Tree Morphology - A Branch of Arboriculture from Renaissance to Raimbault[1]

Neville Fay MA (Hons), FLS, MArborA, FRSA
Treework Environmental Practice

Introduction

The patterns of growth in plants and trees have suggested to observers that there may be underlying rules and therefore natural laws that determine plant growth. Artists and scientists have pondered these mysteries and, since the flowering of Renaissance thought, attempts have been made envision inherent proportions in nature governing the shape of living things including trees. It seems as if the study of form (morphology) has been second nature to the great observers and there is a noble lineage in this from Leonardo Da Vinci (and his pipe-model and area-preserving theories) to Goethe (and his concept of 'plant memory'). Goethe considered the history of events affecting a plant to be 'written in' its form; therefore if morphologist learnt to read this he would be able to interpret the formative relationships affecting plants.

Da Vinci's and Goethe's concepts have proved durable in different ways and offer paths for exploring relationships between growth patterns and physiological processes. The emerging discipline of tree morphology draws on these and other great philosophers and observers of nature. Arguably more than any other aspect of arboriculture morphology owes its development to a convergence between art and science.

While tree morphology has been strong in continental Europe, in Britain its influence on arboriculture has been limited, in part due to restricted availability of English translation of important texts on the subject. Also as early work focused on tropical trees and forests perhaps wrongly reduced interest on the basis that this material was not relevant to temperate British conditions and tree species. However, important European contemporary tree morphologists (Halle, Raimbault and Roloff) have published a substantial body of work. This has much to offer assessment methods on morpho-physiological basis with important tree management implications. Tree morphology incorporates architectural, biomechanical and physiological aspects of the tree as well as areas of science and mathematics such as fractals conducive to computer modeling to enhance understanding of tree growth.

Key words: Morphology, Raimbault, Da Vinci, Goethe, Halle, Fibonacci, hydraulic-driven architecture, pipe-theory, area-preserving rule, axiom of uniform stress

---

[1] A paper presented at '*Tree Morphology, (Part 2), Theory & Practice, Diagnostics & Management*, University of the West of England, Bristol, 15th June 2007, in the Treework Environmental Practice 'Innovations in Arboriculture' seminar series.

Observing Form

Morphology is the study of the many and varied forms of things. In biology this specifically refers to the form of organisms. When we consider tree morphology, we cast our mind on the tree as a biological entity, specifically on the visual properties of its structure and form. Morphology provides a rational basis for making the relationship between the internal and external properties of an organism explicit, providing a theoretical basis for understanding the formative powers of organic structures. Rational morphology therefore seeks to make intelligible from systematic evidence the laws of processes influencing organic form[2].

While tree morphology has been developed as a study discipline, as arboriculturists we simply make explicit a natural tendency to observe form in the world we inhabit. From infancy, the attributes and qualities of the world we observe implicitly inform our perceptions and epistemology. This internalization of the observed world is essential to our ability to respond to and communicate about the world we live in. Therefore, together with our infant selves, we are all natural morphologists. In sensory terms, we are tapping a human faculty that gives the capacity to distinguish shapes and 'annotate' and 'classify' these so that we are able to make comparisons and recognize features in the natural world. This furnishes us with the ability to ascribe different types of meaning and thus distinguish between the different visual forms attached to different species of trees and plants. The more able we are to recognize and define such qualities, the better equipped we are to communicate about the form of things through available media.

The formal study of morphology and the inherent tendency to respond to form in the natural world draws on both aesthetic and scientific faculties. In the arboricultural discipline, this resonates with many of the reasons why those who have become involved with trees are drawn to this field of study. It could be considered that modern arboriculture originated with the renaissance mind, which sought to bring order to a world previously dictated by religious superstition and which is so well expressed in the works of Leonardo da Vinci, who observed and catalogued the natural world through his art also attempted to analyze its content through the application of mathematics, and as such might be considered to be a founding father of classical plant and tree morphology.

