Cellular Biophysics
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Lecture 59
Phyllotaxis Part 02

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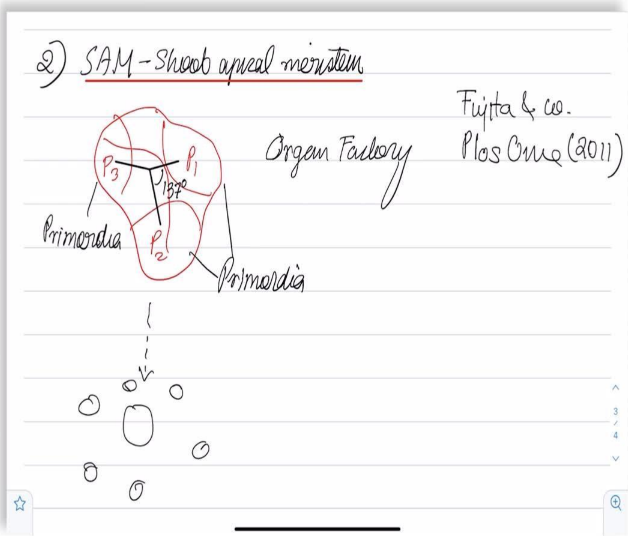

We have so far spoken about the general concept of phyllotaxis and geometric canalization in the conserved patterns. Now, we will talk briefly about a region in the plant, growing plant called shoot apical meristem. Typical scanning electron micrographs represent these typical regions from *Arabidopsis* as P_1, P_2, and P_3 and the angle formed between the regions appears to once more be a golden angle but what these shoot apical meristems are also is an organ factory.

So, in fact these P_1, P_2, and P_3 are all primordial, meaning to say they are the precursors to the mature organs. In some senses as the shoot grows, the apical meristem itself appears to split into sub regions, which can then branch off themselves. In fact, according to a paper by Fujita and company Plos One, you can find it online,, this process of breakup of the shoot apical meristem can be thought of as a reaction diffusion system.

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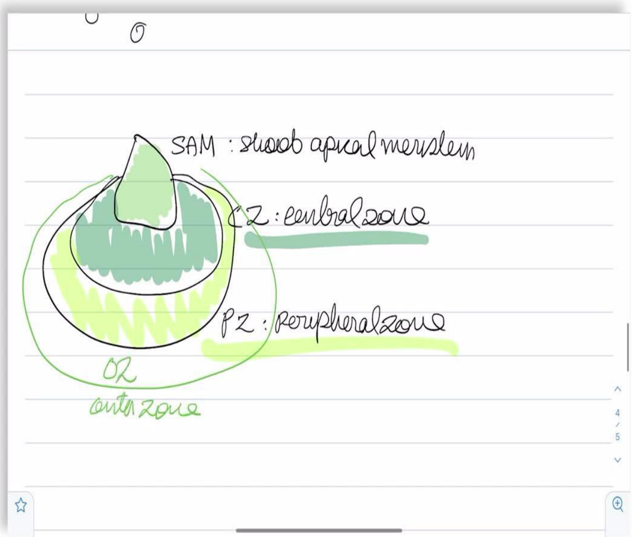

So, if you consider the shoot apical meristem as a region which is then surrounded by, as a region, surrounded by the central zone tissue, which in turn is surrounded by the peripheral zone tissue, let us color this so that we know what we are talking about here. In fact, you could by definition also imagine that there is an outer zone which you will just simply detect as OZ.

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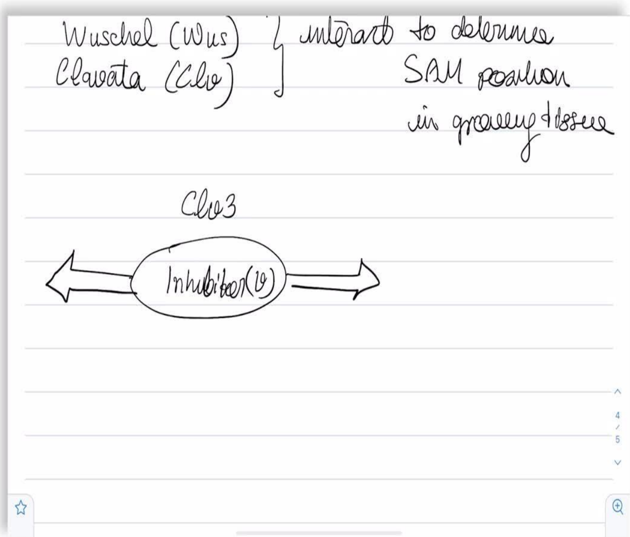

