Triggering the Trap: How Venus Flytraps Sense Their Prey

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Abstract

The venus flytrap is a **carnivorous plant** that lives in the swamps of the Carolinas. These plants function by sensing insect prey with **trigger hairs**, which are attached to lobe cells. When triggered correctly, a **flow of ions** occurs, which alters the potential of the cells and their charge. This is followed by the development of an **osmotic gradient**, which increases **turgor pressure** in **midrib cells** at the base of the plant, causing them to invert, which rapidly shuts the plant’s leaves. When the prey is captured, the plant uses **signal pathways** to decompose it and absorb its nutrients.

Introduction


https://bergenwatergardens.com/venus-fly-traps/

- Venus flytraps are **plants**, and therefore,
    - They do NOT have a central nervous system
- The **action potential** CANNOT be generated by neurons

So what generates the action potential necessary to close the venus fly trap on its prey?

ION FLOW

Introduction

- Venus flytraps are one of more than 600 species of **carnivorous plants**- all of which generate action potentials without a nervous system.

- The soil in the natural habitat of the venus flytrap **does not contain enough nutrients** for their survival. This is why they rely on insects as a nutrient source in addition to the energy gained from photosynthesis.

http://www.youtube.com/watch?v=bPQsVY6rduY

Sensory Transduction

The trigger hairs on the plant act as **mechanoreceptors**. Induced by touch, the trigger hairs' displacement provokes an **ion cascade**, generating an **action potential** (Hedrich, R. & Kreuzer, I.)

calcium ion influx leads to **depolarization**

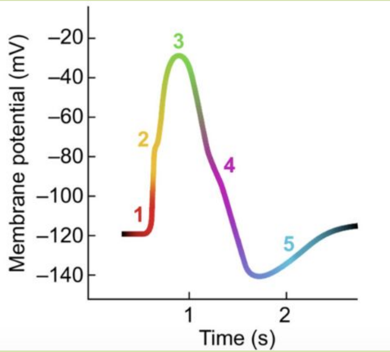
calcium drops, anion channel deactivates, **K+ and H+ are released**, and the cell **repolarizes**

release of K+ results in **turgor loss** in the motor cells of the inner leaflet

pressure balance between inner and outer leaflet collapses

open (**concave**) trap shape flips to closed (**convex**) shape

Sensory Transduction



https://doi.org/10.1111/nph.19113

	AP phase	Ion flux	Transporters involved
1	Increase in $[Ca^{2+}]_{cyt}$, initial depolarization	Ca^{2+} influx and Ca^{2+}-induced Ca^{2+} release from the ER	DmGLR3.6
2	Rapid depolarization	Ca^{2+}-dependent Cl^- efflux	DmALMT9/12
3	Repolarisation	K^+ efflux	DmSKOR
4	Repolarisation and hyperpolarisation	H^+ efflux	DmAHA4
5	Restoration of the resting potential	Re-uptake of K^+ and Cl^-	DmHAK5, NRT-type anion/H^+ cotransporter

https://doi.org/10.1111/nph.19113

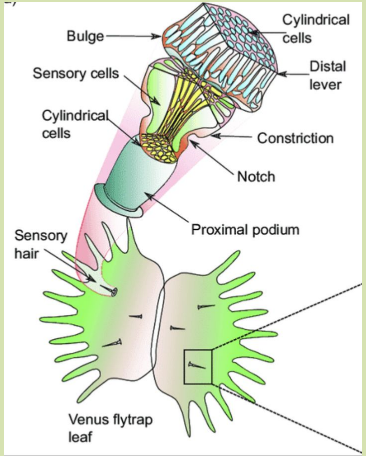
- The **changing membrane potential** is the main supply of energy for the action potential (Hedrich, R. & Kreuzer, I.)

- Rather than neuron signalling, **ion "signalling"** alters this membrane potential and generates flux and charge

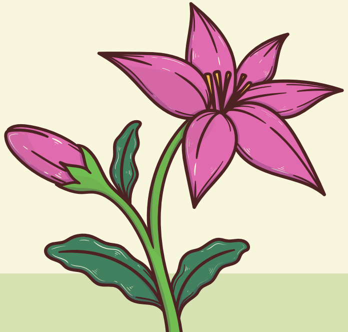
Sensory Transduction

- As the cells move through the phases of the action potentials, **depolarization and repolarization** occur (Hedrich, R. & Kreuzer, I.)

- These changes in polarity cause the **pumps to switch on and off** from activated to deactivated, and vice versa



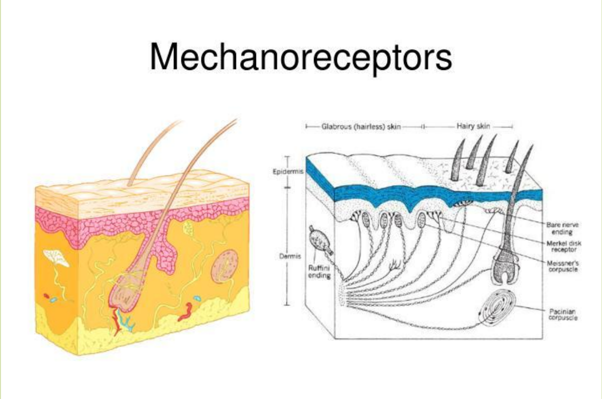
https://www.researchgate.net/publication/348085871_Kinematics_Governing_Mechanotransduction_in_the_Sensory_Hair_of_the_Venus_flytrap



- When a **calcium threshold** is reached, the **electrical signal** can be triggered…

Signal Transmission

When there is enough of a **difference in voltage** in the mechanosensitive ion channels, mechanotransduction occurs in the sensory hair.

