



Module 1

Principles of Hydroponics

2026 Greenhouse Hydroponic Tomato Workshop with Dr. Triston Hooks

Outline

1. What is Hydroponics?
2. What is CEA?
3. Why Hydroponics and CEA?



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center



Principles of Hydroponics

What is Hydroponics?

- Hydroponic means “water working”
- Hydroponics is the method of plant production with a complete nutrient solution and without soil

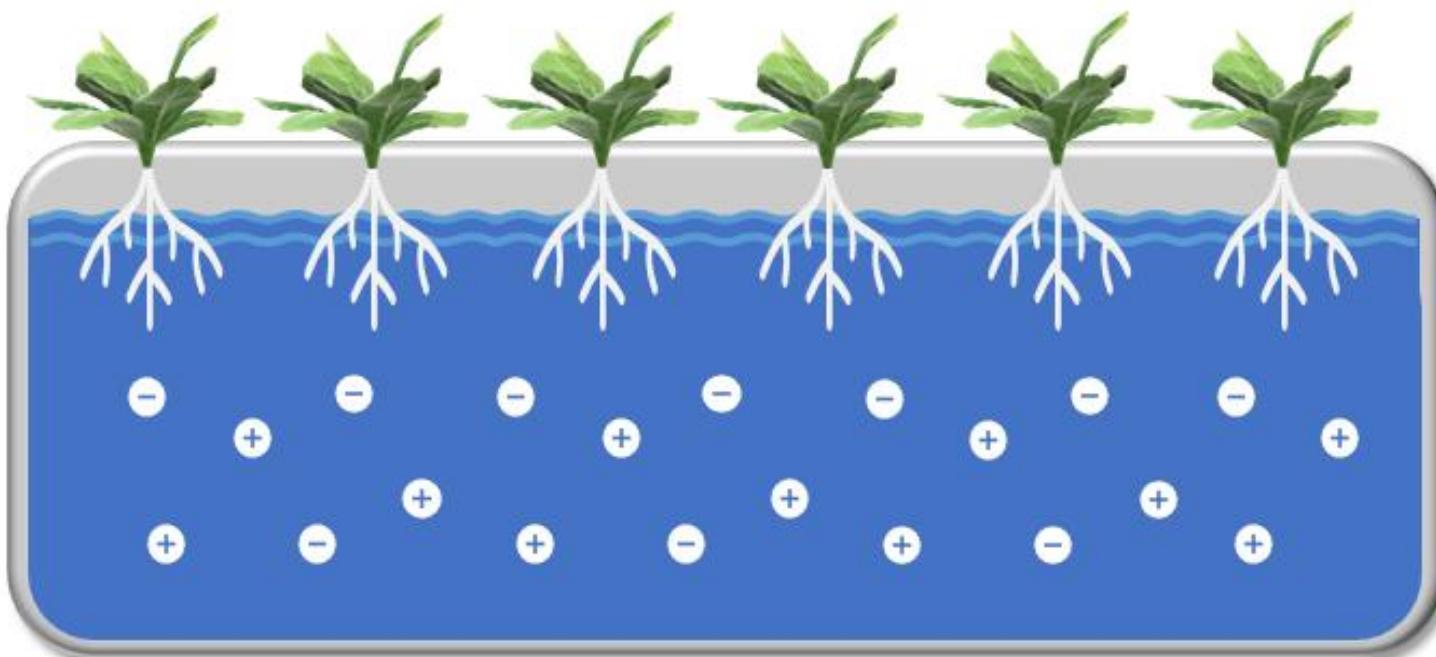


THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center

Principles of Hydroponics

What is Hydroponics?

