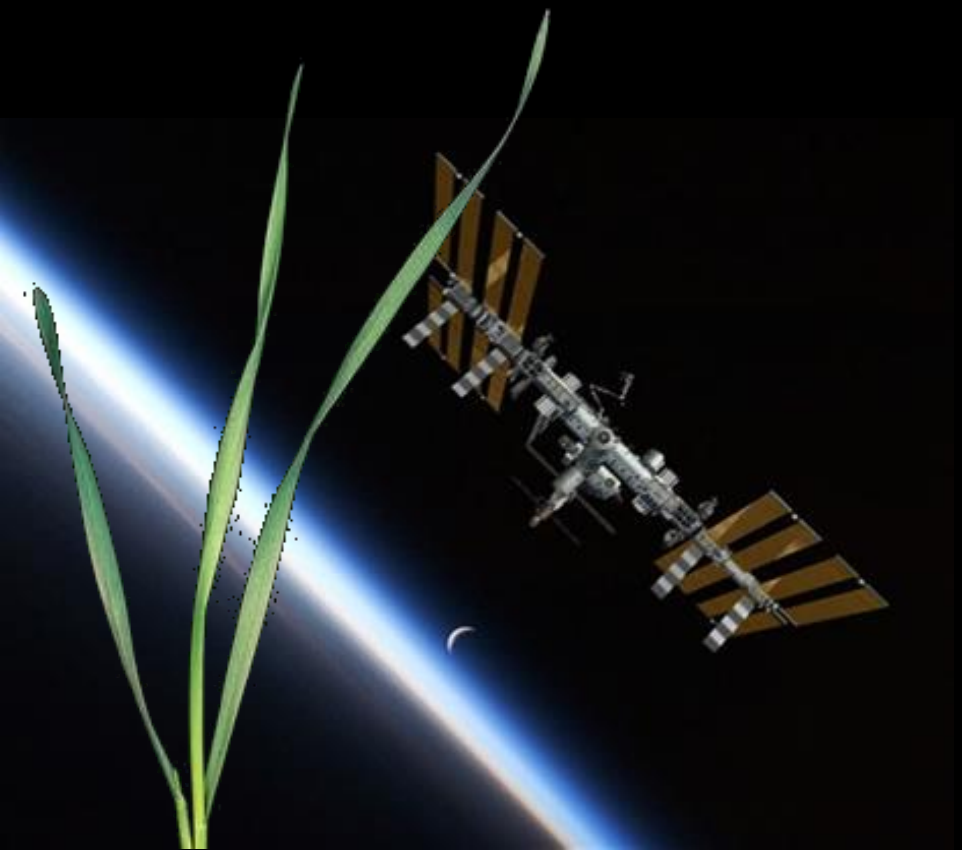
# Physical Forces Affecting Biology in Spaceflight Environments



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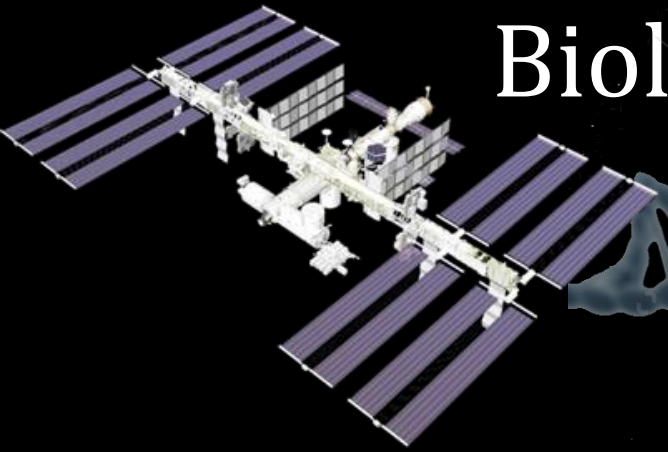
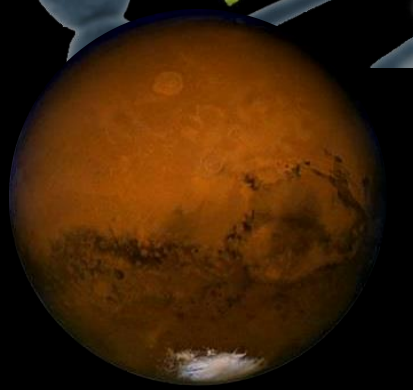
# Biology is impacted by microgravity

- Enabling Biology to thrive in novel gravity environments
  - The intersection of physical and biological science
  - Engineering to mitigate





