Plants In Space

(Or, how do plants know which way is **up**?)

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NASA is interested in how plants might grow in space

- How does gravity change how a plant grows?
- How does a plant react to zero gravity?
- How does a plant know to respond to gravity?

- ***Why*** is NASA interested?
  - food for long space flights
  - keep the air safe for astronauts

Plants can’t get up and run away to Mars…

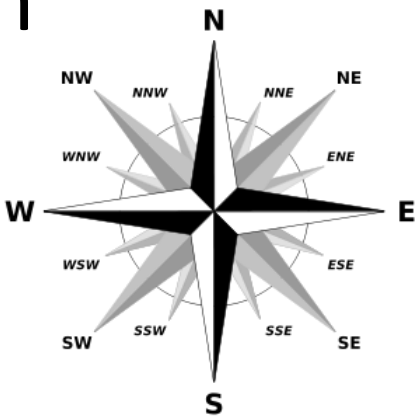
… but they can move in all sorts of other ways…

Growing towards light

"**Photo**tropism"

Photo = ?

tropism = direction



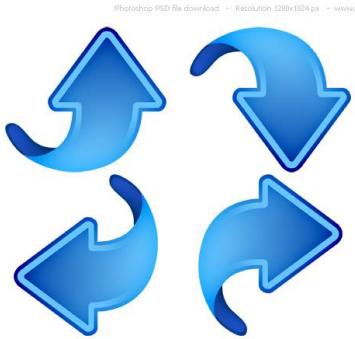


Photo-tropism ➔ directed towards light!

"Thigmotropism"

Some plants can respond to TOUCH

…and grow up other plants

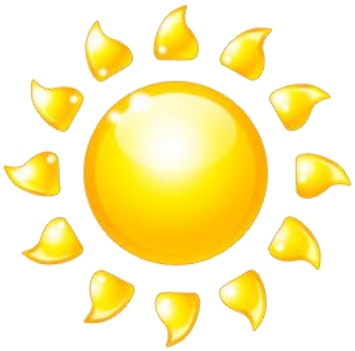
"Thigmotropism"

"Audiotropism"?!

MUSIC

Can you think of any other tropisms?

- Sunflowers follow the sun each day!



→ **Helio**tropism

… and GRAVITY!

"Gravitropism"

Movie: J. Bussell

Today's experiment

…is all about plant growth and gravity

Gravitropism

Plants need to detect gravity to be able to send **shoots up** and **roots down**.

We will grow seedlings and compare…

"Controls"

1. Plants that grow normally and can detect gravity

2. Mutant plants that do not detect gravity very well

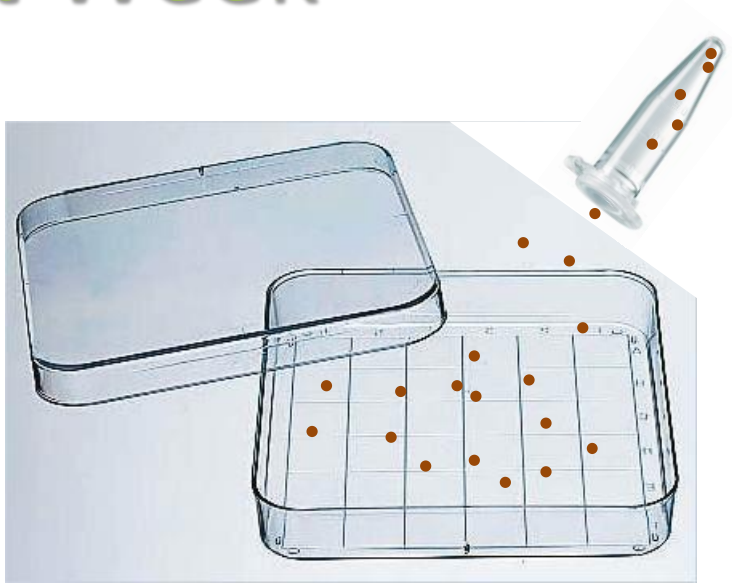
"Mutants"

Today and Next Week

Today:

