Nature And The Cultural Evolution Of Architectural Forms

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We are accustomed to think of 'Nature' as all that is wild and untouched, landscapes of forests and grasslands and shorelines and seas, separate from and unsullied by the activities of mankind. In this enduring image the world turns, the seasons come and go, and life is abundant. Man is different, set apart from the wild, with a life that is ordered by culture and technology. This inherited image is ancient, a culture legacy that derives from creation myths and religious concepts of paradise. Paradise was conceived as a walled orchard garden or an enclosed hunting park, an enclosure of wild nature, but protected from the worst dangers of the wild. 'Nature', created by God, was innocent, beautiful and divine, and sin entered the world only through human corruption. That concept persists today in the distinction that is commonly made between the purity of virgin nature and the depredations of technology. An alternative but equally persistent concept is that mankind was created for the perfection of 'Nature'; and that the natural world is there for the benefit of man, and in mans domination of the natural world so it is sanctified.

The understanding of human beings as part of 'Nature', a species amongst other species, has a much shorter history[1], little more than 200 years. Holbach's '*Systeme de la Nature*', published in France in 1770, posits Nature as following 'only necessary and immutable laws', an immense system in which "Man is the work of Nature: he exists in Nature." The logical extension of that understanding to include human activities is that technology is a natural behavior, and that such natural behavior was developed over time. "Nature sends man naked and destitute into this world which is to be his abode: he quickly learns to cover his nakedness—to shelter himself from the inclemencies of the weather, first with artlessly constructed huts, and the skins of the beasts of the forest; by degrees he mends their appearance, renders them more convenient: he establishes manufactories to supply his immediate wants; he digs clay, gold, and other fossils from the bowels of the earth; converts them into bricks for his house, into vessels for his use, gradually improves their shape, and augments their beauty".

Accepting that '*homo sapiens*' is one species amongst others has the logical implication that the activities of humans, their technologies, are not anymore unnatural than the collective behavior of many species that produce constructions, such as a termites mound or a wasp nest. In this view, the struggle for survival produces activities in all living things; some behavior is adaptive and the species survive, other behaviors are less successful and the species become extinct. All organisms must feed, and do so by gathering from their environment; root systems and photosynthesis for plants, grazing of plants by herbivores, predation by carnivores on smaller animals; and humans do so by agriculture and fishing. These are natural activities, a difference of scale rather a difference of kind. Human activities have played a significant role in shaping the natural world as it is today.

The landscape of the world has been as much shaped by the cultural history of human interventions as it has by climatic effects such as glaciers, and by geological processes of uplift, erosion and deposition. There is no vanished Eden, no singular 'natural landscape' to be found, no single ideal image of nature that can be reconstructed or modelled. The understanding that the earth is very old, that Nature has a history, and that the forms of living creatures were different in the past, begins in the eighteenth century. The recognition that changes to the form of organisms, and that the environment plays some part in that change, comes in the same century. The first systematic examination of fossil evidence, at the beginning of the 19th Century by the French naturalist Cuvier, contains methodical and detailed studies of the shapes of fossil mammoth bones found in Europe and Siberia that demonstrated their differences from living elephant species[2].This comparative morphological study of vertebrate palaeontology established that there is a common skeletal plan for all vertebrate species, and that species that had existed in the past are now extinct. Cuvier stated that life began in the sea, that life on land followed, and that the reptiles had existed before mammals. Once it was posited that the past was different to the present, it became possible to consider that the earth had experienced a series of geological ages, and that each age had its own characteristic landscapes and organisms.

The gradual acceptance of these ideas, and the subsequent development of the sciences and disciplines founded on them, has begun to unfold the relations of the physical world to the life within it. From the long perspective of geological time, it is clear that Nature has no normal state, but is a continuing series of changing landscapes and climates, and that living organisms change and develop accordingly.

A systematic exegesis of the relation between architecture and the natural world begins with the understanding of architecture as a 'natural' activity, and proceeds from the recognition that Nature[3]' is the domain of all living things, and of the dynamic processes and phenomena of the non living physical world within which they exist, and upon which they in turn have such a profound effect. It must include an account of the way that all living things come into being and change their behavior and form, of the physics of the climate and the material and energy of which all things are made.

