# The ARCHI method, a key to understanding trees

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*Recommended citation:*
*Drénou C., 2025 – La méthode ARCHI, une clef pour comprendre les arbres.* Forêt & Innovation, *n°12, p.10-24.*

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ARCHI VITALITÉ DES ARBRES

Centre National de la Propriété Forestière

**Genetics, ageing and environmental constraints determine the shape a tree takes. Based on a reading of tree architecture, the ARCHI method provides a visual diagnosis of tree decline and resilience. Prior training is required.**

How are your trees doing? Are they growing well? Are they showing signs of decline? Is it concerning? To answer these questions, you need to know how to observe and interpret, but what do you do about it? Paul Valéry wrote: "What is simple is false, what is complicated is unusable". The following summary describes the ARCHI method, both as a simplified approach to plant architecture and as a field tool requiring prior training.

The shape of a tree is conditioned by genetics, ageing and environmental constraints. These three parameters will be discussed in turn, leading to a diagnosis of tree vitality and ARCHI keys, the final part of the article.

## 1- Arborescent forms

Trees, and arborescent plants in general, have several genetic determinants of development. The resulting diversity of architectures can be explained, at least in part, by four processes leading to a combinatory of 12 forms.

Firstly, **trunk ramification** (or branching) enables the trunk to give rise to axes different from itself, according to a predictable arrangement and rhythm. For the vast majority of temperate trees, branching is annual. It is synchronized with spring growth and mobilizes the axillary buds at the top of the previous year's shoots.

The second process, **trunk duplication**, enables the trunk to give rise to axes identical to itself, in a predictable pattern and rhythm. Duplication results in the production of master branches arranged in successive forks (terminal duplication) or arranged around the trunk (lateral duplication). Duplication is part of the tree's ageing sequence, without changing its course (unlike reiteration).

The third process, **plagiotropization**, enables the trunk to move irreversibly from orthotropy (vertical growth direction and radial symmetry) to plagiotropy (horizontal growth direction and bilateral symmetry). The result is a plateau-shaped crown. Plagiotropization can occur after one or more trunk duplications, with each duplicated trunk subsequently bending to form one or more trays. It can also occur without any prior trunk duplication.

The final process, **trunk reiteration**, enables the trunk to give rise to axes younger than itself. These are known as orthotropic substitute shoots (formerly known as "epicormic shoots" or "suckers"), and can be recognized by the presence of juvenile thorns or leaves, finer bark, absence of flowering in the first few years, strong growth in height and diameter,

high cuttability, etc. Reiteration is a genetic capacity, but its expression is triggered by the environment, hence its unpredictability.
Ramification, duplication, plagiotropization and trunk reiteration have appeared at different times in evolution. Duplication is the earliest process (early Devonian, 430 million years ago), followed by branching, first deciduous with plagiotropization of the trunk, then perennial, and finally reiteration. This evolution parallels the appearance of true leaves, the formation of a cambium, and the birth of ovules in the Carboniferous (Meyer-Berthaud, 2000).

The 4 processes are independent. Some plants, such as *Carica papaya*, are incapable of ramification and duplication, but can express trunk reiterations. Others do not branch, but are able to duplicate and reiterate (e.g. *Dracæna draco*). Still others, including many conifer species, don't duplicate their trunk – so it remains unique throughout the tree's life – but know how to generate orthotropic substitute shoots when needed. Others, like *Cedrus* sp., combine ramification, duplication, plagiotropization and trunk reiteration. In total, 12 types of arborescence have been identified. There is also a theoretical type for which we would like to discuss with the readers. It involves the discovery of a tree species, probably a conifer, that branches but is unable to duplicate and reiterate its trunk.
In the remainder of the text, unless otherwise stated, the term "Deciduous" refers to the Pedunculate Oak and Italian Poplar types, "Conifers developing by gigantism", i.e. conifers growing without trunk duplication, to the Giant Sequoia type, and "Conifers forming a plateau" to the Corsican laricio Pine and Atlas Cedar types.
In addition to the 12 natural arborescent forms, there are also man-made forms: free forms (expressing themselves freely in the absence of pruning, apart from routine maintenance), semi-free forms (apparently free, but guided and maintained by pruning), architectural forms (artificial forms obtained and maintained by repeated pruning), mixed forms (combining free, semi-free and architectural forms), neglected forms (forms maintained for a long time by appropriate pruning, then suddenly neglected) and mutilated forms (de-structured by a storm or drastic cutting).

## For further information: axes and counter-axes

- The axes resulting from branching are different from the supporting axis as soon as they appear (as is the case with most trees), or acquire their specific characteristics later on (this is known as self-differentiation). Branching is generally delayed by one season (the shoot of year n doesn't branch while the shoot of year n-1 does), but when it takes place at the same time as the elongation of the bearing axis (year n), it is qualified as immediate.
- The process of trunk duplication does not include axes built by stacking identical modules (sympodial growth). Trunk duplications mobilize either axillary buds normally destined for branching, or axes initially derived from branching, and therefore different from the supporting axis, but becoming identical to it through dedifferentiation.
- Plagiotropization of the trunk should not be confused with the transient horizontal deviations of stressed young trees, or with the building of trunks according to the Troll model (stacking of plagiotropic modules).
- Trunk reiterations involve most of the time latent buds that have waited more than one growing season, but sometimes have an adventitious origin (as in the case of root suckers for example). Latent buds are usually located just under the bark, but can also be found in terminal positions on short twigs that have stopped growing (as in the case of *Cedrus* sp.). In species unable to reiterate, axis duplication through dedifferentiation can act as substitute shoots.

The 12 types of arborescent forms

| Types of arborescent forms | Genetic abilities | Examples |
|---|---|---|
| *Cocos nucifera* type | - | Many palm trees |
| *Carica papaya* type | Re | Tree ferns (*Cyathea*) |
| *Hyphaene thebaica* type | TD | *Lepidodendron* (Carboniferous fossil tree) |
| *Dracæna draco* type | TD, Re | *Plumeria* sp., *Nerium oleander* |
| Theoretical type | Ra | |
| *Sequoiadendron giganteum* type | Ra, Re | *Araucaria* sp., *Pseudotsuga menziesii*, *Abies alba*, *Cryptomeria japonica*, *Picea abies* |
| *Calocedrus decurrens* type | Ra, LD | Fastigate cultivars of many conifers (*Juniperus*, *Chamaecyparis*, etc.) |
| *Populus nigra* var. *italica* type | Ra, LD, Re | *Populus tremuloides*, *Prunus avium*, *Taxus baccata* |
| *Pinus pinea* type | Ra, TD, LD | *Pinus halepensis*, *Pinus radiata* |
| *Quercus robur* type | Ra, TD, LD, Re | *Platanus* sp., *Castanea sativa*, *Tilia* sp., *Celtis* sp., *Juglans* sp., *Fagus sylvatica* |
| *Pinus nigra* ssp. *laricio* var. *corsicana* type | Ra, TD, LD, Pl | *Pinus pinaster*, *P. sylvestris*, *P. nigra* ssp. *salzmannii*, *P. uncinata* |
| *Cedrus atlantica* type | Ra, TD, LD, Pl, Re | *Cedrus* sp., *Albizia julibrissin*, *Adansonia grandidieri*, *Delonix regia* |

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Ra = trunk Ramification,

TD = Terminal trunk Duplication,

LD = Lateral trunk Duplication,

Pl = permanent trunk Plagiotropization,

Re = aptitude for trunk Reiteration

## For further information: what is the link between the ARCHI method's 12 arborescent forms and Francis Hallé's 24 architectural models?

