Tree Growth Response Systems

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This publication is a synthesis of the tree growth regulation and correlation literature. General processes and systems presented here represent educational models which professionals can use to better appreciate and understand basic tree functions. These models do not represent actual physiological mechanisms, but simple theoretical means of explaining tree reactions within the environment.

Tree growth and development are dependent upon a few basic mechanisms. These mechanisms are responsible for the tree making holistic adjustments to a changing external environment. These basic mechanisms also allow for correlation of processes internally. One means of understanding tree reactivity to external and internal changes can be partially visualized in shoot/root interactions. Once the basic mechanisms of how whole trees react to change are delineated, additional impacts such as pruning, fertilization, drought, etc. can be better understood.

Trees are complex organisms with highly evolved sense and response systems. Because the tree as a whole is too complex to comprehend at a functional level, simplified models are used to understand tree reactions to change. Reviewed here, in a very basic manner, will be how trees control their own growth and how this growth control changes internal resource allocation patterns.

Basic Tree Model

In the most simple way of visualizing tree reactions, the tree is split into three reactive components: leaves and buds, connecting tissue, and absorbing roots. By keeping tract of how each of these components interact with each other, a manager can develop specific expectations from management inputs and better understand tree reactions. Each of these three tree primary components have specific functions and can react to changes. Each of these three primary components are tied to their respective meristem and associated sensor system. (Figure 1A)

Leaves & Buds — Leaf tissue and growing points are tied to shoot tip meristems, must deploy resources to collect light and carbon-dioxide efficiently, and must draw required resources from storage and from the absorbing roots. Leaves are net photosynthesizers.

Absorbing Roots — Absorbing roots are tied to the root tip meristems, must use resources to effectively collect and control soil resource space (water, essential elements, nutrients), and must draw required resources from storage and from the leaves. The absorbing roots are respiring organs.

Connective Tissues — All the biologically and physically active tissues between the leaves and the absorbing roots are tied to the cambial zone meristem and the bark cambium. The connective tissue provides for storage volume, conversion processing of sugar and starch, material transport and structural support. The connective tissue draws required resources from leaves and absorbing roots. The connective tissues are net respirating areas.

Growth Sensors

All three primary components of a tree listed above use integrated sensors to determine the state of

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external and internal environments, as well as estimating rates of change. There are dedicated biological sensors generating signals which illicite responses from meristems and modify growth control messages to the rest of a tree. Primary sensor locations are: active buds, outer chlorophyl containing cells (cortical-like cells) of twigs and stem, proto-chlorophyl containing cells of roots, active root tips, and leaves.

In order of importance, sensors track: electron flow into the oxidative environment, light (season, quality, and quantity), oxygen status, temperature, water status, essential element status, carbohydrate (food) status, and position and mechanics (leading to trophic, nastic, and reaction wood responses). Trees respond to the sensor messages by generating growth regulator changes which modify the tree's control field, growth control pathways, and resource levels.

Electron Flow Control

A tree system is designed to efficiently use energy collected in the photosynthetic process. Photosynthesis is an electron (energy) concentrating process utilizing the chemical bonds of carbon compounds. These carbon compounds provide the means for transporting and storing concentrated electrons (energy). In this way, benign and movable carbon compounds carrying light-derived energy can be transported to the farthest and darkest reaches of the roots. By breaking chemical bonds between carbons, energy is released. The process of allowing electrons to slowly and systematically leak back to the oxidative environment (respiration) allows tree life to be sustained.

Across cell membranes in a tree is a small but measurable concentration gradient of electrons from inside to outside. Inside the cells, a high levels of electrons are maintained by photosynthesis which acts as an electron pump (and it products). Trees are extremely sensitive to electron loss through damage, pest attack, or environmental changes. Rapid increases in electron flow to the environment are sensed instantaneously. A tree's reaction to slow electron loss is called compartmentalization.

