Researchers in Schools

How did the Leaf get its Veins? – Understanding Biology with Mathematics

Key Stage 4 Programme

Pupil Name

Coursebook Designed by H. Allen

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Uni Pathways launch event

Welcome to Uni Pathways! We are delighted to be able to launch the Uni Pathways programme with you. We hope that you are ready to embark on your Uni Pathways journey and that you enjoy the video.
You will be asked to pause the video at times to complete some work in this workbook, so make sure you have a pen / pencil to hand when you start the video.

By the end of the video, you will have

- Learnt about what studying at university means
- Learnt about some of the skills that you will develop during Uni Pathways
- Heard from pupils who have participated in Uni Pathways or The Scholars Programme (which is the same programme!)
- Heard from current university students talking about what life is like at university

If you are in school your teacher will play the video. If you are at home and logged in to a session with your teacher, your teacher will play the video and show it to you. If you are participating independently your teacher will email you the link to the video or the video file. There are opportunities for you to answer some questions, and you will be told when to pause the video to answer them.

Introduction to Uni Pathways

1. Write down what you think a supra-activity is

_____
_____
_____

2. Independent learning is

_____
_____
_____

3. Write down in your own words what resilience means, and come up with a different example to the one mentioned in the PowerPoint.

_____
_____
_____
_____

4. Why do you think analysis and evaluation skills are useful in your academic career?

_____
_____
_____
_____
_____

5. Why do you think analysis and evaluation skills are useful in life in general?

_____
_____
_____
_____
_____

6. What are the different types of learning that university students do?

Pupils' experience of Uni Pathways

You will now watch some pupils talk about their experience of learning a PhD topic and producing a final assignment. Some may refer to The Scholars Programme rather than Uni Pathways. As you heard in the introduction PowerPoint, The Scholars Programme is a very similar programme to Uni Pathways. Listen carefully and then respond to the questions below. Be prepared to share some of your responses with your peers.

1. How did the pupils describe talking about writing a long essay for their final assignment?

2. Write down something that one of the pupils mentioned was particularly interesting in their course.

3. What were some challenges that the pupils met?

Virtual campus tours

You will now go on a virtual tour of some universities! Once you have seen some of the university campuses, respond to the questions below.
Note down something that you liked out of any of the campus tours you saw. It may be a particular building, space, city etc.

1. Were there any similarities between the different university campuses? If so, what are the similarities?

2. If you had to pick one of those universities to go and visit in person, which one would it be and why?

3. Note down some of the societies that you could join at different universities

Meet university students!

You are about to virtually meet or hear from some current university students.
If you are virtually meeting them, think about what questions you would like to ask the students, share your questions with a partner and note those questions down in the space below.

If you are not meeting them but watching some videos that they have made, use the space below to note down what else you would like to find out about university. You can then ask your teacher during Uni Pathways tutorials!

Reflection

Congratulations on completing the launch of the Uni Pathways programme. Before you go, take some time to reflect on what you have learnt by answering the following questions:

1. Are there any aspects of university style learning that you would look forward to? If so, what are they?

2. What challenges do you think students face when learning at university? How would you try to overcome these challenges?

3. What skills do you hope to develop during your Uni Pathways course?

4. What part of Uni Pathways seems the most challenging for you?

5. What are you most looking forward to about Uni Pathways?

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1			
2			
3			
4			
5			
6 (Feedback)			
7 (Feedback)			

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1	Baseline Assignment	
Tutorial 2	Assignment 2	
Tutorial 3	Assignment 3	
Tutorial 4	Assignment 4	
Tutorial 5	Final Assignment	

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after midnight on *DATE*	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Course Rationale

What do you do when you want to analyse some process, but you can't see it or measure it very easily? That's where maths comes in - we can build a model of a system so that its behaviour can be examined, without needing to do lots of time-consuming or expensive experiments. Mathematical models describe systems using equations - for example the straight-line equation $y = mx + c$ tells you how a line will behave, that is the vertical height y of the line at any horizontal point x.

One area where this is most useful is in the study of plant biology. Plants can take a long time to grow and require a huge amount of growing space relative to their size, furthermore the structure of plant cells makes it very difficult to measure molecules within them without damaging the plants. One of the most important molecules to plants is called auxin, and it is critically important throughout the plant for proper growth and development. However, auxin is not distributed evenly throughout plants, its distribution is tightly controlled by a protein called PIN which is found on the cell membrane. The exact mechanism governing how the auxin is transported by PIN is not completely understood, and one way to try to gain new understanding is to create mathematical models describing these processes and analysing their behaviour compared against biological experiments.

This course will introduce the concept of mathematical modelling and how it can be used in biology. Pupils will learn what mathematical models are, how to derive them, and how to solve them. Pupils will learn the mathematics used for modelling, analysis of models, and techniques for solving models using computers.

Uni Pathways Mark Scheme 2020 – maths-based assignments

	Subject Knowledge	Critical Thinking	Written Communication
1st	The work shows a depth of knowledge and understanding of key concepts and mathematical methods, drawing on sources of evidence where appropriate. Knowledge is used to build and support highly effective mathematical arguments and explanations.	Analyses the available data/evidence and identifies all the relevant mathematical information. Identifies and critically evaluates available mathematical approaches and evidence, deciding on their credibility, strength and relative significance. Makes connections between different pieces of information and puts them together to form accurate solutions and verify answers and assumptions.	Mathematical arguments are complete, and the reasoning behind each step has been clearly communicated to the reader. The work has a coherent flow and is well structured. The writing style is appropriate; mathematical language and key mathematical terms are used accurately and effectively to support the arguments and explanations made. There are no, or very few, errors in spelling or grammar. Consistent referencing, appropriate paragraphing and use of correctly labelled tables and figures; matching the style taught in the course.
2:1	The work shows an understanding of key concepts and mathematical methods, drawing on sources of evidence where appropriate. Knowledge is used to build and support effective mathematical arguments and explanations.	Analyses the available data/evidence and identifies all the relevant mathematical information. Engages with multiple approaches and critically evaluates their utility, forming judgements and using reasoning and evidence to inform problem solving strategy. Shows some understanding of the relative value of evidence and data.	Mathematical arguments are clearly made, with few gaps in logical reasoning. The work is well-structured. The writing style is appropriate; mathematical language and key terms are used correctly. There are few errors in spelling or grammar. Mostly consistent referencing and use of tables and figures; matching the style taught in the course.
2:2	The work shows an understanding of key concepts and mathematical methods, with no major misconceptions. Beginning to apply this knowledge to build and support effective mathematical arguments and explanations.	Identifies and uses basic mathematical evidence and reasoning. Evaluates the quality of mathematical reasoning and evidence, forming judgements. Not yet showing understanding of the relative value of evidence and reasoning.	Mathematical arguments have been constructed, but there is little explanation from step to step. The work has some structure. The writing style can sometimes be informal; occasionally key terms are not used when it would be appropriate to do so.