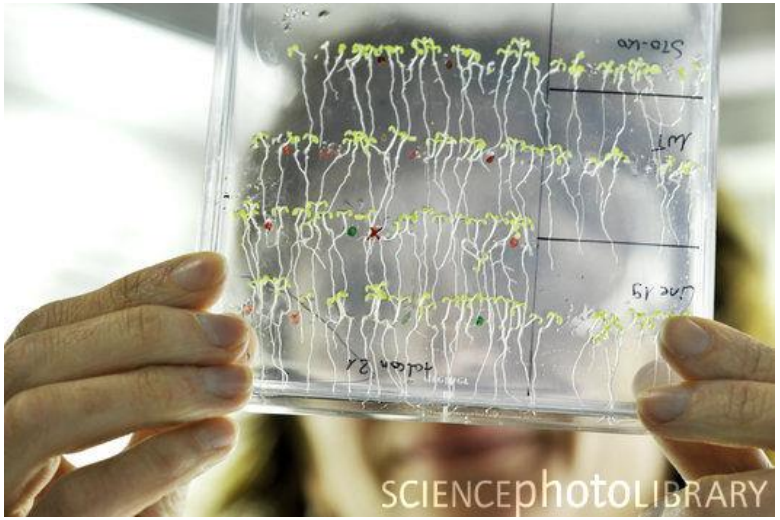
Prepare the experiment:

Sow seeds of both plant types

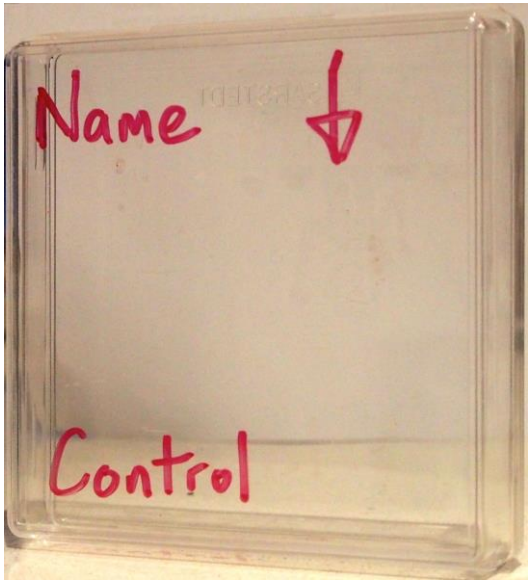


Next Week:

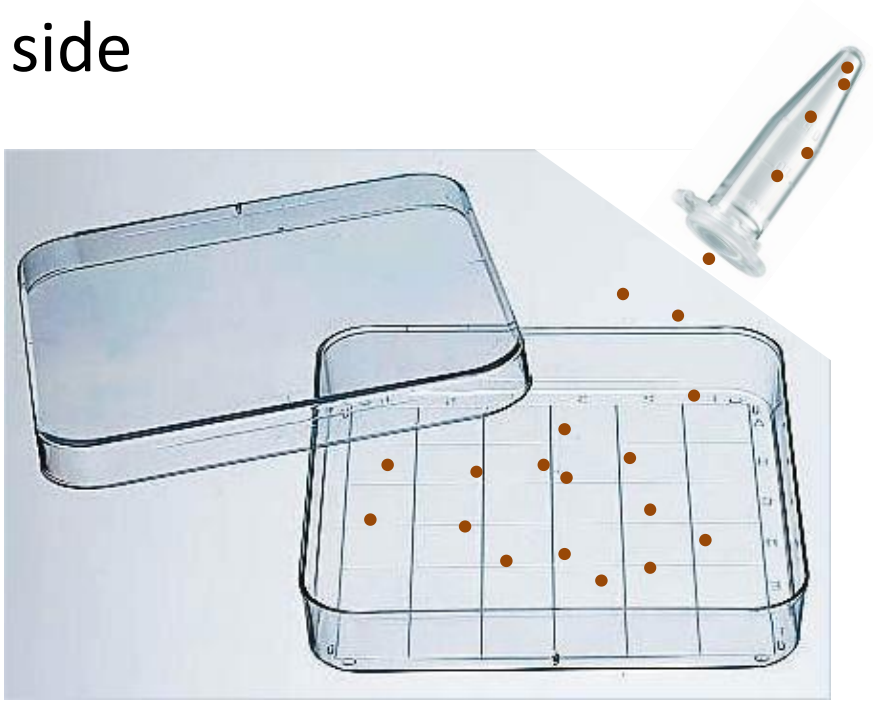
1. Record how they respond to gravity
   (We WILL NOT be throwing plants up in the air to make sure they land again!)
2. Understand why the mutant doesn't grow properly