Renaissance natural philosophy sought to understand underlying principles governing the functioning of nature, while also attempting to unify these observations with metaphysics. The tree became a metaphor, the trunk representing the physical world and the branches morals, medicine, and mechanics. Early views of these arrangements considered it essential that metaphysics (represented by the roots of the tree) should be the primary foundation on which the more material aspects (trunk and branches) are established. While today we may find these ideas anachronistic, this nonetheless illustrates the original convergence of the arts and sciences, both of which inform tree morphology.[3]

---

[2] Driesch, H. (1979) *The Science and Philosophy of the Organism,* 2 vols. New York: AMS. (Reprint ed.; originally published by Adam and Charles Black, London, 1907-1908.)
[3] Russell, B. *The Problems of Modern Philosophy* (1997), OUP, USA.

The psychological capacity to observe form is inherently linked to other aspects of sensory experience and intellectual processes. This has an aesthetic and spatial dimension at the macro level and, in biological terms, may be linked to physiological process at the micro level. The exploration of relationships between tree form, structure, physiological processes and function are aspects of the complex study of tree morphology. Thus, morphology in trees considers the shape and disposition of stem, root, branch and twig arrangements, as well as characteristics of bud, leaf, flower and fruit.

Tree morphology takes into consideration observation of the tree at different stages in the ageing process and how shape and growth pattern characteristics may vary from a conventional model of the species at a given age under different biotic or abiotic conditions. Physiological influences of increased light, exposure, loading, etc. at a macro-level may affect the shape and growth patterns of the trunk and branch system and may lead to 'diagnostics' that in turn inform management considerations. The morphological perceptions of Mattheck and Breloer[4] exemplify this convergence between science and art wherein the interpretation of visual representations of adaptive growth in trees is considered to reflect a possible underlying law of nature, 'the axiom of uniform stress'. Whereas morphological observations of growth deformations might at one time have been considered to indicate an inevitable design weaknesses in the natural architecture of the tree, perceptions of biomechanics according to adaptive growth offer an alternative and potentially more useful view that considers more subtle relationship between mechanical form and function[5]

Renaissance to Present Day Morphology

Modern tree morphology has borrowed from many other spheres of science, including fractal geometry to model tree branching structures. The concept of fractals embodies the notion that trees are composed of self-similar or 'recursively constructed' elements, each of which contains a miniature of the entire design. Conversely, knowledge of the design rules of any part could be used to construct the whole. This approach to morphological modeling offers a method for generating incremental, 'organic' growth without the need for detailed knowledge of anatomic composition or physiological process.

Fig 1: An example of a fractal is a fern leaf design. Each individual leaflet reiterates the entire leaf.

---

[4] Mattheck, C & Breloer, H (1995) *The Body Language of Trees: A handbook for failure analysis* (Rresearch for Amenity Trees **4**), The Stationary Office, London.
[5] Lonsdale, D (2006) *Tree Morphology in Relation to Mechanical & Physiological Factors*. In press.

The tendency for tree parts to reflect and mimic the entire tree form has been studied and expressed in terms of 'reiterative growth'[6]. This inherent property has been studied in terms of an energetic system that is influenced by the need to conserve water flow through transportation paths, while optimizing potential for surface absorption of energy[5].

Whether Leonardo da Vinci could be considered to be a founding father of arboriculture or not, from a modern perspective he clearly took a morphological view. He explored natural patterns in tree growth and form and assumed that there was a relationship between the parts of the tree from the singular trunk to the members of the more complex branch system. He contemplated 'a natural order'; a law of nature that would be capable of being expressed in mathematical terms and predicting the proportions and distribution of branch growth and position of leaf insertion.