			There are some errors in grammar and spelling, but these do not get in the way of communicating the content. Referencing has some consistency; matching the style taught in the course. Limited use of tables and figures.
3rd	Shows a developing understanding of key concepts and mathematical methods, with some misconceptions. Not yet applying this knowledge to build and support mathematical arguments and explanations.	Beginning to analyse mathematical evidence and reasoning. Describes or attempts to solve the problem without any/or little evaluation of whether the approach was reasonable or accurate.	Mathematical arguments to solve problems are poorly sequenced, with little or no explanation. The grammar, spelling, style, and structure of the work need improving in order to communicate ideas to the reader. Key terms are not always used correctly. Limited, or no use of referencing, tables and figures.

Baseline Assignment (problem-set): Pupil Feedback Report

Name of Pupil	
Name of School	
Name of RIS teacher	
Title of Assignment	

How your assignment is graded:

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-level
2:1	60-69	Performing to a good standard at A-level
2:2	50-59	Performing to an excellent standard at GCSE
3rd	40-49	Performing to a good standard at GCSE
Working towards a pass	0-39	Performing below a good standard at GCSE
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Marks

OVERALL MARK / 100		FINAL MARK / 100 (including any deductions)	
DEDUCTED MARKS		FINAL GRADE	

If marks have been deducted (e.g. late submission, plagiarism) the teacher should give an explanation in this section:

Mark Breakdown and Feedback

Subject knowledge	
	mark
Critical thinking	
	mark
Written communication	
	mark

Problem Set	
Comment	*mark*

Final Assignment (essay based): Pupil Feedback Report

Name of Pupil	
Name of School	
Name of RIS teacher	
Title of Assignment	

How your assignment is graded:

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-level
2:1	60-69	Performing to a good standard at A-level
2:2	50-59	Performing to an excellent standard at GCSE
3rd	40-49	Performing to a good standard at GCSE
Working towards a pass	0-39	Performing below a good standard at GCSE
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Marks

OVERALL MARK / 100		FINAL MARK / 100 (including any deductions)	
DEDUCTED MARKS		FINAL GRADE	

If marks have been deducted (e.g. late submission, plagiarism) the teacher should give an explanation in this section:

Mark Breakdown and Feedback

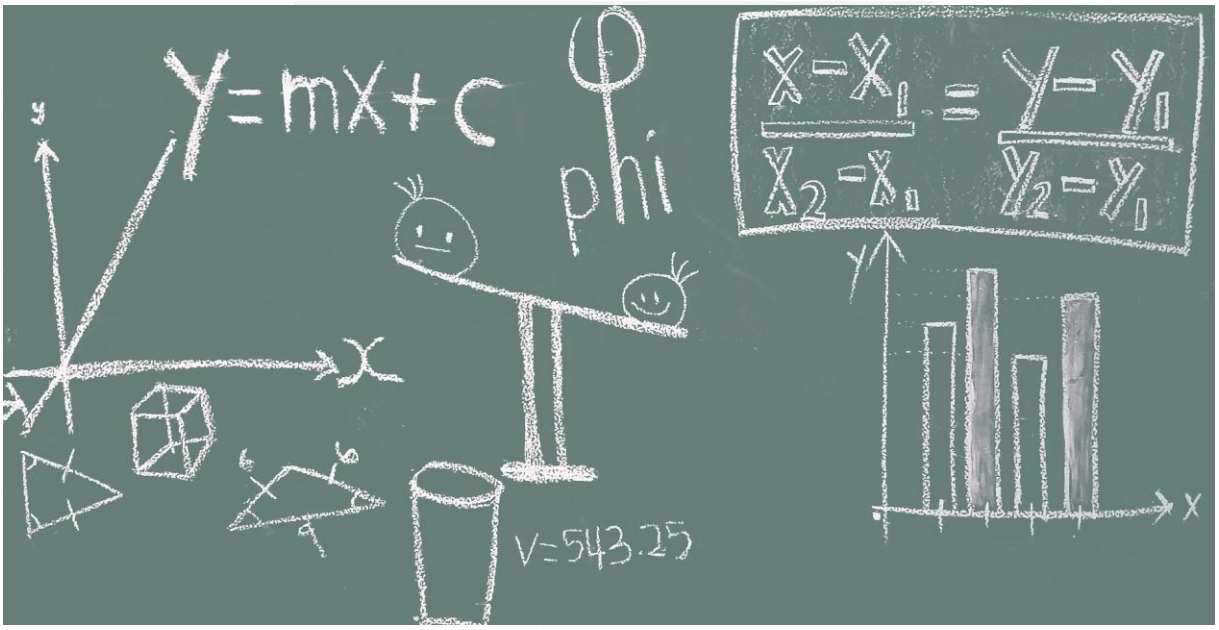
Subject knowledge	
	mark
Critical thinking	
	mark
Written communication	
	mark

Subject Vocabulary

Word	Definition	In a sentence
Mathematical Model	A description of a concept/system using mathematical language, based on knowledge and assumptions about how the concept/system operates.	The mathematical model to determine students' A-level and GCSE results this year was rubbish.
Differential Equation (DE)	A common type of mathematical model that describes the rate of change of each component in the system as being dependent upon all components of a system.	We used differential equations to predict what tomorrow's weather will look like based upon today's weather.
Variable	Components of a mathematical model that can change and need to be measured, usually describing components of the relevant system.	The variables in the line equation $y = mx + c$ are y and x.
Parameter	Components of a mathematical model that stay the same, usually describing rates of processes in a system.	The parameters in the line equation $y = mx + c$ are m and c.
Steady State	A fixed point of a DE where the rate of change has become zero. The variables will remain fixed at this point without any outside influence.	The ball reached a steady state at the very top of the hill where it was flat, and didn't roll down either side.
Stability	A property of a steady state of a DE. A steady state is stable if after a small shift away from it the variables return to the same steady state, and unstable if after a small shift away from it the variables arrive at a different (stable) steady state.	At the top of the hill the ball lacked the stability that it had at the bottom of the valley below
Auxin	One of the most important plant hormones that has crucial roles in regulating its growth and development.	The plant died because of a lack of auxin.
PIN	Protein responsible for moving auxin across the cell membrane.	The cell had a high level of auxin because it was being transported in from a neighbouring cell with a high level of PIN.
Auxin Transport	The process of auxin being moved from one cell to a neighbouring cell, controlled by the protein PIN.	While growing, auxin transport maintains high levels of auxin at the very tip of the root.
Distribution Pattern	The uneven levels of auxin that can be observed in groups of neighbouring cells, regulated by auxin transport. The type of the	Veins in plant leaves form around the cells with high levels of auxin in the auxin distribution pattern.

	pattern has important implications for the development of those cells.	