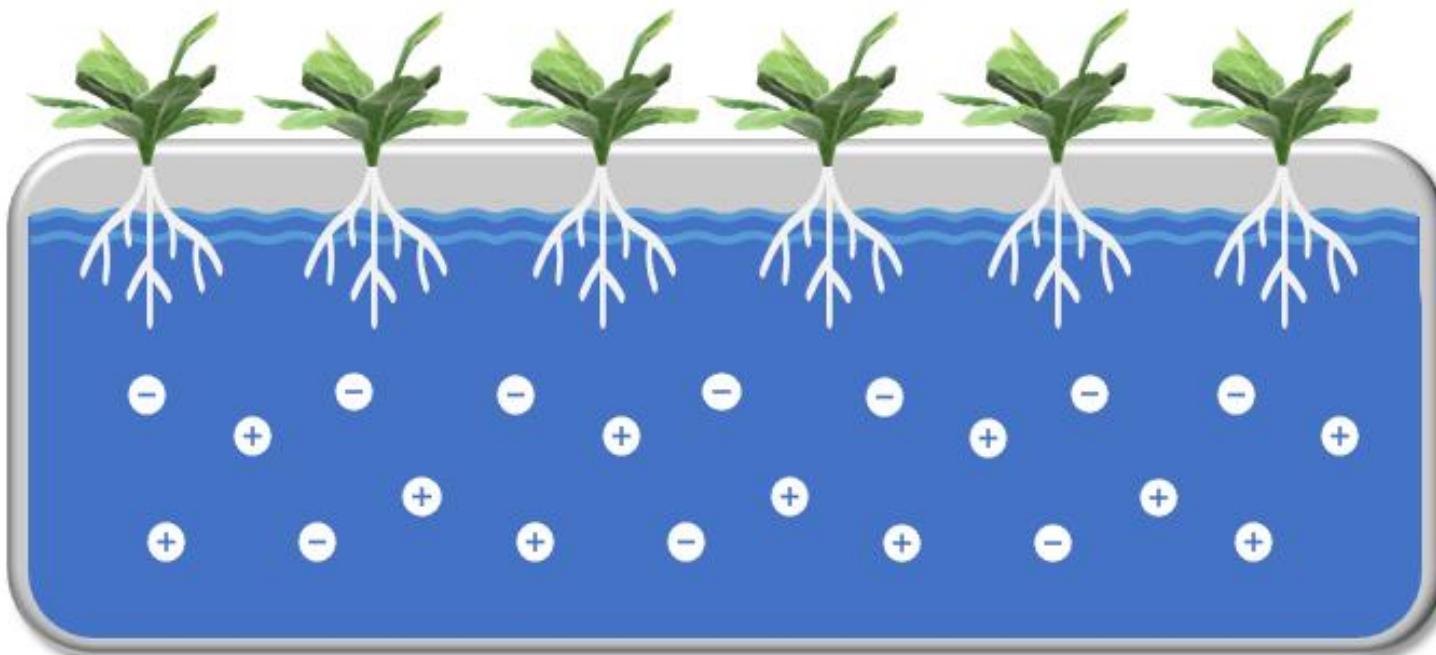


- Hydroponics uses a complete nutrient solution which contains water and all essential elements
- An essential element is required for a plant to grow and complete its lifecycle

Principles of Hydroponics

What is Hydroponics?

- 13* essential elements:
 - 6 Macro (N P K Ca Mg S)
 - 7 Micro (Fe Cl B Zn Mn Cu Mo)
- Dissolved in water as inorganic ions for plant roots to uptake





Principles of Hydroponics

What is Hydroponics?

- Hydroponics is soilless which means it doesn't rely on soil in the ground for plant production
- However, hydroponics commonly uses a substrate to hold moisture and anchor the plant



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center



Principles of Hydroponics

What is Hydroponics?

- Therefore, hydroponics enables plant production outside of traditional agricultural constraints
- This allows for unique and limitless methods for growing plants – the future of farming!