In such a system it turns out from genetics the two genes that are called Wuschel that is with the name Wus and Clavata that is Clv, interact to determine the SAM position in growing tissue. It so that happens that you can represent one of the upstream regions Clv3 as an inhibitor, we will call it v, which has a diffusion coefficient that is large enough and can go between cells, be transported, in other words, trans cellular movement.

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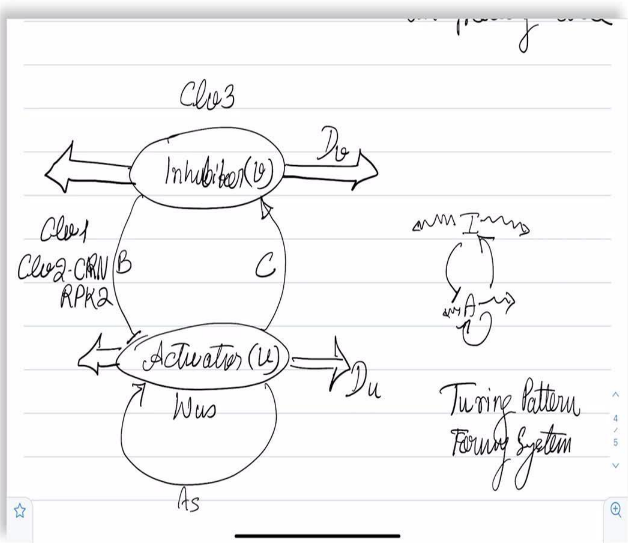

And an activator, Wuschul, we will represent it as symbol u, which has a smaller diffusion coefficient and it cannot be transported across cells as far as we know. (u) also activates itself by a turn As, and the inhibition of Wuschel happens by a combination of multiple sub factors of the Clavata family. So, Clv1, Clv2CRN and RPK2. In turn, the activation occurs directly by Wuschel.

Like what we had described earlier, it is nothing but an inhibitor that inhibits the activator. Activator activates itself and the inhibitor, and this has a larger diffusion coefficient, this has a smaller difference coefficient. This is nothing but Turing pattern forming system. So, this is a, there is already a pattern forming system in the phyllotaxis system coming out of the shoot apical meristem. But it turns out that in addition, there is something else going on.

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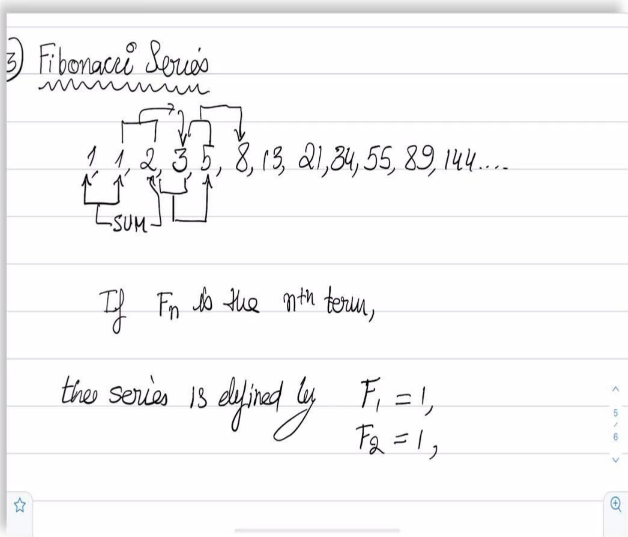

