XX. *Upon the extent of the expansion and contraction of timber in different directions relative to the position of the medulla of the tree.* *By* Thomas Andrew Knight, *Esq. F. R. S.* *In a Letter addressed to the Right Hon. Sir* Joseph Banks, *Bart. G. C. B. P. R. S.*

Read May 8, 1817.

My Dear Sir,

Many attempts have been made by writers on vegetable physiology, to account for the force with which the sap of trees has been proved by Hale to ascend during the spring, without any hypothesis having been offered, which has been thought satisfactory: and almost all, which have been offered, have been justly rejected as wholly inadequate. I have suggested in the Philosophical Transactions of 1801, 2d Part, page 333, the expansion and contraction of those cellular processes, which proceed from the bark to the medulla, which I have there called the true, or silver grain of the wood; and which have, generally, though most improperly, been called medullary processes. I have there shown, that this substance expands and contracts very considerably under changes of temperature and moisture; and I have stated that a board of oak, which has been formed by cutting across the supposed medullary processes, can scarcely be made, by any means, to retain the same form and position when subjected to various degrees of heat and moisture. I had not at that time ascertained, with accuracy, the comparative expansion

and contraction of timber, when divided in different directions relative to the medulla of the tree, and I was not in possession of any fact which enabled me to prove the existence of any such power, in a state of action, in the living tree. But experiments, which I have made at different subsequent periods, have afforded very satisfactory evidence of the presence of this power in a state of action in living trees, and have also enabled me to ascertain some facts, which appear interesting, and likely to prove useful in directing the proper mode of application of wood for various purposes, in which it is important that it should permanently retain its primary extent and form. These experiments were made upon timber of many different kinds; but as the results were all very nearly the same, I shall confine myself to those made upon the oak, the ash, the beech, and poplar.

Some thin boards of the wood of two of the above mentioned species of trees, the ash and the beech, were cut in opposite directions relative to their medulla, so that the convergent cellular processes crossed the centre of the surfaces of some of them at right angles, and lay parallel with the surfaces of others; by which means I became enabled to mark the comparative extent of their expansion and contraction when they were subjected to various degrees of heat and moisture. Both were placed under perfectly similar circumstances in a warm room, where those, which had been formed by cutting across the convergent cellular processes, soon changed their form very considerably, the one side becoming hollow, and the other raised; and in drying these contracted nearly fourteen per cent. relative to their breadth. The others retained, with very little variation, their primary form, and did not contract more than

three and a half per cent. in drying. Both were, subsequently, several times subjected to various degrees of temperature and moisture, and each expanded nearly in the same degree that it had contracted, the form of the one remaining very nearly permanent, and that of the other constantly changing.

A beech and an ash tree, each somewhat exceeding twenty inches in diameter, were felled in the end of January (at which time the buds of both had become sensibly enlarged) and a transverse section of about an inch in thickness, and necessarily of a circular form, was immediately cut off from the trunk of each, near its base. An incision was then attempted to be made with a saw from the bark to the medulla, directly in the line of the convergent cellular processes, with the expectation that these, on each side, would expand, and impede the action of the saw. The result was just what I had anticipated, and long before the saw approached near the medulla, it became so strongly compressed that my assistant could scarcely move it. A much thinner saw, which I had in readiness, was then employed; and the incision, which was kept open by a wedge, was extended to the medulla. The wedge was then withdrawn, and the opposite sides of the division instantly came in contact with great force. A second incision, similar to the preceding, was then made to commence at the bark, about an inch distant from the preceding, and to terminate, like that, at the medulla; by which means, a wedge of wood, an inch square at the bark, and ending in an edge at the medulla, and ten inches in length, was wholly detached. This, nevertheless, did not quit its position, being retained in it by the expansion of the wood from which it had been separated.

The opposite sides of the same transverse sections of wood were divided by the saw in a direction diametrically opposite to that above mentioned; under which circumstances, the expansion of the convergent cellular processes could not, as in the preceding cases, occasion any pressure upon the sides of the saw, which consequently continued to move with perfect freedom.

These circumstances led me to infer, that the medullary canal must be subject to considerable variations of diameter, with the increase or diminution of the quantity of moisture in the wood; and I conceived, that I should easily be able to ascertain the truth or falsehood of this conjecture by the following means. I selected, in winter, some parts of the stems of young trees as soon as they were felled, which I retained in such a situation as might occasion them to lose a considerable part of the water they contained, though not to such an extent as to destroy, or endanger, life. The medulla of these was then removed; and the space it had occupied was filled with cylindrical pieces of metal, which were so large that they could not be introduced without considerable force. The pieces of wood were then deposited in a damp soil, from which they absorbed much moisture; and at the distance of ten days, I found the medullary canal so much enlarged, that the pieces of metal dropped through without any pressure being applied.

I am prepared to prove, in a future communication, that the quantity of moisture in the alburnum is subject to great variations in the living tree, and therefore I conclude, that the medullary canal frequently changes the extent of its diameter.

It appears probable that, by means of this kind of expansion, the internal parts of timber trees so frequently become rifted or cleft. Winds have been assumed by some, and frost by others, as the cause of these injuries. But winds cannot possibly be the cause, as pollared oak trees, upon which these can exert but very little power, are almost always rifted; and the frost of this climate is rarely, or never, sufficiently intense to congeal the winter sap of trees. This agent must also, I conceive, act suddenly, if it act at all, and the trunks of large oaks can not suddenly be cleft asunder in silence. The oak timber of England is also much more frequently rifted than that of the north of Europe. The force with which the cellular substance of timber expands, is fully equal to produce the preceding effects. I have often seen it overcome the pressure of many tons: it is therefore greatly more than equal to give the impulse to the sap, which was observed by HALE; and as it is obviously in action in the living tree, I must retain the opinion which I formerly gave, that it is the agent by which motion is given to the ascending fluid. How it immediately acts upon the passages through which that fluid ascends, and whether that fluid passes through the cells themselves, or through the intercellular passages described in the elaborate work of Dr. KIESER,* I confess myself to be wholly ignorant, and the slow motion of the fluid, the excessive minuteness of the passages, and the varieties of directions in which it is often moving at one and the same time, will ever render this a question of extremely difficult solution.

There is another kind of contraction in timber whilst drying, and of expansion when subsequently wetted or moistened,

* Mémoire sur l'Organization des Plantes.

which is observable only in lifeless wood; and which has apparently no connection with the power by which the sap is raised in the living tree. The interior and older layers of wood are much more solid and specifically heavy, than the external layers in the same tree; and the latter, consequently, contract more longitudinally in drying than the former, and the edge of every board (that has been cut with surfaces nearly parallel with the line of the convergent cellular processes) which lay nearest the medulla in the tree, will therefore in drying become convex, whilst the opposite edge will become concave. The ill effects of this are often felt when oak timber is employed to form joists, part of these in drying always rising above, and others sinking below the first and proper position. The cause of some musical and other instruments being put out of order by changes of weather, whilst others, apparently similarly constructed, are free from such defects, may probably be traced to one of the sources above-mentioned.

I am, my dear Sir, &c.

T. A. KNIGHT.

Downton, April 26, 1817.

The Right Hon. Sir Joseph Banks, Bart. G. C. B. P. R. S.