Combined Proceedings IPPS 74:82-86. 2024.

From a Miniscule Ball of Cells to a Giant: How Meristems are Involved in Producing Giant Trees

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Keywords: apical meristem, cell differentiation, cell division, cell growth, cork cambium, lateral meristems, totipotency, vascular cambium

Summary

This article is about how some trees grow to be so large. It talks about the various types of meristematic tissue, their similarities and differences in form and function and how meristems can be of relevance to plant propagators.

INTRODUCTION

How do some things get so big? An African Bush Elephant is not an animal to cross. They are huge. The Blue Whale is thought to be the largest animal to have ever lived. Larger even than the dinosaurs. There are squids with eyes the size of basketballs. These, however, pale into insignificance compared with the majesty of tall trees.

In Tasmania, there is an *Eucaluptus regnans* that is just a touch over 100 meters (330 feet) tall. It even has a name: Centurion. It is amongst the tallest of all the flowering plants. Centurion must be one of the largest organisms to have ever lived in the history of our planet. Another *E. regnans* with the not so majestic name of Still Sorrow has an above ground volume of 400 cubic meters. It is one of the most massive living hardwood trees in existence.

How do some trees get so large? What is the mechanism that causes this growth?

MERISTEMS

Meristems aren't the most talked about parts of plants. Indeed, as a conversation starter they pale into insignificance compared to flowers and foliage and the like, but they have an interest of their own and are worth more consideration than they usually get around the dinner table.

Considering how small most meristems are, it is quite easy to spot where one could be found. Meristems are found wherever there is new growth on a plant. So, we are talking about for example growing tips of stems and branches. To be more accurate, at the very tip of the growing tips. Meristems are the ultimate source of all new growth in plants. This is their function. This ensures continual growth throughout the plants' life by providing a continual supply of new plant cells.

So, what is a meristem? Meristems are made up of very specialized cells that are different from anything in the rest of the plant. They have a superpower called totipotency. This power allows meristem cells to change just about everything about themselves like their size, shape and function. They are at the start of a biological assembly line that forms the leaves and flowers. Meristems are where new growth comes from. The cells that make up a meristem are very small with their interiors consisting mainly of the cell's nucleus which contains the genetic information coded into genes which control the structure and operation of a plant's growth and development. Meristematic cells divide rapidly. That is their job. When a meristematic mother cell divides into two daughter cells something happens that sets off new plant growth. One of the daughters stays within the meristem so maintaining the number of meristematic cells inside the meristem. The other daughter cell forms on the outside of the meristem and it is these cells and their daughters and their daughters that differentiate, divide and grow that ultimately produce new growth that is evident at growing tips on the shoots and roots.

Where would we find a meristem. They are small, microscopically small. The shoot apical meristem or SAM as it is known by generally ranges in size between 50 and 200 micrometers in diameter and the root apical meristems are smaller again at between a few tens to around 100 micrometers. For reference, human hair is around 100 micrometers in diameter. So, because of their size, finding a meristem can be daunting to say the least. They are also not all that obvious a structure since they are under a surface layer of cells which makes spotting them difficult. However, there is a hint given in the name apical meristem. The term "apical" refers to the apex of a branch or stem. This is the absolute tip of the growing tip. All other parts of the plant are behind this point. It represents the newest of the new growth found at this place. As the meristem produces new cells behind it, the meristem moves upward and the plant extends upward in the case of the SAM or downward in the case of root apical meristems, which are, not surprisingly, known as the RAMs.

DIVIDING, GROWING AND DIFFERENTIATING

Shoot and root growth is more than just the apical meristems producing new cells. These new cells have three jobs to do.

Firstly, they themselves need to divide and divide repeatedly to get the cell number up to what is required to produce mature leaves and branches. The meristem itself produces new cells very rapidly, but more are required so the daughter cells themselves need to divide many times to raise the cell count. Every cell produced can trace its line of descent back to the meristem.

Secondly, the new cells need to grow quite a bit. Meristematic cells are so tiny they make normal plant cells seem huge by comparison. So, growth is about producing more cells that themselves grow larger. However, producing more cells that themselves grow will not by itself produce new tissue types by which we can recognize plant tissue.

This is where the third process takes place where these cells turn into the cell types we recognize as normal plant cells such as epidermal cells or parenchyma cells or any of the other cell types we find. This is the process of cellular differentiation. This is where the plant comes into being so to speak.

Apical meristems, a blob of undifferentiated cells found at the tip of stems and branches and roots produce daughter cells that themselves divide, grow and differentiate and are the source of all new growth both upwards and downwards. Meristems and new growth go together. Without meristems there is no new growth. This is the importance of meristems and most of the action takes place in the first few millimeters of the root or shoot apex.