The tree's growth regulation system maintains electron flows that will facilitate tree life and minimize electron theft by the environment (atmosphere, pests, stresses, etc.). Tree systems sense and regulate electron flow changes, and the production and use of electron-dense materials (food).

Food Storage

Storage materials in a tree are concentrated electron (energy) sources. Carbohydrates can only be stored and retrieved within a living cell. Storage of critical resources require efficient control systems to assure materials can be removed from storage, transported and used where needed. Carbohydrate storage in the tree is in parenchyma cells, primarily ray cells. Only cells in the last few annual rings are utilized. Easy access is an important part of storage systems.

The major source for new growth is the locally available carbohydrate immediately behind the expanding growing point. Once the growing point is expanded and self-sufficient in food production, this old storage center of last season is not restocked because now the needs of the branch will be near its tip.

Branch Autonomy

Food is made locally, stored locally and used locally in trees. Each twig and branch is almost completely autonomous in suppling its own food. There is little sharing, and no welfare provided for marginal or net food-loss areas. Those twigs or branches that cannot generate enough food for themselves and some extra to ship away will be seen as electron loss areas and be compartmentalized off from the living tree. Branch autonomy is the principal reason proper branch and twig pruning can work without massive physiological damage to the tree.

A growing point expands using carbohydrate stored just behind the buds and in the outer annual rings. (Figure 1B) With full expansion of the shoot and leaves, the first priority in the shoot is deposition of carbohydrate behind the new buds. Shoot storage is always filled with carbohydrate from the tip downward. As new light resource areas are expanded into, these spacial gains are consolidated with storage of carbohydrate at the site of the next expansion. Electron dense materials are positioned where they are needed in order to hold space and support growth.

Growth Segments and Sheaths

Trees are modular or segmented organisms. (Figure 1C) An autonomous twig expands to the limits of its resources. If expansion has yielded potential for further resources, healthy twigs will further expand into the area when growth is again allowed. The connections between twigs and branches, and branches and stems, contain boundary setting zones. These boundary zones can seal-off any branch not generating net carbohydrates, or can act as a barrier to the environment if the branch is removed by storm or pruning. Mechanically and biologically, trees are composed of modular growth units which allow the tree to fall apart (or be taken apart) in these modular units.

Each growing period the tree expands its biological size. The tree form a new functional sheath of tissues over last growing season's xylem from stem tip to root tip. Unfortunately this continued expansion of living mass can not be sustained. The tree keeps only the most efficient and effective modular units. The other parts that may not be carrying their own weight plus some extra for the rest of the tree will be shed. Trees shed materials to the outside that dies and eventually falls or pulls away from the tree. Trees also shed materials to the inside. The internally shed area inside a tree is called heartwood. The model that describes this process is termed a "skin / core" system. (Figure 1D)

Conclusions

Trees are complex reacting organisms which grow in dynamic, rapidly changing environments. Tree biology must provide for defense, reproduction, growth, and control of resources. Understanding simple models of tree growth can prepare tree managers for anticipating internal and external changes.

Suggested Literature On Shoot / Root Interactions and Tree Growth Control

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Wilson, J. Bastow. 1988. A review of evidence on the control of shoot:root ratio, in relation to models. Annals of Botany 61:433-449.

