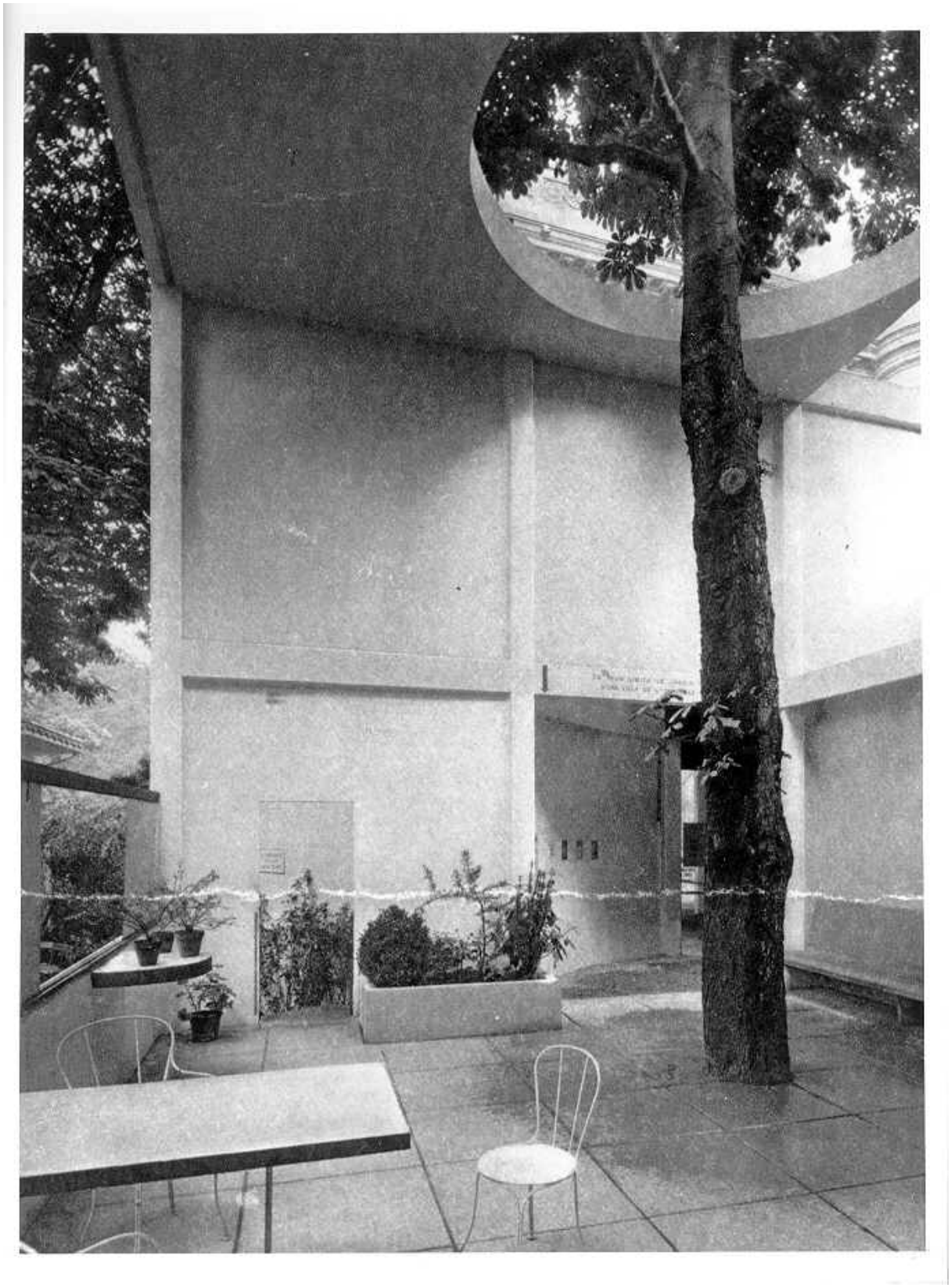

Figure 3: Pavilion de l'Esprit Nouveau 1924. Fondation Le Corbusier.