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

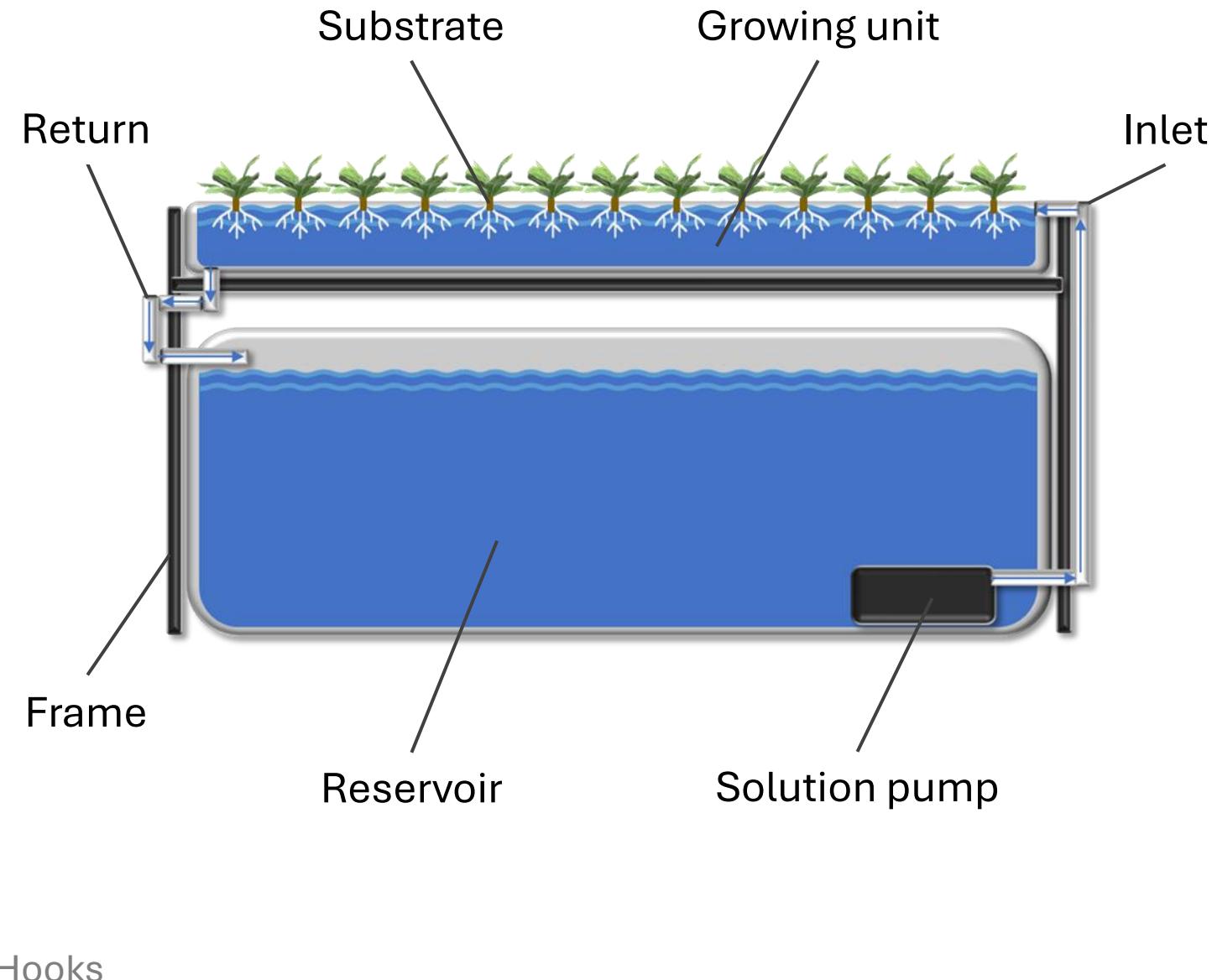
Controlled Environment
Agriculture Center

Principles of Hydroponics

What is Hydroponics?

Common components of hydroponic systems:

- Reservoir
- Solution pump
- Inlet/Return
- Growing unit
- Substrate
- Frame



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center

Principles of Hydroponics



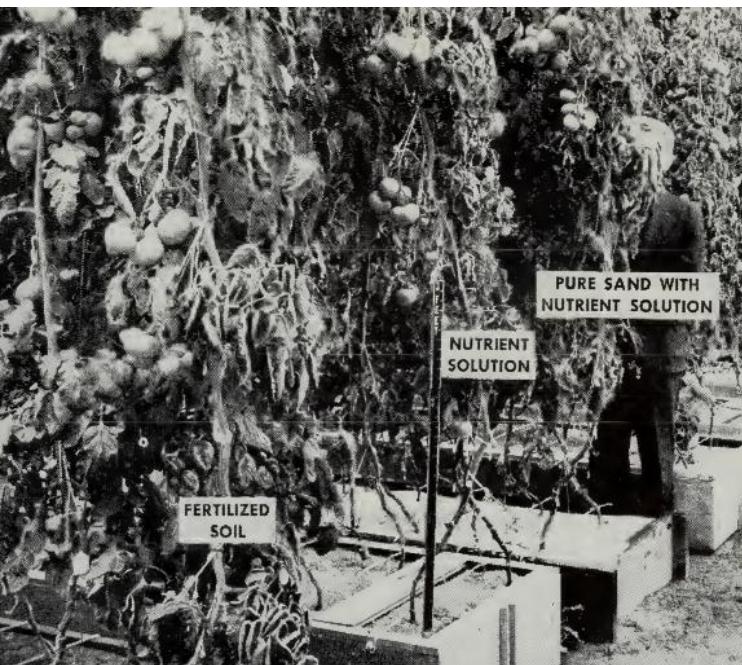
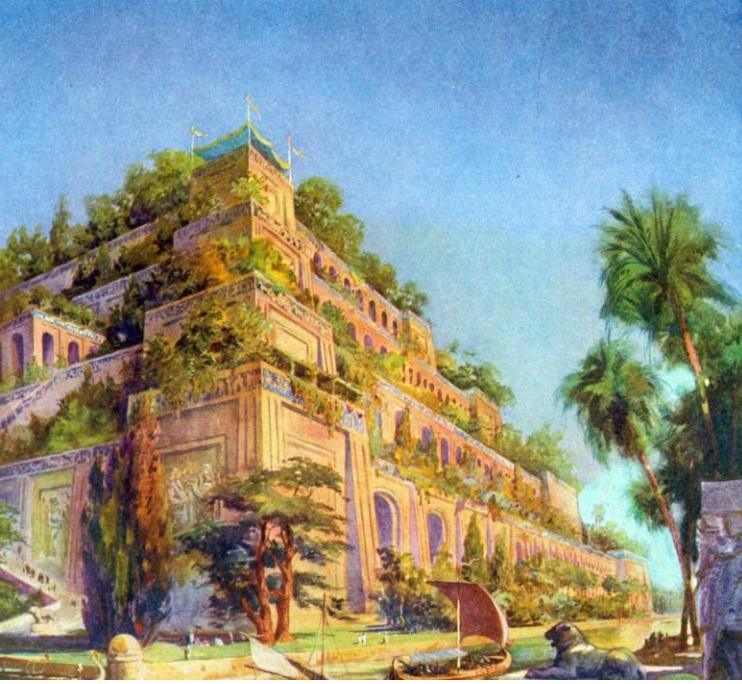
What is Hydroponics?