Tutorial 1 – Introduction to Mathematical Modelling



What is the Purpose of Tutorial 1?

- Define the terms Mathematical Model, Variable, and Parameter.
- Explain how mathematical models are developed.
- Identify three key reasons that mathematical modelling may be useful for biologists.

Task 1 – Key Definitions

In the spaces below write down definitions in your own words of:

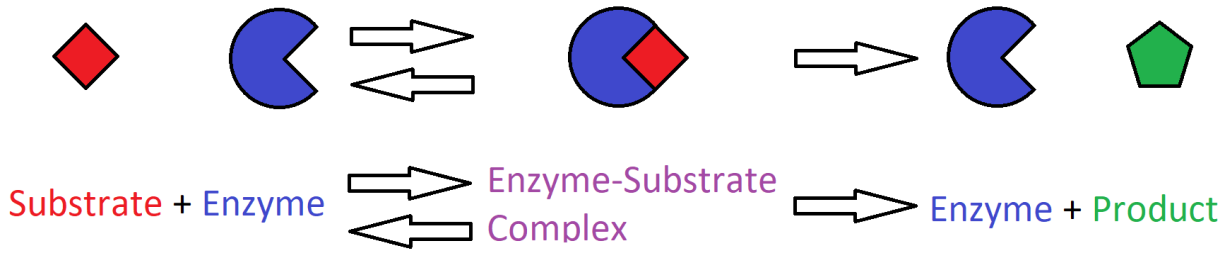
Mathematical Model

Variable

Parameter

Task 2 – Modelling Enzyme Catalysis

In biological organisms, enzymes catalyse reactions. Enzymes act on molecules called substrates and change them into different molecules which are called products, without the enzyme being used up. This process is illustrated in the diagram below.



In the table below, list the reactions, write down what are the variables and what are the parameters, as well as any notes you feel might be useful. There are three reactions. The first one has been done to help you.

Reactions	Variables?	Parameters?	Notes
1. Substrate + Enzyme → Enzyme-Substrate Complex S + E → C	Amount of substrate Amount of enzyme Amount of complex	Rate (speed) of substrate-enzyme bonding	Reaction is reversible It is the opposite/inverse of reaction 2
2.			
3.			

Task 3 – Why do we model?

In pairs, try to come up with 2 or 3 reasons why it might be useful to use a mathematical model rather than do an experiment. One has been done to help you.

Expensive	Biological experiments can be very expensive (require organisms, instruments, machines etc.), but once an accurate model is derived it is comparatively much, much cheaper.

Baseline Assignment

Assignment Title: Mathematical Modelling and Auxin Transport

Instructions:

- Carry out some independent research on the plant hormone auxin. Consider: what it is, what it does, why this is useful, and why/how it is modelled mathematically (some research articles to get you started are listed in Appendix 3).
- Write a report on the importance of mathematical modelling in biology, with specific reference to the plant hormone auxin (min. 250 words). A good report will discuss several examples of the use of maths in a biological context, before then discussing auxin specifically. You may discuss examples that have been talked about in tutorial 1, however you must include at least one example that is new and independently researched by you. (50%)
- Solve a problem sheet with 10 questions. (50%)

Success Criteria:

- Your report should be targeted towards someone with no experience of mathematical modelling, i.e. when you use key words/concepts in your essay you must define them in your own words. Examples discussed should be referenced appropriately (see Appendix 1).
- Your solutions to the problems in the problem set should clearly show your thought processes, and be logically sequenced. Solutions must also be presented in a style appropriate to mathematics (see Appendix 2).

The baseline assignment should be typed in Microsoft Word, and contain both your essay and solutions to the problem set on separate pages. Please remember to include your name on all pages of the assignment, and if possible staple multiple pages together.

Tutorial 2 – Modelling with Differential Equations

What is the Purpose of Tutorial 2?

- Understand a differential equation as an equation that describes the rate of change of a variable.
- Construct appropriate mathematical models from descriptions of biological systems.
- Explain how the standard model of auxin transport relates to the biological properties of the system.

Task 1 – Rates of Change

In the space below, write a definition of rate of change in your own words, and an example

Task 2 – Converting reactions into equations

Read the table below, and compare the reactions to the equations that model them. Note that the symbol ∅ denotes something that we are not interested in modelling.

Type of Reaction	Description	Diagram	Function(s)
Binding	e.g. enzyme e binding to substrate s to produce complex c at rate β	s + e → c	$s' = -\beta se$ $e' = -\beta se$ $c' = \beta se$
Dissolution	e.g. enzyme-substrate complex c breaks back down into separate	c → s + e	$c' = -\gamma c$ $s' = \gamma c$

	enzyme e and substrate s at rate γ		$e' = \gamma c$
Conversion	e.g. enzyme-substrate complex c converts into enzyme e and product p at rate δ	c → e + p	$c' = -\delta c$ $e' = \delta c$ $p' = \delta c$
Production	Production of a molecule that we want to model from something we are not interested in modelling at rate α	∅ → x	$x' = \alpha$
Degradation	Destruction of a modelled molecule at rate μ	x → ∅	$x' = -\mu x$
Activation	e.g. production of molecule y at rate α is activated when the amount of molecule x is above θ	$\emptyset \rightarrow y$ ↑ x	$y' = \alpha \frac{x}{\theta + x}$
Inhibition	e.g. production of molecule y at rate α is inhibited when the amount of molecule x is above θ	$\emptyset \rightarrow y$ T x	$y' = \alpha \frac{\theta}{\theta + x}$

What do you notice about the letters and symbols used to denote a) variables and b) parameters?

What do you notice about which variables the equations depend on?