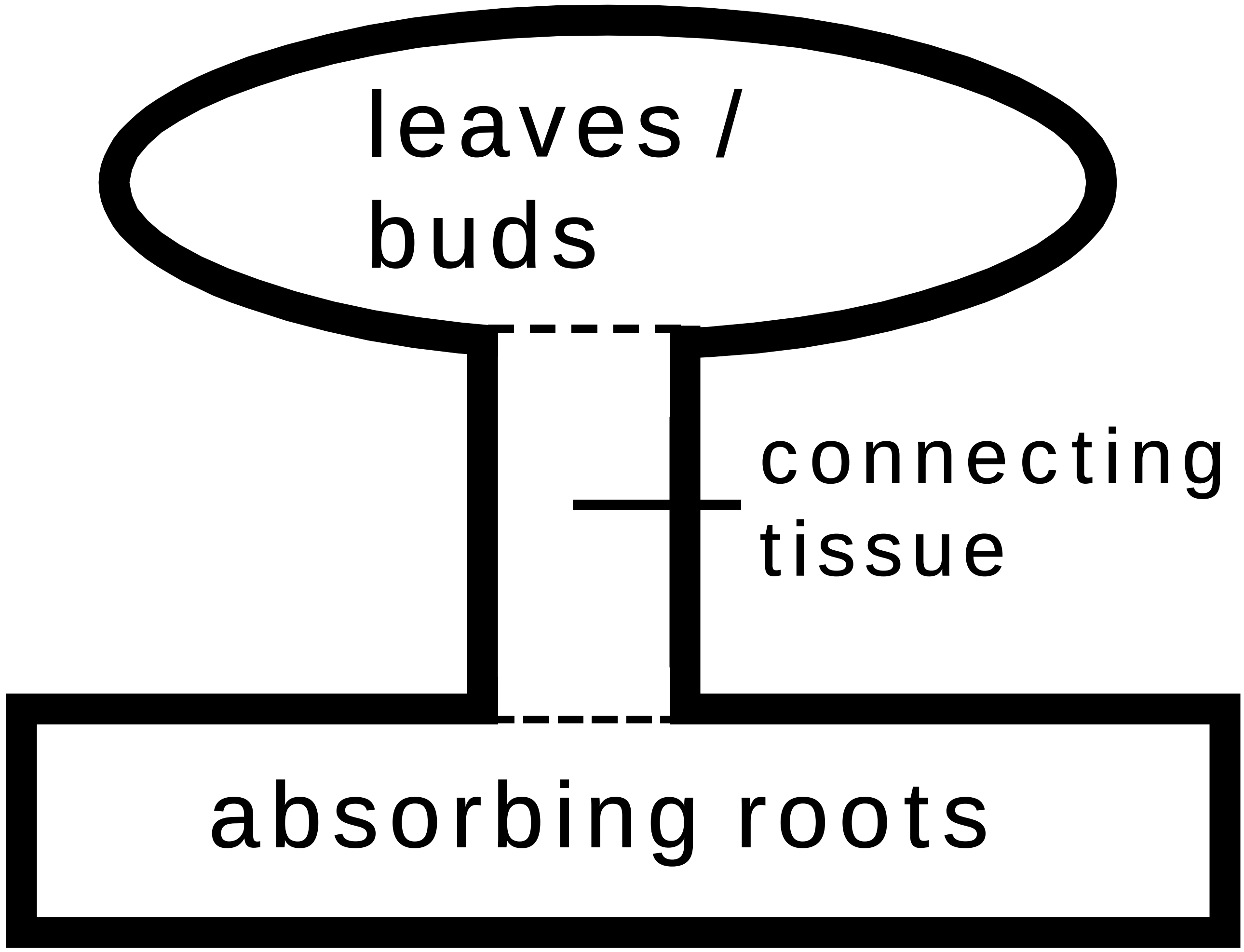

Figure 1A: Tree control systems have three main anatomical components: leaves & buds, connecting tissues, and absorbing roots. Each of these components have their own sensors for registering change in the environment and their own signals to dispatch throughout the tree to throw genetic witches. Through the process of sense and signal, the primary components of the tree generate responses, and circuits of supply-and-demand develop, change or evaporate. All of these processes influence the allocation of resources within the tree.