Experiment WEEK 1



1. write your NAME and "**control**" or "**mutant**" on the bottom of the plate
2. mark the edge that will face down when the plates are on their side



3. spread the seed as shown
4. wrap tape around the plates to seal them closed

Experiment WEEK 1

1. leave the plate over-night in the light
   Arabidopsis seeds need water (in the gel) and light to germinate
2. tomorrow morning, make sure there is an arrow on the edge that will be down
3. carefully wrap the plates in two layers of foil
   (We don't want any more light on these seeds)
4. incubate them vertically until next week

Plants In Space

WEEK 2

(Or, how do plants know which way is **up**?)

Photo: NASA

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A down to earth experiment…

…about plant growth and gravity

Gravitropism

Plants need to detect gravity to be able to send **shoots up** and **roots down**.

We've been growing seedlings to compare…

"Controls"

1. Plants that grow normally and can detect gravity

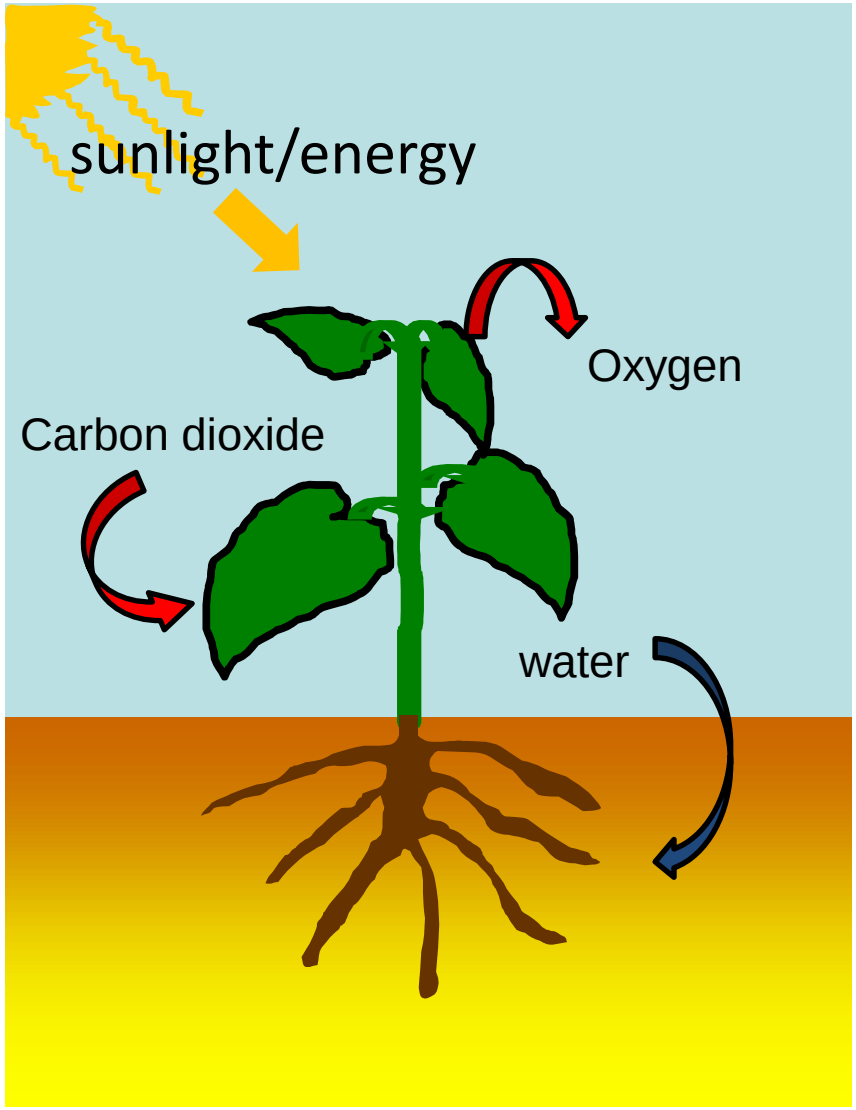
2. Mutant plants that do not detect gravity very well