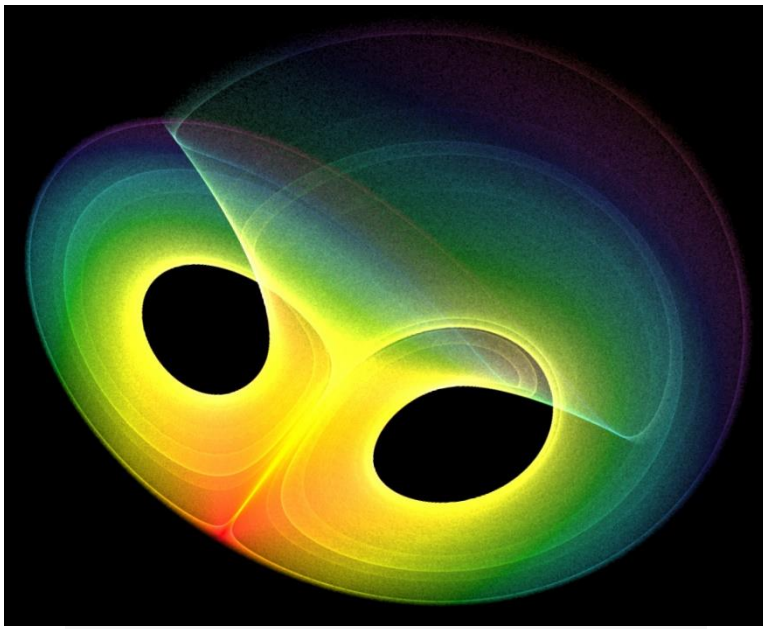
Task 3 – A Mathematical Model of Enzyme Catalysis

Now, working in pairs, try to write a mathematical model which describes the enzyme catalysis reaction that we considered in the last tutorial

Assignment 2

Complete the problem set on matching equations and reactions.

Tutorial 3 – Analysing Differential Equations



What is the Purpose of Tutorial 3?

- Define the terms initial condition and steady state.
- Describe the conditions for a differential equation to be a reasonable model of a biological system and explain how this differs from a model being realistic.
- Classify the three key types of steady state solution to the auxin transport model and explain how to test their stability.

Task 1 – Estimating the Rate of Change

We can estimate the rate of change of a function $f(x)$ with the formula

$$f'(x) \approx \frac{f(x+h) - f(x)}{h}$$

when h is sufficiently small (close to zero).

What happens to $f'(x)$ when $f(x+h) = f(x)$? What do you think this means for $f(x)$?

Rearrange the formula to make $f(x+h)$ the subject. Assuming that $f(x)$ is defined for $0 \leq x$, what does this mean if we know $f(0)$? What are the advantages of this if we know what $f'(x)$ is, but don't know what $f(x)$ is?

Task 2 – Steady States and Initial Conditions

In the spaces below write down definitions in your own words of:

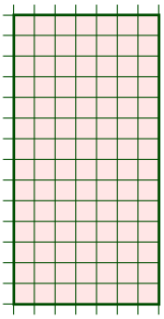
Steady State

Initial Condition

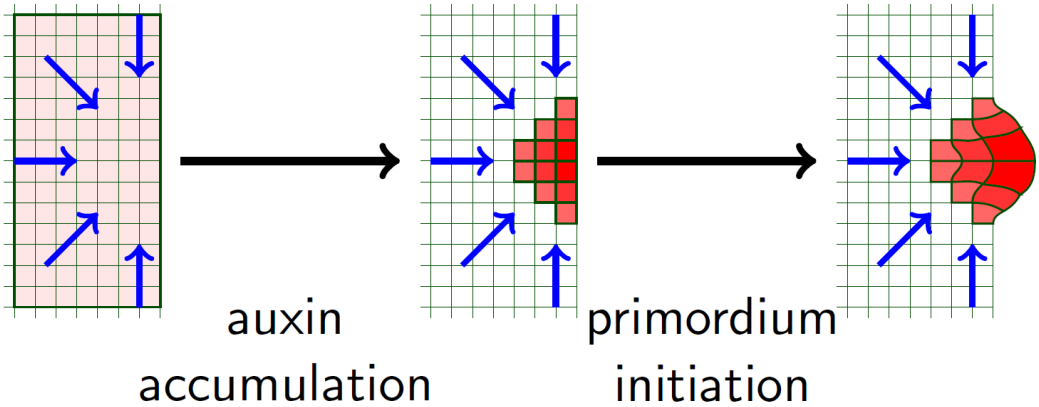
Task 3 – The key types of Auxin Distribution Patterns

The diagrams below are examples that describe the main types of auxin distribution patterns encountered in nature. In the diagrams, the shade of red represents the level of auxin (darker shade meaning more auxin), and blue arrows represent the direction of PIN-mediated auxin transport.

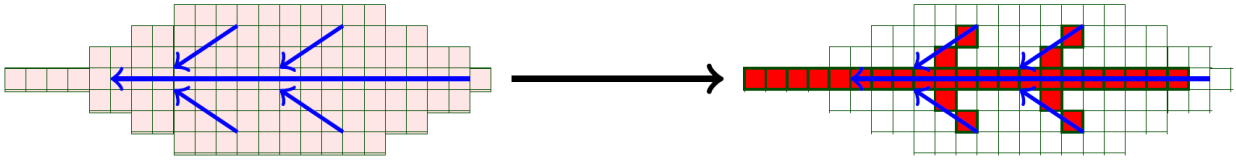
Examine the diagrams, and write down a description of the distribution patterns (focus on how much auxin there is, how it is distributed, how/where is it being transported) in the space provided.



Homogeneous Pattern



Spot Pattern

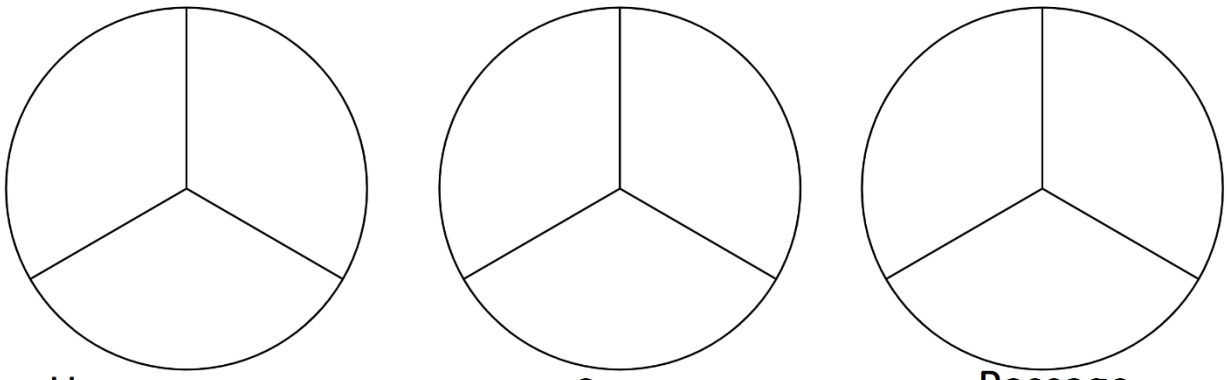


vein formation

Passage Pattern

Recall the three-cell auxin model that we discussed in assignment 2. Based on the descriptions of types of pattern, why do you think we use a three-cell domain to examine the model?