Figure 4: Interior of the Pavilion Suisse 1930. Fondation Le Corbusier

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Endnotes

[1] https://www.nature.com/collections/gdtjmkkbjr#news
[2] ibid
[3] Bettencourt, Luis, and Geoffrey West. "A unified theory of urban living." *Nature* 467.7318 (2010): 912.
[4] Bettencourt, Luís MA, José Lobo, Deborah Strumsky, and Geoffrey B. West. "Urban scaling and its deviations: Revealing the structure of wealth, innovation and crime across cities." *PloS one* 5, no. 11 (2010): e13541. Kühnert, Christian, Dirk Helbing, and Geoffrey B. West. "Scaling laws in urban supply networks." *Physica A: Statistical Mechanics and its Applications* 363, no. 1 (2006): 96-103.
[5] West, G. (2017). *Scale: The Universal Laws of Growth, Innovation, Sustainability, and the Pace of Life in Organisms, Cities, Economies, and Companies*. Penguin.
[6] J Morgan Grove et al. (2015) *The Baltimore School of Urban Ecology: Space, Scale, and Time for the Study of Cities* Yale University Press.
Marchetti, C. (1994). Anthropological invariants in travel behavior. *Technological forecasting and social change*, *47*(1), 75-88.
[7] Davison, G. (1983). The city as a natural system: theories of urban society in early nineteenth century Britain. *The pursuit of urban history*, 349-370.
[8] Weller, R. (2016) The City is Not an Egg, in Frederick R. Steiner, George F. Thompson and Armando Carbonell (eds), *Nature and Cities: the ecological imperative in urban design and planning,* Lincoln Institute of Land Policy.

[9] Comte, Auguste. *System of Positive Polity: Social dynamics; or, the general theory of human progress*. Vol. 3. Longmans, Green and Company, 1876. [p.240] I am grateful to Robert Freestone for this quote

[10] Batty, M., & Marshall, S. (2017). Thinking organic, acting civic: The paradox of planning for Cities in Evolution. *Landscape and Urban Planning*, *166*, 4-14.
[11] R. Freestone. Australian environmental planning: origins and theories. In J. Byrne, N. Sipe, and J. Dodson, editors, Australian Environmental Planning: challenges and future prospects, pages 21–35. Routledge, London, New York, 2014.
for Australia, C. Wood. Environmental planning. In B. Cullingworth, editor, British Planning: 50 years of urban and regional policy, pages 250–263. Athlone Press, London and New Brunswick, NJ, 1999, for the UK, T. L. Daniels. A trail across time: American environmental planning from city beautiful to sustainability. Journal of the American Planning Association, 75(2):178–192, 2009 for the US.
[12] D. Houston, J. Hillier, D. MacCallum, W. Steele, and J. Byrne. Make kin, not cities! multispecies entanglements and 'becoming-world' in planning theory. Planning Theory, 0(0):1473095216688042, 0.
[13] The twenty first century is expected to be the so-called 'age of biology' in which life-sciences are meant to revolutionise human progress and potentially lead to solutions to avoid ecosystems collapse. For example see the OECD proclaimed in 2012 the age of biology: https://www.oecd.org/sti/biotech/A%20Glover.pdf. Indeed West's departure from the world of theoretical physics is linked to the defunding of the Superconducting Super Collider in 1993 by the Clinton administration (West, 2018, 83). On cities being both the origin and solution to environmental crises: Rees, William, and Mathis Wackernagel. "Urban ecological footprints: why cities cannot be sustainable—and why they are a key to sustainability." *Environmental impact assessment review* 16, no. 4-6 (1996): 223-248.
[14] M. V. Melosi. The historical dimension of urban ecology: frameworks and concepts. In A. R. Berkowitz, C. H. Nilon, and K. S. Hollweg, editors, Understanding Urban Ecosystems: A New Frontier for Science and Education, pages 187–200. Springer, New York, NY, 2003
[15] J Morgan Grove (2015) *The Baltimore School of Urban Ecology: Space, Scale, and Time for the Study of Cities* Yale University Press.