"Mutants"

Plant Food

Feeding the world

Photosynthesis



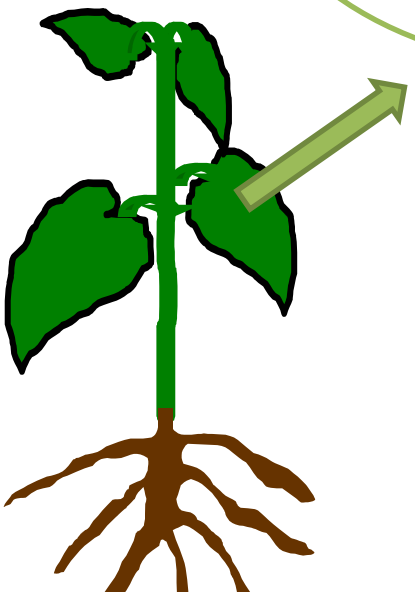
150,000,000 kg of CO_2 is made into sugar by plants every minute!

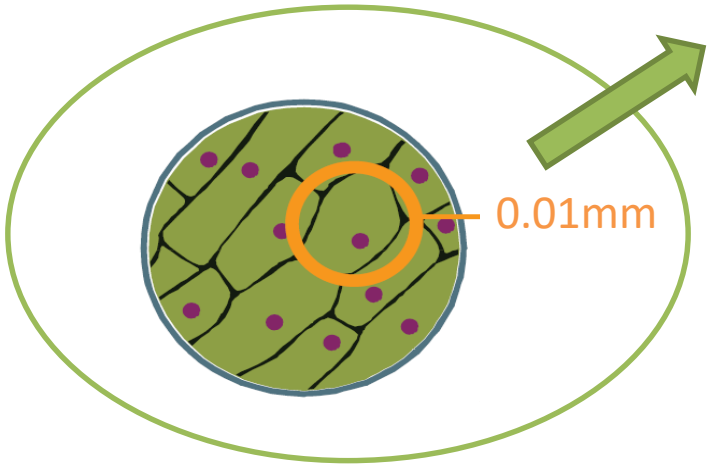
That's more than 3,750,000,000 cans of coke!

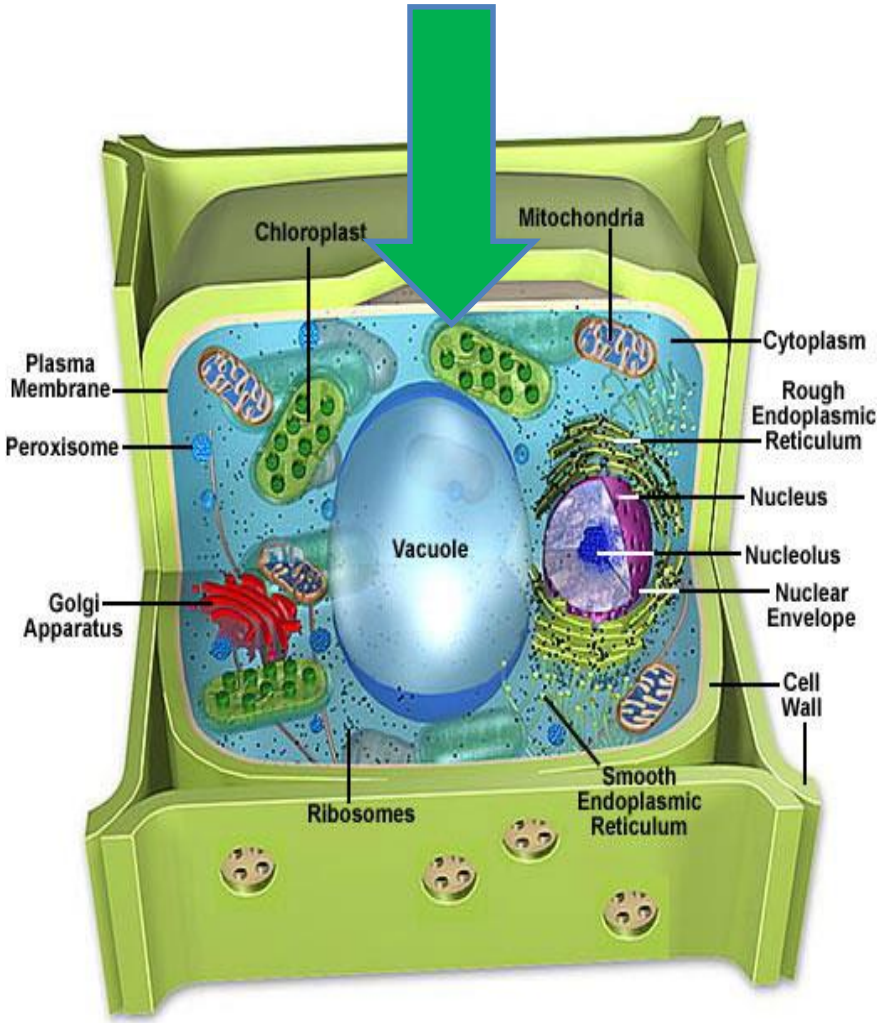
carbon dioxide + water + sunlight ⇨ **sugar + oxygen**