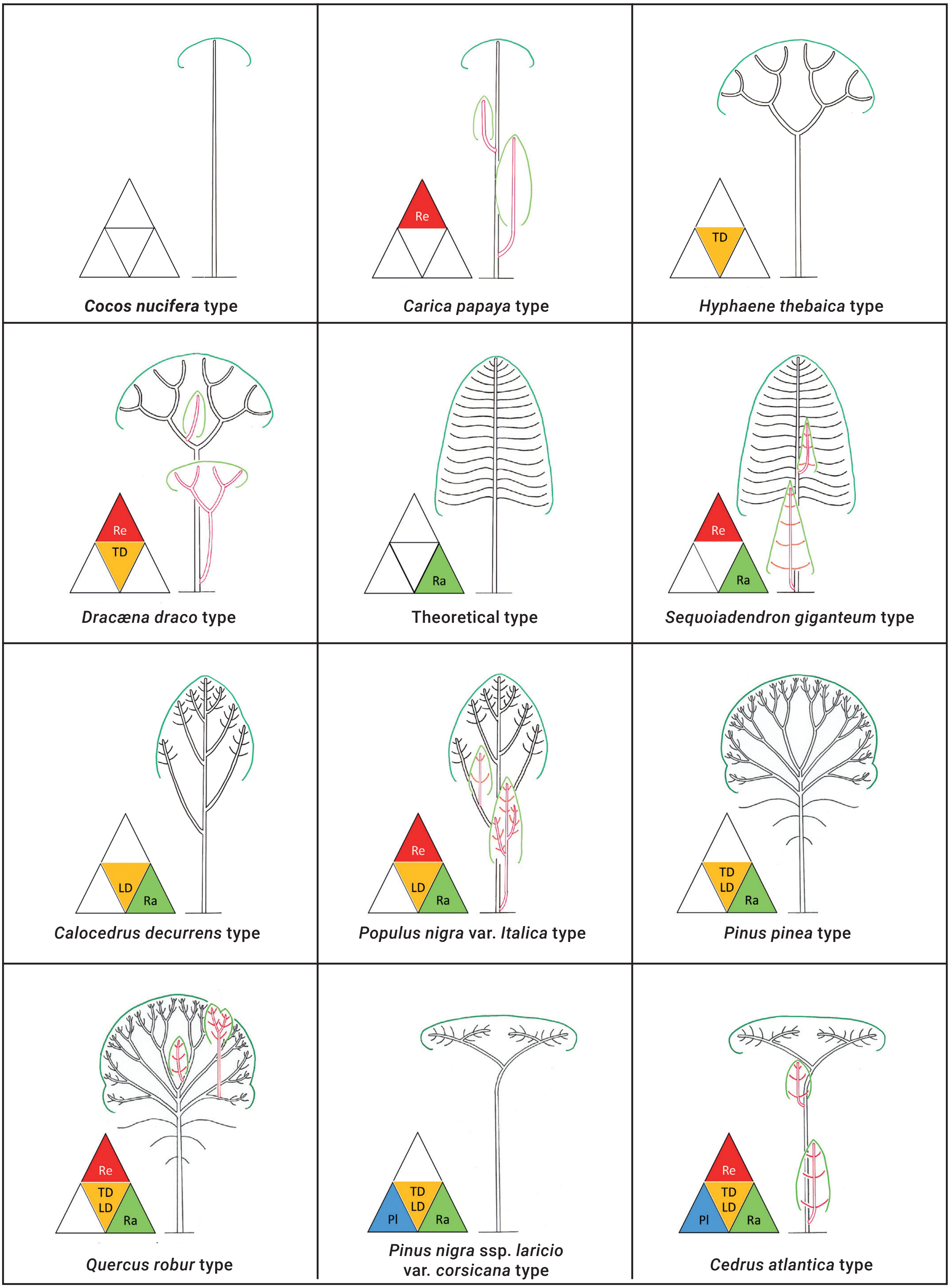
**The 24 architectural models proposed by Hallé and Oldeman in 1970 are dedicated to young trees, grasses, lianas, shrubs and bushes. The 12 arborescent forms describe only mature trees and certain related plants.**

**The models use only three parameters (trunk branching, branch growth orientation and flower position) and, in principle*, do not incorporate duplication or reiteration. As a result, species belonging to different models when young may converge on a limited number of arborescent forms as adults. For example, *Celtis australis* (Troll's model), *Populus nigra* (Rauh's model), *Aesculus hippocastanum* (Scarrone's model), *Magnolia grandiflora* (Fagerlind's model) or *Bombax ceiba* (Massart's model) all end up building a tree form of the Pedunculate oak type.**

**On the other hand, in the case of certain primitive plants, there is a perfect correspondence between models and arborescent forms (the Coconut palm type is represented by Corner's model, the Doum palm type corresponds to Schoute's model, and the Dragon tree type (*Dracæna draco*) belongs to Leeuwenberg's model).**

*In principle, because, in reality, Leeuwenberg's model is built by terminal duplication of Holttum's model, and Oldeman's model, reserved for lianas, is made up of an elementary axis and an unlimited number of unpredictable reiterations.

## The 12 types of arborescent forms in pictures



***Cocos nucifera*** **type** — ***Carica papaya*** **type** — ***Hyphaene thebaica*** **type**

***Dracæna draco*** **type** — **Theoretical type** — ***Sequoiadendron giganteum*** **type**

***Calocedrus decurrens*** **type** — ***Populus nigra*** **var.** ***Italica*** **type** — ***Pinus pinea*** **type**

***Quercus robur*** **type** — ***Pinus nigra*** **ssp.** ***laricio*** **var.** ***corsicana*** **type** — ***Cedrus atlantica*** **type**

Drawings and diagrams: Christophe Drénou © CNPF

**Legend of the drawings:**
Green outline = foliage
Double lines = trunk and main branches produced by trunk duplication
Single lines = branches produced by ramification of the trunk
Red = orthotropic substitute shoots produced by trunk reiteration

**Legend of the triangles:**
Ra = trunk Ramification
TD = Terminal trunk Duplication
LD = Lateral trunk Duplication
Pl = permanent trunk Plagiotropization
Re = aptitude for trunk Reiteration

# 2- Stages of development

The natural ageing of a tree manifests itself in 2 opposing movements. On the one hand, ramification, in terms of the number of axis categories, reaches its peak very early on in the young tree, then slowly but irreversibly declines. On the other hand, duplication, non-existent at the outset, gradually becomes predominant. As the ability to reiterate diminishes at the same time, the whole tree is driven towards inescapable senescence. So, while ramification involves all parts of a tree when young, it remains limited to the periphery of adult crowns, in a zone that continues to shrink until it disappears at senescence, leaving room for duplications of unbranched axes.