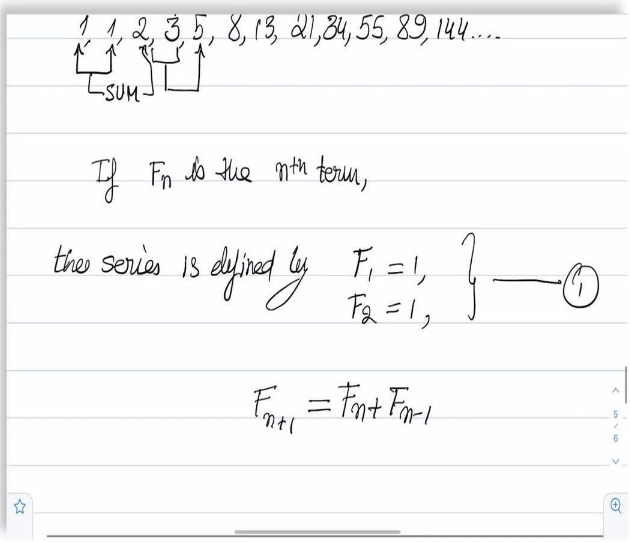

That is something else requires us to spend some time discussing some of the classical mathematical ideas. And those are the ones that allow us to think in terms of simple arithmetic, connect to series concepts and go back to organ formation on the regularity and this is the Fibonacci series. Let us write down one of these so, 1, 1, 2, 3, 5, 8., I hope you know what I am doing. I am taking the initial two values as 1 and 1, summing them and putting them in here.

Now, I take these two values sum them and put it here. Now, I take these two values sum them and put it here and so on and so forth. And I can drag the series a bit more 13, 21, 34, 55, 89, 144 and so on and so forth. In more compact and general terms, I can say that if F_n is the nth term, the series is defined by F_1 is equal to 1, F_2 is equal to 1. And F_{n+1} is equal to F_n

plus F_{n-1}. That is to say the n+1 th value is equal to the sum of the two previous values. We have got this equation 1.

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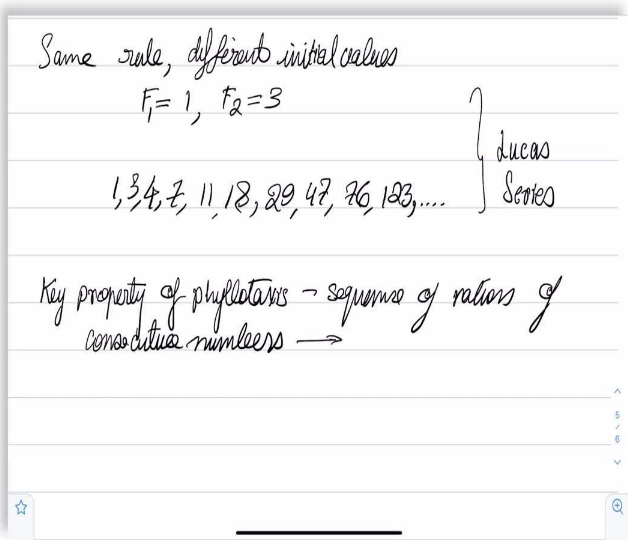

The same rule can also give other series, provided we use different initial values. So, if F_1 is equal to 1 and F_2 is equal to 3, then we get a sequence which looks like this 1, 3, 4, 7, 11, 18, 29, 47, 76, 123 and so on. This sequence with this definition is called the Lucas series. It is not relevant to us right now, but it is important to know that in the case of phyllotaxis a key property is that the sequence of ratios of consecutive numbers has a special property. It converges to something.

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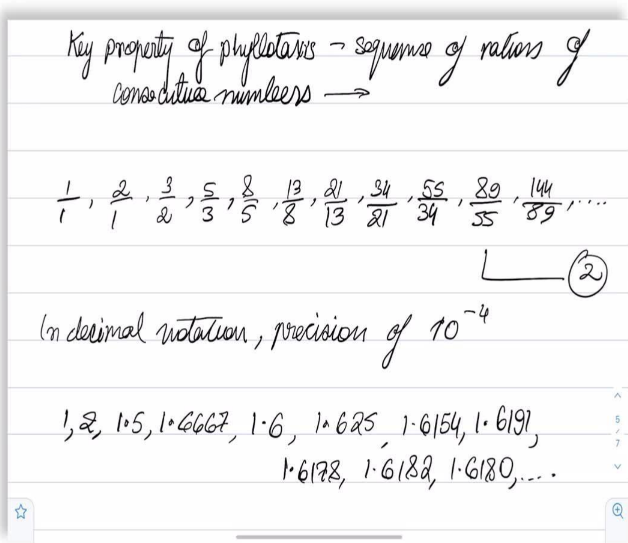