[16] Taylor, N. (1998). *Urban planning theory since 1945*. Sage.
[17] Batty, M., & Marshall, S. (2017). Thinking organic, acting civic: The paradox of planning for Cities in Evolution. *Landscape and Urban Planning*, *166*, 4-14.
[18] To name but one example see his essay on the construction and evolution of automobiles as a proxy for functional form: "L'établissement d'un standart procède de l'organisation d'éléments rationnels suivant une ligne de conduite rationnelle également."
[19] See for example: Welter, Volker M. *Biopolis: Patrick Geddes and the city of life*. mit Press, 2002. Also: Ponte, Alessandra, and Jessica Levine. "Building the stair spiral of evolution: The Index museum of sir Patrick Geddes." *Assemblage* 10 (1989): 47-64.
[20] Welter, Volker. The Valley Region: from figure of thought to figure on the ground. In Ibañez Daniel and Katsikis Nikos (eds). *Grounding Metabolisms,* Harvard University Press, Mass. 2014.
[21] Amati, Marco, Freestone, Robert and Robertson, Sarah. "Learning the city": Patrick Geddes, exhibitions, and communicating planning ideas. *Landscape and Urban Planning*. (2017) 166,
[22] Defries, Amelia. "The Masque of Learning." In *Revival: The Interpreter Geddes (1928)*, pp. 41-56. Routledge, 2018.
[23] Meller, Helen. *Patrick Geddes: social evolutionist and city planner*. Routledge, 2005.
[24] Geddes, Patrick. "A Suggested Plan for a Civic Museum (OR Civic Exhibition) and its Associated Studies." *The Sociological Review* 1 (1906): 197-230.
[25] Van Acker, Wouter. "Architectural Metaphors of Knowledge: The Mundaneum Designs of Maurice Heymans, Paul Otlet, and Le Corbusier." *library trends* 61, no. 2 (2012): 371-396.
[26] Shoshkes, Ellen. "Jaqueline Tyrwhitt translates Patrick Geddes for post world war two planning." *Landscape and Urban Planning* 166 (2017): 15-24.
[27] Von Moos, S. (2009) Le Corbusier Elements of a Synthesis. 010 Publishers, Rotterdam.
[28] López-Durán, Fabiola. *Eugenics in the Garden: Transatlantic Architecture and the Crafting of Modernity*. University of Texas Press, 2018.
[29] Winter, Pierre. "Le Corps nouveau." *L'Esprit nouveau. Revue internationale illustrée de l'activité contemporaine* 15 (1922): 1755-1758.
[30] López-Durán, Fabiola. *Eugenics in the Garden: Transatlantic Architecture and the Crafting of Modernity*. University of Texas Press, 2018.
[31] Mumford, Eric Paul. *The CIAM discourse on urbanism, 1928-1960*. MIT press, 2002.
[32] Ibid.
[33] Jacobs, Jane. "The death and life of great American cities." *New York: Vintage* (1961).
[34] Khan, Naveeda. "Geddes in India: town planning, plant sentience, and cooperative evolution." *Environment and Planning D: Society and Space* 29, no. 5 (2011): 840-856.
[35] Mandelbrot, Benoit. "How long is the coast of Britain? Statistical self-similarity and fractional dimension." *science*156, no. 3775 (1967): 636-638.
[36] Batty, Michael. *Cities and complexity: understanding cities with cellular automata, agent-based models, and fractals*. The MIT press, 2007.
[37] West, G. (2017). *Scale: The Universal Laws of Growth, Innovation, Sustainability, and the Pace of Life in Organisms, Cities, Economies, and Companies*. Penguin.
[38] Batty, Michael. *Cities and complexity: understanding cities with cellular automata, agent-based models, and fractals*. The MIT press, 2007.
[39] Berry, Brian JL. "Cities as systems within systems of cities." *Papers in regional science* 13, no. 1 (1964): 147-163.
[40] Harvey, David. *Social justice and the city*. Vol. 1. University of Georgia Press, 2010.
[41] T. L. Daniels. A trail across time: American environmental planning from city beautiful to sustainability. Journal of the American Planning Association, 75(2):178–192, 2009
[42] J Morgan Grove (2015) *The Baltimore School of Urban Ecology: Space, Scale, and Time for the Study of Cities* Yale University Press.
[43] Geddes, Patrick. *Cities in evolution*. Williams & Norgate, 1949.