Renaissance painters explored such natural relationships and sought to express these as an inherent aesthetic predicated on the mathematics of the time. The spiral arrangements and the spacing of branches on the trunk were testament to such 'divine' proportions This conjoining of science and art is evident in paintings of the time and is reflected in the Golden Section or Mean, believed to be embodied in the ratio 1.618:1 (incorporating the principle that the whole is contained in the parts and vice versa). This concept is used today in understanding phylotaxis and is expressed mathematically in Fibonacci[7] ratios that define natural growth forms such as the vortex of nautilus shells and the spiral seed cones and of branch insertions.[8]

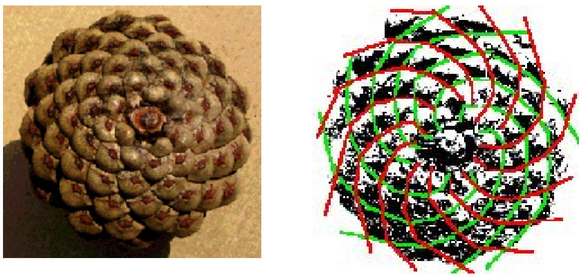

Fig 2: Morphological patterns in a pine cone. Fibonacci numbers are considered to embody a code describing spiral growth and how things are optimally 'packed' in nature.

---

[6] Raimbault, P. (1995) *Physiological Diagnosis.* The proceedings of the second European congress in arboriculture (Versailles 26-30 September 1995), Societe Francaise d'Arboriculture.

[5] Halle, F., Oldemann, A. A & Tomlinsom, P. B. (1997) *Tropical Trees & Forests: an architectural analysis.* Springer-Verlag, New York, USA.

[7] Leonardo Fibonacci was a 12th Century mathematician In mathematics, the Fibonacci numbers form a sequence defined 'recursively' by numbers starting from zero, where each one is the product of the previous two lower order numbers, forming an incremental sequence; 0, 1, 1 , 2, 3, 5, 8, 13, 21, etc. One of the properties of Fibonacci numbers is that numbers above 3 approximate to 1.618 times the preceding number (Golden Mean, see Footnote 7).

[8] A golden ratio is defined by two quantities where the sum of the two is in equal proportion as the larger part as the larger part is to the smaller part. Thus if (a) is the larger and (b) is the smaller then $a + b/a = a: b$.

Goethe and the beginnings of modern plant morphology

Classical morphology tended to focus more on the connection between forms than on the morphogenic or adaptive processes that influence them, and are obviously pre-Darwinian. Morphological study in its rule-seeking method attempts to derive standards for comparison between organisms to provide a basis for classification for all kinds of purposes, particularly through the identification of features that are similar (homologous; morphological correspondence) and those that are at variance from homologies. Classical morphology therefore built on an Aristotelian model perceiving nature in terms of idealized forms. Variations from the ideal indicated a dissonance in relation to an ideal.[9]

Johann Goethe (1749-1832) might be regarded to be a father of 'modern' plant morphology. Goethe was a polymath; a playwright and author of the classic work *Faust*, as well as a philosopher, poet and botanist. Building on previous botanical concepts of the leaf being a suppressed branch, he developed the perhaps curious idea of the leaf being the most fundamental form in plants that all other structures are derived from, conceiving a transformational process whereby plant organs (sepals, petals, stamens, etc.) all relate to this common leaf archetype. The leaf in his view was a generalized plan for the 'homology' of all other organs. The 'everything is leaf' concept might be considered to be reductive but Goethe's view was more complex than this, in that he conceived of morphology dynamically. While leaves resemble one another, each species' leaf can be clearly identified. Furthermore, in taking the leaves growing on an individual shoot in their sequence from oldest to youngest, the leaf-series, while showing clearly that each is similar to the other, also demonstrates an underlying progression. This theme is destroyed if the order of leaves is shuffled.

Goethe argues that a natural order of continuous movement can be perceived and that, by extension, if we could be sufficiently trained, we would be in a position to better understand the dynamic life-history of an individual plant, 'written into' its form. He termed this morphological record 'plant memory' and his views of scientific perception might be considered to sit with modern concepts of the *gestalts* (in which the whole represents something of the essential characteristics of the parts)[10].

