Thirsty for Life - Osmosis

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Introduction

The modern carrot (*Daucus carota*) is a root vegetable that is cultivated around the globe. The carrot is composed of a storage root that is buried beneath the ground, with a stem and shoots that protrude towards the sunlight (fig. 1). The storage root contains the nutrients the carrot requires to grow the stem and shoots until maturity, although water loss through evaporation means additional water must be obtained from the environment.

The carrot is composed of plant cells, which utilise osmosis to obtain water from the surrounding environment. Osmosis is the net movement of water across a semi-permeable membrane into a region of higher solute concentration. Therefore, due to the carrot containing higher salt and sugar than the soil, water will move into the carrot, providing it with the needed water. Our **aim** was to determine how osmotic pressure influences the carrot shoot growth. We expect that **if** the solution surrounding the carrot has a lower level of dissolved salt/sugar **then** the carrot cells will take up a reduced amount of water and will have impeded growth.

Methodology

Carrot tops of 1cm thickness were cut and hypocotyls were trimmed to ensure equal starting conditions. Carrot tops were cultured in petri dishes with 10mL of the following solutions: dH_2O, 10mM NaCl (low salt), 2M NaCl (high salt), 10mM sucrose (low sugar), 2M sucrose (high sugar), isotonic sports drink. Temperature and exposure to natural light were controlled. After 7 days, effects of different culturing conditions on growth were measured by two means:

- length of the longest formed shoot
- counting the number of formed shoots.

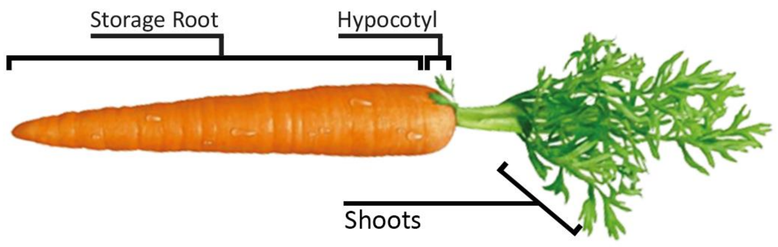


Figure 1. Diagram of Daucus carota (domestic carrot), regions necessary for the experiment are indicated.