In the three-cell domain diagrams below, shade the levels of auxin and draw arrows representing the transport of auxin for each of the three types of pattern.

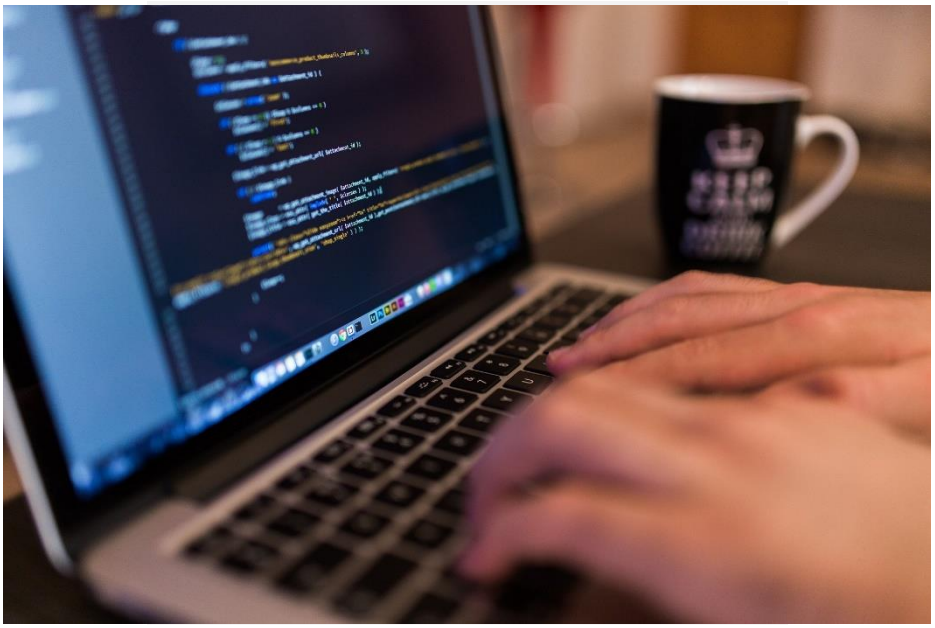


Homogeneous Spot Passage

Assignment 3

Complete the worksheet on calculating steady states.

Tutorial 4 – Solving Differential Equations in Python



What is the Purpose of Tutorial 4?

- Understand basic Python syntax.
- Formulate a differential equation, solve it numerically, and visualise the solution all in Python.
- Assess the stability of the three types of solution to the auxin transport model using Python.

Task 1 – Getting to Grips with Python

After completing the worksheet on calculations with Python, answer the following questions:

Does Python Obey the rules of BIDMAS?

How do we define the a) multiplication, b) index operations in Python?

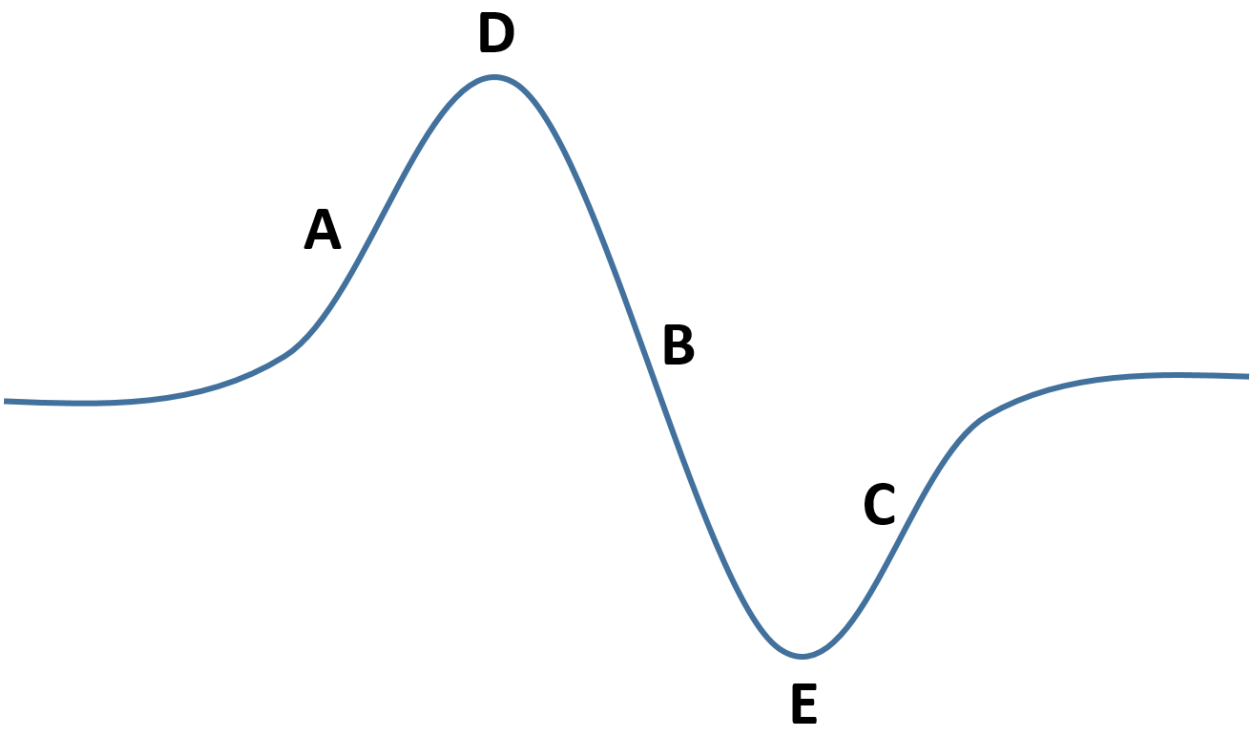
What is an array? Which elements are accessed by a) [0], b) [5], c) [-1]?

Can you multiply an array by a number? What happens?

How do you a) specify a function, b) specify a function's output?