These changes allow us to divide the life of a tree into 4 stages of development.

## From seedling to young tree

This first stage is characterized by the intercalation of several axis categories between the trunk and the leaves. Let us take the example of a species with 4 axis categories (trunk = A1, branch = A2, long shoot = A3, short shoot = A4). The young stem A1, just out of seed, will start to bear only leaves. It is only later that short branches of type A4 will appear between the stem and the leaves. After a few time, the stem will produce A3 category axes, which will branch out to give A4 axes and, finally, the trunk will produce its first complete branch (A2 axes carrying A3 axes carrying A4 axes). Thus, between the trunk and the leaves came successively short axes, then long axes, then finally real branches.

## The young tree

For all branched arborescent forms, the young tree shows strong apical dominance, i.e. a single trunk (no main branch duplicating the trunk), a pyramidal outline and linear branches (without forks because they are not duplicated).

The order of branching is genetically limited: 1 for Palms (a single unbranched axis), 2 for *Wollemia nobilis* (unbranched branches, deciduous after 5 to 10 years of existence), 3 for Walnut and Common Ash, 4 for Chestnut, 5 for Atlas Cedar, sometimes 6 (*Cupressus sempervirens*), but this is the maximum found in plants. The higher the order of branching is, the smaller the leaves tend to be.

## From young to adult tree

Constrained by a low branching order, arborescent forms use the duplication process to densify their foliage. The adult stage is thus preceded by the formation of draperies of twigs along the branches (characteristic of certain conifers such as Spruces) and by the appearance of forks at the ends of branches. At the same time, in species preparing to duplicate their trunk, the angle of branch insertion decreases.

## The adult tree

For deciduous trees, as well as for the *Calocedrus* and *Pinus pinea* types, adult trees are those that have begun the process of duplicating their trunk. Their top branches are vertical and rectilinear.

As adults, conifers developing by gigantism retain a pyramidal outline. They can only be distinguished from young conifers by their forked lower branches.

In the case of conifers forming a plateau, the top of the crown becomes rounded as the end of the trunk naturally curves.

## Transition from adult to mature tree

Arborescent forms that have duplicated their trunk in the previous stage repeat the process several times, thus increasing their crown volume.

However, those that do not duplicate their trunk, continue to duplicate their branches. The forks at the ends of the branches first appear in the lower part of the crown, then gradually progress to the top of the tree.

In the case of conifers forming a plateau, the trunk develops horizontally, duplicating its own architecture several times over.

## The mature tree

Mature deciduous and coniferous trees duplicating their trunks: the crown contour is irregular, the lower branches are extended by axes curved into arched structures (characteristic arches), the upper branches droop slightly and the number of successive forks along the main branches, when the tree produces them per terminal duplication, is greater than 5.

Mature conifers developing by gigantism: unlike young or adult trees, the crown is rounded.

Mature conifers forming a plateau: the horizontal, forked main branches at the top have upright branching structures on their upper surface, giving the plateau a brush-like appearance.

## The transition from mature to senescent tree

The transition from maturity to senescence is gradual and slow, and can take several centuries.

For the majority of branched tree forms, during this long period, the lower branches evolve into structures composed of axes known as "string-like axes". The latter are indeed characterized by a flexible, supple appearance, a small, constant diameter and a lack of branching and fruiting. Made up of very short annual shoots bearing male sexuality, they can be very old.

## The senescent tree

A senescent deciduous tree produces unbranched axes arranged in a multitude of closely spaced forks and/or summit arches. The contour of the crown is fragmented and gradually invaded by natural mortality. The number of successive forks along the main branches, when the tree produces them per terminal duplication, is greater than 10.

A conifer developing by gigantism is senescent when the loss of apical dominance of the crown leads to the formation of forks and plagiotropization of the trunk.

A conifer forming a plateau, at the time of senescence, presents a flattened plateau made up of string-like axes and/or short twigs.

Whatever the arborescent form considered, once senescence is reached, fruiting becomes scarce and the tree becomes incapable of producing vigorous orthotropic substitute shoots.

## For further information: is it always possible to recognize stages of development?

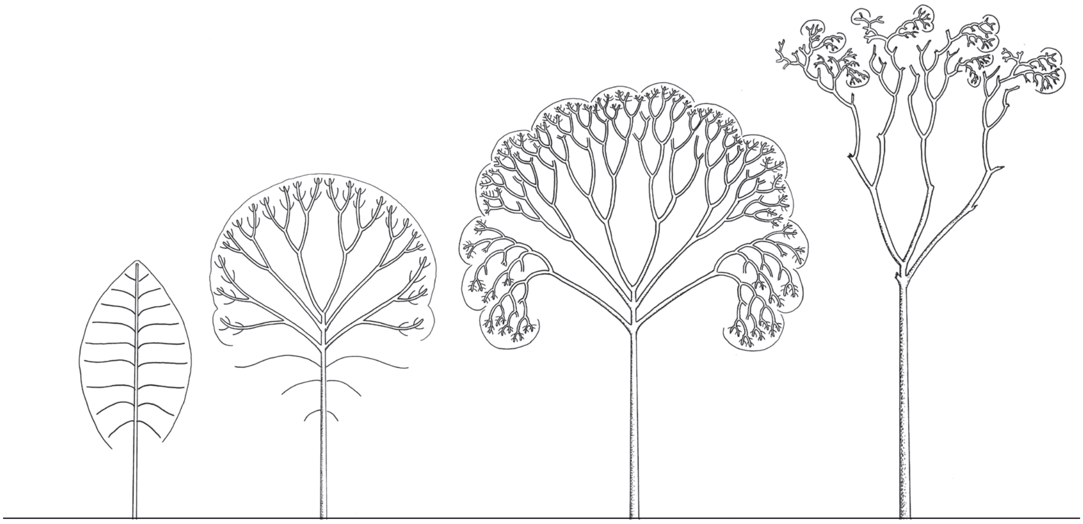
**The answer is no. But this should not prevent the observer from using ARCHI keys to continue the diagnosis until a physiological state is identified.**