Goethe's concept of 'dynamic order' and 'plant memory' links morphology with internal physiological process.[11]. Goethe further developed this theme by considering that in the case of the sequential order of leaves, the underlying trend appears generated not by the individual leaves but by the movement itself, indicating to him a law of nature that, again if understood, could be used to generate new forms[12]. In his science, the recognition of

---

[9] So it could be said that morphology might have roots even back to 4th Century BC philosophy, with Aristotle's view of the 'essence' of a thing being the distinctive qualities without which it cannot be understood or discussed.

[10] Ronald H. Brady, *Form and Cause in Goethe's Morphology* in Amrine, F. and Zucker, F. J. eds, *Goethe and the Sciences: A Reappraisal, Boston Studies in the Philosophy of Science*, vol 97, Dordrecht, 1987.

[11] Portmann, A. (1987), *Goethe and the Concept of Metamorphosis*. Reidel Publishing Comp., Boston (in: *Goethe and the Sciences* BSPS 97).

[12] Arber, A. (1950) *The natural philosophy of plant form.* Cambridge, UK: Cambridge University Press

this process reveals a manifest quality in the form that, while being sensually perceived, is nonetheless conducive to objective analysis[13].

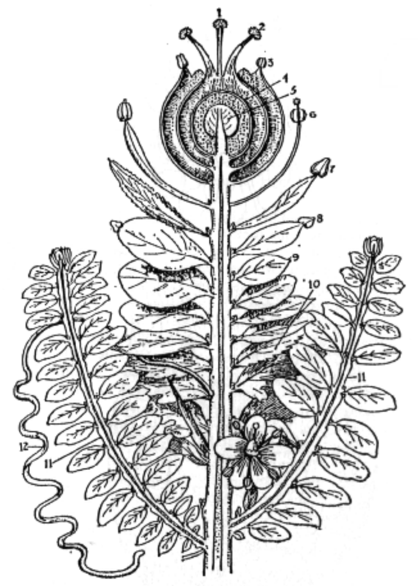

Figure 1. Part of Goethe's figure of the variations of leaf form according to which he interpreted the parts of the flower: 1 and 2 the stigmas of carpels; 3 and 4 walls of the seed-box; 5 the seed leaves or cotyledons; 6 typical stamen; 7 slightly petaloid stamen; 8 intermediate between stamen and petal; 9 petal; 10 sepal; 11 compound leaf with pinnules; 12 a leaf transformed into a tendril.

Fig 3: The "Urpflanze", Goethe's archetypal plant concept form, from which all plants are derived. This might be considered to be a morphological plant patent.

Leonardo's morphological concepts of the tree and its relationship to hydrology

Leonardo da Vinci considered that the ramified design of tree architecture was influenced by hydrology and functioned through naturally defined ratios such that overall areas are conserved and replicated from section of higher order parts to lower order parts. Thus, illustrated in a sketch from his notebook (see Fig 3), if measured at any one level of branching the total cross-sectional area of each branch would be equal to measures taken at any other level.[14] This he regarded to be a mathematical expression of a hierarchical link between lower order and higher order branches, i.e. the sums of the diameters of child branches are equal to that of the originating higher order stem (and therefore to the originating trunk diameter). This rule would apply at every stage of height (see Fig 1). As this applies to the cross-sectional areas at these points it is known as the 'area-preserving rule'.

---

[13] This methodical approach to perceiving and observing nature as a way of making plant form intelligible became known as a 'Goethean Step' but was more focussed on reading the dynamic underlying process generating form rather than the 'snapshot' approach of taking evidence at any one time as defining form as an indication of a static condition.