*Mark Weislogel*

Biological processes evolved with gravity as an integral part of the equation

- Fluid Dynamics

- Convection-driven mixing
  - Temperature
  - Gasses

But can be largely overcome by Engineering

# Managing the liquid environment - problems

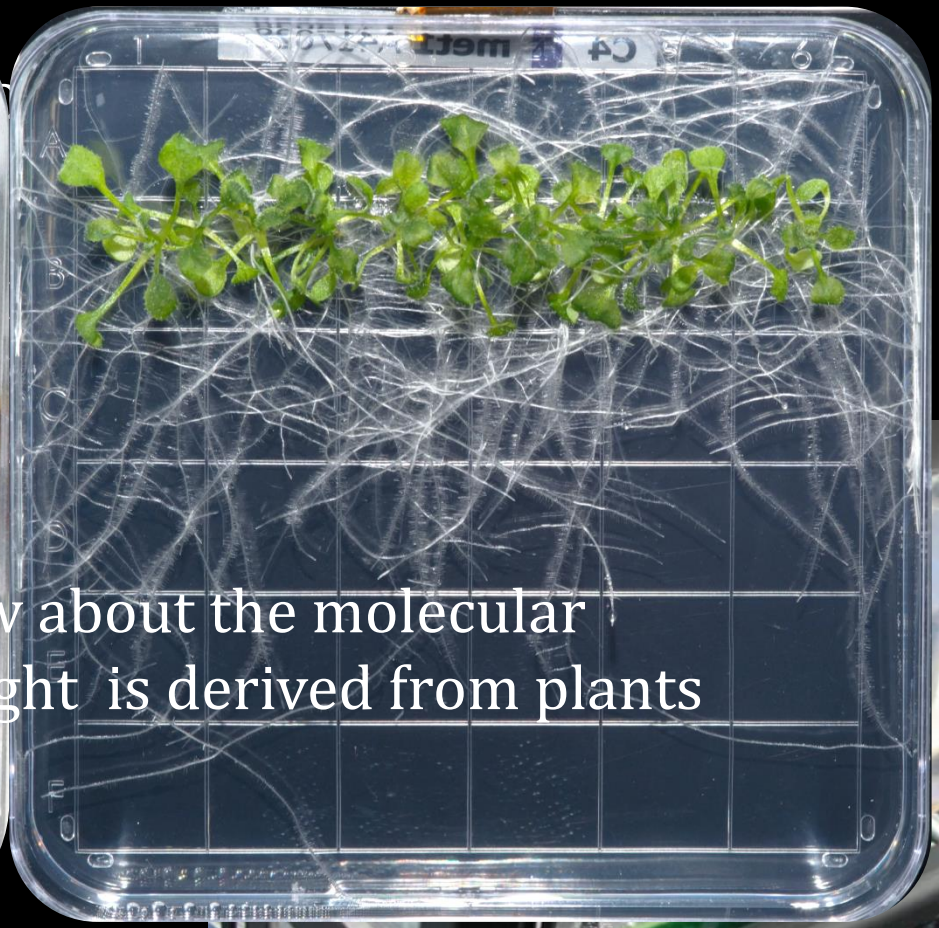
Without gravity,

Liquid behavior dominated by capillary and viscous forces

Liquid properties (e.g. as a carrier of solutes) impacted

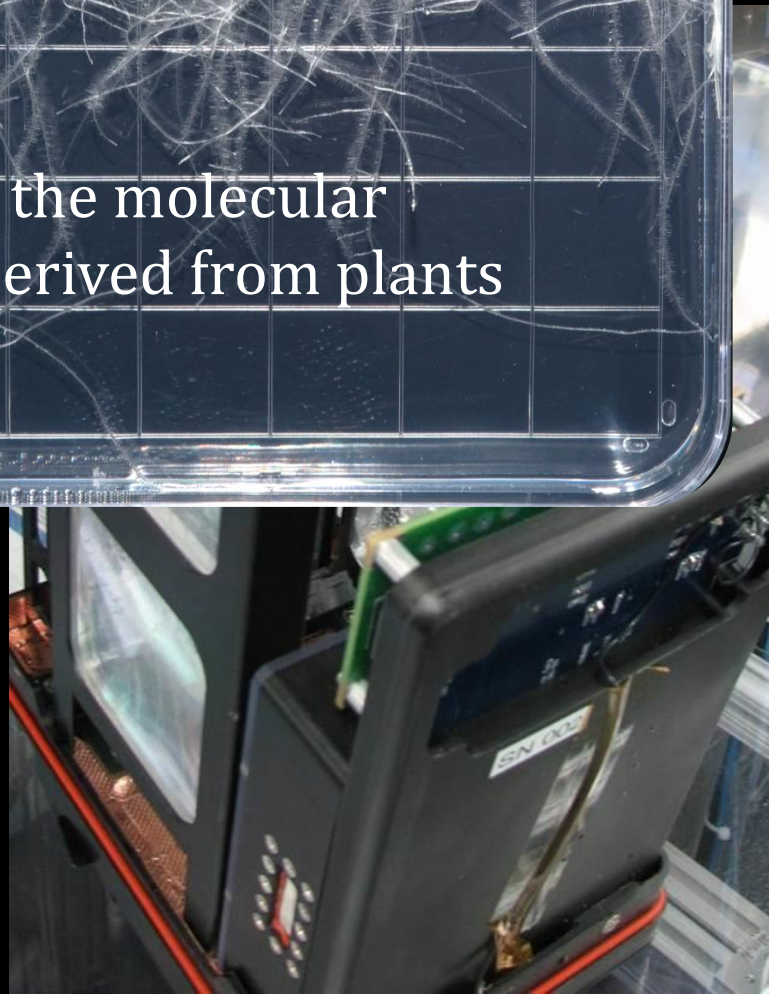
- Liquid around a root or leaf can…
  - Strongly adhere, causing “flooding” as dissolved O2 is locally depleted and not replenished
  - May not reach the root zone as capillary action directs it elsewhere, causing “drought”.

Mitigated by engineering of media supports, materials and active fluid management



Currently, virtually all we know about the molecular responses of plants to spaceflight is derived from plants grown on a gel surface

