PhD Diary Entry for week beginning October 1st 2018

Nathan Hughes

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Contents

1 Review Papers

1.1 Biosynthesis of salicylic acid in plants

- Link: https://doi.org/10.4161/psb.4.6.8392
- SA is found in range of projaryotic and eukaryotic organisms
- *"The most established role of SA is as a signal molecule in plant defense responses."*
- has info on biosynthesis pathways
  - 2 have been proposed in plants
- Studies show it's joint to regulatory functions in plant
- With some plants, it's used to activate "putrid-smelling" compounds that attract pollinating insects
- *"plants synthesize SA from cinnamate produced by the activity of phenylalanine ammonia lyase (PAL)"* - this is found in biochemical studies
  - *Ethyl cinnamate is the ester of cinnamic acid and ethanol. It is present in the essential oil of cinnamon. Pure ethyl cinnamate has a "fruity and balsamic odor*
- *"Genetic studies, on the other hand, indicate that the bulk of SA is produced from isochorismate."*

1.2 Plasmadesmata: A signalling hub at the cellular boundary

- Effective intercellular communication is crucial for the survival of plants.
- Because plant cells are encased in rigid cell walls, direct exchange of cytoplasmic content is only possible via PD
- PD are membrane-lined nanotubes that connect the cytoplasm of adjacent cells.
- PD are highly dynamic communication channels, that can undergo various structural changes and functional modifications
- Recent findings suggest that defence signalling pathways are tightly linked to regulation of PD.
- The restriction of PD-mediated cell-to-cell communication is an essential innate immune response to microbial pathogens
- There is a hint in findings that PD have a novel role as a signalling hub for both symplasmic and cross-membrane pathways.
- In the apoplasmic pathway, signal-generating cells secrete specific ligands into the extracellular matrix, recipient cells perceive the ligands by producing membrane-anchored cognate receptors on the cell surface
- In the symplasmic pathway, signalling molecules are commonly thought to move cytoplasmically through the PD that connect signal-generating cells to their adjacent recipient cells.
- Molecular composition and architecture of PD are unknown (**as of 2015, maybe this has been discovered by now?**)
  - Though a number of proteins have been identified

- The recruitment of specific PD-associated proteins to defence signalling as well as the dispatch of defence proteins to PD illustrate how the regulation of PD is integrated into specific signalling pathways during biotic stress
- Basal immune responses require activation via signalling pathways
  - Including thoes mediated by defence hormones such as SA
  - Elevated levels of SA concentrations during pathogen infection induce restriction to cell-to-cell movement
  - This is done by transcriptomically upregulating the expression of the PD regulators
  - Accumulation of `PDLP5` (*PD-located protein 5*) affects the activity of PD
  - PD permeability is changed by callose deposition
- Effective innate immune responses also involve the recognition of pathogens via membrane-bound receptors at the cell surface levels (Pretty sure this is the same ligands)
- Receptors are partitioned to PD (*clarify what this means*).
- Plant cells can sometimes lose the control of PD gating, this means that the basal defence and systemic resistance are compromised

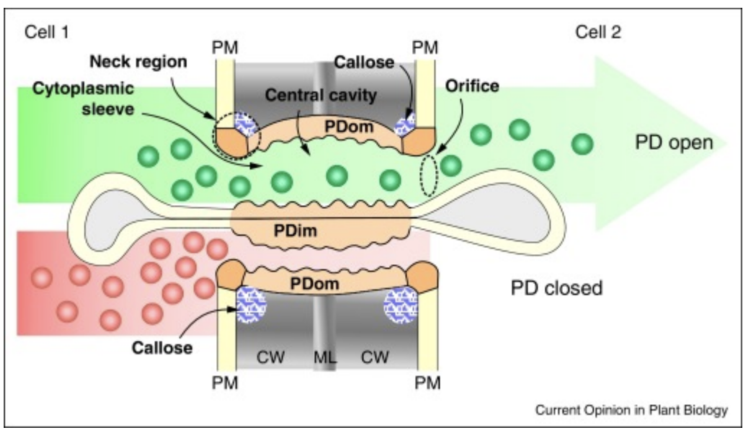

Figure 1: Figure from review on PD - captioned by reviewer: Structure of PD and movement of soluble molecules through PD. Subdomains of PD include: PDom, PD outer membrane; PDim, PD inner membrane; APR, appressed ER; neck region; central cavity; and cytoplasmic sleeve. Green and red balls represent soluble molecules that can move through the cytoplasmic sleeve of PD when PD are open. Increased callose accumulation from basal levels leads to a PD closure. CW, cell wall; ML, middle lamella; PM, plasma membrane.