- Nutrient Film Technique (NFT) systems are the most common and versatile hydroponic systems, globally
- These systems consist of channels with a thin film of solution running through them

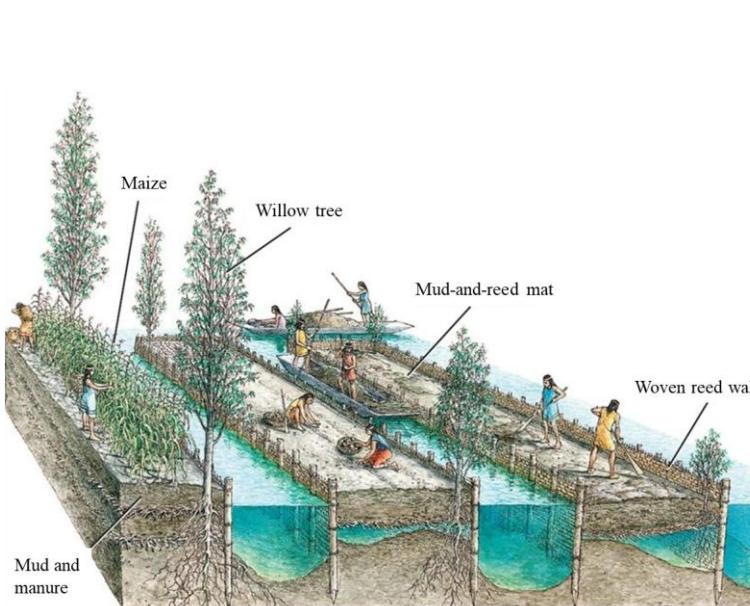


THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING
Controlled Environment
Agriculture Center