Task 2 – Introducing Stability

Consider the diagram below



If the curve above can be defined by $y = f(x)$ for some function of x, what can you say about the values of the rate of change of $f(x)$ (i.e. its gradient or $f'(x)$) at the points A, B, and C?

Since the curve is 'smooth' (i.e. no breaks or sharp changes), what would you infer about the 'smoothness' of its rate of change?

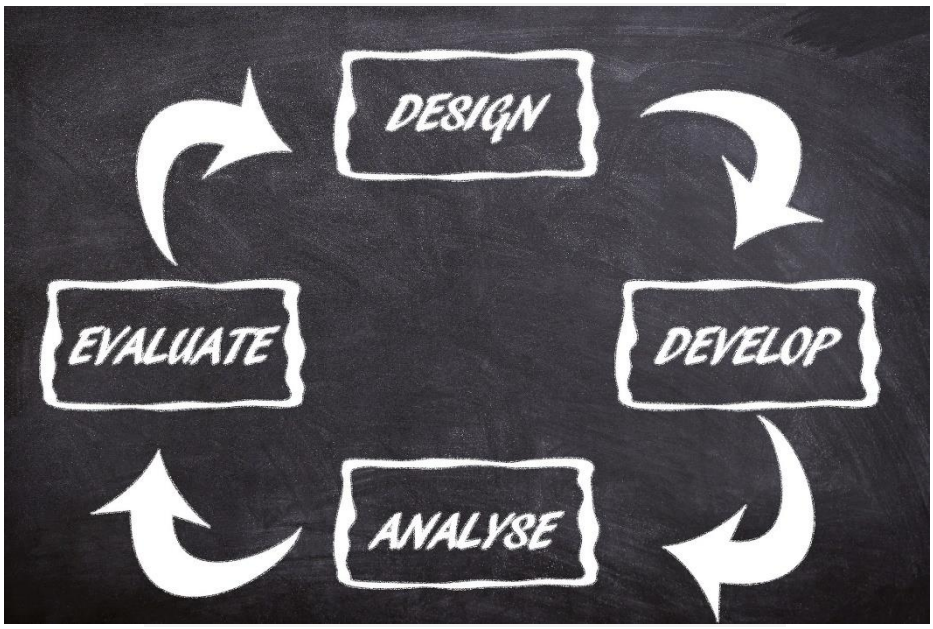
From this can you deduce what the rate of change of $f(x)$ is at the points D and E?

Imagine a ball perfectly at rest at point D. What would happen if you gave it a small push to either the left or right? What if you did the same but at point E?

Assignment 4

Complete the Python worksheet on formulating functions and plotting solutions.

Tutorial 5 – Evaluating Mathematical Models

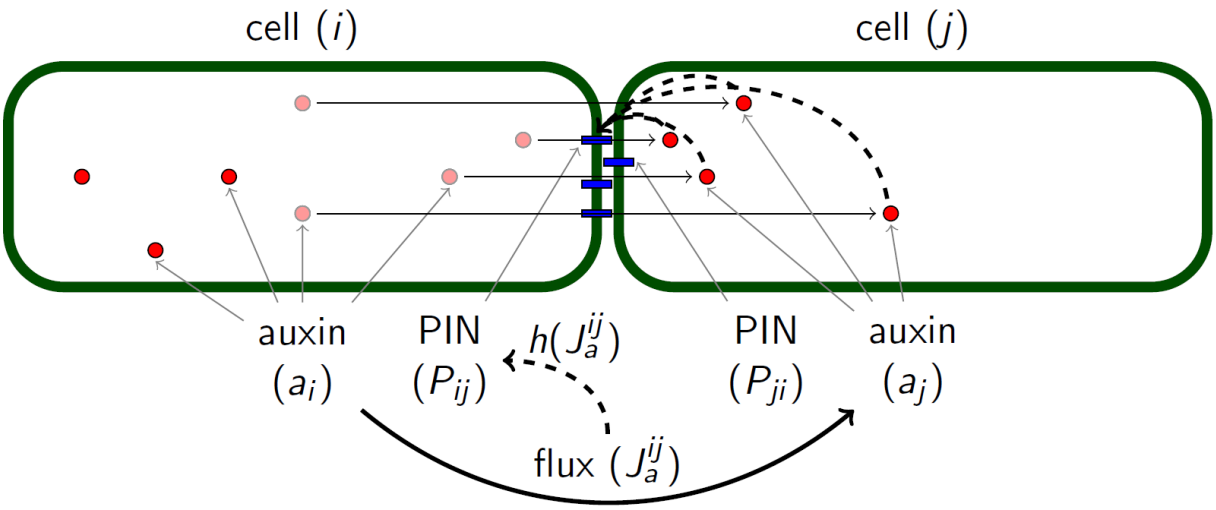


What is the Purpose of Tutorial 5?

- Identify some assumptions made about the biological system when its mathematical model was derived.
- Interpret what the analysis of a mathematical models suggests about the biological system.
- Suggest ways in which models can be improved.

Task 1 – Identifying Assumptions

Examine the diagram below describing a model for auxin transport.



According to the diagram, what causes PIN proteins to become bound to the cell membrane?

Look at the distribution of the auxin in the diagram, and the distribution of the PIN, how is it different to the model we have discussed?

Auxin must move through the cell wall to travel between cells, what does the model we have discussed assume about the time that this takes to happen?

In the model, we only consider the PIN that is bound to the membrane and how the binding is influenced. Since PIN is a protein which is produced within cells, what does this assume about what happens to PIN within the cell?

For your reference, here is the model that we have discussed.