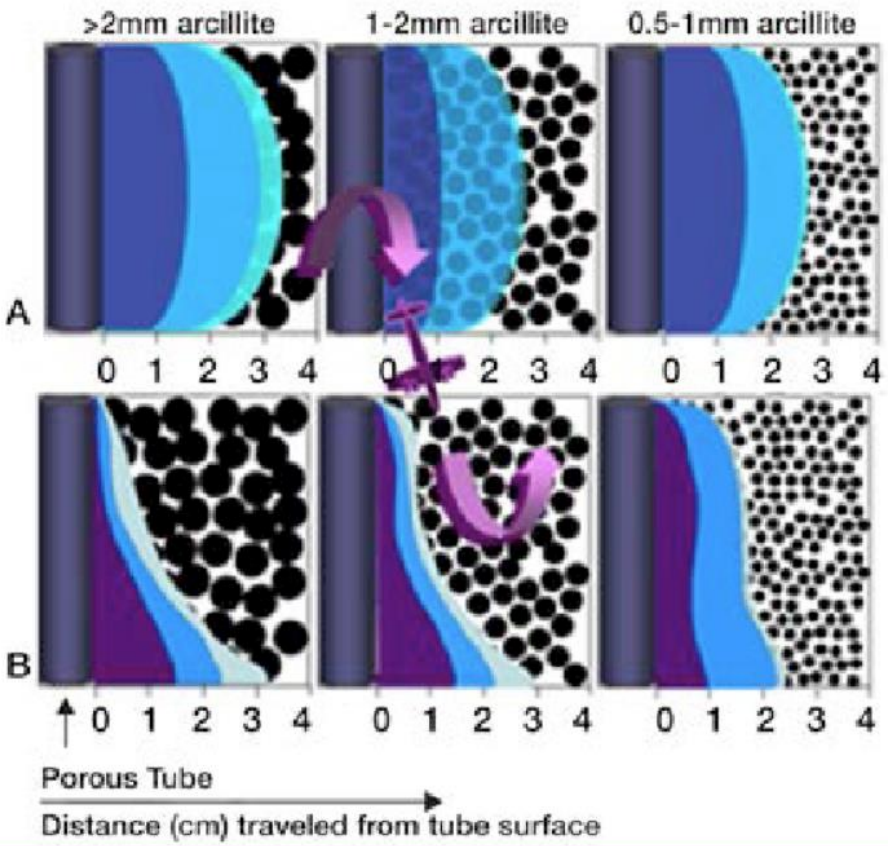
Light engineering also important when gravity cues are absent

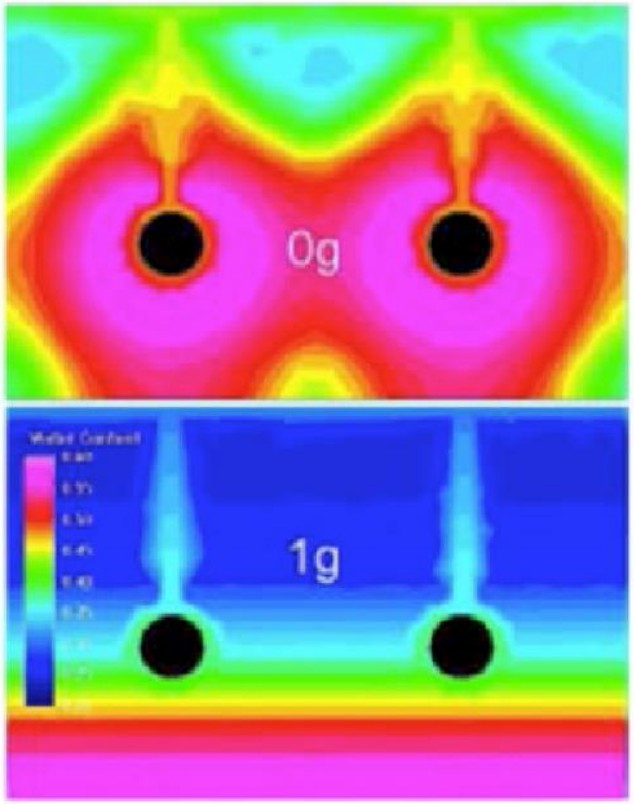


# Managing the liquid environment – solutions

## Root Zone Fluid Dynamics

From: A Researcher's guide to ISS Plant Science  Stutte et al.




# Managing the liquid environment – solutions

## Modifications of the theme

actively deliver and disperse water to the root zone (no tube)

- media matrix in membrane “pillows”
- roots are watered through the capillary movement of the liquid introduced to pillow

VPS – Vegetable Production System (aka Veggie)

# 1990 physics and engineering in support of a microgravity plant habitat

Plant nutrient delivery system having a porous tubular member US 4926585 A - Tom Dreschel