THE PROBLEM OF GIRTH

Trees grow up and down and they also grow outwards. Trunks and branches increase in girth and each year a new tree ring develops which represents a years' worth of girth. This constitutes new growth and wherever there is new growth there are meristems involved. So, we expect the presence of totipotent, undifferentiated meristematic cells that in turn produce cells that divide, grow and differentiate and ultimately give us new plant growth.

This outwards growth or as it is termed the lateral growth of tree trunks, roots and branches has one major difference to the meristems that occur at growing tips of shoots and roots and that difference is in the structure of the meristem itself. Apical meristems are blob-like, a bit like a slightly flattened sphere sitting at the tippy top of stems, roots and branches. Lateral meristems that produce girth have a different structure completely.

When you look at a tree trunk you can't actually see anything that is alive. The bark is obviously dead and hard up against the trunk is another layer, the "cork" that is made of large air-filled cells that are also dead. The living part of a tree trunk is below all this.

If you carefully pick away at the bark and cork of a tree you will find below an outer layer of living cells. This layer envelops the entire tree. If you had the inclination and a steady hand you could skin the tree and end up with a huge but very thin layer of cells. This is the cork cambium, and it contains a layer of undifferentiated meristematic cells. It is a meristem. A thirty-meter-high tree trunk with a diameter of one meter would have a lateral meristem with an area over 90 square meters and a thickness of tissue paper. Large trees could have hundreds of square meters of this type of meristem. If that isn't enough, you would need to double the area of meristem because there are in fact two layers of meristems under the bark. They are the cork cambium meristem and the second is the vascular cambium meristem.

The cork cambium is fairly specialized and, in most trees, mainly produces the outermost protective layer of cork and bark. The vascular cambium is responsible for producing the vascular tissue consisting of the phloem vessels that move sugars from the leaves to the rest of the plant and the xylem vessels that take water and dissolved minerals up from the roots to the rest of the plant. In both cases the meristematic tissue of undifferentiated cells in that thin layer of cells produces cells that in turn divide, grow and differentiate into different cell types and produce new growth.

The annul cycle of the seasons results in tree trunks growing faster or slower depending on conditions and produces the growth rings that can be seen when trees are cut down. The size of the ring indicates exactly the amount of new trunk growth that has occurred in any year. The initial cause of this are meristem cells existing in two thin layers. The life of a tree trunk is a surface phenomenon where layers of living cells are laid over a core of dead xylem vessels that make up the heartwood of the tree. It is the xylem vessels that are mostly responsible for the formation of wood which gives a tree its structural rigidity which allows some tree species to get so large to become some of the largest organisms that have ever existed.

MERISTEMS IN ACTION

Around us we can see meristems in action. Most plant people are aware that some plants just keep on growing along the main stem with little or no branching at all. Sometimes this can be good, but maybe a bit of branching would be nice. To get that effect the simplest way is to pinch out the growing tip. This may seem to be rather extreme since all that needs to be removed is the apical meristem as we remember is a blob of cells about the diameter of a human hair, but human fingers are not exactly a precision scientific instrument but mostly is all we have at hand.

This is an example of apical dominance where the apical meristem inhibits side branch growth and when the inhibition is removed the side-branches grow. This is new growth so where are the meristems that produce this? The base of a leaf stalk, where it meets the stem is called the leaf axil where buds and shoots can develop. The meristems found at the leaf axil are suppressed by the dominance of the top apical meristem. When that is removed the axillary meristem springs into action and new growth happens and side-branches grow and the entire structure of the plant changes.

Striking roots on plant cuttings is another example of where meristems are of importance. A cut through a leaf node and a dip in a rooting hormone gel is often all that is needed. However, sometimes there are plant species that will never set roots. It could be that there isn't a meristem in the first place, and this is probably the reason that new root growth will never happen.

There is an interesting phenomenon in some of the difficult to root species where they can be given a "hormonal sledgehammer" which turns normal everyday plant cells back into a meristematic state. This is the reverse of everything we have been talking about. We can de-differentiate cells and make them meristematic again and with this comes the power of totipotency and they can be differentiated or changed into the root cells we wanted in the first place. This sort of thing is worth exploring because it can help solve problems with difficult-to-propagate species.

Mericloning of orchids is a specialized type of tissue culture where growing tips of plants are cultured and manipulated using plant growth regulators which act on the actual apical meristem to make it produce the mericlones, exact copies of the mother plant.

CONCLUSION

Next time you stand before a mighty tree you might consider the actual number of meristems there are on that one plant. There are meristems at the tips of every branch and branchlet, every place there is new growth there are meristems in action. Thousands and thousands of them. Think of how many root tips are out of sight but still there pumping out the initial step in root growth, and the simple fact that there are not one but two separate meristems that wrap almost the whole of the tree. And they all have one job and that is to produce new plant growth. Meristems are where tall trees come from.

Acknowledgement

The author would like to acknowledge the kindness and patience of Dr Ranjith Pathirana, Honorary Research Fellow at the University of Adelaide for his assistance in editing the paper.