**It is important to remember that the criteria for recognizing stages of development have been defined for trees in natural or semi-free form. They are inoperative in the case of artificial forms such as curtains, arbors, balls and so on. They are misleading when the branches of the original crown, broken or pruned, are being replaced by orthotropic substitute shoots. The latter, which go through a more or less lengthy rejuvenation phase, do not reflect the tree's stage of development.**

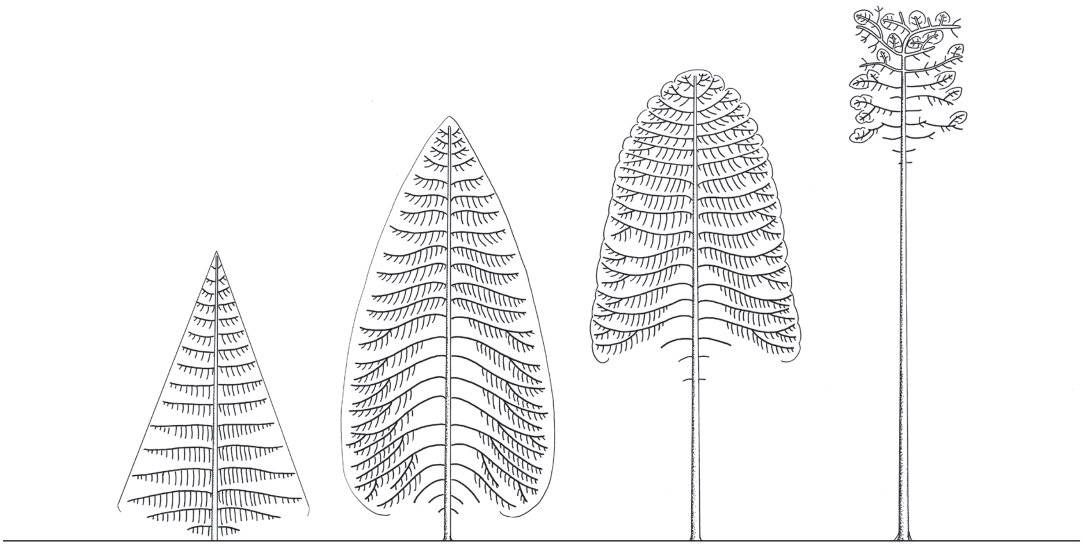
**The number of successive forks along the main branches is a development marker that is useless in the case of arborescent forms built by lateral duplication, i.e. not forming main forks (Calocedar and Italian Poplar types). In practice, this number of forks is difficult to calculate. It requires a clear distinction between accidental forks and master forks, which is not always easy, so that only the latter can be counted. It also implies looking only at "true" master branches, as we know that substitute shoots, due to their increased growth, produce fewer forks than the norm.**

**Finally, the "characteristic arches" criterion can only be used if low branches are present.**

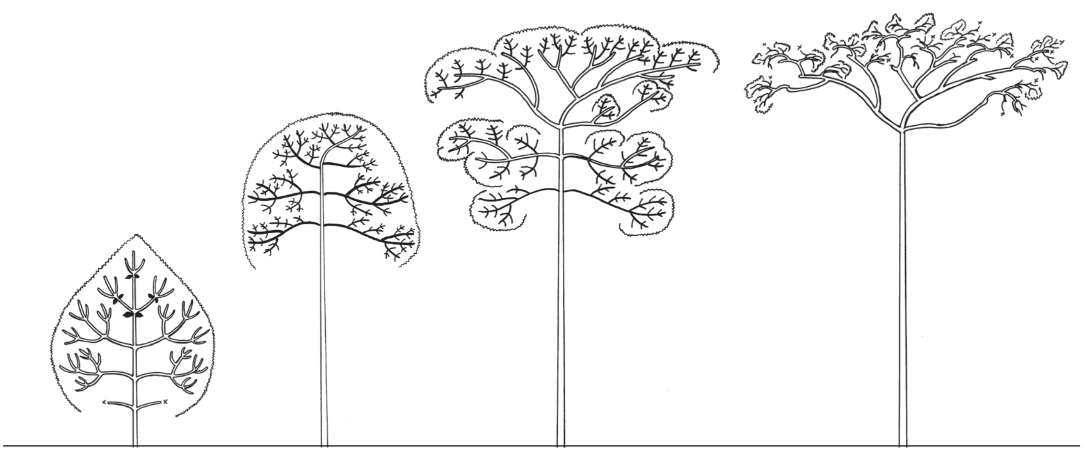
## The four stages of development - young, adult, mature and senescent



For the majority of deciduous trees.



For conifers developing by gigantism.



For conifers forming a plateau.

# 3- Physiological states

During their lifetime, trees in temperate climates inevitably go through difficult periods (storms, drought, cold, disease, severe pruning, transplanting, etc.). Despite the damage they sometimes suffer, some are able to restructure themselves to such an extent that it is very difficult to detect any after-effects later on.

By characterizing developmental stages, we can detect deviations from normal (stressed trees), returns to normal (various forms of resilience) and points of non-return to normality (irreversible decline). Visual markers, known as DMA (DendroMarqueurs Architecturaux), are used for this purpose. The ARCHI method has 20 of such markers. 4 DMA are enough to identify a mature, healthy tree, but 9 DMA are needed to diagnose a mature tree in irreversible decline. In any case, there is never any need to go through all 20 DMA.

Some DMA relate to the crown (contour, abnormal mortality), others to the branches (change in branching mode, direction of growth), still others to the axes (sting-like axes, apical dominance), and finally it is at the level of the entire aerial part that the substitute shoots are observed.

The three types of substitute shoots identified during an ARCHI diagnosis are, in decreasing order of vigor, orthotropic, plagiotropic and ageotropic.

In total, if we exclude the dead tree, the ARCHI method has 6 physiological states.

In the first state, **the healthy tree** has an architecture that conforms to the expressed stage of development.

In the second state, **the stressed tree** shows an architecture that deviates from the norm, without any indication of its future (restoration or deterioration). Generally speaking, in response to aggression, the tree must first deal with the most pressing problems, i.e. replacing the amputated or diseased chlorophyll surface and replenishing its stocks of sugars and starch. Large leaves are therefore immediately produced in large quantities thanks to the emergence of numerous substitute shoots. These can be distributed locally in the crown, often near wounds, or diffusely along the branches and trunk. In the latter case, the tree gives the impression of great confusion and it is impossible to guess which substitute shoots will become dominant. However, it is among the stressed individuals that some will manage to express resilience. It is therefore important not to be too hasty in condemning trees that deviate from the norm.