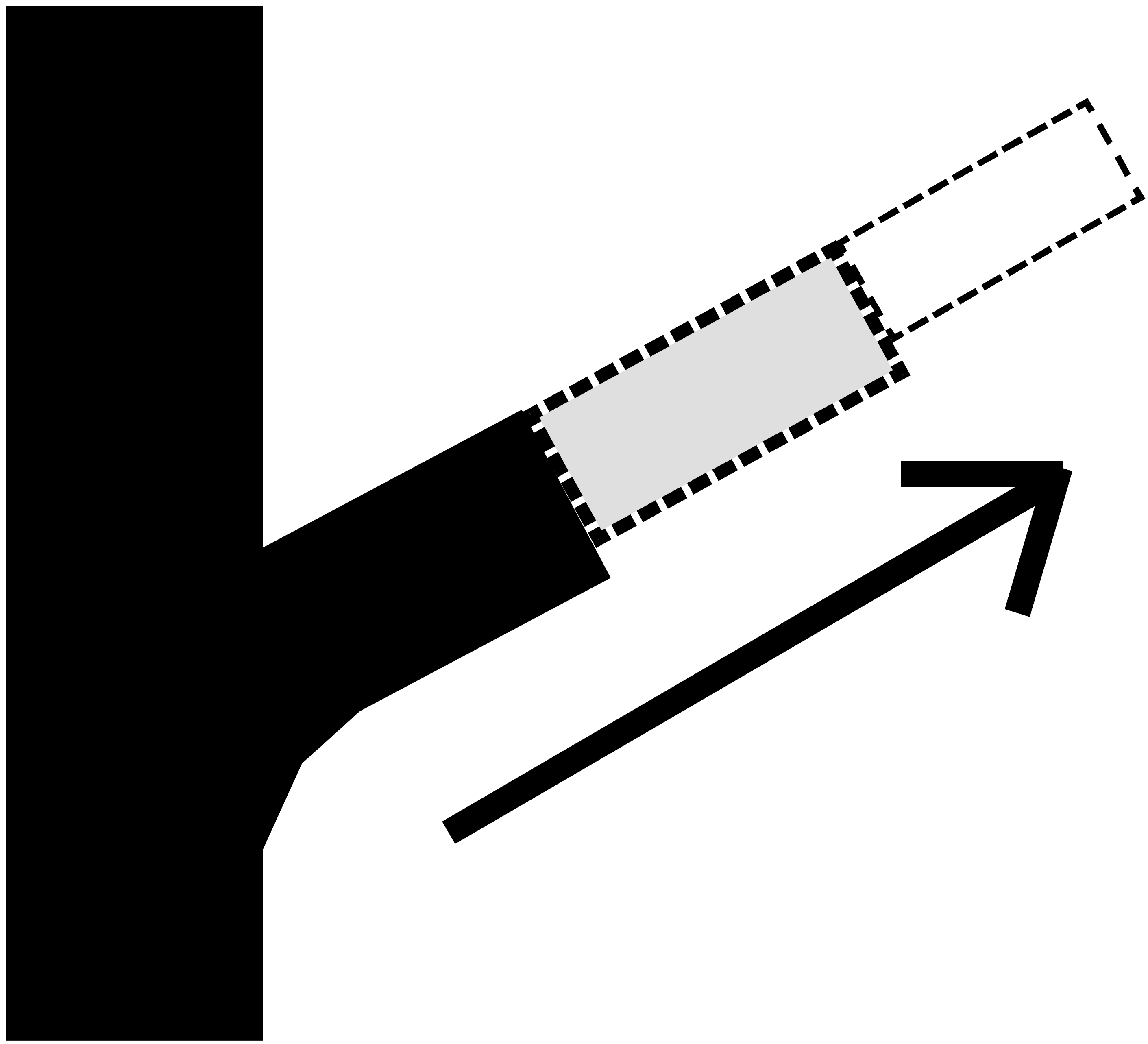

Figure 1B: Trees consolidate control of resource space through episodic elongation of twigs followed by periods of filling-in behind each expanded segment with food in preparation for the next elongation period. Carbohydrates are positioned for taking and controlling resource space.