- Structurally each PD contains a cytoplasmic sleeve
  - Formed between outer and inner membrane linings
  - They are continuous with the PM (Plasma membrane) and endoplasmic reticulum (ER)(figures 2 and 1)
  - The sleeve is thought to provide a passageway for soluble molecules to move through
  - On the other hand, the two membrane linings may provide specialised lipophilic surface within which hypothetic proteinaceous materials are embedded, or to which cytoskeletal elements are attached.

- Current understanding about the outer and inner PD membranes based on lipid composition and trafficking studies hold that they probably differ in their physical and chemical properties from PM and cortical ER.

1.2.1 PD Pore types

- PD pores can be further divided into distinct spatial subdomains:
  - Orifices (two ends of the cytoplasmic sleeves open to the cytoplasm)
  - Neck regions (PD outer membrane at the orifices)
  - Central cavity/region (plasmodesmal bulge occurring at the middle lamella)

1.2.2 Defence signalling pathways regulate PD by recruiting specific PD-associated proteins

- Many environmental signals and challenges alter PD dynamics
- Recent studies have begun to unravel how carious cell signalling pathways might be integrated with the regulation of PD permeability
  - Especially during biotic stress
- These suggest that PD closure is linked to basal defence via proteins that associate or partition to PD from the PM

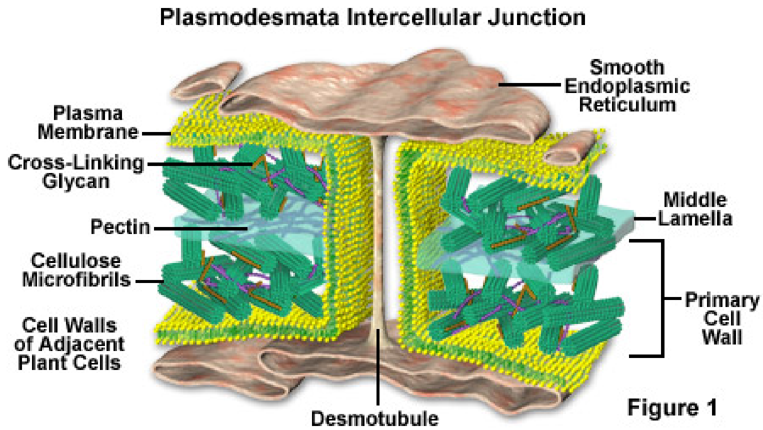

Figure 2: Figure stolen from https://micro.magnet.fsu.edu/cells/plants/plasmodesmata.html

1.3 Signalling Mechanisms underlying systemic acquired resistance to microbial pathogens

- Link: https://doi.org/10.1016/j.plantsci.2018.01.001
- In plants active defence against microbial pathogens involves he induction of elaborate defence signalling pathways
- Some of these can provide protection locally to the infection
- Others provide systemic resistance throughout the plant (including non-infected parts)

- Local resistance includes species level resistance to non-host pathogens
  - Basel resistance to virulent pathogens
  - Or race-specific resistance to avirulent (Avr) pathogen isolates.
- Discusses how pathogen infection has two mechanisms, besides local defence
  - Systemic acquired resistance (SAR)
  - Induced systemic resistance (ISR)
- SAR is great, it might be possible to use to create transgenerational immunity
- SAR is very rapidly moving, the mobile signals for which are able to activate within 4-6 hrs of primary infection
- Symplast
  - Network of cytoplasm interconnected by specialised openings called Plasmadesmata (PD)
- SAR mobile signals are highly conserved because petiole exudate from pathogen-infected plants of one species can induce SAR in unrelated plant species
  - *I don't quite understand this?!*

2 Meeting with Richard

2.1 Important names to look up

- Katherine Denby, York
- David Wild, Warwick

3 Key buzz words/phrases to expand knowledge of

3.0.1 PAMP

- https://www.sciencedirect.com/topics/immunology-and-microbiology/pathogen-associated-molecul
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2949051/
  - It was clear that purified molecules or curde extracts from microbes or plants could induce activation of general defence responses
  - "gene-for-gene hypothesis" - *was* often associated with hyper sensitive response and highly used in breeding programmes
- Pathogen-associated molecular pattern
- pathogen and damage associated molecular patterns (PAMPs and DAMPs) are produced by pathogen and host cells, respectively
- They interact with multiple families of pattern recognition receptors (PRRs)