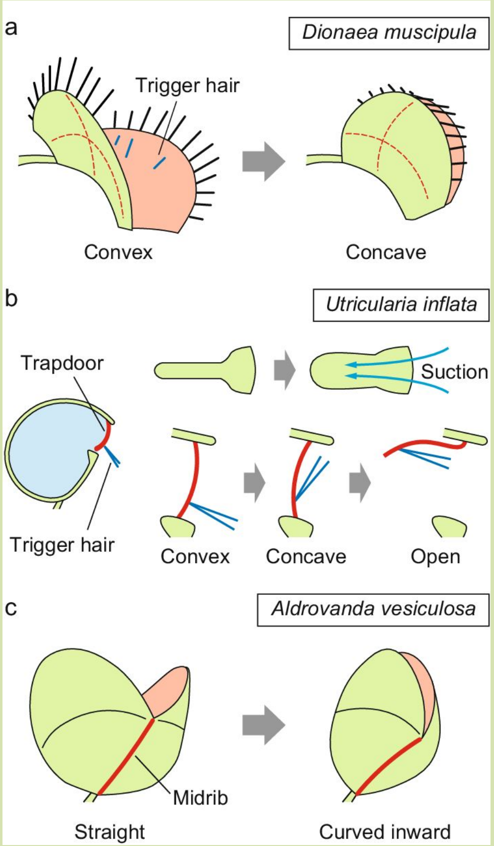


Slideserve.com

- This causes an **electrochemical response** at the hair base, which spreads to the lobe cells.(Saikia et al. 2021)
- As this electrical charge moves towards the center of the trap, it opens **specialized pores** in the outermost layer of the trap's cells, allowing water to rush from cells on the inside of the lobes to cells on the outside. The dramatic change in cell **turgor pressure flips the lobes**, which snap shut. (Jabr, Ferris. 2010.)

Signal Transmission

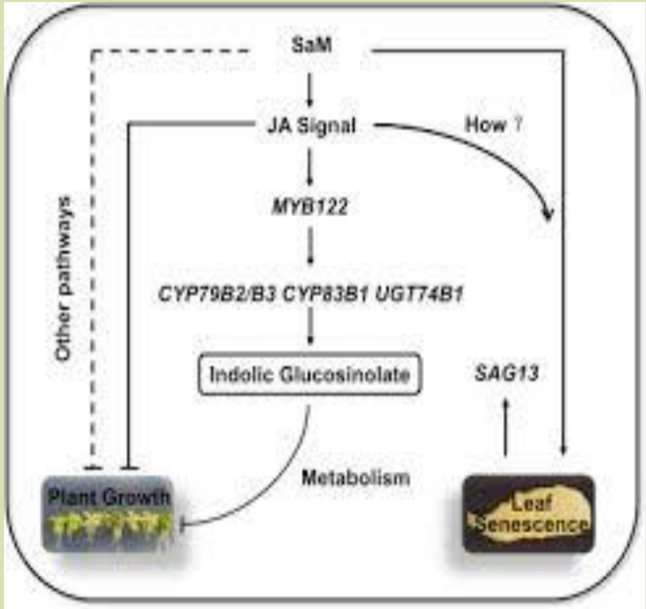
- The **flow of Ca ions** into a midrib cell causes water to rush into the vacuole (**osmotic gradient**), raising turgor pressure. (botany.org)
- When the pressure is high enough, the **midrib cells invert**.
- The trap snaps shut!
- As the prey fights more, the trap closes tighter.
  - More pressure means more cells invert.



https://www.researchgate.net/figure/The-3D-structures-of-carnivorous-plants-contribute-to-their-rapid-movements-a-Snap-trap_fig4_348324260

Signal Transmission

- Upon closure of the trap, **glands** covering its inner surfaces are activated
- Prey-induced **haptoelectric stimulation** activates the **touch hormone** jasmonate (JA) (Scherzer, 2017)
- The JA signal pathway initiates the secretion of an acidic **hydrolase** mixture
    - This **decomposes** its prey which allows the fly trap to absorb its nutrients (Scherzer, 2017)



https://www.sciencedirect.com/science/article/pii/S0168945217300869

Fun Facts!

- The venus flytrap is the **only member of its genus** (Dionaea muscipula)
- Venus flytraps are native to only **North and South Carolina**, specifically in a 75-mile radius around Wilmington, NC.
- **Digestion** of an organism can take 3-7 days, and venus flytraps go about 1-2 months between meals
- Venus flytraps can live for up to **20 years**

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