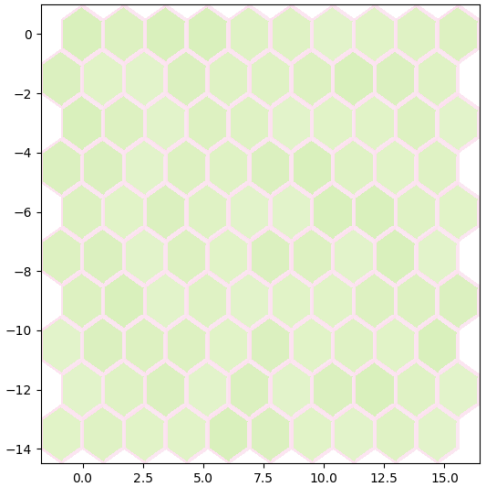
$$
\begin{aligned}
a_1' &= \alpha - \mu a_1 - \beta(a_1P_{12} - a_2P_{21}) - \beta(a_1P_{13} - a_3P_{31}) \\
a_2' &= \alpha - \mu a_2 - \beta(a_2P_{21} - a_1P_{12}) - \beta(a_2P_{23} - a_3P_{32}) \\
a_3' &= \alpha - \mu a_3 - \beta(a_3P_{31} - a_1P_{13}) - \beta(a_3P_{32} - a_2P_{23}) \\
P_{12}' &= \omega|a_1P_{12} - a_2P_{21}|^+ - \delta P_{12} \\
P_{13}' &= \omega|a_1P_{13} - a_3P_{31}|^+ - \delta P_{13} \\
P_{21}' &= \omega|a_2P_{21} - a_1P_{12}|^+ - \delta P_{21} \\
P_{23}' &= \omega|a_2P_{23} - a_3P_{32}|^+ - \delta P_{23} \\
P_{31}' &= \omega|a_3P_{31} - a_1P_{13}|^+ - \delta P_{31} \\
P_{32}' &= \omega|a_3P_{32} - a_2P_{23}|^+ - \delta P_{32}
\end{aligned}
$$

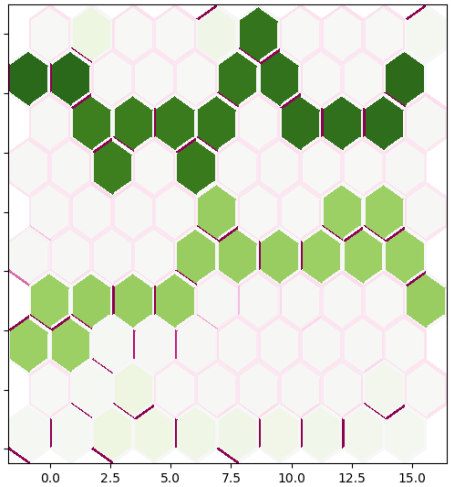
Look at the parameters in the model. What do they suggest about the similarities and differences between cells?

Can you think of any other possible assumptions that have been made about the mathematical model? Describe them here.

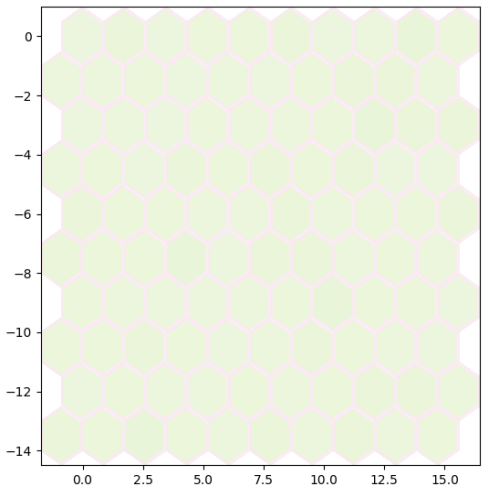
Task 2 – Evaluating Model Solutions

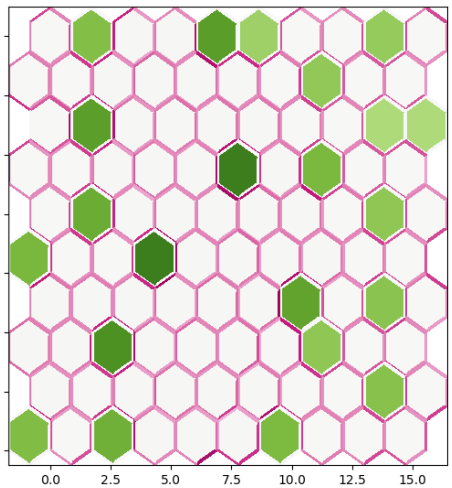
Below is a sample initial condition and steady state solution of a mathematical model of auxin transport (not necessarily the one that we have previously discussed).





Here is another solution of the same model, using different parameter values.





Without knowing the precise structure of the model, what can we say about the assumptions that it was based on, and what this suggests about the biological system?

Task 3 – Improving Models

Based on the assumptions that you listed earlier, write some suggestions about how the model might be improved.

Final Assignment

Solve and analyse a mathematical model of auxin transport in plants and produce a report (2000 words) based on your work. Your models will resemble the basic auxin transport model that has been discussed in tutorials, however you will each be assigned a different term describing the allocation of PIN. You may include extra terms if you wish, but make sure to justify their inclusion carefully and discuss their influence.

The report should consist of four main parts:

1. Introduction: Define auxin, discuss its role in healthy plant growth and how this relates to its transport. Introduce the concept of mathematical modelling and how it can help scientists researching plants.
2. Modelling: Present your mathematical model, making sure to explain how each term is derived, specifically how it relates to the relevant biological process. Briefly discuss the methods you will be using to solve and analyse your model.
3. Results: Perform an analysis of your model, making sure to include the types of patterns it can generate, and how the initial conditions and parameters affect the final patterns. Present some numerical solutions of your model, making sure to include the initial conditions and parameter values in each case. (Any computer code used to solve or analyse your model should be included either in the form of an appendix, or submitted as a separate file.)
4. Conclusion: Summarise what your model tells you about auxin transport in plants, what does your analysis suggest about the biological conditions for certain types of patterns to be formed?

Success Criteria

- All my work is correct and neatly presented
- I have used correct terminology throughout
- I have used evidence from research articles to support my description of auxin and its transport, and referenced these appropriately
- I have analysed my model carefully and presented the results clearly and logically (if possible, a diagram would be good!)
- I have presented some sample solutions of my model, making sure to include the relevant initial conditions and parameter values (a table of these might be a good idea)
- I have labelled all equations, figures, and tables and referred to each of these within the main body of text (consider carefully whether an equation, figure, or table is necessary for your essay if you do not refer to it naturally in your text)
- My word count is within +/- 10% of 2000. Remember that references, captions of figures, and contents of tables do not count towards the word count.

Tutorial 6 – Feedback tutorial

What is the Purpose of Tutorial 6?

- To receive feedback on your final assignment
- To respond to the feedback from your Uni Pathways teacher
- To write targets for improvement on your final assignment

Final assignment feedback from your Uni Pathways Teacher

(Remember to look at the mark scheme to help you understand what you have done well so far, and how you can do even better in your final assignment)

Here are three things that my Uni Pathways Teacher thought I did well in my draft assignment
•   •   •

Here are three things that my Uni Pathways Teacher thinks that I could do to get a higher mark in my final assignment
•   •   •

Tasks from my Uni Pathways Teacher to do during the feedback tutorial to help me improve
•   •   •
My response:

Actions I will take to improve my final assignment after this tutorial…
•   •   •

Hand in date for my final assignment:	

Tutorial 7 – Final tutorial

What is the Purpose of Tutorial 7?