Plants grow mostly at night using sugar stored as starch during the day!

Where is the sugar made?





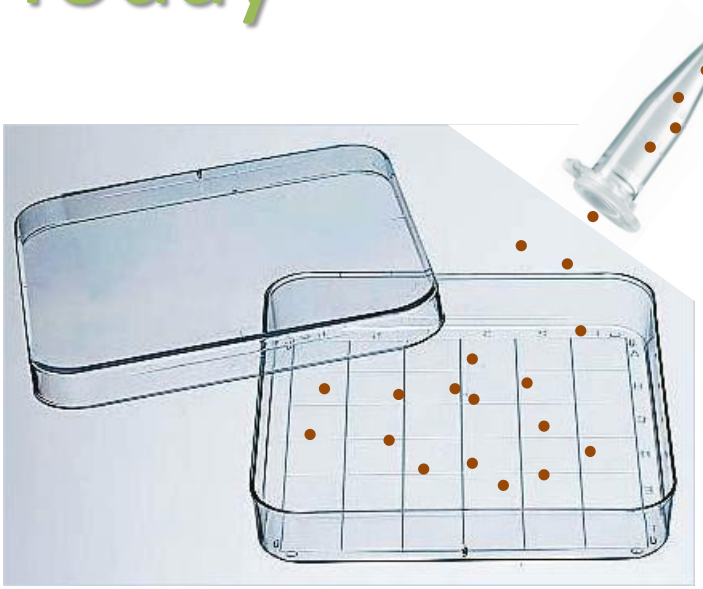


Last Week and Today

Last Week:

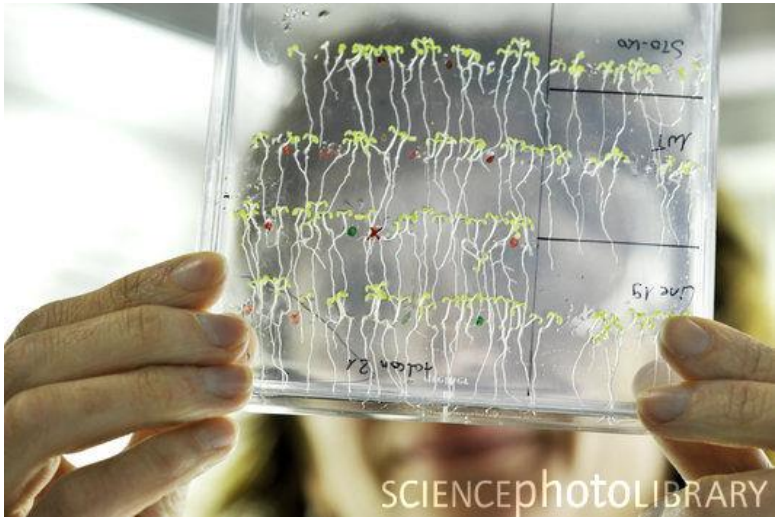
Prepared the experiment:

Sowed control and mutant *Arabidopsis* seeds



Today:

1. Record how they respond to gravity
2. Understand why the mutant doesn't grow properly



Experiment WEEK 2

How did the plants respond to gravity?