The three types of substitute shoots according to the ARCHI method

| Substitute shoot | Semantic (Greek) | Morphology | Function |
|---|---|---|---|
| Orthotropic | *orthos*: upright<br>*tropos*: direction | - Vertical growth direction<br>- Radial symmetry of vertical axis<br>- Large-diameter, fast-growing main axis as soon as it appears | Substitute for the trunk and its duplications |
| Plagiotropic | *plagios*: oblique<br>*tropos*: direction | - Horizontal to oblique growth direction<br>- Bilateral symmetry<br>- Main axis of medium diameter | Substitute branches |
| Ageotropic | *a*: without<br>*géo*: earth<br>*tropos*: direction | - No preferred growth direction<br>- Lack of symmetry<br>- Reduced growth and branching<br>- Main axis often small<br>- Limited lifespan | Ensuring the survival of the supporting axis |

In the third state, **the resilient tree** forms orthotropic substitute shoots to restore the original crown. It is therefore in a dynamic state of returning to normal after experiencing stress. Obviously, a subject in the process of becoming resilient may once again experience stress which, depending on its intensity, will delay or block its recovery. Resilience was originally defined in terms of architecture, but subsequent observations show that it is also physiological (resumption of cambial activity and water circulation) and biomechanical (production of reinforcing wood and roots in trunk cavities).

In the fourth state, **the tree in a crown retrenchment** builds a second crown under the original crown. The appearance of substitute shoots is a necessary but not sufficient condition. To form a new crown, the substitute shoots must be arranged in a hierarchy, i.e. some dominant and others dominated, so that their outline is identical to that of a structured crown. Crown retrenchment concerns both deciduous and coniferous trees such as *Taxus baccata*, *Pseudotsuga menzisii* or *Sequoiadendron giganteum*.

It is rare for a tree to achieve record longevity without one day, for one reason or another, experiencing a crown retrenchment. This is why crown retrenchment has been associated for a long time with ageing. In reality, it is only when the plant is no longer able to express a crown retrenchment that it enters in a natural death. On the other hand, a senescent tree can go through a state of fallback.

In the fifth state, **the tree in a fallback** has a compartmentalized architecture, with the top dying off and the bottom continuing to develop normally without producing substitute shoots. Such a situation is not common, except in pines.

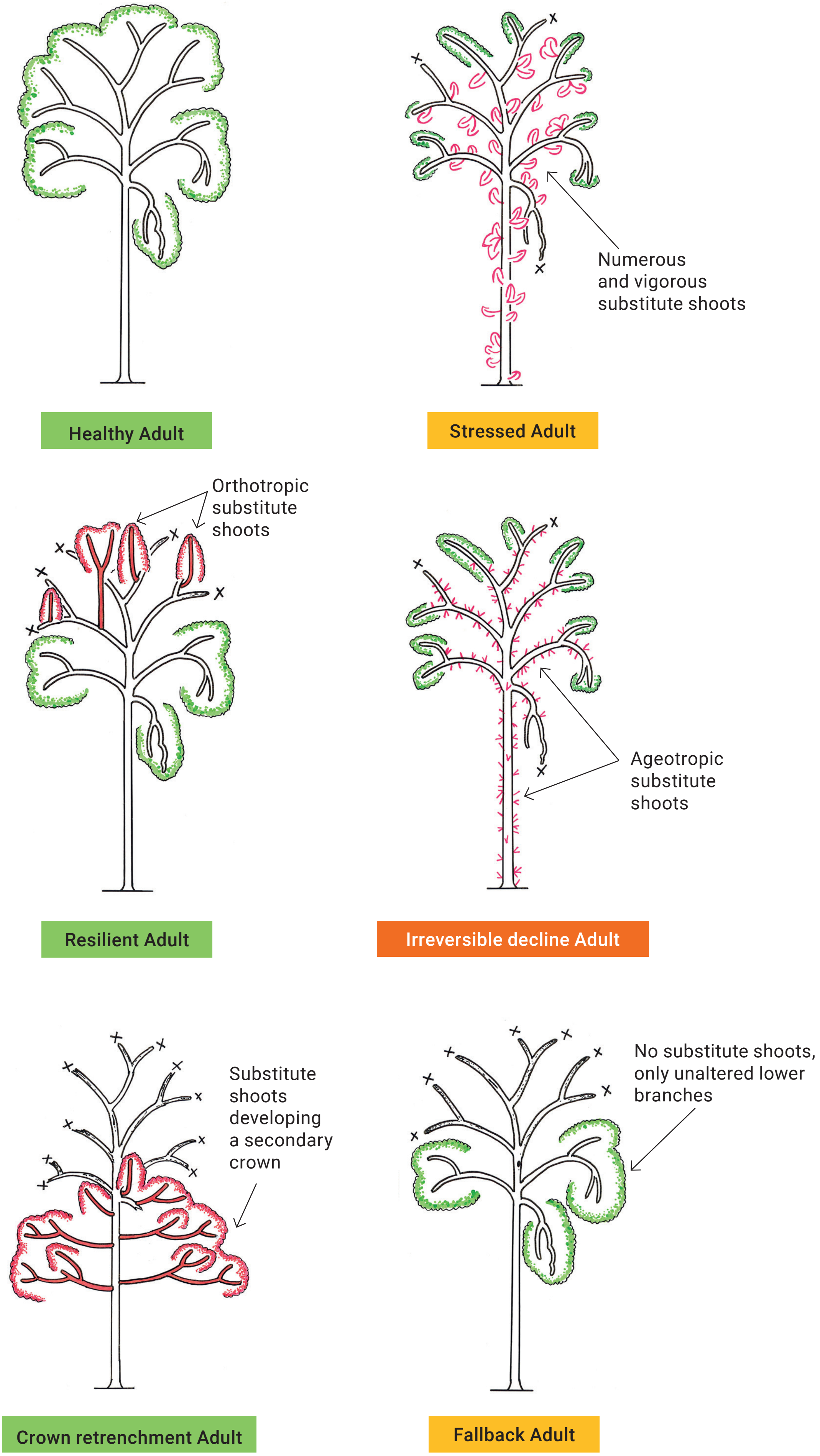
The sixth state is **irreversible decline**, when the tree's architecture is so degraded that it has reached the point of no return to normal. The lifespan of the plant depends on changes in its environmental conditions. It is always difficult to look into the future and say that a situation is definitively irreversible. The ARCHI keys therefore add several confirmation questions before leading the observer to such a result.

## For further information: what links are there between the 4 stages of development of the ARCHI method and Raimbault's 10 stages?

