NOTES ON THE TERMINOLOGY USED TO DESCRIBE QUALITY AND QUANTITY OF NEW STRUCTURAL WOOD IN TREES

These notes have arisen as a result of queries on the Arbtalk website about the meaning of terms like 'Adaptive Growth', 'Reactive Wood' and 'Reaction Wood' and how they overlap.

A limited number of sources have been examined, chosen to reflect a range of informal to formal texts and spanning a number of years. In particular, the terms Reaction Wood, Adaptive Growth, Compression Wood and Tension Wood have been looked for.

Trees: Their Natural History (Thomas)

Reaction Wood – not defined
Adaptive growth – not defined or used
Compression Wood – not defined or used
Tension Wood – not defined or used

<u>Relevant Narrative</u> – "The controlling factor behind **reaction wood** appears to be the hormone auxin, although the exact mechanism is not clear. In a leaning stem, the normal flow of auxin down the tree is displaced by gravity and it accumulates on the lower side."

Modern Arboriculture (Shigo)

Reaction wood – "is wood altered as a response to lean."
Adaptive growth – not defined or used
[Refers to tension wood and compression wood acting as types of reaction wood]

Wikipedia

Reaction Wood – not strictly defined (see narrative relating to its occurrence and origin).

<u>Relevant Narrative</u> - **"Reaction wood** forms when part of a woody plant is subjected to mechanical stress, and helps to bring parts of the plant into an optimal position (Jourez). This stress may be the result of gravity, wind exposure, snow build-up, soil movement, etc.

"The **reaction wood** is not externally visible, although asymmetric growth is a reliable indicator. The vascular cambium in the affected part of the trunk is more active on one side, leading to thicker growth rings. Branches practically always have **reaction wood**, since they need support to maintain their horizontal or nearly horizontal position. There are two different types of **reaction wood**, which represent two different approaches to the same problem by these groups of plants:

"In angiosperms reaction wood is called **tension wood**. **Tension wood** forms on the side of the affected part of the plant, pulling it towards the affecting force (upwards, in the case of a branch). It is composed almost entirely of cellulose.

“In conifers it is called **compression wood**. **Compression wood** forms in the bend on the opposite side of the applied force, thereby lengthening/straightening the bend. **Compression wood** is rich in lignin.”

<u>Conclusion</u> – This Wikipedia entry cites *Jourez (XXXX)* as its source of definition. Jourez in turn cites the *Dictionnaire forestier multilingue. Métro, 1975. Which defines* ***Reaction wood*** *as “*Bois qui présente des caractères plus ou moins distinctifs ; il se forme typiquement dans les portions de tiges penchées ou courbées et dans les branches ; tout se passe comme si le végétal s’efforçait de reprendre une position normale en réagissant de la sorte. Pour les dicotylédonés il en résulte du bois de tension, et dans les conifères un bois de compression.”

This translates [JM’s translation] roughly as “Wood that has more or less distinctive character; it typically forms in the portions of stems that are leaning or curved and in branches, as if the plant was trying to resume a normal position by reacting this way. For dicotyledons [most broadleaf trees – JM] this results in **tension wood**, and in coniferous wood results in **compression wood**.

Therefore the primary definition in Wikipedia of **Reaction Wood** appears to be incorrect relative to other sources, and most significantly is incorrect relative to its cited source (Metro *per* Jourez).

Body Language of Trees (Mattheck and Breloer)

Reaction Wood – not defined but widely and informally used
Adaptive growth – not defined but informally used
Compression Wood – not defined or used
Tension Wood – not defined or used

Principles of Tree Hazard Assessement and Management (Lonsdale XXXX)

Reaction Wood - not defined but used so extensively that a precise or very restricted meaning can be inferred (principally “**Reaction wood** forms in place of normal wood as a result of the response of the cambial cells to gravity”.)
Adaptive growth - “is the process whereby wood formation is influenced both in quantity and quality by the action of gravitational force and mechanical stresses on the cambial zone.”
Compression wood – not defined or used
Tension wood – not defined or used

<u>Relevant narrative</u> – “Variations in incremental growth occur because cambial activity is influenced by the local availability of food materials and also by the magnitude and duration of mechanical stress.

“Wood quality is largely under genetic control, but within the genetic repertoire there is a capacity to produce special types of wood – known as **reaction wood** –which has the function of withstanding stresses which are predominantly of one type; either compressive or tensile.

“**Reaction wood** tends to form when the cambial cells are orientated other than vertically.

“The term ‘**adaptive growth**’ has been used to describe the growth responses of the cambium to mechanical stresses and to its orientation within the gravitational field [citing *The Body Language of*

Trees]. For the tree as a whole, **adaptive growth** helps to bring about a condition in which no part is either under-loaded nor over-loaded.