1. Open the plates that were kept in foil and compare and record the growth of **control** and **mutant** plants

2. Check the BONUS EXPERIMENT plates that were grown in the light and rotated earlier in the week. Can you see a difference between the **control** and **mutant** plants?

Experiment WEEK 2

Can we explain the differences between the **control** and **mutant** plants?

1. **Staining for starch** in mature plants
   - What differences are there between the **control** and **mutant** mature plants?

2. **Staining for starch** in seedlings
   - (Hint: look in the root tips)

POST-LAB: Class discussion

POST-LAB: What's Going ON?

IN LEAVES

- During the day, **starch** is made from sugars that were made by photosynthesis
- During the night the plant uses **starch** to grow

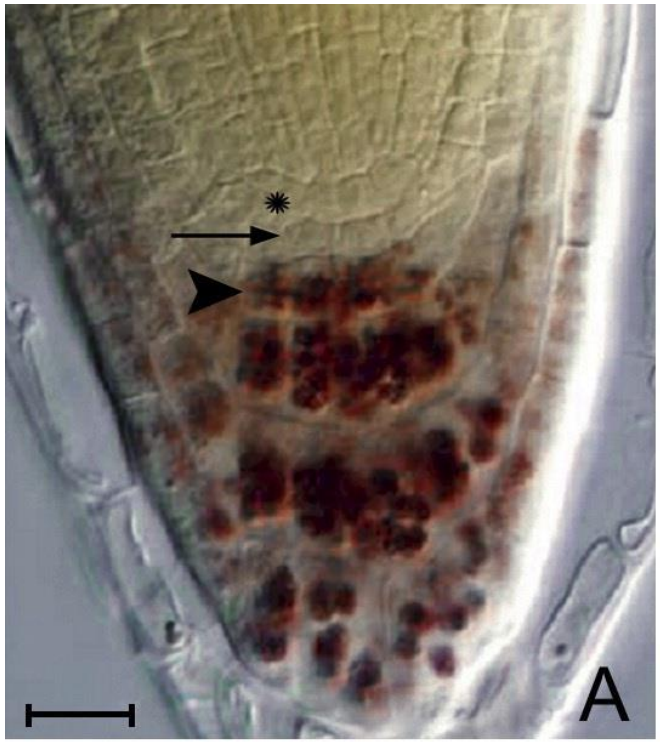
Pictures: J. Bussell

Aside: Can plants “talk”?

But what does this have to do with gravity?!!?