**In terms of diagnosing the condition of trees, the first method to use plant architecture was developed in France by Pierre Raimbault, Professor at INH in Angers (Raimbault, 1993 and 1995). It was a considerable success, as expectations were high, and it is still found today in some of the literature. It is an empirical approach which defines 10 stages but, unfortunately, does not distinguish between obligatory, genetically programmed pathways and optional events caused by the environment. As a result, stages of development and physiological states are mixed up, leading us, for example, to wrongly equate a crown retrenchment (physiological state) with senescence (stage of development).**

**However, I would like to emphasise Pierre Raimbault's great intuition. Indeed, if we group together the first 5 stages describing the transition from seedling to young tree, and if we exclude the last 2 stages because they correspond to physiological states and not to stages of development, we arrive at the 4 stages of the ARCHI method. In addition, it is particularly instructive to re-read Raimbault's articles 30 years after their publication: 'The severe drought of 1988 to 1992 profoundly affected the way the trees function, and any research carried out since 1989 will not be able to clearly distinguish normal functioning of the "senescence" type from disturbed functioning of the "decline" type, and we must be aware of this'. 'Nevertheless, it seems certain that the older a tree gets physiologically, the less its ageing process can be slowed down by pruning'. 'It is possible that a true senescent state is acquired during stage 8'.**

**The 6 physiological states of the ARCHI method**
The drawings illustrate the case of adults, but also apply to young and mature trees.



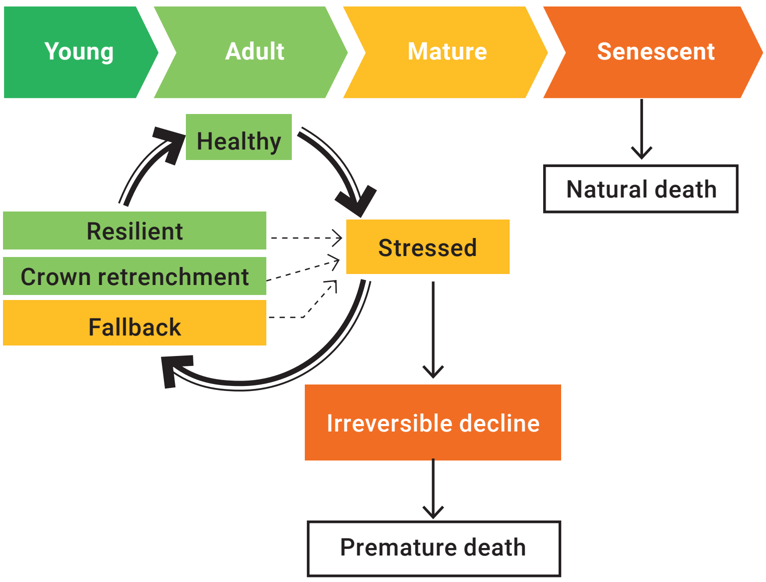
# 4- Tree vitality

Vitality 'refers to the quality of a tree capable of exploiting the conditions of a given environment through vigorous and healthy growth, activating a force of resistance against harmful environmental influences, rapidly repairing any damage, and reproducing abundantly by vegetative and/or sexual means' (Otto, 1998).

Vitality is conditioned by genetics, a variable that cannot be adjusted, as well as by two fluctuating factors: ageing on the one hand (decrease in vitality during ontogeny) and environmental constraints on the other (generally much higher in towns than in forests). Its assessment requires a dual diagnosis, ontogenic to define its stage of development (4 stages: young, adult, mature, senescent) and physiological to qualify its state (6 states: healthy, stressed, resilient, crown retrenchment, fallback, irreversible decline).

The problem is that there is no unit for measuring vitality. Changes in ring width over time are undoubtedly the best way of measuring vitality. Cambial growth incorporates all the physiological variations in a tree, both above and below ground level. Moreover, a study combining the ARCHI method and dendrochronology shows a significant correlation between changes in ring width over the last 7 years and the ARCHI 'Healthy', 'Resilient' and 'Irreversible decline' types (the other types were excluded from the study due to insufficient numbers).

Consequently, individuals classified as resilient from an architectural point of view are also resilient in terms of radial growth (Lebourgeois *et al.*, 2015). We will use these results to discuss three cases.




Above: principle of the dual diagnosis of the ARCHI method, ontogenic diagnosis (large horizontal arrow) and physiological diagnosis (cycle). The diagram illustrates the case of adults, but also applies to young and mature plants.

Below: table cross-referencing stages of development and physiological states to obtain different levels of theoretical vitality expressed as the average width of the last ring formed.

| | Young | Adult | Mature | Senescent |
|---|---|---|---|---|
| **Healthy** | Very strong | Strong | Medium | Weak |
| **Resilient** | Very strong | Strong | Medium | - |
| **Crown retrenchment** | Very strong | Strong | Medium | - |
| **Fallback** | Strong | Medium | Weak | Very weak |
| **Stressed** | Strong | Medium | Weak | - |
| **Irreversible decline** | Medium | Weak | Very weak | - |

Theoretical vitality level, expressed as the average width of the last ring

- Very strong
- Strong
- Medium
- Weak
- Very weak
- - Impossible situation

Diagrams: Christophe Drénou © CNPF

The first scenario is that of an adult tree going through three successive states: Healthy, Stressed and Resilient. We can see that reductions in ring width occur in the same year as stress (drought, for example), that they can be significant (-30% to -50% compared with an average calculated over a 10-year reference period), and that they are followed by a rapid recovery (2 to 4 years) as soon as growing conditions become favourable again.

The second scenario involves an adult tree that is moving towards irreversible decline. Its initial resistance is identical to that of the previous tree. However, its resilience capacity is lower, resulting in the production of thin rings with less end wood and fewer and smaller initial vessels. Above all, the tree's ability to recover decreases with each new stress, until, in the end, being reduced to nothing.

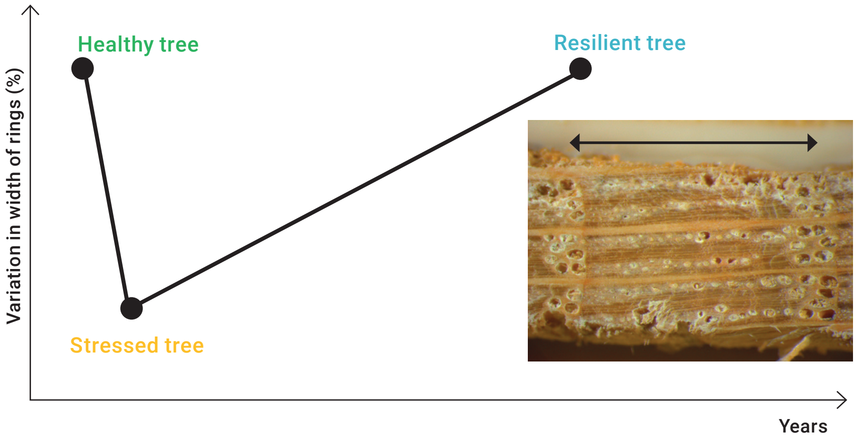
The last case scenario considers 3 resilient trees that have been subjected to the same type of stress but at different stages of development. The negative effects of stress are very likely to be stronger and more immediate in young trees because of their low carbon reserves. On the other hand, there is every reason to suppose that resilience times increase as the tree develops. We will take 3 examples. It takes 5 years for the architectural resilience of a young plane tree to develop if the leader and all the branches have been cut off at planting. An adult Sequoia (*Sequoiadendron giganteum*) toppled by the storm of 1999 at the Château de Champs-sur-Marne (Seine-et-Marne, France) takes 16 years to achieve architectural resilience. The time required for the architectural resilience of the mature Pedunculate Oak at Kerverné (Morbihan, France) after dieback is 80 years (Drénou, 2022).
A major study published in 2022 corroborates the previous cases (Au *et al.*, 2022). Based on 20,000 trees belonging to 120 different species spread over 5 continents, the study uses dendrochronology to show that, when faced with drought, young trees are less resistant (resistance: limiting the loss of growth during stress) but more resilient (resilience: returning to normal growth after stress) than older trees. Hence the importance of age diversity within a woodland!