[14]Richter. J. P., 1939: The Literary Works of Leonardo da Vinci. 2 vols. Oxford University Press, London

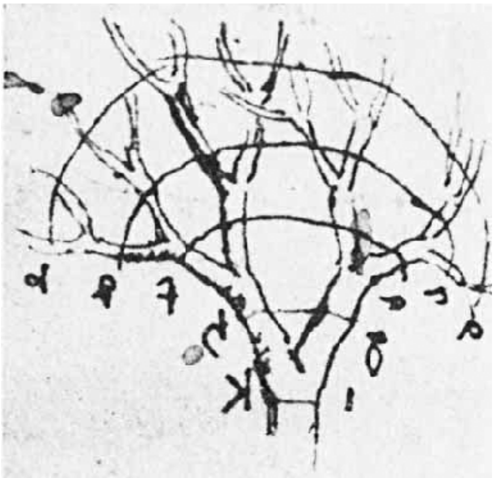

Figure 3: Leonardo da Vinci's concept of the 'area-preserving rule' (Richter 1939, plate 27). Tree branching patterns in each of the arcs indicate that the thickness of branches is equal to one another and to the total trunk thickness.

To Leonardo da Vinci, a tree was a river on end.

Da Vinci observed that "All the branches of a tree at every stage of its height when put together are equal in thickness to the trunk….All the branches of water at every stage of its course, if they are of equal rapidity, are equal to the body of the main stream."[15] In da Vinci's view the tree represents an inverted river system, where the hierarchical arrangement is reflected in stream networks, with higher-order upstream components flowing into lower-order confluences. While flow rates may change, the volume of water at any one cut-off point in his conceptual river (with its own branching tributaries) would contain the same amount of water. He applied these thoughts to observation of trees, which influenced attempts to design the notion of the 'perfect tree'. This water flow model has been subsequently formalized in terms of a 'pipe model theory of the tree[16]', which is based on the assumption that a unit of foliage is considered to require a constant amount of conducting tissue. Leonardo furthermore conceived of the tree as composed of a bundle of pipes that separate at different points into tributary branches (as if the trunk is in reverse the reception reservoir from lower order tributaries), with each bundle of pipes supporting a related proportion of foliage[17].

It is apparent that Leonardo da Vinci has impacted upon morphological perspectives of trees; particularly from his area-preserving hypothesis. This can be thought of as being based on the principles of hydraulic-driven architecture and research demonstrates that tree hydraulics influences branch architecture reflecting an area-preserving rule. While this is the case, there is some evidence that there is a tendency to for the cross-sectional area to increases slightly at the peripheral extent where crown twig tips proliferate about the tracery in comparison with the lower crown[18]. It is easier to see how da Vinci

---

15 Richter, J. P. (1970). *The Notebooks of Leonardo da Vinci*, Dover. reprint from the original 1883 edition.

16 Mäkelä, M. (2002), *Derivation of stem taper from the pipe theory in a carbon balance framework,* Tree Physiology, 22:891–905, Victoria, Canada.

17 Zimmermann M.H., (1983). *Xylem structure and the ascent of sap*. Springer-Verlag, Berlin, Germany

18 Aratsu, R. (1998) *Leonardo Was Wise: Trees Conserve Cross-Sectional Area Despite Vessel Structure* Journal of Young Investigators.

conceptualized tree morphology in terms of both water-flow and area-preserving models as he observed growth and separation from higher order parts to those functioning at a lower order.

Da Vinci's perceptions of branch morphology and the inherent proportionality between higher and lower-order parts have strong resonance with the so-called pipe-model[19]. He imagined this in terms of a number of bundled strings (perhaps we might imagine the strings are more like a bunch of fibrous 'plastic' straws) that at each node (point of bud-branch origin) the strings are divided between those that remain in the trunk and those smaller bundles that bend away and separate at the node to form a branch, considering that branch thickness is directly dependant on the branching angle so that the less acute the angle between the branch and the parent stem the greater thickness of the new branch. Therefore he considers that water flow is a primary influence upon tree morphology. Certain research has indeed endorsed da Vinci's area preserving rule, though this appears more appropriate to open-grown conditions.[20]