1 The Forms And Processes Of Nature

The forms of Nature – living forms such as plants or animals, and non-living forms such as river deltas, hurricanes or desert sand dunes, have an intricate relationship. They interact with each other and with their local environment, and in doing so they modify that environment, which in turn may change sufficiently to induce further reciprocal modifications. Natural forms have the capacity to change significantly and to generate new forms, structures and properties from existing ones. There are many complicated and interlinked processes involved, with significant variations of spatial scale and of time. The formation of a snowflake and a hurricane, for example, are both dependant on energy (temperature) and humidity, but their differing sizes are separated by 8 orders of magnitude[4]. Geological processes are also energy critical, for example the movement of tectonic plates and the raising up of mountain ranges, the release of strain energy by earthquakes and eruption of volcanoes are all powered by the flow of internal heat from the earths core to the cooler outer surface. Energy is the most significant factor too, in the relationships between living organisms and the physical world. All living things require energy to grow and to maintain themselves, and to propagate themselves into the future.

Non-living forms, the forms of the land, the forms of clouds, of snow and storms, of dunes and rivers, are not permanent, static things but are dynamic three-dimensional patterns that are produced by the continuous physical processes of the natural world, and are constantly being broken down and renewed. Living forms, the forms of grass and trees, of fish, reptiles, birds and mammals, are also subject to change but persistent over time, organized by their internal biological processes and by exchanges with their environment. So a biological form persists through long generations, never exactly the same from one generation to the next, and over extended periods responds to the external changes of its environment. Form, in this way of thinking, is something like the wave that appears down-

stream of the pier of a bridge in a fast flowing river, consistent in the sense that it remains in approximately the same place and with approximately the same geometry but also constantly subject to small changes as the velocity and volume of the river fluctuates. We can say that all forms emerge from the dynamic processes by which natural systems, both living and non-living, produce organized arrangements of material in space and time.

The complex interrelations of the many phenomena that emerge in Nature, each consisting of millions of parts or elements, each with their own processes and in turn affecting other processes, suggests that the classical methods of analysis (the breaking down of a whole into constituent parts) will not completely suffice. Fossil evidence implies that the history of biological evolution is a sequence, from simple cell organisms to the higher complexity of plants and animals. Organisms of increasing complexity spontaneously appear, each new level of complexity emerging from a preceding simpler organization, from molecules to single cells organisms, from small multicellular organisms to plants, and to animals including humans. Each new level of complexity produces forms and behavior that are different from the level below. This tendency towards increasing complexity raises a general question about the study of biological forms or organisms. The morphology and behavior of a tubeworm does not predict the emergence of the species of lobsters or scorpions, both of which evolved from the simple tubeworm. This is also true of individual organisms, for example investigating the cells of a leaf separately and in isolation will help to understand leaf cells, but that necessarily ignores how changes in one group of cells affect other cell arrangements, and the behavior, (such as phototropism or the transpiration of water and gasses) of the whole tree. A similar, although lesser difficulty, is apparent in the forms of non-living Nature – a study of the shapes of individual sand grains is helpful, but is not sufficient to predict the varied morphology of sand dunes, or how some migrate across the desert and maintain a consistent form whilst doing so. Natural forms are not created by a single force or event, nor by the simple coexistence of many parts; it is the interactions of each part to its immediate surroundings that initiates processes that over time produce coherent forms.

2 The Evolution Of Humans And Material Culture

The evolutionary development of anatomically modern humans is coupled to an acceleration in cognitive capacity, to the manufacturing and refinement of artefacts such as tools and weapons, and to increasingly complex architectural constructions. The transference of material knowledge by spoken, graphical and numerical languages constitutes a system of information transmission that is distinct from the biological system of transmission, the genome. Culture acts to transmit complex, social and ecologically contextualized rules for material practices laterally between local populations and vertically down through time. The evolution of anatomically modern humans from the ancestral family of the great apes is coupled to the development of a material and architectural culture that modified their environment and extended their ecological range[5]. The landscape of the world has been as much shaped by the cultural history of human activities and constructions as it has by climatic effects such as glaciers, and by geological processes of uplift, erosion and deposition. The emergence of the biological form of anatomically modern humans cannot be separated from the development of human culture; they have always been and continue to be interlocked in a co-evolutionary process. The emergence of increased brain size and enhanced cognition is strongly coupled to the evolutionary development of material technology that extends and enhances individual and collective human metabolism. Humans have three times the cranial capacity of the great apes[6], and positive feedback operated between brain size and the increasing complexity of culture, so that each has acted to accelerate the development of the other. Bigger brains enabled a more complex culture, and in turn more complex culture enhanced the ecological 'fitness' of the group and so positively modified the regime of natural selection in favour of bigger brains. The profound effects that humans have had on the world suggests a significant difference between biological and cultural evolution. Whereas biological evolution has adapted all other living species

to their environments, the cultural evolution of humans has adapted environments to the human species.