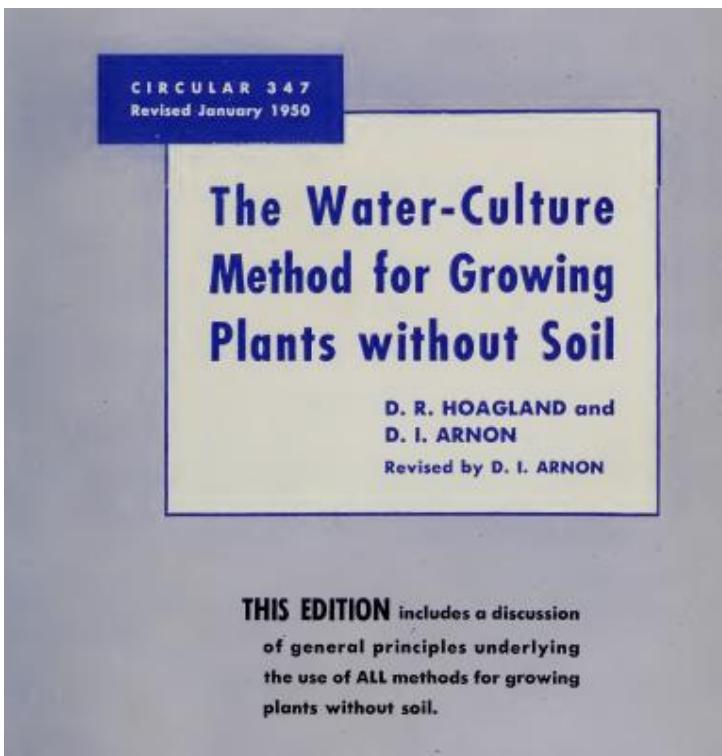
Principles of Hydroponics



Hoagland and Arnon 1950



Thearchaeologist.org



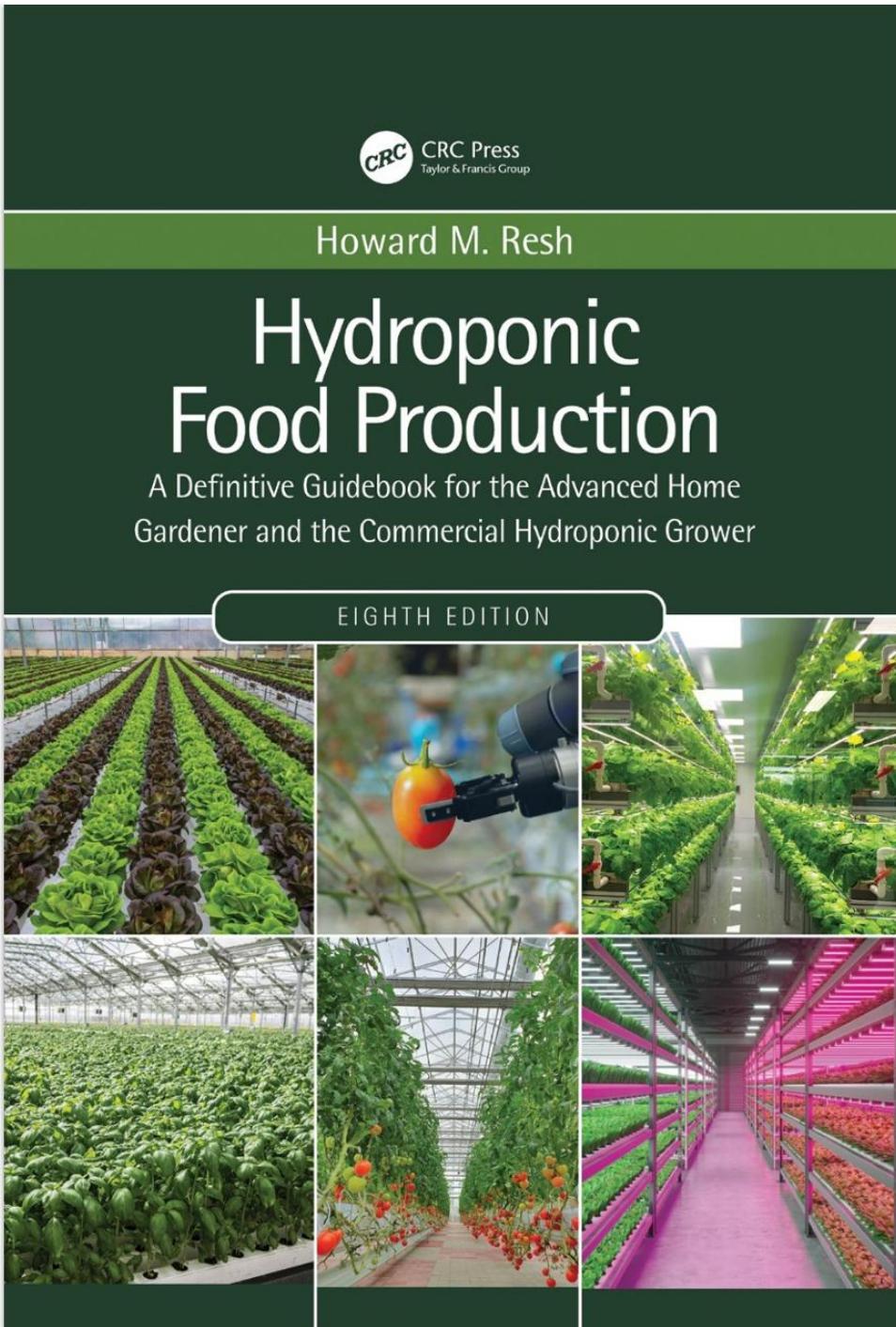
What is Hydroponics?