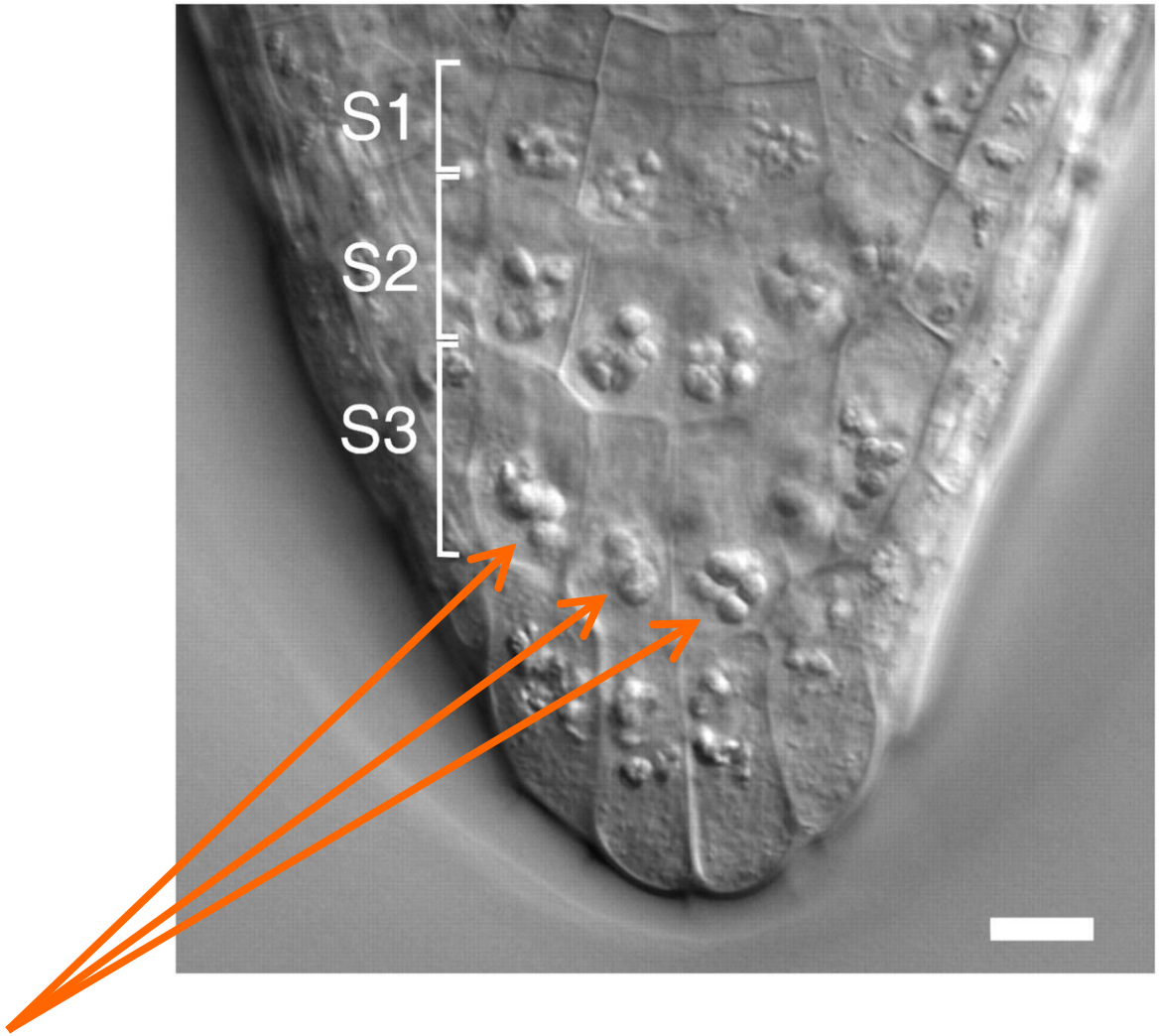
IN ROOTS

- The only place that starch is found in roots is in the very tip!
- There the **STARCH** makes heavy little "balls" which are in fact sensors that the plant needs to detect gravity
- (STATOLITHS)