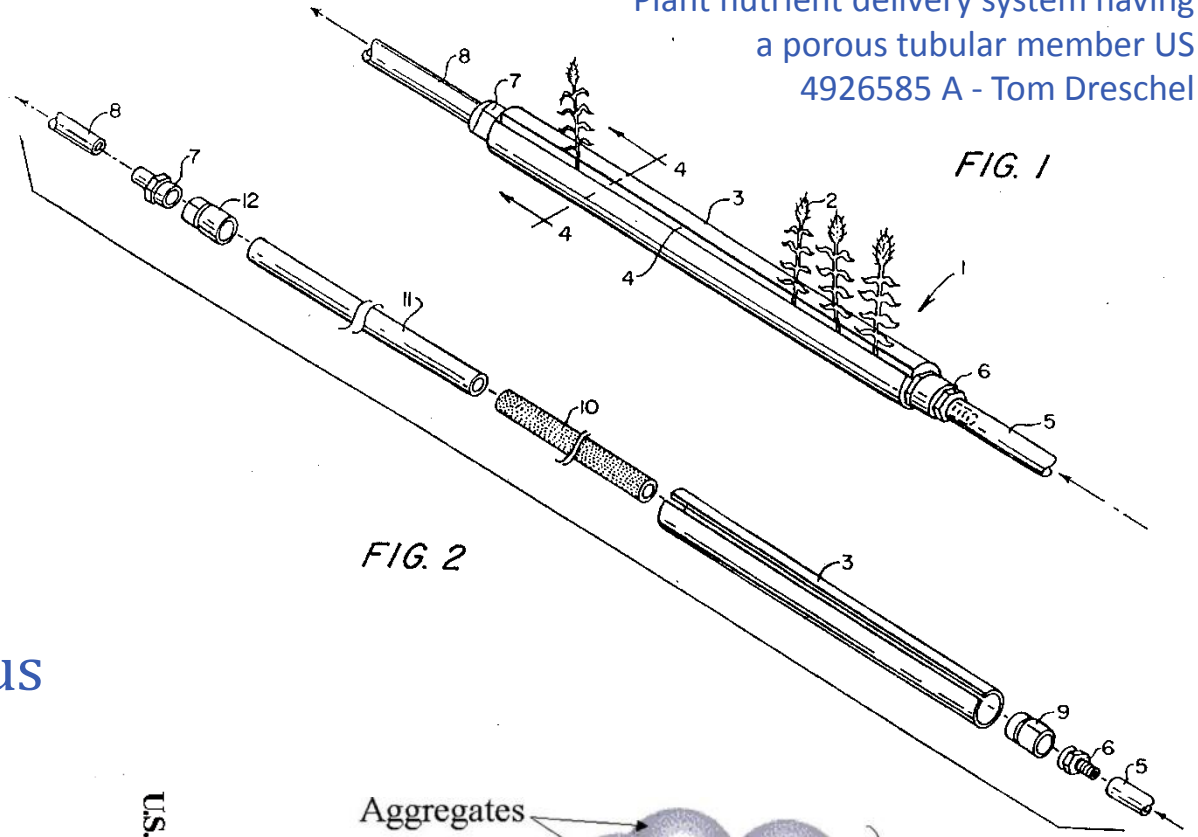



FIG. 1

FIG. 2

## Core technology: porous tubes

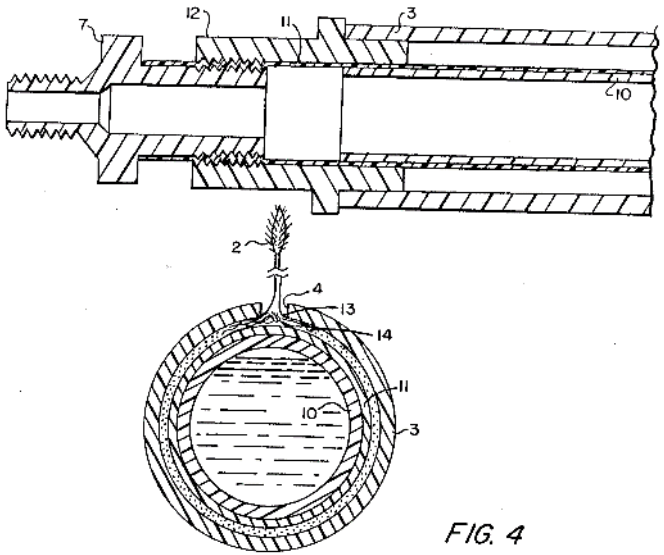
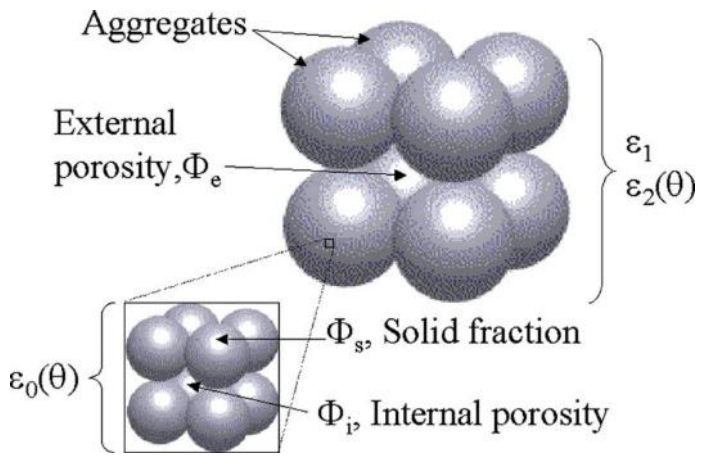



FIG. 3

FIG. 4

U.S. Patent May 22, 1990 Sheet 2 of 6 4,926,585



# 2013 physics and engineering in support of a microgravity plant habitat –

Core technology: Specialized hydrophilic polymer fused to microporous hydrophobic sheet