The pipe-model considers the morphological implications directly related to the way that the cross-sectional area (CSA) of sapwood in any tree part is proportional to the foliar or fine root bio-mass served by it. As such, many studies have been undertaken in attempts to quantify the derivative, lowest-order roots and shoots. This translates morphologically to a tree model with branches act as smaller trees that are 'rooted into the trunk', which builds in a view of a systematic, internally-regulated hierarchical pattern. This determines the hydraulic architecture in that in-built mechanical factors influence the way trees develop and grow, and ultimately their morphological properties at both the macro and micro level. These factors relate to 'hard-wired' conditions that trees are required to respond to. Stem cross-sectional area is inherently proportional to the area of foliage it supports. However, branch strength is directly related to the cross-sectional area and therefore is proportional to the square of its diameter while branch weight is a cubic function of branch diameter so that weight will tend to exceed strength. To respond to these biomechanical features of growth, trees have evolved to accommodate photosynthetic systems[21], and their water-conducting and mechanical functions and these are important in determining patterns of hydraulic tree architecture[22].

---

[19] Shinozaki *et al* (1964), *A Quantitative Analysis of Plant Form: The Pipe model theory. I. Basic analysis.* Japanese Journal of Ecology **14**.
[20] McCulloh, K. and Sperry, J.S. (2005), *Patterns in hydraulic architecture and their implications for transport efficiency*. Tree Physiology **25**.
[21] Rust, S and Roloff, A. (2002), *Reduced photosynthesis in old oak (Quercus robur): the impact of crown and hydraulic architecture*. Tree Physiology **22**.
[22] Sterck, F. *et al* (2004), *Tree growth: consequences of leaf traits for whole tree performance*, Proceedings of 4th International Workshop on Functional-Structural Plant Models.

Raimbault and the French school of tree morphology

Tree morphology has certainly developed a little over the centuries since da Vinci (who died in 1519). In the twentieth century it has flourished as a well-established niche concept in French arboriculture and is used for tree assessment and management elsewhere in mainland Europe. The main proponent Pierre Raimbault, a scientist and teacher, has developed a simplified ten-stage developmental model for ageing in trees that takes both above-ground and root architecture into consideration. This is used as a powerful tool for building up a picture of the evolving and changing complexity of the root, trunk and branch form as the tree ages from seed to senescence.

While this school of arboriculture is in France and elsewhere used to assist with interpreting the significance of tree form it is not well known in Britain. Continental European tree morphologists include other exponents in France (Christophe Drenou, Catherine Ducatillon, Yves Caraglio, Claude Edelin, Pascal Genoyer), Roelof Oldeman in the Netherlands, and Andreas Roloff (at the Institute of Forest Botany and Forest Zoology) in Germany.

Professor Halle published on architectural analysis in the late nineteen sixties and his work has influenced botanists and taxonomists. He explored key architectural types in both living plants and fossils, illustrated with tree models incorporating the reiterative process. This self-similarity approach to trees resonates with Leonardo and Goethe's models, as well as the later fractal theory. Implicit in this highly detailed study is the importance of having knowledge of the growth processes throughout the ageing of a tree.

Halle's pioneering work further focused on the detailed exploration of the many aspects upper canopy, principally in rain forests, using his specially designed 'blimp-born' inflatable raft. While much research in the field is borrowed from established systems and studies of botanical and horticultural morphology some have focused on ornamental trees, others have studied morphological aspects of tropical trees, while still others have observed orchard trees.

More recently Raimbault has focused on root architecture. While there is not a great deal of available published literature in English, a key published text (perhaps difficult to discover) is worth tracking down titled *La Gestion Des Arbres D'ornement: Une methode d'analyse et de diagnostic de la partie aerienne* (Raimbault. P., Tanguy M. & Bertrand, H. (1993) Revue Forestière Française XLV-*2*). This offers guidance to understanding the relationship between 'morphological development' and 'physiological age' in trees. Another, Drenou, C.(1999) *'La taille des arbres d'ornement'* (IDF ed., provides guidance for considering pruning and management options from understanding the relationships between tree morphology and tree biology.