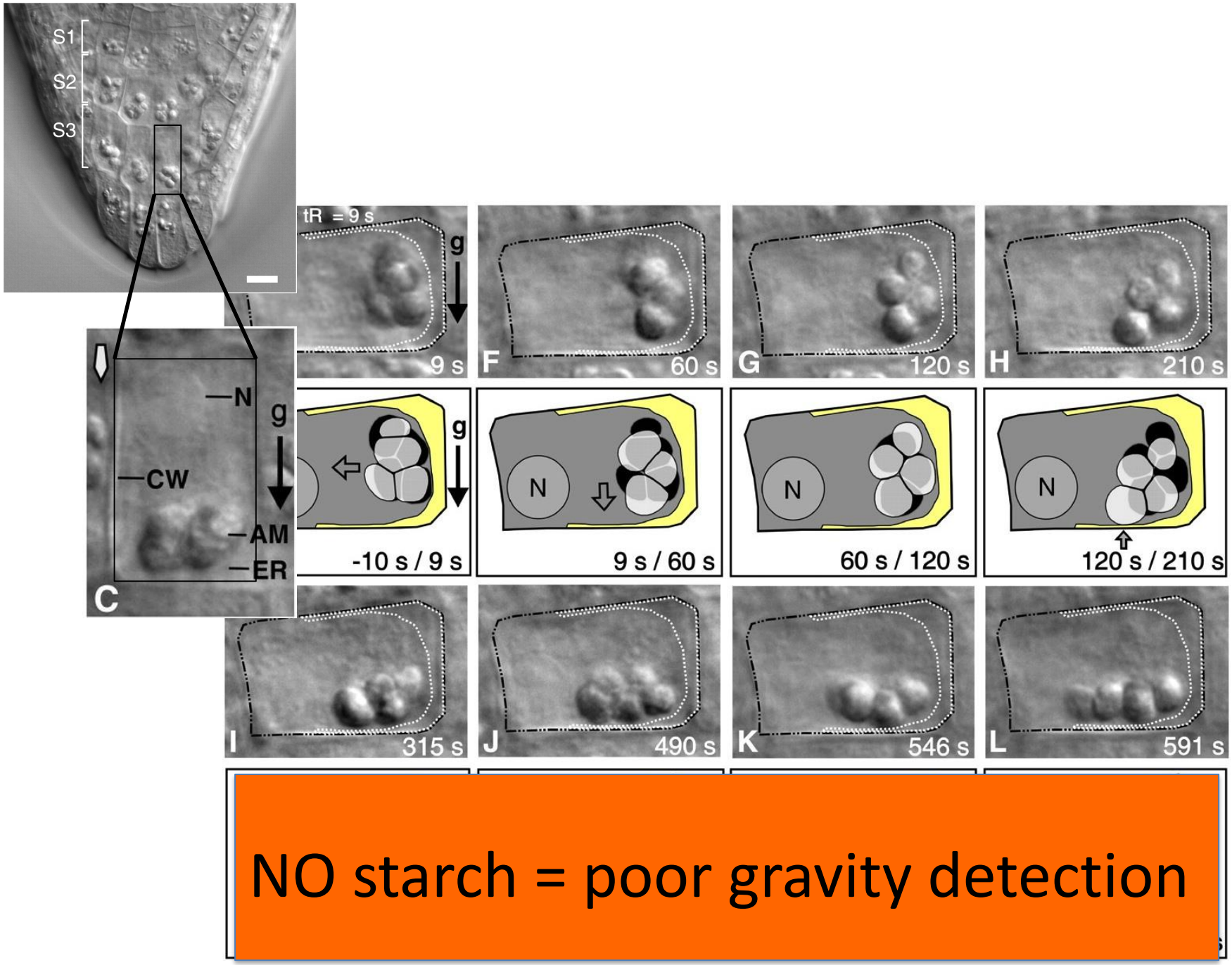
Picture: Wildwater et al., Cell 123:1337-49 (2005)

A Plant Root Tip



Starch in root tips is required for plants to detect gravity!

Pictures: Leitz et al, Plant Cell 21:843-60 (2005)



NO starch = poor gravity detection

Acknowledgements

This presentation was made at the ARC Centre of Excellence in Plant Energy Biology, University of Western Australia by:

- John Bussell
- Rowena Long
- Alice Trend

It was based on the ABRC *TRAINED Educational Kit* CS19986 "How Can Plants Tell Which Way Is Up?"

We thank Roger P. Hangarter and the University of Indiana for making available the beautiful *Plants In Motion* videos! (http://plantsinmotion.bio.indiana.edu)

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Selected Scientific Literature Documenting Gravitropism and Plants in Space

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- **Ferl R, Wheeler R, Levine HG, Paul AL** (2002) Plants in space. Curr Opin Plant Biol **5:** 258-263
- **Halstead TW, Dutcher FR** (1987) Plants in space. **Annu Rev Plant Physiol 38:** 317-345
- **Kiss JZ, Millar KD, Edelmann RE** (2012) Phototropism of Arabidopsis thaliana in microgravity and fractional gravity on the International Space Station. **Planta 236:** 635-645
- **Leitz G, Kang BH, Schoenwaelder ME, Staehelin LA** (2009) Statolith sedimentation kinetics and force transduction to the cortical endoplasmic reticulum in gravity-sensing Arabidopsis columella cells. **Plant Cell 21:** 843-860
- **Limbach C, Hauslage J, Schafer C, Braun M** (2005) How to activate a plant gravireceptor. Early mechanisms of gravity sensing studied in characean rhizoids during parabolic flights. **Plant Physiol 139:** 1030-1040
- **Monje O, Stutte GW, Goins GD, Porterfield DM, Bingham GE** (2003) Farming in space: environmental and biophysical concerns. **Adv Space Res 31:** 151-167
- **Saether N, Iversen TH** (1991) Gravitropism and starch statoliths in an Arabidopsis mutant. **Planta 184:** 491-497
- **Walker LM, Sack FD** (1990) Amyloplasts as possible statoliths in gravitropic protonemata of the moss Ceratodon purpureus. **Planta 181:** 71-77

- [Of course there are many, many more papers available…]

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