Darwin argued that all living and extinct beings were the offspring of common parents, 'descended from an 'ancient progenitor, and that 'all past and present organic beings constitute one grand natural system'. The diversification and proliferation of all living forms, the historical development of all the species of life, was driven by variation and selection[7]. The question arises 'is cultural development over time comparable to the evolution of the species and forms of living things?' Knowledge exists in and is transmitted by culture, and practices manifest that knowledge in the material forms of architecture. Just as the transmission of biological information by the genome is not always accurate, the transmission of cultural information may be mutated or modified by inaccuracies. As mutations to the known forms of organisms occur naturally, so too the small innovations, theoretical 'errors' and design mutations have driven the historical evolution of architecture from ancient material constructions of the first humans into to the built forms of the contemporary world. Culture is a system of 'descent with modification', in which social and ecological forces determine which cultural variants are transmitted through time. Culture evolves.

It is clear that material culture is inherited by descendants, there is descent with modification, and that the material forms of buildings and even cities can be grouped into morphological taxonomies. There are, however, significant differences between the mode operation of material cultural evolution and of biological evolution. Such differences include the mode of inheritance, which in culture may be horizontal or oblique, as cultural practices concerned with material construction diffuse between distinct social groups. Acculturation is the anthropological term for the process of change brought about through continuous contact between two or more distinct societies. The changes will reflect something of the character of that contact. For example, peaceful contact will result in the emergence of a new variant, in which the beliefs and practices of both societies converge, whilst political or military domination will usually result in one society completely absorbing the other's cultural patterns by a process of selection and modification. Perhaps the most significant difference between biological and cultural evolution lies in the 'selection' of forms that survive to pass on their genes or information to their descendants.

Information transmission has been an essential characteristic of human culture since anatomically modern humans evolved from the great apes, although the means of transmission were slower, with less immediate effects. The transmission of the information of material practices and architectural forms has been accelerated exponentially several times, with the sequential emergence of large trading networks, mathematical notation, writing and drawings systems, printing, shipping and world wide navigation. For example, as printed images and text opened up an exchange of knowledge, strong geographical separations between cultures were weakened: people, materials and artefacts were no longer bound to their place of origin. Until very recently the working methods of architects were determined by the basic pattern of late-nineteenth-century drawing systems of engineering industries. These were the product of what was then a new practice of industrial drawing, which had acquired a central role in the production of ships, railway carriages and engines and, later, motorcars and aeroplanes. The hierarchy of designers and draftsmen set an increased distance between the origination of the design and the execution of its construction. Embedded in the discipline were the concepts of industry, particularly standardization and accurate repetition, functional instruments of control with an emphasis on the interchangeability of parts, standardization of forms, and 'management' of design, materials and fabrication.

The interaction of contemporary computational systems, the transmission of information by the internet, and the emergence of a world wide network of rapid transit systems has acted in turn as a positive feedback on cultural transmission and diffusion, and collectively they have produced a marked contemporary tendency to the convergence of architectural forms and material practices right across the world. This as true of motorcars and mobile phones, of clothes and computers as it is of skyscrapers and shopping malls. The convergence of cultural forms and practices is also linked to other historical and contem-

porary effects of human cultural practices – the severe and continuing reduction in biological variation and diversity of species. The substantial recent changes to culture, climate, and energy economies construct a new regime of 'natural selection' that has destabilized the prior relationship of the material cultural and physical ecology within which architecture is produced and inhabited. Material practices are at the beginning of a substantial reconfiguration, and our future practises are to be located in the intersecting fields of knowledge and data flows.