Tree morphology, ageing and physiological correlations

Raimbault's morphological interpretation as applied to arboricultural diagnosis requires first that there is an understanding of morphological stage of development of the tree (i.e. its branching disposition, architecture, patterns, order and distribution of growth of parts of the tree in relation to one another). The understanding of the tree within the particular developmental stage of growth can be considered to inform treatment options. He recognizes that the *art of tree assessment* and management is based on predictive outcomes. Therefore the effects (usually remedial) that are intended need to be stated and then interpreted in the light of the eventual result both intended and actual. In this sense all arboricultural management proposals are experimental. The proper way to evaluate and add to knowledge then is through systematic recording, inter-communication within the profession, review and re-interpretation.

This tree morphology approach asserts that a set of key morphological stages can be used to observe the tree as it grows in a number of settings, though in a generic sense there are overarching patterns that can be drawn from a typical range of developmental stages from 'seed to senescence'. By learning about these growth stages an understanding can be achieved to determine the type of specific functioning of a tree, linking its physiognomy to its physiological age (in Raimbault's case he uses his ten stages of morphological age). This then provides a morphological basis for diagnosing tree condition and for predicting future development to determine management options.

Raimbault's method focuses on the way that branch and root architecture is influenced by the dominance[23] of the apical meristems[24]. The expression of apical dominance and how this may change reflects the many external influences upon growth that are current at the time of observation. He describes the way that at the first phase of growth the apical meristems is dominant and the pattern of lateral branching is predictably sequential for the species (Fig 1: 1 & 2).

In the second phase of growth, second order branches (those derived from the first central stem) and third order branches (derived from second order limbs (Fig *1: 1 & 2*)) replicate to an important extent the growth form of the first stage. Thus in this way lower order branches give the appearance of a separate 'mini' tree.

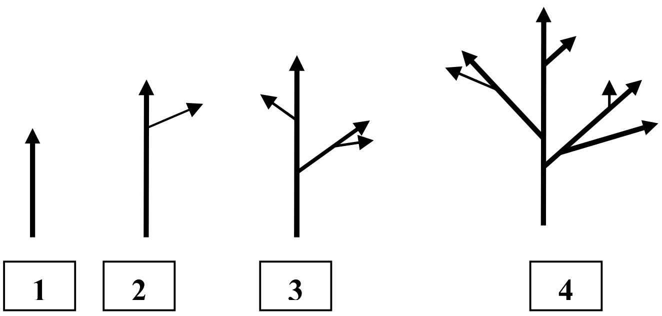

Fig 2:
Illustration of ramification from single stem (1); from higher order to first lower (second) order branch (2); second order to third order branches (3).Beginning of loss of apical dominance (4).

[23] Precedence in relation to branches below and control of development for the benefit of the terminal (leading) shoot
[24] The undifferentiated tissue at the tip of a stem or root from which new cells are derived.

These replicating forms Raimbault refers to as *reiterations*[25] and terms *sylleptic* reiterations as those reiterations that appear to replicate the parent stem [26], while also having the capacity to compete with it and to become physiologically autonomous units if sufficiently developed and allowed to 'break free from the system' as a whole. A tree composed of multiple, potentially independent units describes in Raimbault's terms a transition from a 'unitary' to a 'multiple' tree.

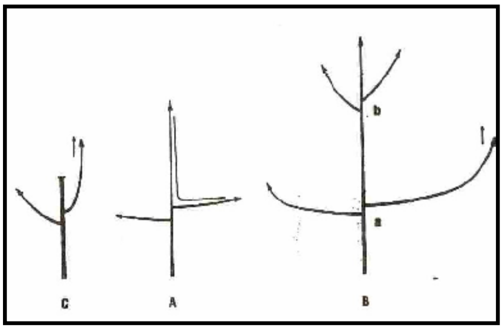

Fig 4

Fig.4 is taken from Raimbault's morphological interpretation of branching patterns, reflecting the effects of removing apical control of branches. In Fig 4, (A) illustrates initial branch growth with buds starting to bend upward at extremities showing a tendency to 'self-prune' in later aging stages and fall (proleptic reiterations); (B) shows growth of a large branch axis showing the general location of the leaves (Figs 3 & 4 Reference[27]). Branches are found on lower branches that partially replicate the carrying branch, and when, as the tree ages these are found in the upper crown, they become significant for determining branch / crown shape. When in the later stage of the ageing process these reiterations can be found growing close to the base of branches or directly growing from the trunk such *proleptic reiterations* have the capacity to take over from parts of the crown that may be lost through damage and the natural ageing process.