Hydroponics is not new!

- Hanging Gardens of Babylon
- 'Chinampas' Aztec floating gardens
- 'Nutriculture', 'Water-Culture', and finally 'Hydroponics' by Dr. William Gericke in the 1930s



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING
Controlled Environment
Agriculture Center



Principles of Hydroponics

What is Hydroponics?

- Today, hydroponics is used worldwide to grow many different crops and compliment/supplement traditional agriculture
- Hydroponics is commonly used in Controlled Environment Agriculture (CEA)



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING
Controlled Environment
Agriculture Center

Principles of Hydroponics



What is CEA?

- Controlled Environment Agriculture (CEA) is an integrated science and engineering-based approach to provide specific environments for plant production



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING
Controlled Environment
Agriculture Center

Principles of Hydroponics



What is CEA?

To provide a specific environment for plant production, CEA can control:

- Air temperature
- Humidity
- Air flow
- Light
- CO₂
- and more...



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center

Principles of Hydroponics

What is CEA?

- CEA is made possible primarily by a structure that enables environmental control
- The structure can be equipped with more or less technology to enhance the level of environmental control



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center



Johnny's Select Seeds

Principles of Hydroponics

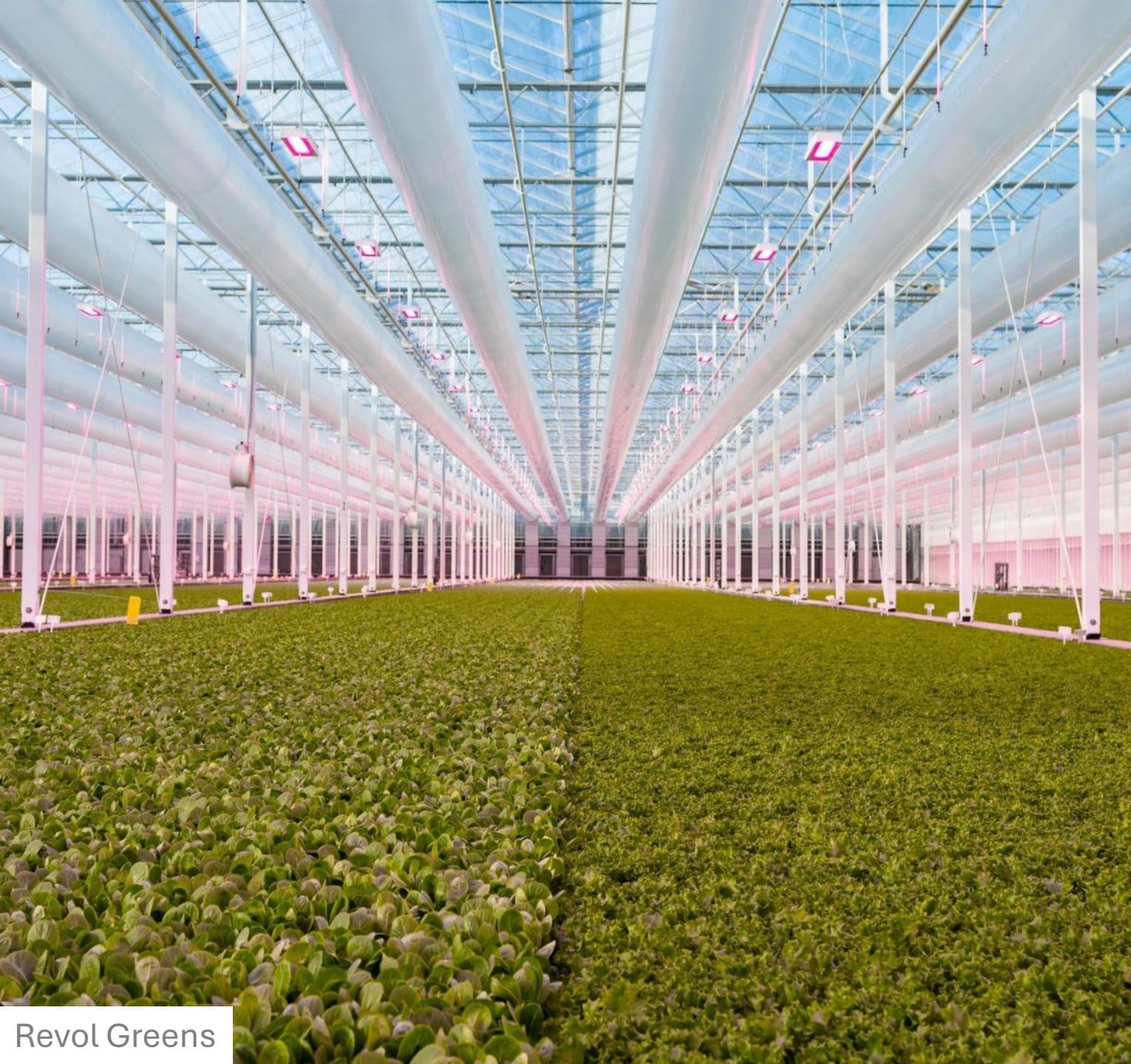
What is CEA?