Bibliography:

Amati, Marco, Freestone, Robert and Robertson, Sarah. "Learning the city": Patrick Geddes, exhibitions, and communicating planning ideas. *Landscape and Urban Planning*. (2017) 166,
Batty, M., & Marshall, S. (2017). Thinking organic, acting civic: The paradox of planning for Cities in Evolution. *Landscape and Urban Planning*, 166, 4-14.

Batty, Michael. *Cities and complexity: understanding cities with cellular automata, agent-based models, and fractals*. The MIT press, 2007.
Berry, Brian JL. "Cities as systems within systems of cities." *Papers in regional science* 13, no. 1 (1964): 147-163.
Bettencourt, Luis, and Geoffrey West. "A unified theory of urban living." *Nature* 467.7318 (2010): 912.
Bettencourt, Luís, José Lobo, Deborah Strumsky, and Geoffrey B. West. "Urban scaling and its deviations: Revealing the structure of wealth, innovation and crime across cities." *PloS one* 5, no. 11 (2010): e13541.
Comte, Auguste. System of Positive Polity: Social dynamics; or, the general theory of human progress. Vol. 3. Longmans, Green and Company, 1876.
Daniels, T. L. A trail across time: American environmental planning from city beautiful to sustainability. *Journal of the American Planning Association*, 75(2):178–192, 2009
Davison, G. (1983). The city as a natural system: theories of urban society in early nineteenth century Britain. *The pursuit of urban history*, 349-370.
Defries, Amelia. "The Masque of Learning." *In Revival: The Interpreter Geddes* (1928), pp. 41-56. Routledge, 2018.
Freestone, R. . Australian environmental planning: origins and theories. In J. Byrne, N. Sipe, and J. Dodson, editors, *Australian Environmental Planning: challenges and future prospects*, pages 21–35. Routledge, London, New York, 2014.
Geddes, Patrick. "A Suggested Plan for a Civic Museum (OR Civic Exhibition) and its Associated Studies." *The Sociological Review* 1 (1906): 197-230.
Geddes, Patrick. *Cities in evolution*. Williams & Norgate, 1949.
Harvey, David. *Social justice and the city*. Vol. 1. University of Georgia Press, 2010.
Houston, D. J. Hillier, D. MacCallum, W. Steele, and J. Byrne. Make kin, not cities! multispecies entanglements and 'becoming-world' in planning theory. *Planning Theory*, 0(0):1473095216688042, 0.
Jacobs, Jane. *The death and life of great American cities* New York: Vintage (1961).
Khan, Naveeda. "Geddes in India: town planning, plant sentience, and cooperative evolution." *Environment and Planning D: Society and Space* 29, no. 5 (2011): 840-856.
Kühnert, Christian, Dirk Helbing, and Geoffrey B. West. "Scaling laws in urban supply networks." *Physica A: Statistical Mechanics and its Applications* 363, no. 1 (2006): 96-103.
López-Durán, Fabiola. *Eugenics in the Garden: Transatlantic Architecture and the Crafting of Modernity*. University of Texas Press, 2018.
Mandelbrot, Benoit. "How long is the coast of Britain? Statistical self-similarity and fractional dimension." *Science* 156, no. 3775 (1967): 636-638.
Marchetti, C. (1994). Anthropological invariants in travel behavior. *Technological forecasting and social change*, 47(1), 75-88.
Meller, Helen. *Patrick Geddes: social evolutionist and city planner*. Routledge, 2005.
Melosi, M. V. The historical dimension of urban ecology: frameworks and concepts. In A. R. Berkowitz, C. H. Nilon, and K. S. Hollweg, editors, *Understanding Urban Ecosystems: A New Frontier for Science and Education*, pages 187–200. Springer, New York, NY, 2003
Morgan Grove, J. (2015) *The Baltimore School of Urban Ecology: Space, Scale, and Time for the Study of Cities* Yale University Press.
Mumford, Eric Paul. *The CIAM discourse on urbanism*, 1928-1960. MIT press, 2002.
Ponte, Alessandra, and Jessica Levine. "Building the stair spiral of evolution: The Index museum of sir Patrick Geddes." *Assemblage* 10 (1989): 47-64.
Rees, William, and Mathis Wackernagel. "Urban ecological footprints: why cities cannot be sustainable—and why they are a key to sustainability." *Environmental impact assessment review* 16, no. 4-6 (1996): 223-248.

Shoshkes, Ellen. "Jaqueline Tyrwhitt translates Patrick Geddes for post world war two planning." *Landscape and Urban Planning* 166 (2017): 15-24.
Taylor, N. (1998). *Urban planning theory since 1945*. Sage.
Van Acker, Wouter. "Architectural Metaphors of Knowledge: The Mundaneum Designs of Maurice Heymans, Paul Otlet, and Le Corbusier." *Library trends* 61, no. 2 (2012): 371-396.
Von Moos, S. (2009) *Le Corbusier Elements of a Synthesis*. 010 Publishers, Rotterdam.
Weller, R. (2016) The City is Not an Egg, in Frederick R. Steiner, George F. Thompson and Armando Carbonell (eds), *Nature and Cities: the ecological imperative in urban design and planning*, Lincoln Institute of Land Policy.
Welter, Volker M. *Biopolis: Patrick Geddes and the city of life*. MIT Press, 2002.
Welter, Volker. The Valley Region: from figure of thought to figure on the ground. In Ibañez Daniel and Katsikis Nikos (eds). *Grounding Metabolisms*, Harvard University Press, Mass. 2014.
West, G. (2017). *Scale: The Universal Laws of Growth, Innovation, Sustainability, and the Pace of Life in Organisms, Cities, Economies, and Companies*. Penguin.
Winter, Pierre. "Le Corps nouveau." *L'Esprit nouveau. Revue internationale illustrée de l'activité contemporaine* 15 (1922): 1755-1758.
Wood, C. Environmental planning. In B. Cullingworth, editor, *British Planning: 50 years of urban and regional policy*, pages 250–263. Athlone Press, London and New Brunswick, NJ, 1999