Through observation of these processes (particularly the relationship between tree architecture and ageing) morphologist have shown considerable openness and have borrowed from other disciplines (including botany, hydrology and art) to arrive at models and concepts to describe tree architecture in an increasingly sophisticated ways. On the one hand allowing refinements to be incorporate in description and definition of shape, structure and the relationships between the tree and its parts, and on the other to apply knowledge acquired from 'reading' the tree's form to the interpretation of physiological status.

---

[25] *Reiteration* could be considered to be the way that the form of the whole tree is replicated in the architecture of lower order subsidiary parts

[26] *Sylleptic reiteration* is a branch that when dominated by the hormone control of the apical meristem of the higher order branch shows similar architecture to the dominant stem. However, following release from dominance has the capacity to attain independence and, as it is released from dominance, bends upwards in competition for light thus replicating the part that supports it.

[27] Raimbault. P., Tanguy M. & Bertrand, H. (1993), *La Gestion Des Arbres D'ornement: Une methode d'analyse et de diagnostic de la partie aerienne,* Revue Forestière Française XLV-*2*.

Conclusion

Understanding morphological principles helps to connect aesthetic appreciation with logical processes. In the same way that a plane within a sphere, no matter how it is maneuvered, is defined by fundamental mathematical relationships expressed through the ratio π (pi), there are underlying morphological relationships that define patterns of growth. Improving this awareness helps deepen and refine our perceptions of living structure at a macro and micro level. Given that human development is inherently connected to the same influences that affect all biological processes, these relationships have deep resonance in our rational mental processes and aesthetic perceptions.

Both art and science are embedded in deciphering relationships. This paper explores concepts that have attempted to understand underlying rules that influence and govern the form and architecture of the tree. The changing form of the tree reflects genetic, developmental processes and responses to environmental influences. Its perceived expression is rooted in a long-evolved human relationship with trees. As the appreciation of the multitude of forms trees are capable of has conscious and subconscious dimensions, improving awareness of morphological expression lies at the heart of refining our observational faculty, to improve our understanding trees and our diagnostic abilities.

Thought processes relating to tree morphology span some five hundred years - though early stirrings of the 'arboricultural mind' as expressed by artists such as Leonardo da Vinci remain largely unappreciated as influences in current arboricultural thinking. Da Vinci had a view of hydraulically influenced tree architecture. The connection between tree form and water relations is an important observation in understanding the expression of tree physiological processes. Conceptually Raimbault and Halle lie in a direct lineage with da Vinci-inspired early 'Renaissance arboriculture'. Shigo's notion of compartmentalization[28] and Mattheck and others' appreciation of the 'axiom of uniform stress' (expressed through the body language of trees) reflect parallel observations, largely unconscious, to da Vinci's area-preserving 'string theory' of branching.

Morphological study is based on heightened observation of the physical expression of natural processes, drawing on both human artistic and scientific faculties. Renaissance flowering of thought kindled a particular kind of rational approach to aesthetics. The arboricultural legacy from this is more coherently expressed as a discipline in some countries and cultures than others. Morphological schools would argue that by refining our appreciation of tree form and raising this to a more conscious level, we will be better able to appreciate their qualities and to improve our diagnostic and management abilities.

[28] Eisner, N. J., Gilman, E. F. & Grabosky, J. C. (2002), *Branch Morphology Impacts of Compartmentalization of Pruning Wounds*, Journal of Arboriculture (28) 2, 99 - 105