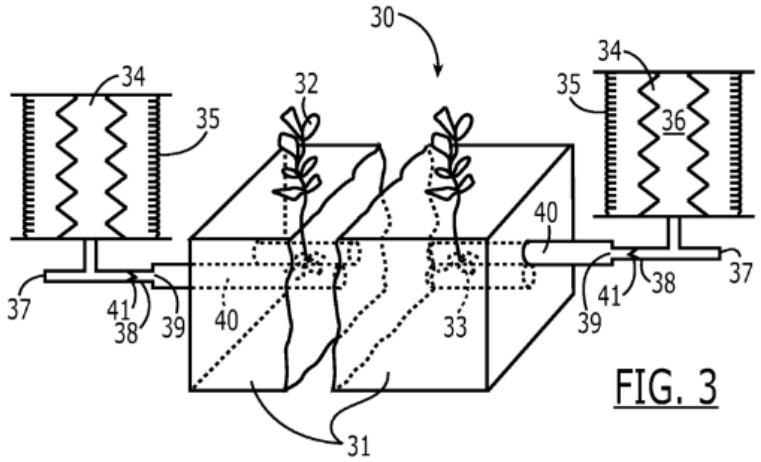


FIG. 3

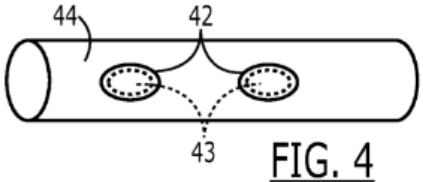


FIG. 4

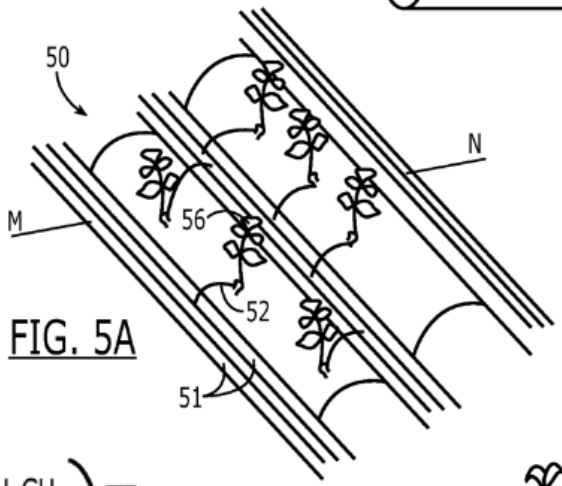


FIG. 5A

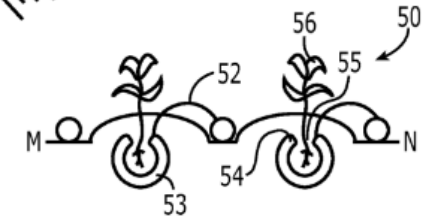
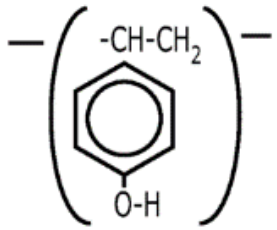


FIG. 5B



POLYHYDROXY-STYRENE

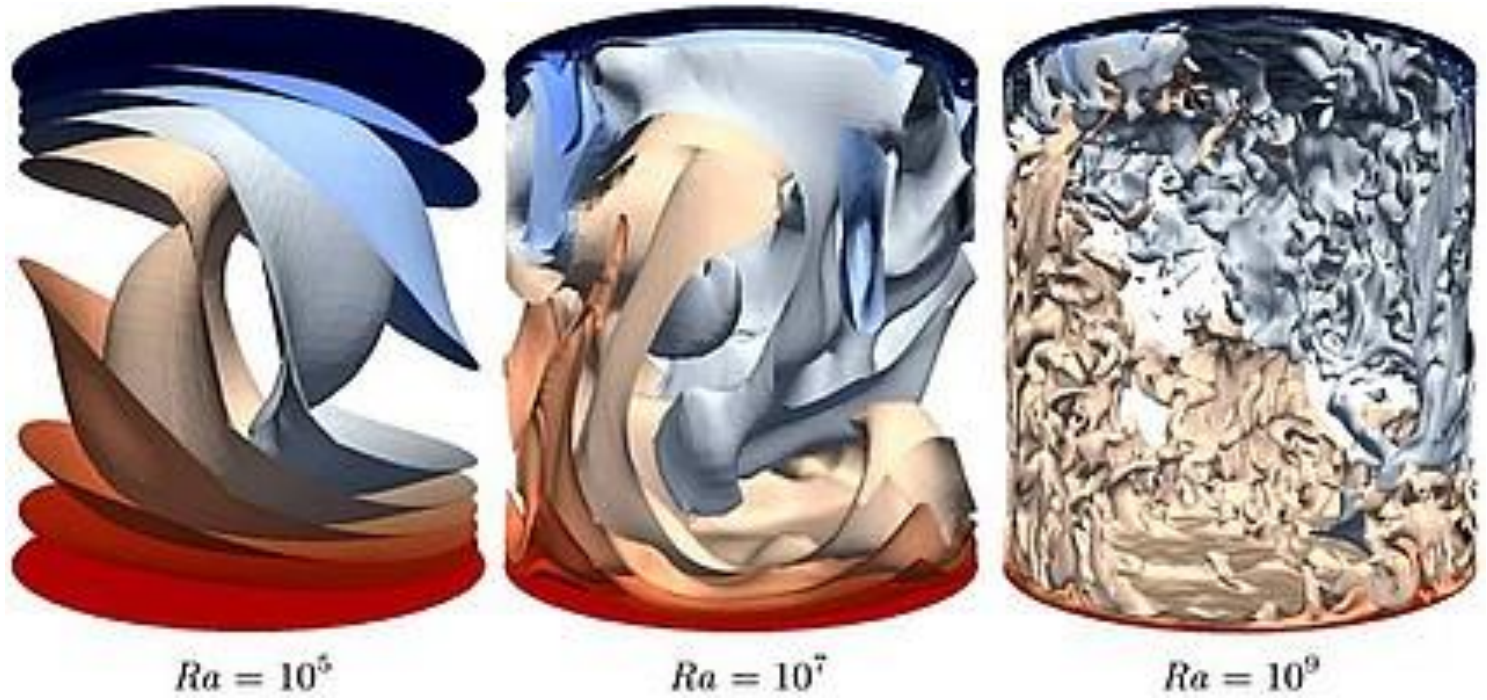
FIG. 6

Fluid nutrient delivery system and associated methods . US 8584398 B2- Hyman D. Gesser, Donald R. T. Lafreniere