3 Emergent Forms And Behavior

Architecture has begun a systemic change, driven by the changes in culture, science, industry and commerce that are rapidly eroding the former boundaries between the natural and the artificial. The complex interaction between form, material and structure of natural material systems has informed 'biomimetic' industrial processes, generating 'artificial' materials that can be manufactured with specific performance characteristics., Such new materials have radically transformed everyday consumer products, motor vehicle and aerospace design. Manufactured cellular materials, especially metals and ceramics, offer an entirely new set of performance and material values, and have the potential to reinform and revitalise the material strategies of architectural engineering and construction. Biomimetic strategies that integrate form, material and structure into a single process are being adopted from the nanoscale right up to the design and construction of very large buildings.

The material practices of contemporary architecture cannot be separate from this paradigm shift, as the context in which architecture is conceived and made has changed. In the natural world change is normal, but its intricate choreography is now further accelerated and perturbed by human activities. Global climate change is upon us, and its effects will be local and regional – more energy trapped in weather systems produces emergent behavior and consequences that are not entirely predictable. So too, the emergent behavior of local economies and cultures, now connected and interlinked globally, are substantially reconfigured.

The cultural parameters of the 'new regime of selection' that is driving the evolution of a new architecture are clear. There is a growing cultural fascination with the new understanding of nature and of natural form both living and non living. The architectural and material manifestations of fluidity and dynamics, of networks and new topologies are at the centre of architectural discourses and innovations. The materiality of the boundaries between interior and exterior space, between public and private territories, is no longer so relentlessly solid and opaque. The increasing transparency of such boundaries is accompanied by less rigid territorial demarcations. Spaces flow into one another, programmes are not so strictly confined within the building envelope, where connections and co-existence are enhanced. The experience of being in spaces that flow one into one another, with 'soft ' transitions between private and public domains, and between interior and exterior space, is increasingly recognized as an essential characteristic of contemporary life. The largest public spaces, for example in the concourses of transit spaces such as airport terminals, ports and railway interchanges, have boundaries that are achieved less by rigid walls than by extended thresholds of graduated topographical and phenomenological character, enhancing spatial connectivity and coded communication. This form of spatial organization is not confined to transit systems, but is increasingly found in many architectural forms that ranges from the scale of the apartment or house, through the largest high rise buildings to new urban configurations and spaces.

New working methods of architectural design and production are rapidly spreading through architectural and engineering practices, as they have already revised the world of manufacturing and construction. They include computational form generating processes based on 'genetic engines' that are derived from the mathematical equivalent of the Darwinian model of evolution, and from the biological science of evolutionary development that combines process of embryological growth and evolutionary development of the species. Evolutionary computational strategies for morphogenesis have the potential to be

combined with advanced structural and material simulations of behavior under stresses of gravity and load.

The conceptual apparatus of architecture has always given a central role to the relations of mankind and nature. The human body has been a source of harmonious proportions and the shapes of many living organisms have been adapted for architectural use. Architecture's current fascination with nature is a reflection of the availability of new modes of imaging the interior structures of plants and animals, of electron microscopy of the intricate and very small, together with the mathematics of biological processes. The new emerging architecture, that relates pattern and process, form and behavior, with spatial cultural parameters, offers new behaviors and adaptations to the changing economies and conditions of the natural world. It proceeds from the recognition of architectural constructions not as singular and fixed bodies, but as complex energy and material systems that have a finite lifespan, exist as part of the environment of other active systems, and as one instance of a series that proceeds by evolutionary development. In the natural sciences, metabolism refers to all energy transformations, the sum of the complex chemical and physical changes that take place within an organism and promote growth and sustain life. A metabolic model abstracted from natural systems can be developed to enhance the performance of individual buildings so that their 'metabolic' systems are responsive to their internal and external environment. Groups or clusters of environmentally intelligent buildings can be interlinked with a systems for material and energy flows, organized to generate oxygen, sequester carbon, fix nitrogen, collect and purify water, acquire solar energy, and respond intelligently to local climate changes. The emergence of new architectural forms will only proliferate across the world as constructed material artefacts if they are more closely and symbiotically related to the systems and processes of the natural world. As energy plays a critical role in all biological scales, from the cell to the ecosystem, so energy flows and metabolic systems for buildings and cities will central to their performance and behavior.

4 Endnotes

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4. For example, a hurricane of 100 kilometres diameter (10 to the power of 5) and a snowflake of 1.5mm 'diameter' (10 to the *minus* power of 3)
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