High-tunnel (low-tech)

- Simple but effective structure that can enable season extension
- Benefits include low cost, energy, and maintenance
- Suitable for small scale rural, urban, or off-grid agriculture



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING
Controlled Environment
Agriculture Center



Principles of Hydroponics

What is CEA?

Greenhouse (medium-tech)

- The most common CEA structure for year-round production
- Offers a balance between environmental control and cost/energy
- The most scalable and versatile form of CEA!



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING
Controlled Environment
Agriculture Center



Principles of Hydroponics

What is CEA?

Indoor farm (high-tech)

- The apex of environmental control at the expense of cost/energy
- Most suitable for densely populated urban areas or unique/extreme environments (e.g. Antarctica, the ISS, or the moon!)



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center



Principles of Hydroponics

What is CEA?

- Technically, environmental control is not new and has been applied in nursery and potted plant production for a long time
- However, the combination of hydroponics and CEA for crop production is a relatively new and exciting method of agriculture – the future of farming!



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center



Principles of Hydroponics

Why Hydroponics and CEA?

- Create an optimal growing environment for consistent, fast, and high-quality yield
- Extended or year-round production that is protected from adverse climate or soil conditions



Village Farms

Principles of Hydroponics

Why Hydroponics and CEA?

- Up to 7x plant density and up to 20x greater yield per unit area compared to traditional agriculture
 - Tomato yield = 6x
 - Peppers = 9x
 - Lettuce = 11x
 - Cucumbers = 20x



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center

Principles of Hydroponics

Why Hydroponics and CEA?

- Less water, fertilizer waste, and pesticides due to closed, precise, and recirculating systems
 - 20% - 95% less water
 - Zero fertilizer waste from leaching or runoff
 - Minimal pesticide use with IPM*