## For further information: what links are there between ARCHI and DEPERIS?

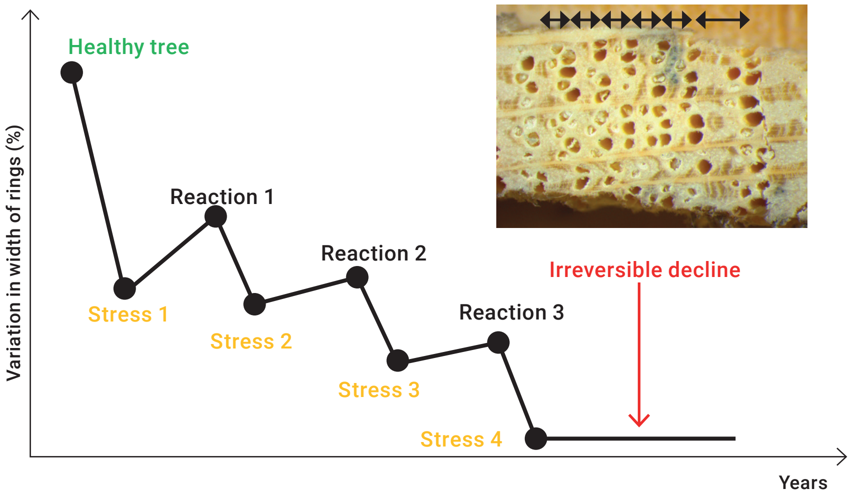
The DEPERIS method, developed by the DSF (Department of Forest Health of the Ministry of Agriculture and Food Sovereignty) in 2018, assesses the level of tree dieback in forests. The two criteria used are branch mortality and lack of branching (for broadleaves) or needles (for conifers). DEPERIS is a simplified version of the DEPEFEU method (Nageleisen, 2005).

As part of the project 'Les chênaies atlantiques face aux changements climatiques: comprendre et agir (2009-2013)', the CNPF compared DEPEFEU and ARCHI on 345 pedunculate oaks. There was a good correspondence between the extreme ratings of the two methods, i.e. between the DEPEFEU 0 rating and the ARCHI Healthy type on the one hand, and the DEPEFEU 4 rating and the ARCHI Irreversible Decline type on the other. However, the median DEPEFEU 2 score (140 oaks) is composed of 50% trees of the future according to ARCHI (10% healthy and 40% resilient) and 50% other ARCHI types (20% irreversible decline, 25% stressed and 5% crown retrenchment).

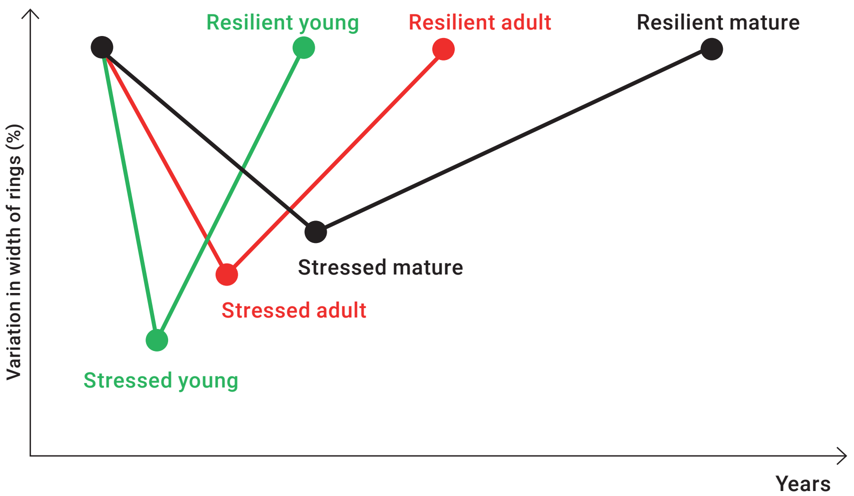
**AN ADULT TREE** going through three successive states: Healthy, Stressed and Resilient.
Photo: ring of a Resilient pedunculate oak (the double arrow marks 1 ring).




**AN ADULT TREE** that is progressing towards irreversible decline.
Photo: rings of a pedunculate oak in irreversible decline (each double arrow marks 1 ring).




**THEORETICAL CASE** of 3 Resilient trees that have undergone the same type of stress but at different stages of development. Green: young tree. Red: adult tree. Black: mature tree.




Common legend: the y-axis shows the relative variation in ring width for each year, in % compared with an average reference width calculated over a past period of 10 years; the x-axis represents the years. The axes are deliberately not graduated, as the purpose of the graphs is to describe general trends. Photos are on the same scale.