"Progressive bending and cracking would occur in [parts of the tree undergoing predominantly tensile or compressive stresses] were it not for the localised production of specialised type of wood known as **reaction wood**, which differs from ordinary wood in its mechanical properties.

"**Reaction wood** is usually laid down in wider annual increments than occurs elsewhere around the stem or branch circumference, so that the cross section is often asymmetric or elliptical. The function of **reaction wood** is to help maintain the angle of the bent or leaning part by resisting further downward bending."

<u>Conclusion</u> – Lonsdale appears to present the most thorough and precise statements of the 'adaptive growth' process and the characteristics, location and circumstances of 'reaction wood'. He also refers to the relationship between quantity of new wood and the availability of nutrients, reminding the reader that there are more factors at play than gravity and mechanical stress.

Discussion

Lonsdale uses the words '**normal wood**' in an undefined sense, representing a default condition of freely growing annual increments of wood free from the influence of gravity perpendicular to the direction of growth. This must be the presumed situation in a vertically growing stem (or branch). In such a situation there is of course considerable stress on the lower stem from the weight of the upper stem, and as such some of the specialisms of 'reaction wood' are to be expected in lower stems.

In discussions of reaction wood as a response to gravity, his summary refers only to growth as influenced by auxin concentration. He does not refer to negative geotropism (the tendency of many plants or parts of them to grow upwards away from the gravitational force. Again this is often a default condition in stems, where there is no perpendicular component of gravity, and the effect in isolation is to eliminate any perpendicular component. It is generally understood (at least for the purposes of this discussion) that negative geotropism in woody pants is achieved by the elongation if new cell growth on the underside of stems or branches, with sufficient force in some cases not only to support lateral loads but to jack up the lateral branch or stem towards the vertical.

A brief introduction of 'thigmorphogenesis' and the narrow subset of this relating to stress-induced growth is needed. Clearly compression and tension wood (if such terms exist, and which can collectively be called 'reaction wood') are permanently subject to a perpendicular component of stress; we might consider this to be static compression, largely unfluctuating and largely a consequence of dead loads. However, there is another element of stress, namely (and the term is coined here informally and temporarily) dynamic stress, which would include stem flexure under oscillating wind loads and branch bouncing or swaying under wind loads. I am going to term these informally 'flexure wood' and assume that additional wood may be of a compression or tension type depending on plant species and side of the branch/tree.

To outline the overall balances of various effects, a few additional rough definitions are now introduced temporarily, these are not intended for adoption and the definitions are if anything deliberately vague to avoid distraction from their purpose, namely to aid explanation of the combined effects of a number of influences on new wood quality and quantity at any point in a tree.

Thus,
'normal wood' has the meaning above that I have inferred from Lonsdale, with the clarification that it comprises enough vascular and ancillary cells to meet the vascular needs of the parts of the plant supplied through that part of the tree.
'nutritional wood' is the additional wood put on at any location by virtue of abnormally privileged access to nutrients or the reduction in normal wood growth due to restricted access to nutrients.
'negatively geotropic wood' is wood reacting to gravity whose nature is to orientate new or existing growth towards the vertical.
'seasonal load' is the additional load imposed by the weight of foliage in deciduous trees.

I have chosen not to introduce the complications of reaction zones on the basis that simplistically these can be considered as special cases of 'flexure wood'.

Now, the wood at any point on a tree at any moment can be considered the sum of at least the following factors.

Wood = normal wood ± nutritional wood ± flexure wood + negatively geotropic wood + seasonal load flexure wood + reaction wood.

It seems inevitable that new wood performing one of these functions may perform another function and pre-empt the need for additional wood under that other function. Also, functions could be met in some situations by quantity of wood and in others by quality of wood, or both, or neither.

It is also to be noted that the mechanisms that allow trees to sense these needs are not entirely understood, but enough is known to appreciate that effects can cancel each other out or act in fine balance, such that for example the classic 'tree' shape' is a result of lateral branches not responding fully to negatively geotropic influences (and other tropisms such as phototropism), due among other things to leader auxin suppression of side growth.

At least 2 notes of caution are needed. Firstly due to natural variations between individual trees, observable forms should not always be deemed successful since they may not endure. Indeed, as long as a tree has grown and reproduced, the concept of success for it does not necessarily have to include longevity. Secondly, conventional chainsaw dissection of trees tends to provide immediately apparent conclusions based on additional wood quantity (observable by increment size and eccentricity) but the quality of the additional wood is much harder to read as it may entail only elevated levels of lignins or cellulose and at a sub-microscopic level the orientation of cellulose within cell walls. In common observation, it is my experience that quantity of wood is the dominant empirical evidence of 'adaptive growth'.

Draft V1
Julian Morris
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