Plenty



Principles of Hydroponics

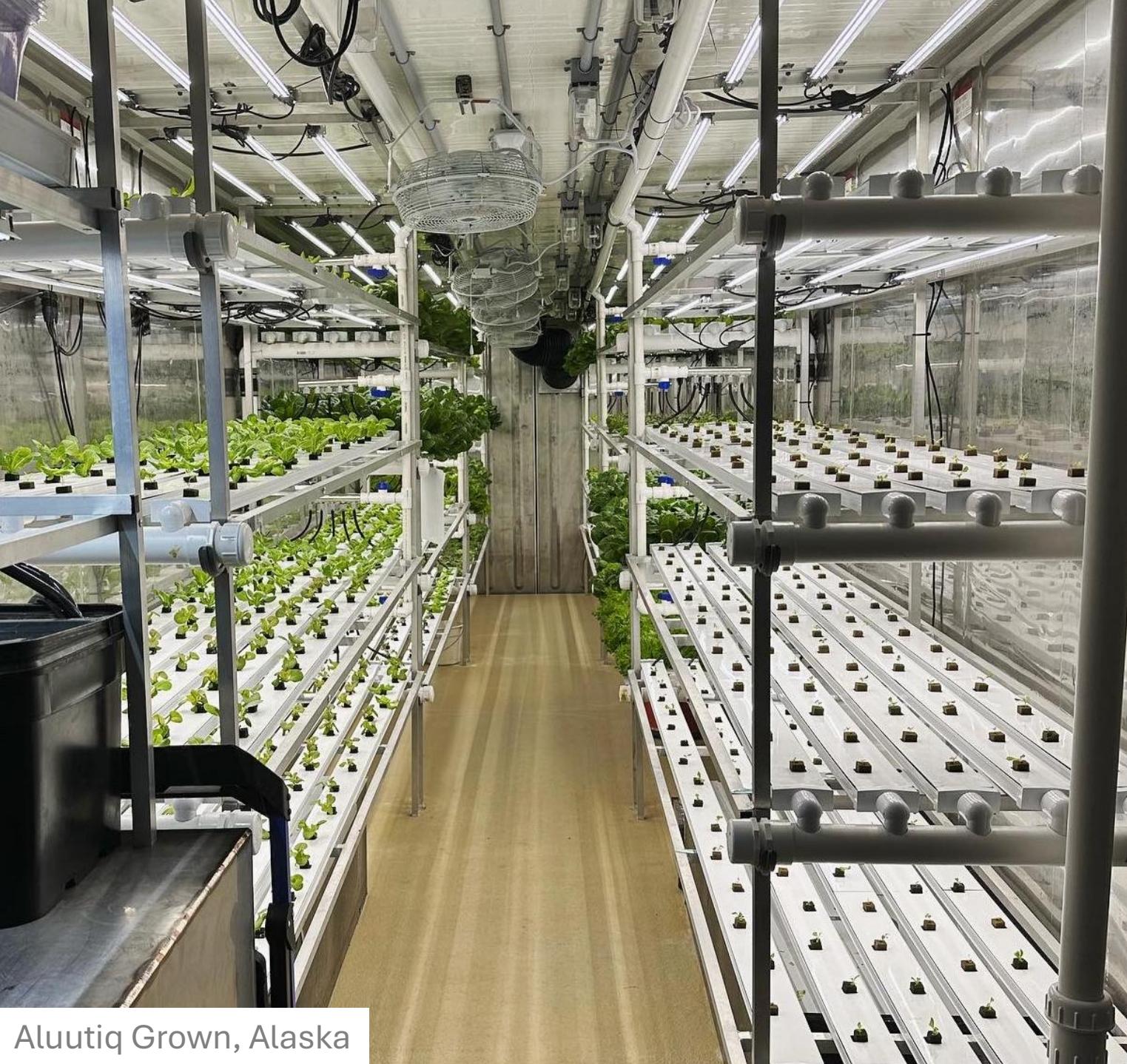
Why Hydroponics and CEA?

- New crops, such as peppers, melons, eggplant, beans and peas, berries, edible flowers, and more!
- New nutrient solution recipes, environmental setpoints, and plant production methods!



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center



Aluutiq Grown, Alaska

Principles of Hydroponics

Why Hydroponics and CEA?

- Food travels an average of 1500 miles from farm to table in the US
- Hydroponics and CEA can reduce food miles by 96% or more!
- Sustainable food systems that can strengthen food security



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center

THE ROOFTOP GREENHOUSE

In Collaboration with the Student Union, Campus Pantry, and Biosystems Engineering Department

Our mission is student-grown hydroponic produce delivered weekly to the Campus Pantry to strengthen food security on Main Campus!

Follow us on Instagram @ua_rooftopgreenhouse

Contact Dr. Hooks for more information!
tristonh@arizona.edu

USDA-ER

Controlled Environment Agriculture Center

THE UNIVERSITY OF ARIZONA Campus Pantry

College of Agriculture, Life & Environmental Sciences COLLEGE OF ENGINEERING Biosystems Engineering

Principles of Hydroponics

Why Hydroponics and CEA?

- Food security is the availability and accessibility of safe and nutritious food
- Impacts ~800 million worldwide, including the U.S.
- Hydroponics and CEA can provide fresh food in urban and rural food deserts!



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center



AeroFarms

Principles of Hydroponics

Why Hydroponics and CEA?

- Lots of challenges, lots of unknowns, but lots of opportunities!
 - Energy (up to 100x more!)
 - Cost of technology
 - Cost of labor



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center



Principles of Hydroponics

Why Hydroponics and CEA?

- Conclusion...
 - Hydroponics and CEA offer unique and sustainable food production systems that can strengthen food security, complement traditional agriculture, and help grow a better future!



Module 1

Principles of Hydroponics

2026 Greenhouse Hydroponic Tomato Workshop with Dr. Triston Hooks

References

- Epstein and Bloom, 2004, *Mineral Nutrition of Plants*
- Resh, 2022, *Hydroponic Food Production*
- Jensen, 1997
- Barbosa et al., 2015
- Maureira et al., 2022
- Hooks, 2023-2024, UA-CEAC Teaching Greenhouse and NFT Greenhouse unpublished data
- EPA.gov and WRI.org
- Food, Fuel, and Freeways



THE UNIVERSITY OF ARIZONA
BIOSYSTEMS ENGINEERING

Controlled Environment
Agriculture Center