3.0.2 Avirulent

Not virulent - nonpathogenic

3.0.3 Avirulence genes

- https://www.sciencedirect.com/science/article/pii/S1369526600000820?via%3Dihub
- Originally defined by their negative impact on the ability of a pathogen to infect their host plant
- Though many are now known to represent a subset of virulence factors involved in the mediation of the host-pathogen interaction.
- Characterisation of avirulence genes has revealed that they encode an assortment of proteins and belong to several gene families
- Although the biochemical functions of the avirulence gene products are unknown.
- Studies are beginning to show the relationship between avirulence and virulence activities of the proteins
- Understanding of these genes is said to vital to generating insight into plant defence mechanisms

3.0.4 Gene-for-gene relationship

- https://www.sciencedirect.com/science/article/pii/S0065352709075010
- Thought as a "race-specific" resistance
- wherein the outcome of an attempted infection is determined by the genotypes of both host and pathogen

3.0.5 Pattern recognition receptors (PRR)

- https://www.sciencedirect.com/science/article/pii/S1471490614000945

3.0.6 Ligands

- https://www.khanacademy.org/science/biology/cell-signaling/mechanisms-of-cell-signaling/a/signal-perception
- In coordination chemistry, a ligand is an ion or molecule that binds to a central metal atom to form a coordination complex.
- It's a binding site / receptor
- They all come in matched pairs
- With a receptor recognising just one (or a few) specific ligands, and a ligand binding to just one (or a few) target receptors.
- Binding of ligands to a receptor changes its shape or activity.
- Binding allows it to transmit a signal or direclty produce a change inside of the cell

3.0.7 Gene regulatory network

- A GRN is a collection of molecular regulators
- They interact with each other and with other substances in the cell
- They govern the gene expression levels of mRNA and proteins.
- They play a central role in morphogensis
  - is the biological process that causes an organism to develop its shape.
  - Along with control of cell growth and cellular differentiation it is a fundamental aspects of developmental biology

3.0.8 Transcription

- Transcription is the first step of gene expression
- In which a particular segment of DNA is copied into RNA (particularlly mRNA)
- By the enzyme RNA polymerase
  - RNAP locally opens the double-stranded DNA (usually about four turns of the double helix)
  - This exposes the nucleotides so they can be used as a template in transcription

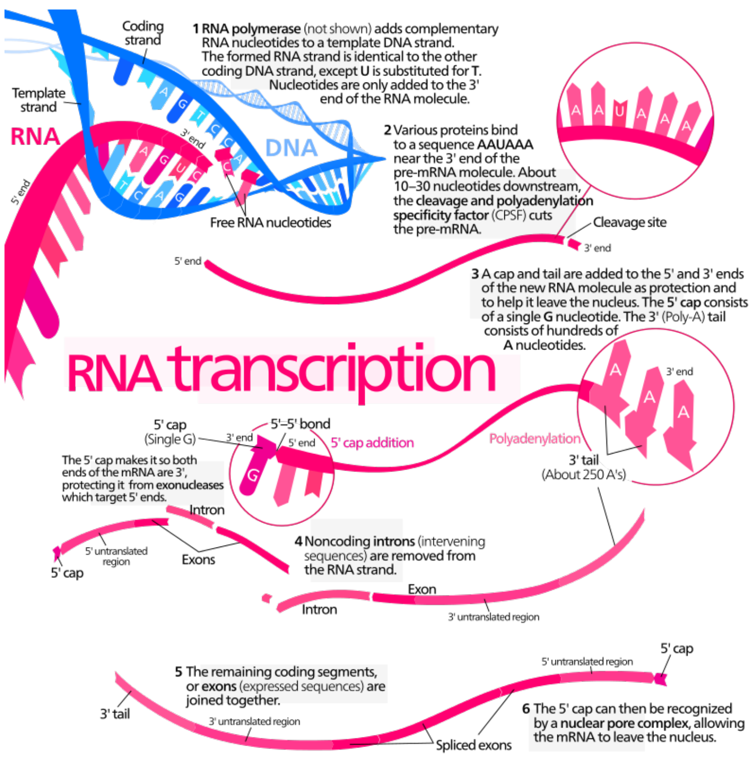

Figure 3: Transcription stages

3.0.9 Transcription factors

- A transcription factor (TF) (or sequence-specific DNA-binding factor) is a protein that controls the rate of transcription of genetic information from DNA to mRNA by binding to a specific DNA sequence