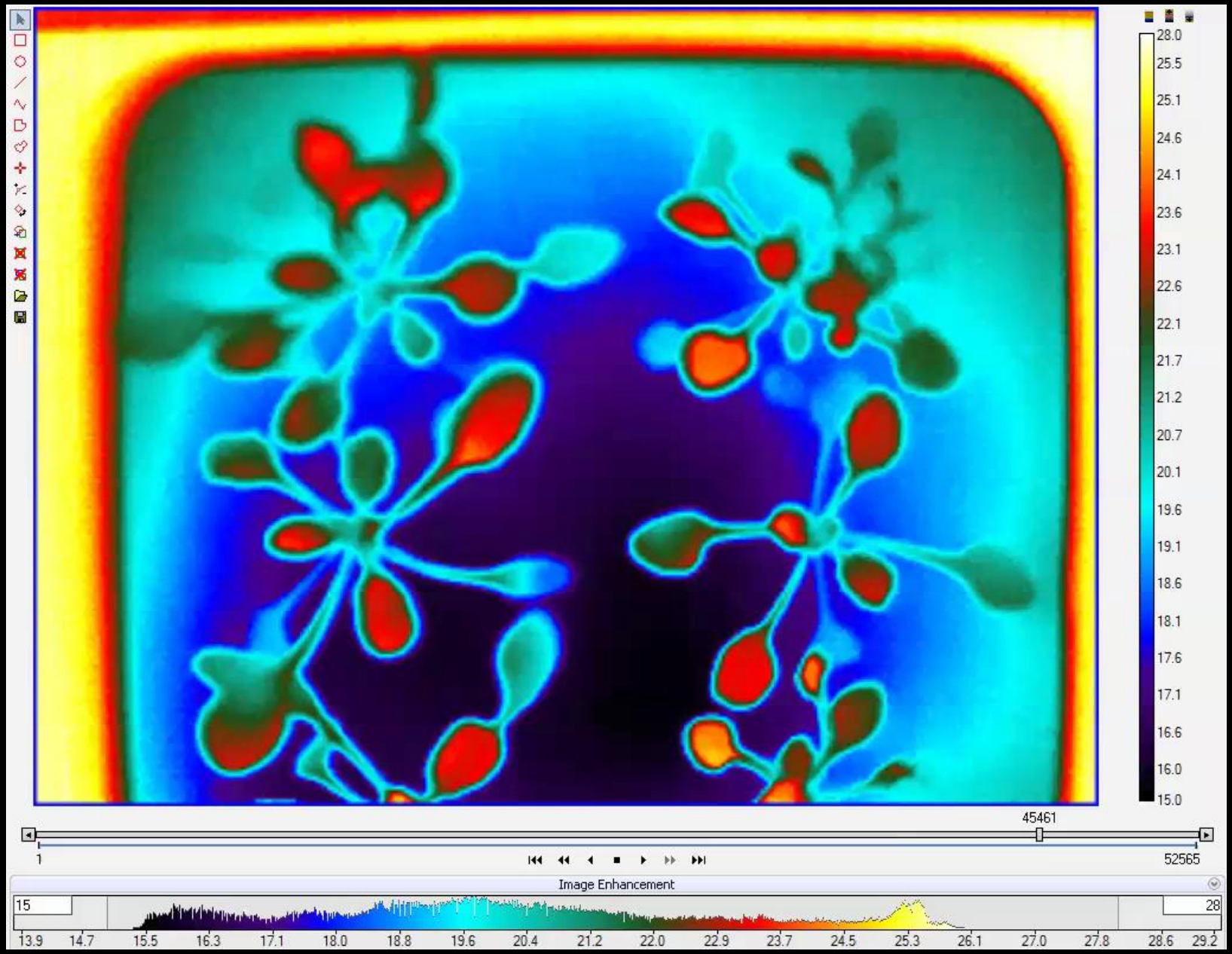
# Natural Convection

Driven by

- physical characteristics of materials
- volume of the area
- gravity




Dr. Claus Wagner
German Aerospace Center (DLR)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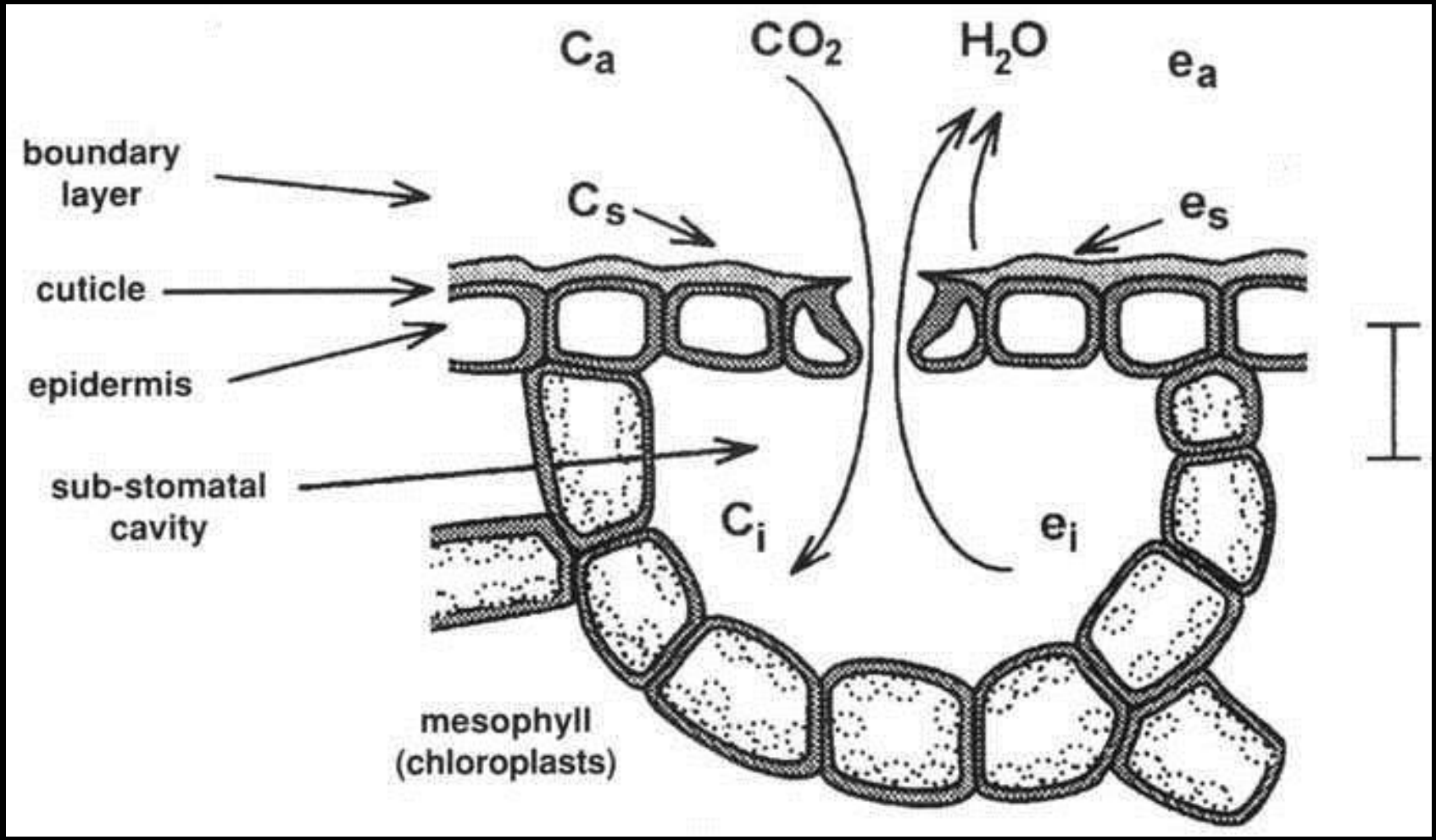
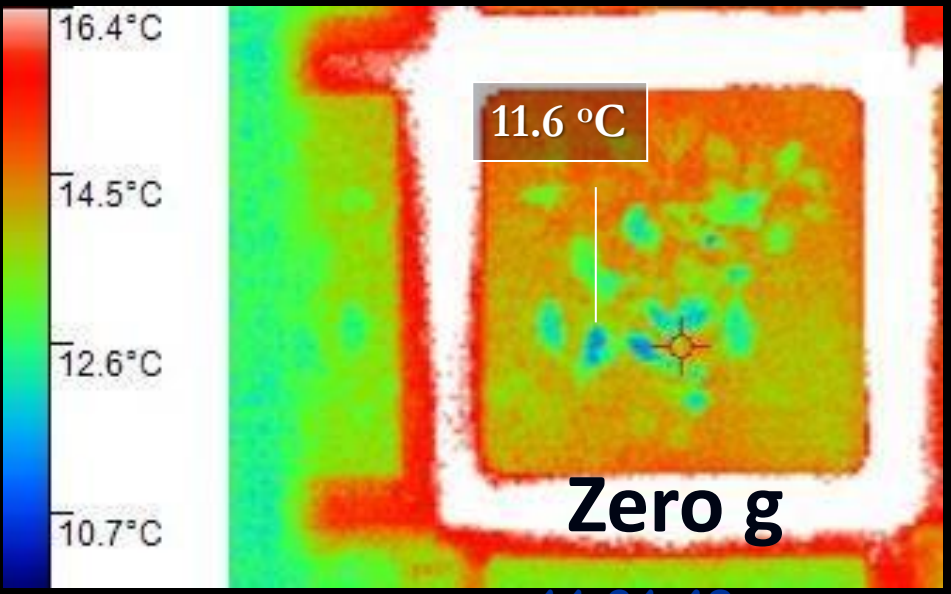
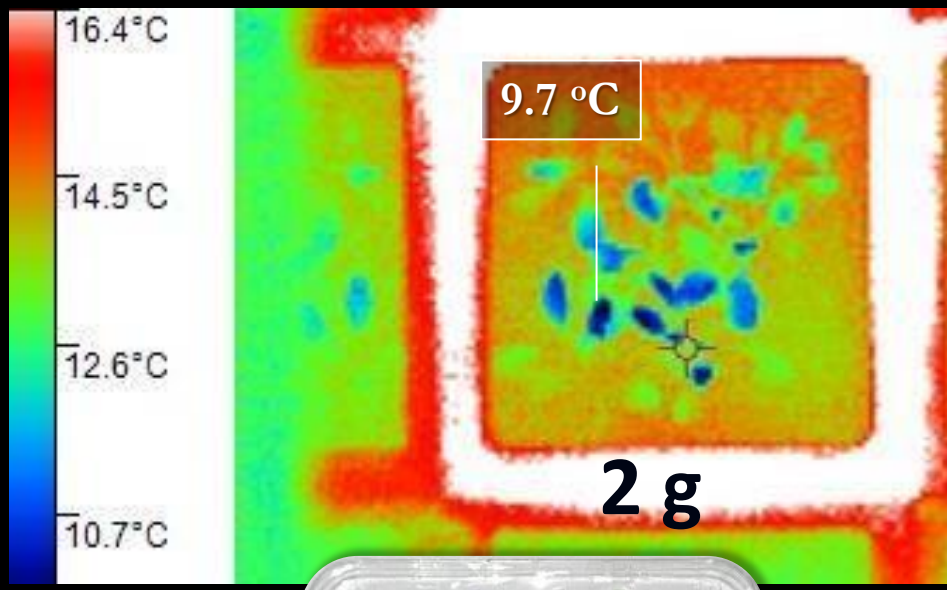
# Managing the gaseous environment