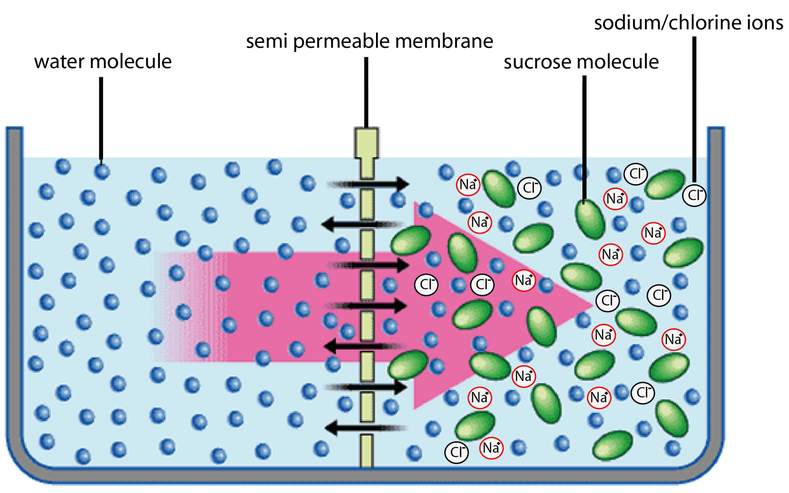


Figure 2. The principle of osmosis

Results

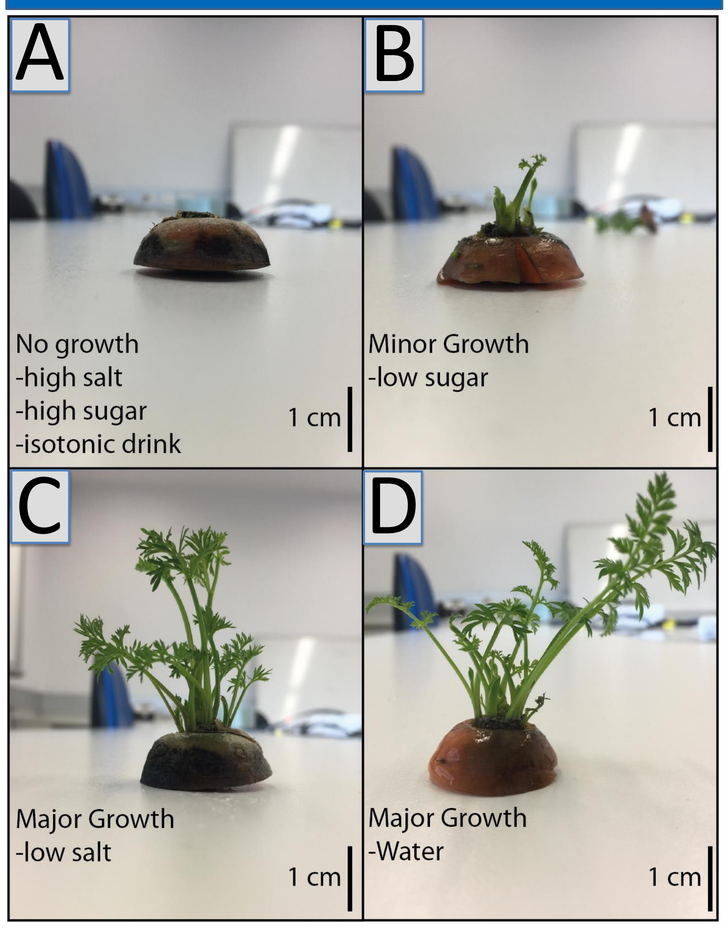
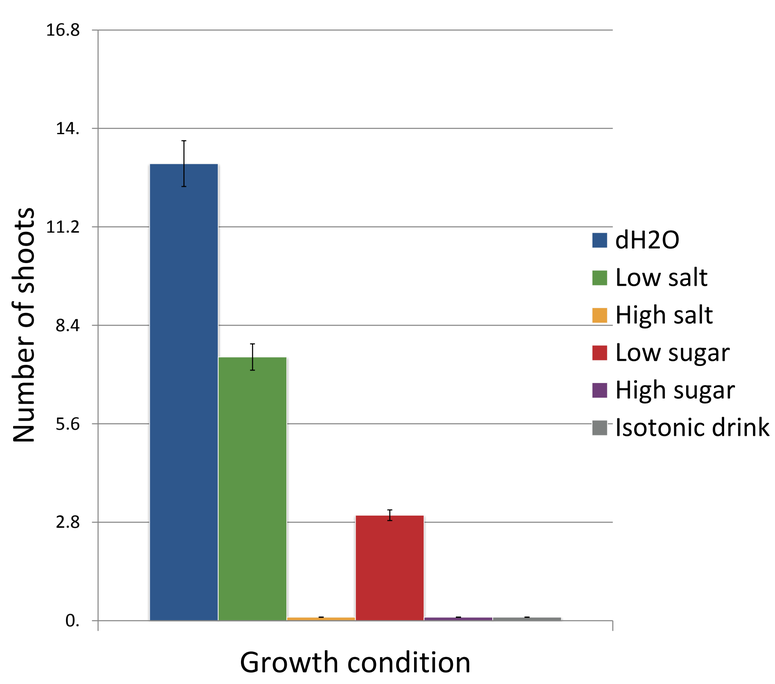


Figure 3. Carrots were grown for 7 days in the indicated solutions then a representative photograph was taken. Growth and conditions are indicated on the images.

Growth condition	Shoot growth average [cm]	Number of shoots average
dH_2O	4.2	13
Low salt	3.0	7.5
High salt	n.g.	n.g.
Low sugar	1	3
High sugar	n.g.	n.g.
Isotonic drink	n.g.	n.g.