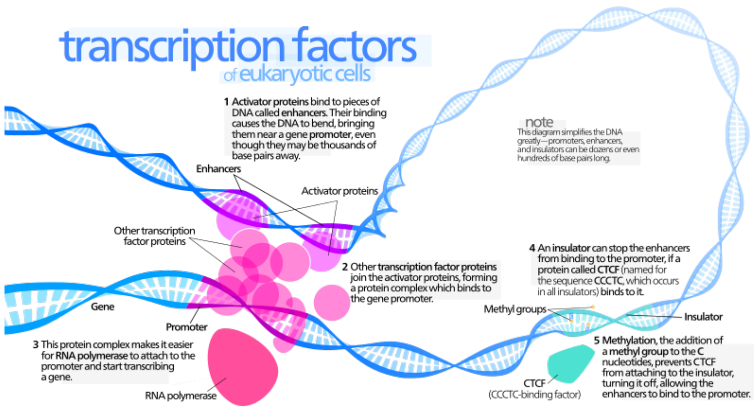

Figure 4: Transcription Factors (wikipedia sourced)

3.0.10 Phloem

- https://www.diffen.com/difference/Phloem_vs_Xylem

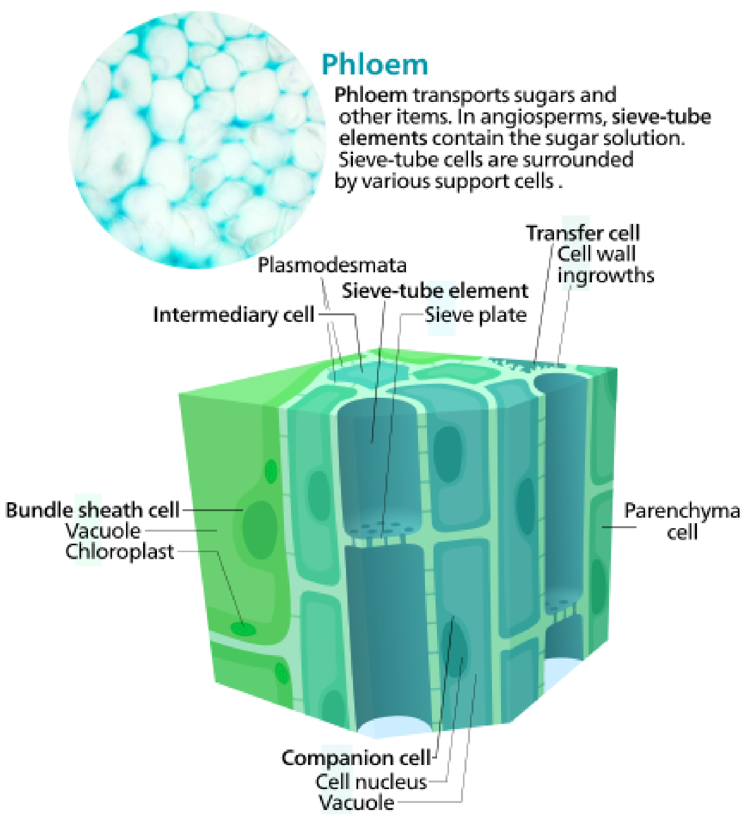

Figure 5: Phloem diagram (stolen from Wikipedia)

3.0.11 Apoplast /Symplast

- An apoplast is the space outside the plasma membrane within which material can diffuse freely.
- Symplast is the inner side of the plasma membrane in which water and low-molecular-weight solutes can freely diffuse. Symplast cells have more than one nucleus

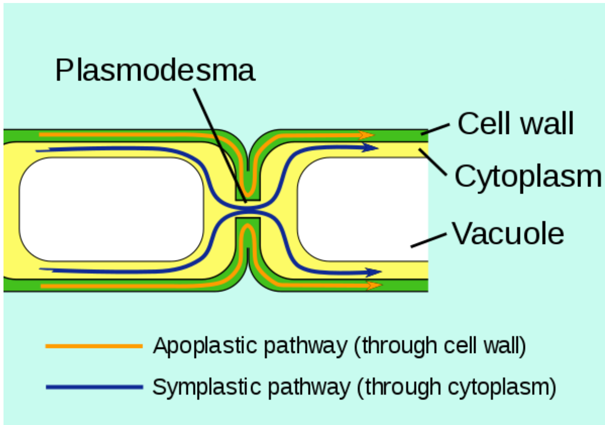

Figure 6: Pathways diagram (stolen from Wikipedia)

3.0.12 Signalling pathways

- https://www.khanacademy.org/science/biology/cell-signaling/mechanisms-of-cell-signaling/a/introduction-to-cell-signaling