So, let us write it down. So, we know the first few easily 1 by 1 that is 1, 2 by 1 the higher number by the smaller number, bigger number, smaller number 3 by 2, 5 by 3, 8 by 5, 13 by 8, 21 by 13, 34 by 21, 55 by 34, 89 by 55, 144 by 89 and so on. We will call this 2. In decimal notation, keeping a precision of 10^{-4}, we obtain 1, 2, 1.5, 1.6667, 1.6 this this, this, this, 1.625, 1.6154, 1.6191, 1.6178 and 1.6182 and so on.

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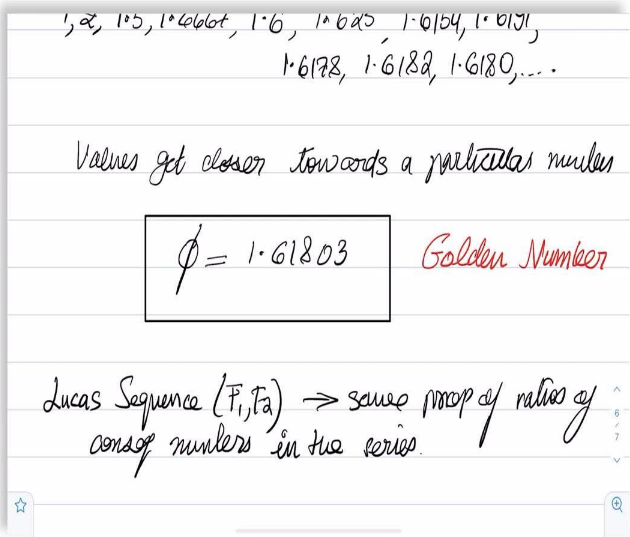

One thing you should observe is that the values get closer as we go to higher values towards a particular number, and that is we call it, denoted by the symbol phi is equal to 1.61803. This, according to many people and funny notations you will find in, if you google this is called a golden number. Interestingly, the sequence we said we will not deal with so much, Lucas sequence, whose only difference is in F_1, F_2 values, meaning the starting values, also shows the same property, property of ratios of consecutive numbers in the series.

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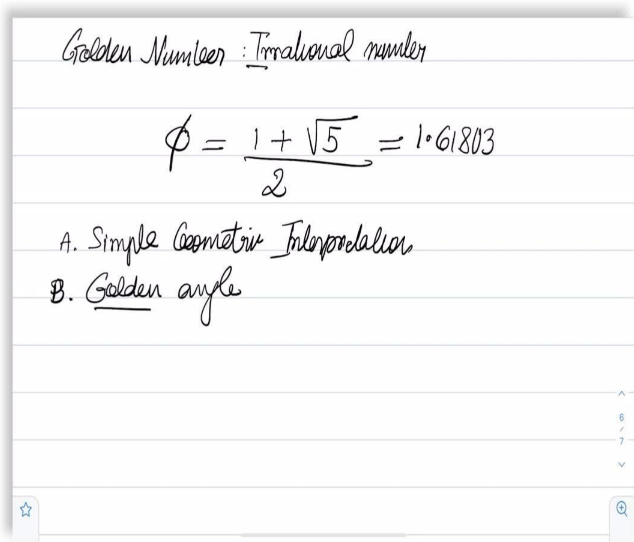

The golden number is an irrational number and can be written as phi, the symbol ϕ, the Greek letter is equal

$$\phi = \frac{1+\sqrt{5}}{2} = 1.61803$$

to 1 plus root 5 upon 2 which is 1.61803. Now, there are two kinds of interpretation, we are going to talk about next. One is the simple geometric interpretation and the second, which is relevant for our phyllotaxis problem, is the Golden angle.