Table 1. Carrots were grown for 7 days in indicated solutions, then length (cm) and number of shoots were measured.



Graph 1. Number of shoots produced by carrots in each condition were counted after 7 days. N = 2, error bars represent standard deviation.

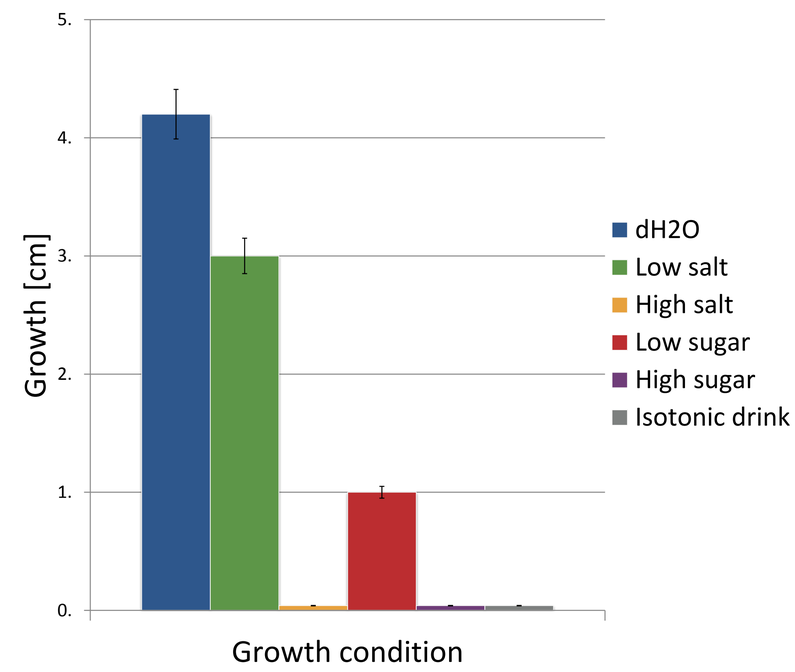


Figure 5. Length (cm) of shoots produced by carrots in each condition were counted after 7 days. N = 2, error bars represent standard deviation.

Discussion

Carrots utilise osmosis to take up water from the environment in order to maintain cell functions and growth. The hypocotyl region of the carrots can grow shoots when placed in water. To demonstrate the effects of osmotic pressure upon growth, we placed carrots in solutions with varying concentrations of solute.

As expected the most prominent shoot growth occurred when carrots were cultured in dH_2O (solute concentration ~2%) since the difference in solute concentration between carrots (high) and culturing solution (low) was at its greatest causing cells to take up water via osmosis.

When carrots were cultured in a 10mM NaCl (low salt) solution shoot growth was only slightly diminished. This indicates that the concentration of salt ions in the carrots was higher than 10mM enabling water to move through the cell walls into the carrot where it aided growth.

Culturing carrots in a 10mM sucrose solution resulted in significant growth reduction, suggesting that the concentration of dissolved sugar in the solvent was higher than in the carrots. This is due to the majority of sugar being stored as starch in the storage root[1]. This sugar is only released and mobilised when energy in the form of sugar is required. In other culturing solutions (high salt, sugar and isotonic drink) the concentration of solutes were significantly higher than in the carrots, causing water to be drawn out of the plants and thereby causing death.

In order to achieve greater significance, larger sample size is required. Furthermore, to avoid mould growth, more sterile technique need to be applied.

Conclusion

- Deionised water displayed the lowest osmotic pressure, allowing greatest shoot growth.
- As solute concentration increased, so did osmotic pressure.
- The increased osmotic pressure in the high salt, sugar and isotonic drink solutions drew water out of the carrot, killing the carrot.

References

1. http://www.carrotmuseum.co.uk
2. Figure 2 adapted from https://pmgbiology.com/tag/osmosis/

Acknowledgements

We would like to thank all the carrots that gave their lives in order to teach osmosis.
We would like to thank the Walter and Eliza Hall Institute for providing materials.