Diagrams and photos: Christophe Drénou © CNPF

# 5- ARCHI keys

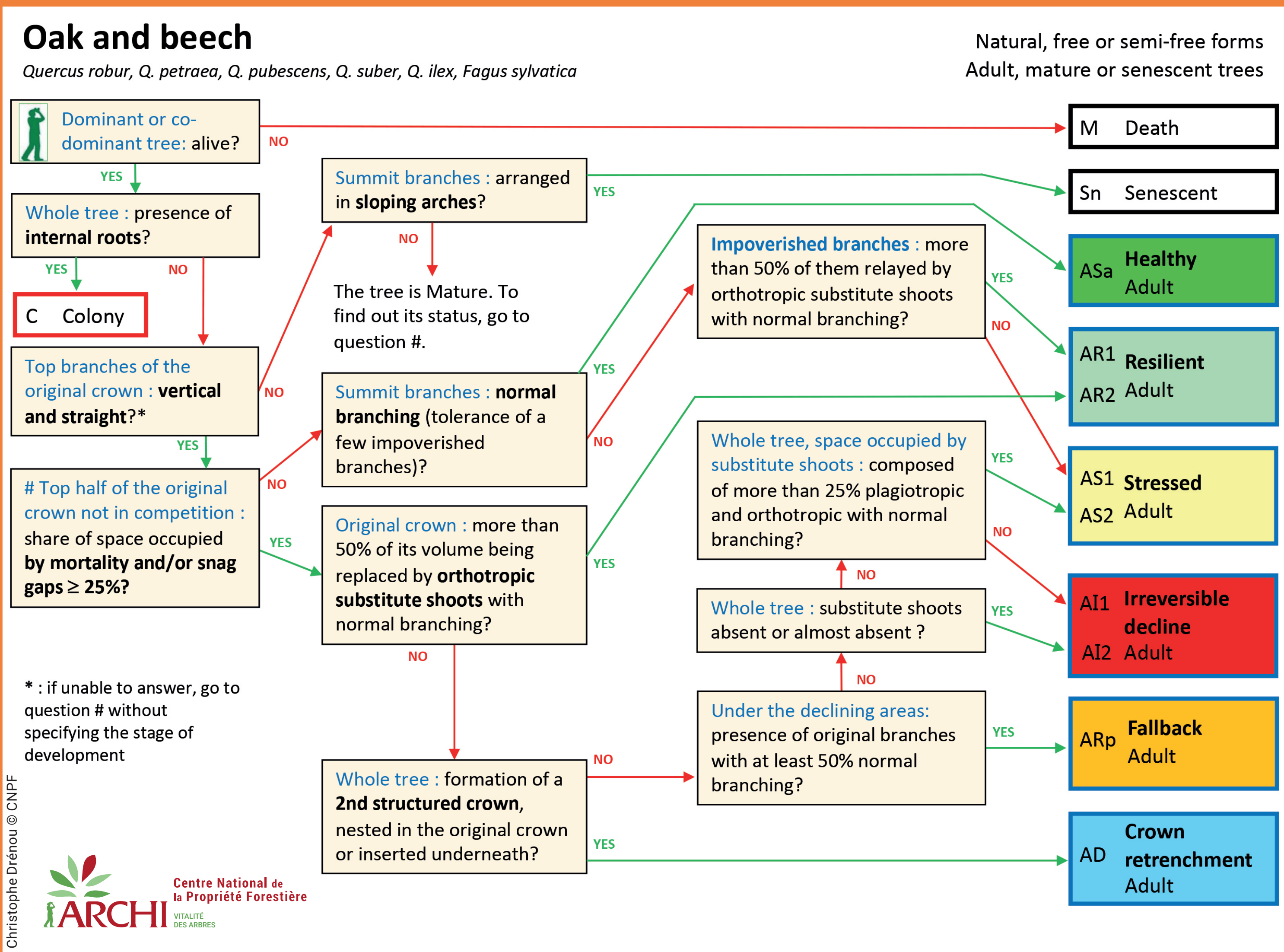
For several tree species, ARCHI type determination keys are available for graders. They have been designed to facilitate observations and ensure that the results obtained are consistent. The observer is guided by a series of questions. In each box, the blue text delimits the area of the tree to be observed. The results are coded using capital letters (sometimes followed by a small letter) and 1 optional number. The latter has no diagnostic value; it differentiates between itineraries leading to the same result. Example: AR1 (Adult, Resilient, itinerary 1).

The 'Colony' box indicates that the tree should be considered as a colony of autonomous individuals or individuals in the process of becoming independent, which may require a separate diagnosis for each entity.

The vertical order of the results ('Healthy' at the top and 'Crown retrenchment' at the bottom) does not prejudge the seriousness of a decline.

Currently (2025), eight ARCHI keys are available for 18 species: *Platanus x acerifolia*, *Castanea sativa*, *Quercus* (*robur* + *petraea* + *pubescens*), *Quercus suber*, *Quercus ilex*, *Fagus sylvatica*, *Pseudotsuga menziesii*, *Picea abies*, *Pinus* (*pinaster* + *sylvestris* + *uncinata* + *nigra* ssp. *nigra* + *nigra* ssp. *laricio* var. *corsicana* + *nigra* ssp. *salzmannii*), *Cedrus atlantica* and *Abies alba*.

The key below applies to 6 oak and beech species (*Quercus robur*, *Q. petraea*, *Q. pubescens*, *Q. suber*, *Q. ilex*, *Fagus sylvatica*).



# Conclusion

Any decision relating to the management of trees requires regular assessment of the condition of the plants throughout their life. After planting, to judge the quality of new growth; during development, to adapt the type, frequency and intensity of pruning; following an environmental constraint, to anticipate the reversible or irreversible nature of a decline; at the time of a mechanical diagnosis, to estimate the physical resilience of a tree deemed to be fragile; and at the end of life, to recognize the natural or premature nature of a death.

The existence of a scientifically validated method lends credibility to the advice given by managers of green spaces and forests, especially those whose job is to assess trees. With a little training and experience, the ARCHI keys can be used to diagnose a tree's stage of development and physiological state in just 3 to 5 minutes, in order to assess its general vitality. The method helps to rule out the possible temporary symptoms that can be misleading (leaf deficit, abnormal coloration, mortality, etc.), and to give a chance to trees going through a reversible decline. ■

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## Summary


**This article provides an overview of tree architecture. It describes the diversity of tree forms and their genetic determinism, the obligatory pathways that the stages of development represent from youth to senescence, and the different physiological states in which a plant may find itself at any given time. Shapes, stages and states are the three links in the ARCHI method, a visual tool designed to diagnose the vitality of trees.**



**KEY WORDS : ARCHI method. Arborescent forms. Stages of development. Physiological states. Vitality.**


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# USER GUIDE TO THE ARCHI METHOD (2023)

**Christophe Drénou**


This pocket guide (in french) recalls the principles of the method and explains how to use it.

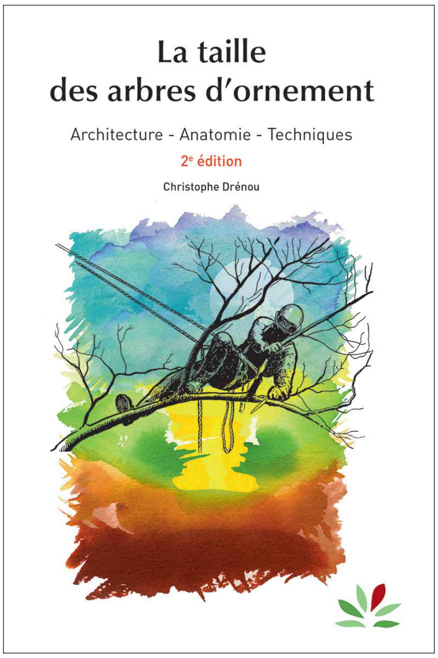
The first part includes 20 descriptive sheets, one for each DMA (Architectural DendroMarker).

The second part includes 8 identification keys for the main species, both deciduous and coniferous trees.

Very practical and widely illustrated, it is the essential tool for all those who love trees and work for them.

The guide fits in the hand and fits perfectly in a pocket: ideal for field missions.

This publication is an appendix to the book "*La taille des arbres d'ornement*", 2nd edition (2021) by the same author.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