- To receive feedback and a grade on your final assignment.
- To reflect on the programme including what you enjoyed and what was challenging.
- To ask any questions you may have about university.

Final assignment feedback from my Uni Pathways Teacher

Final mark:	University style grade:
Feedback: Here are three things that my Uni Pathways teacher thought I did well in my final assignment • • •	

Here are three things that my Uni Pathways teacher thinks I should remember for when I am doing this kind of study in the future
• • •

University

What questions do you still have about University after taking part in Uni Pathways?
• • •

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?
• • •

What did you find challenging about the programme?	How did you overcome these challenges?
• • •	• • •

Appendix 1 – Referencing correctly

When you get to university, you will need to include references in the assignments that you write, so we would like you to start getting into the habit of referencing in your Brilliant Club assignment. This is really important, because it will help you to avoid plagiarism. Plagiarism is when you take someone else's work or ideas and pass them off as your own. Whether plagiarism is deliberate or accidental, the consequences can be severe. In order to avoid losing marks in your final assignment, or even failing, you must be careful to reference your sources correctly.

What is a reference?

A reference is just a note in your assignment which says if you have referred to or been influenced by another source such as book, website or article. For example, if you use the internet to research a particular subject, and you want to include a specific piece of information from this website, you will need to reference it.

Why should I reference?

Referencing is important in your work for the following reasons:

- It gives credit to the authors of any sources you have referred to or been influenced by.
- It supports the arguments you make in your assignments.
- It demonstrates the variety of sources you have used.
- It helps to prevent you losing marks, or failing, due to plagiarism.

When should you use a reference?

You should use a reference when you:

- Quote directly from another source.
- Summarise or rephrase another piece of work.
- Include a specific statistic or fact from a source.

How do I reference?

There are a number of different ways of referencing, and these often vary depending on what subject you are studying. The most important to thing is to be consistent. This means that you need to stick to the same system throughout your whole assignment. Here is a basic system of referencing that you can use, which consists of the following two parts:

1. **A marker in your assignment**: After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written it your own words) you should mark this is in your text with a number, e.g. [1]. The next time you use a reference you should use the next number, e.g. [2].
2. **Bibliography**: This is just a list of the references you have used in your assignment. In the bibliography, you list your references by the numbers you have used, and include as much information as you have about the reference. The list below gives what should be included for different sources.

    a. **Websites** – Author (if possible), title of the web page, website address, [date you accessed it, in square brackets].

    E.g. Dan Snow, 'How did so many soldiers survive the trenches?', http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [11 July 2014].

    b. **Books** – Author, date published, title of book (in italics), pages where the information came from.

    E.g. S. Dubner and S. Levitt, (2006) *Freakonomics*, 7-9.

    c. **Articles** – Author, 'title of the article' (with quotation marks), *where the article comes from* (newspaper, journal etc.), date of the article.

    E.g. Maev Kennedy, 'The lights to go out across the UK to mark First World War's centenary', Guardian, 10 July 2014.

Appendix 2 – Writing Mathematically

When writing your assignment it is important that you write in a mathematical style. If you want to talk about a variable, a parameter, or a short equation within the main body of text it must use a mathematical font. For instance, if I wanted to refer to the line equation $y = mx + c$ it must be inserted using Insert -> Equation -> Insert New Equation.

For a longer equation/working it should be presented separately from the main text:

$$\begin{aligned} x &= \left(20 \times 6 - \sqrt{16}\right) \div 4 \\ &= (120 - 4) \div 4 \\ &= 116 \div 4 \\ &= 29 \end{aligned}$$

The equation should be presented by itself, centred, with a line break between either side of the equation and the main text. Displayed equations should also be aligned at the = sign. To do this you must first write the equation over multiple lines by pressing shift + enter at the end of each line to immediately start a new equation, then selecting all the lines in the equation, right-click and select 'Align at ='. There should only ever be one = per line!

If there is an equation that you will be referring to a lot, say $y = mx + c$ again, then it should be presented as a display and labelled as follows:

$$y = mx + c. \tag{1}$$

You do this by writing the equation as before, then on a new line underneath write the (1) label, making sure to align it to the right. You can then refer to this equation anywhere in the main body of your text as Equation (1). Equations should be numbered in ascending order, starting from the first one, so the next equation could look like

$$y = ax^2 + bx + c. \tag{2}$$

You can then refer to this as Equation (2). Remember, this should only ever be done for displayed equations that you will be referring to multiple times in the main text.

Appendix 3 – Suggested Literature

Auxin

- O. Leyser, 'Auxin Signaling', *Plant Physiology*, January 2018.
- J. Blakeslee, W. Peer, and A. Murphy, 'Auxin Tranport', *Current Opinion in Plant Biology*, October 2005.
- J. Wiśniewska, J. Xu, D. Seifertová, P. Brewer, K. Růžička, I. Blilou, D. Rouquié, E. Benková, B. Scheres, and J. Friml, 'Polar PIN Localization Directs Auxin Flow in Plants', *Science*, May 2006.
- T. Bennett, G. Hines, and O. Leyser, 'Canalization: what the flux?', *Trends in Genetics*, February 2014.
- M. Sauer, S. Robert, and J Kleine-Vehn, 'Auxin: simply complicated', *Journal of Experimental Botany*, June 2013.

Mathematical Modelling

- K. van Berkel, R. de Boer, B. Scheres, and K. ten Tusscher, 'Polar auxin transport: models and mechanisms', *Development*, May 2013.
- F. Feugier, A. Mochizuki, and Y. Iwasa, 'Self-organization of the vascular system in plant leaves: Inter-dependent dynamics of auxin flux and carrier proteins', *Journal of Theoretical Biology*, October 2005.
- Y. Hayakawa, M. Tachikawa, and A. Mochizuki, 'Mathematical study for the mechanism of vascular and spot patterns by auxin and PIN dynamics in plant development', *Journal of Theoretical Biology*, January 2015.
- M. Heisler and H. Jönsson, 'Modelling auxin transport and plant development', *Journal of Plant Growth Regulation*, November 2006.
- D. Muraro, H. Byrne, J. King, and M. Bennett, 'Mathematical modelling plant signalling networks', *Mathematical Modelling of Natural Phenomena*, July 2013.

Notes

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