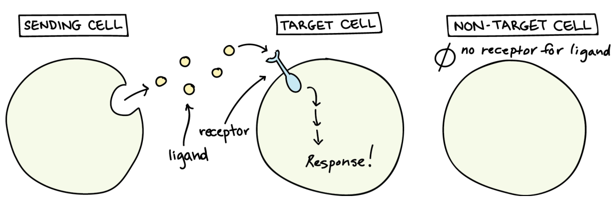

Figure 7: Cell Signalling

- Signalling revolves around a signalling molecule (ligand) binding to a receptor as per fig:7.
- Intracellular receptors are receptor proteins found on the inside of the cell
  - Typically in the cytoplasm or nucleus
  - Usually small and hydrophobic since they must be able to cross the plasma membrane to reach their receptors
  - When a hormone enters a cell and binds to its receptor it causes the receptor to change shape allowing the receptor-hormone complex to enter the nucleus (if it wasn't already there)
  - It the ncan regulate gene activity.
  - Hormone binding exposes regions of the receptor that have DNA-binding activity
  - Meaning that they can attach to specific sequences of DNA
- Cell surface receptors are membrane-anchored proteins that bind to ligands on the outside surface of the cell

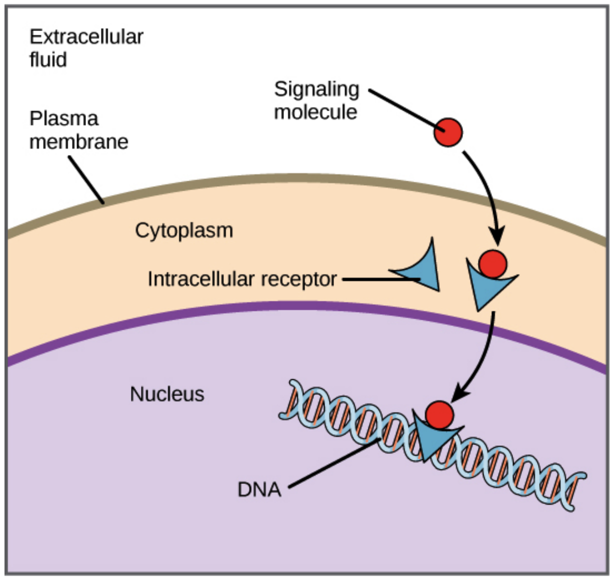

Figure 8: Receptors/Ligands

- In this type of signalling, the ligand does not need to cross the plasma-membrane
- So, many kinds of molecules (including hydrophilic) may act as ligands
- A typical cell-surface receptor has three different domains, or protein regions:
  - Extracellular
  - Hydrophobic
  - Intracellular
- The size and structure of these domains can vary a lot depending on the type of receptor
- the hydrophobic region may consist of multiple stretches of amino acids that criss-cross the membrane

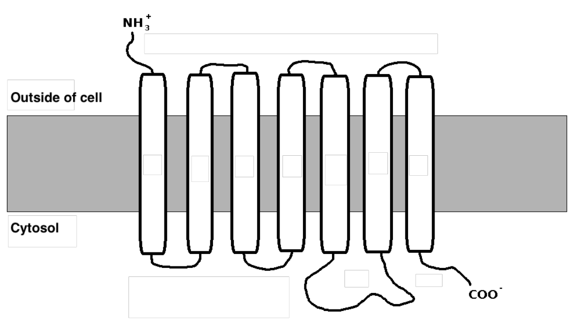

Figure 9: This diagram shows a G protein-coupled receptor (GPCR) (stolen from Khanacademy)

3.0.13 Callose

- https://www.wikiwand.com/en/Callose
- Callose is a plant polysaccharide

- Is composed of glucose
- It's very important for the permeability of plasmodesmata in plants
- Plants' permeability is regulated by PDC
- The amount of callose that is built up at the plasmodesmatal neck determines the conductivity of the PD

4 Random bits of Nomenclature

- `HR` Hypersensitive reaction
- `Hrp` HR and pathogenicity
- `NLS` nuclear localisation signals
- `R` Resistance

5 Moved to next week!

5.0.1 TODO Transcriptome

5.0.2 TODO Kinase

5.0.3 TODO DNA Methalation

5.0.4 TODO DNA Aceltylation

5.0.5 TODO Pathways

5.0.6 TODO Induced systemic resistance (ISR)

5.0.7 TODO Systemic acquired resistance (SAR)

6 Thoughts/Questions

- The understood pathogen-defence systems, they occur in *all* plants or are there known exceptions and why?
- Salicylic acid, plants which respond to it positively how does their immune response get triggered?
- What's the difference in how PD work and other forms of transport, are they just larger?
  - ATP-binding cassette (ABC) transporters for example?
- Do some cells work as repeater towers for signals? Or is it a linear signalling amount throughout a chain. i.e. does a signal ever need to be made stronger when travelling
- When do PD appear in the Phylo, do algae have them? What did things do before they evolved?
  - Single celled algae obviously don't, though is there perhaps other methods used in older species?