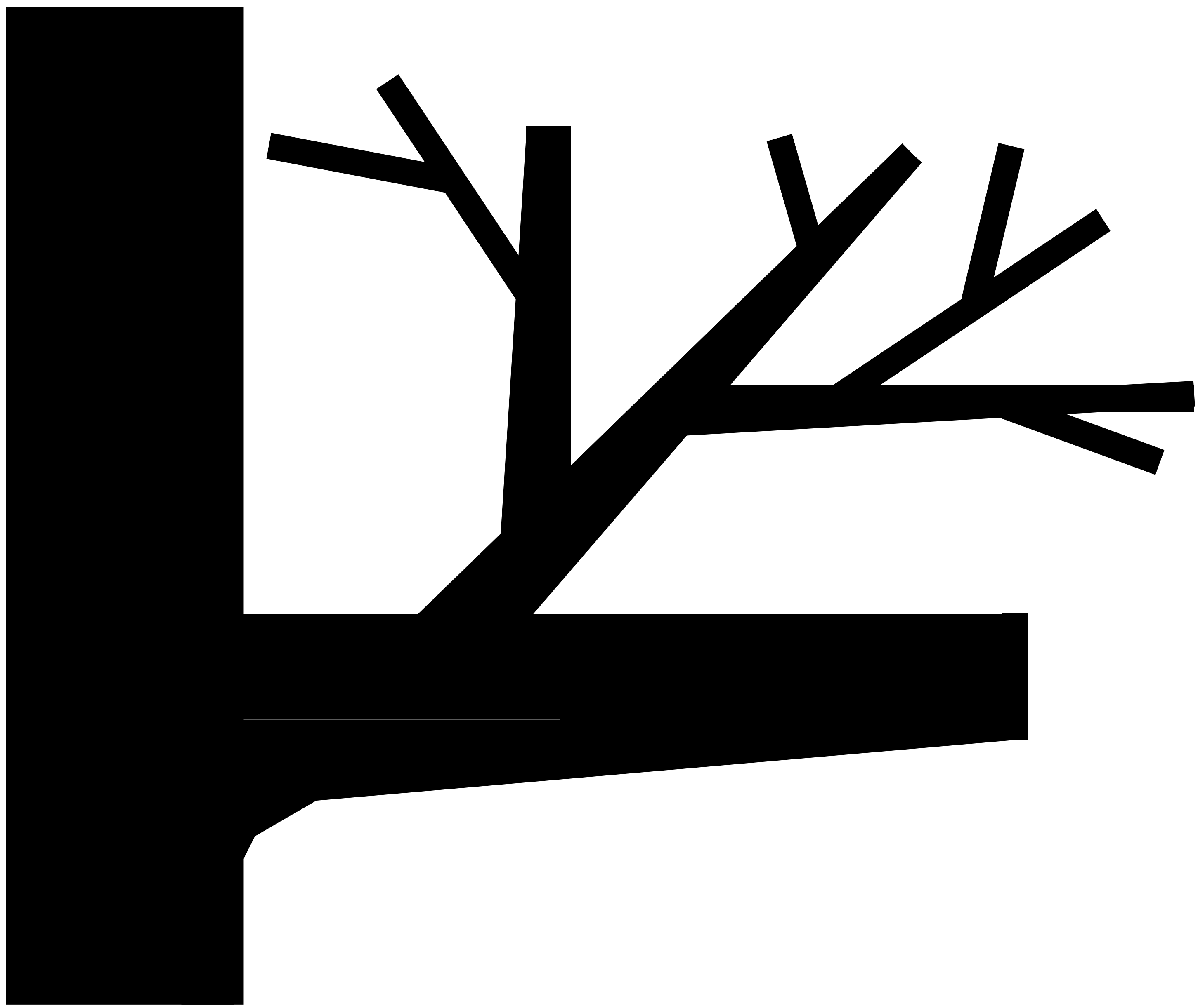

Figure 1C: Tree are modular and segmented in their assembly through growth, and through their natural disassembly in death. Growth segments occupy space, secure and control resources in that space, and remain disposable through compartmentalization at each basal boundary zone.