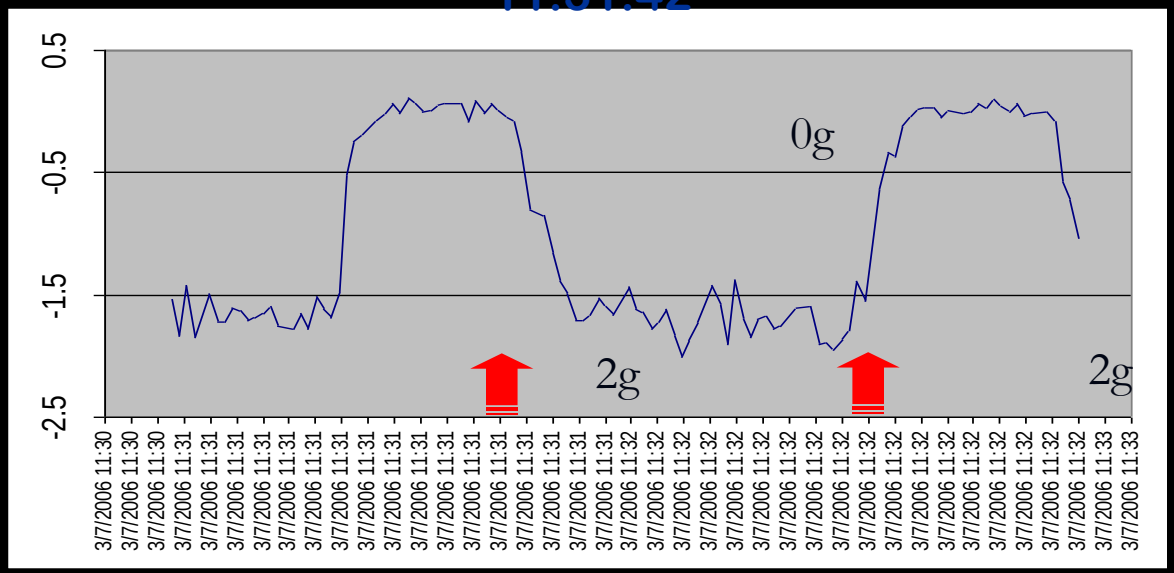



All impacted by Atmospheric Pressure environment

# Managing temperature in microgravity – short term data



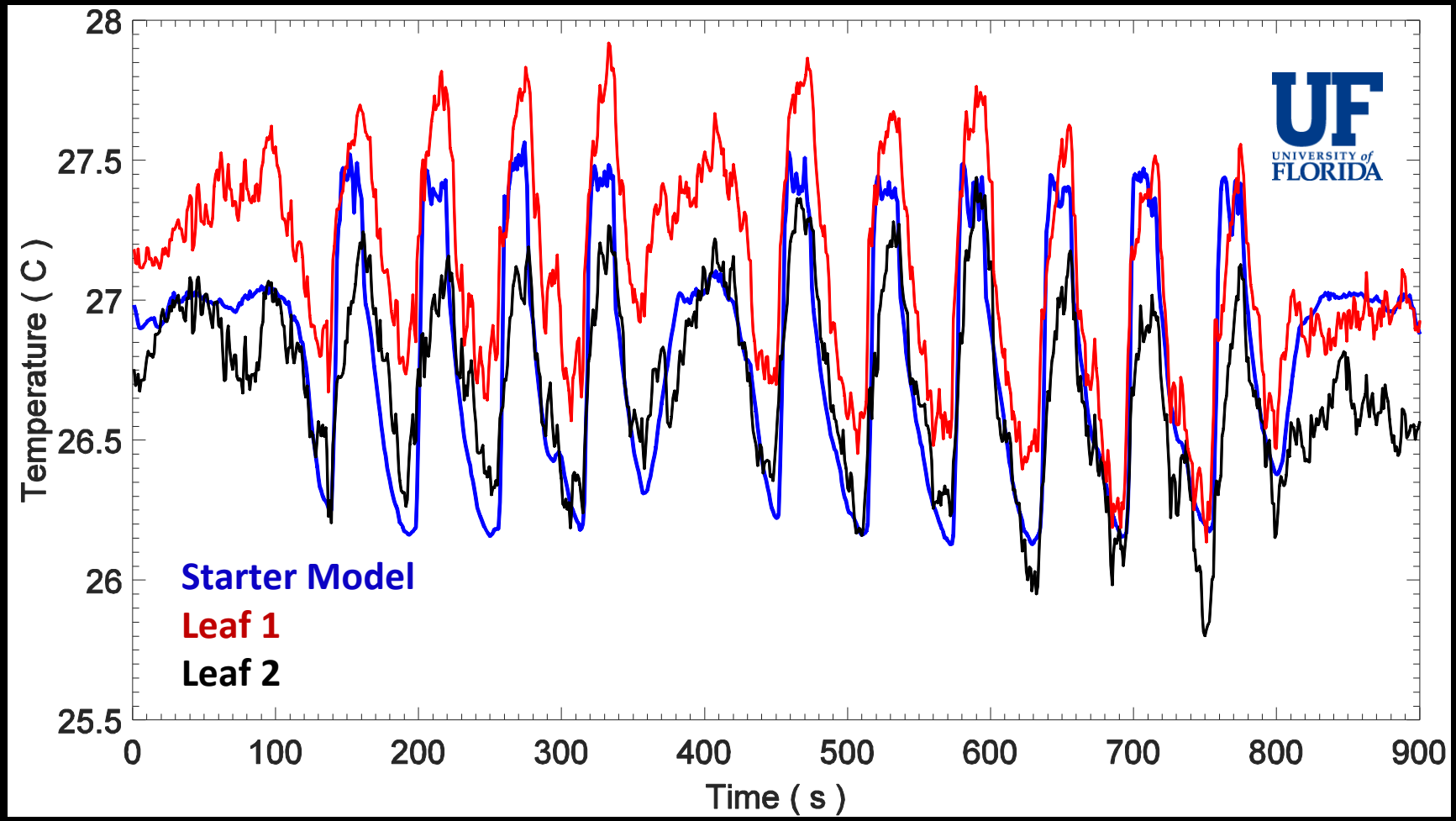




Parabolic flight campaign UF 2004

See also Kitaya et al (2001). Adv Space Res 28: 659-664

# Managing temperature in microgravity – long term modeling

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# Closing thoughts

NASA/TM—2002–210774

**Plant Production Systems for Microgravity: Critical Issues in Water, Air, and Solute Transport Through Unsaturated Porous Media**

*Editors:*


*Susan L. Steinberg, PhD* — *Liberated Technical/JSC*
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*Don Henninger, PhD* — *NASA/JSC*


Much has been done to mitigate the physical effects of microgravity that affect biological systems

But there are limits to what *can* be done with current levels of understanding

There remain unanswered questions that need further investigation