skin / core system

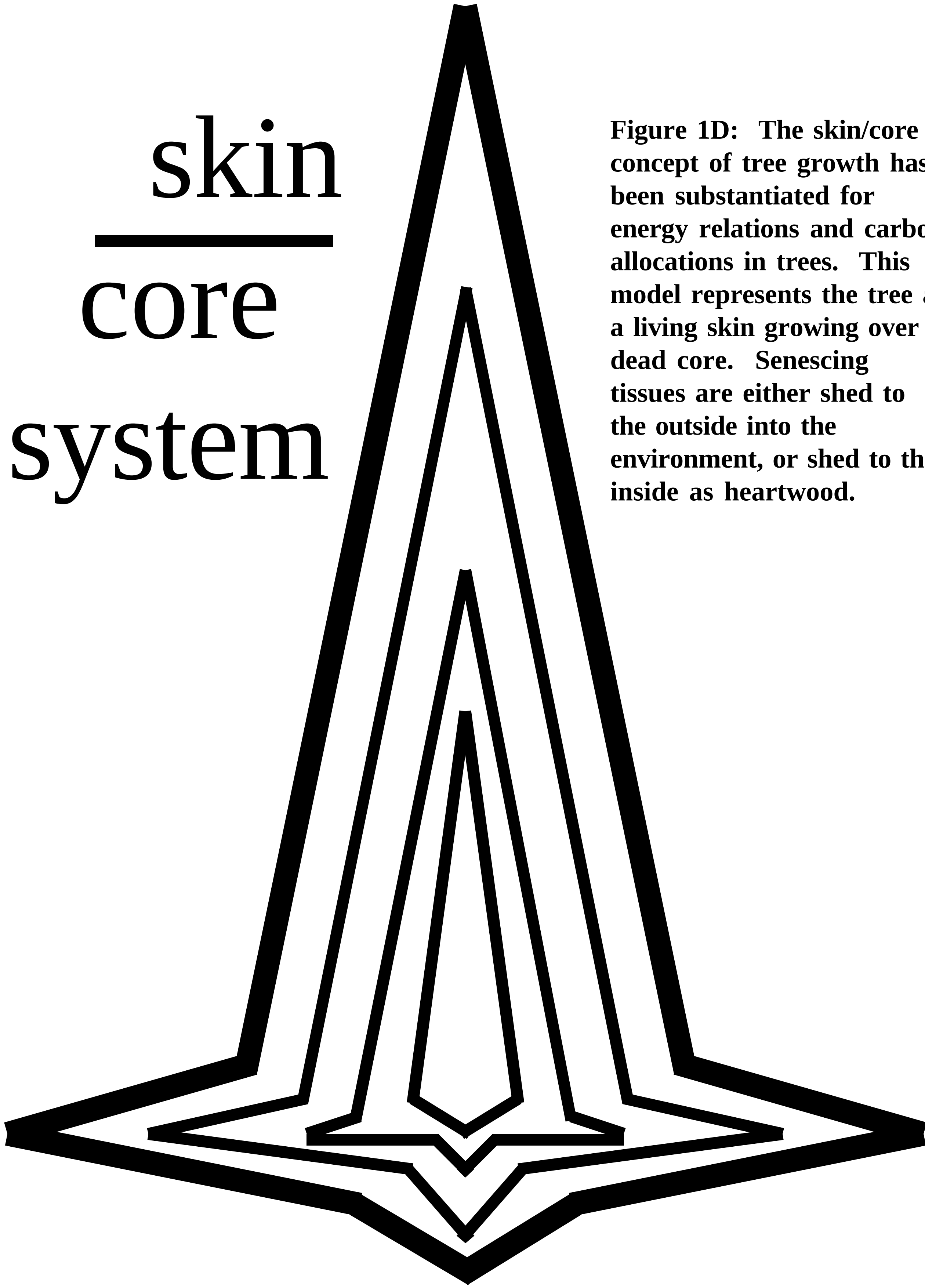

Figure 1D: The skin/core concept of tree growth has been substantiated for energy relations and carbon allocations in trees. This model represents the tree as a living skin growing over a dead core. Senescing tissues are either shed to the outside into the environment, or shed to the inside as heartwood.