

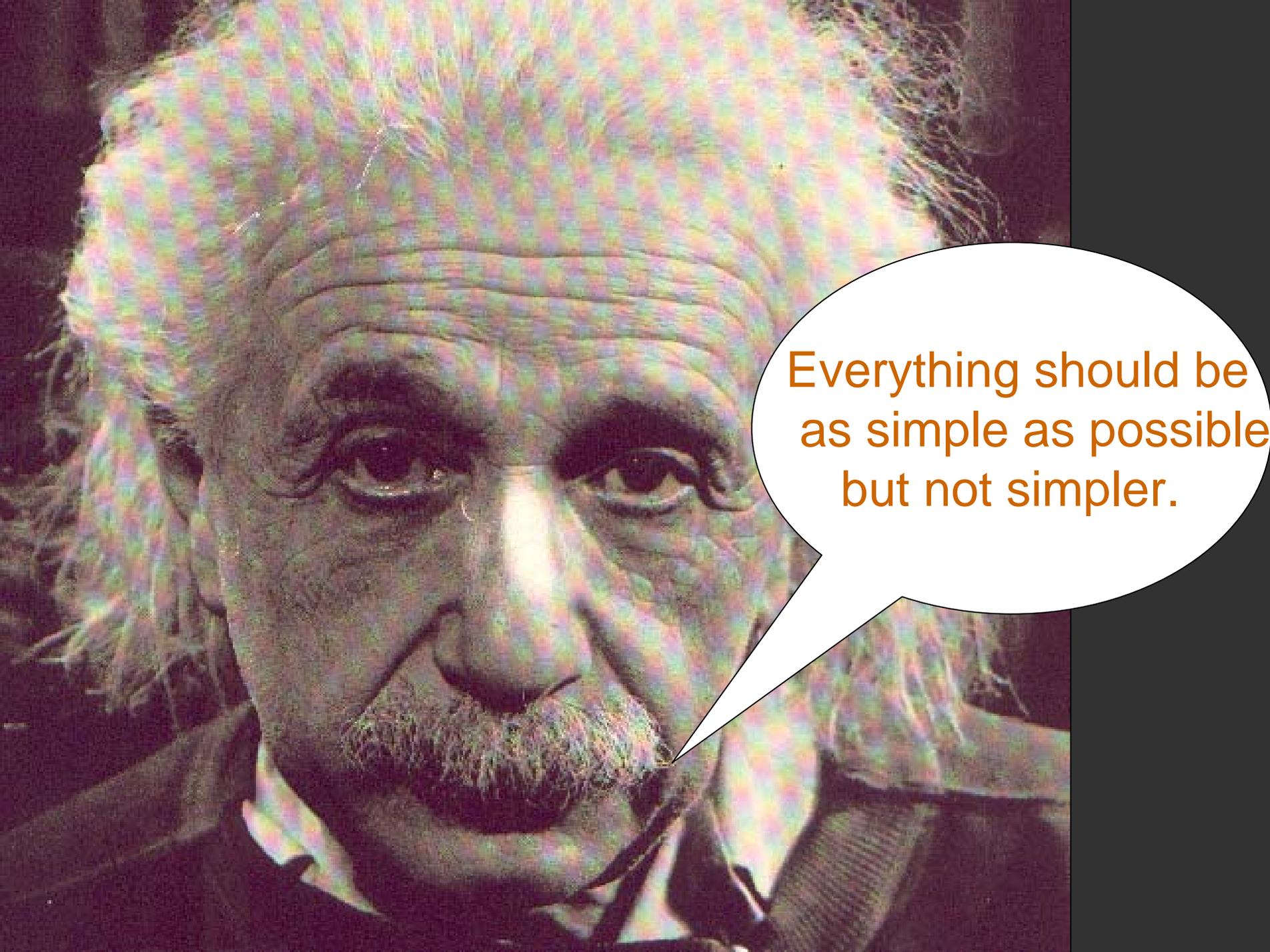
# The motion for simplicity

Presented as part of a debate on the trade-offs between simple and real environmental control in plant growth studies

Norwich, UK, 5 pm, *September 11<sup>th</sup>, 2001*



**Bruce Bugbee**  
**Utah State University**



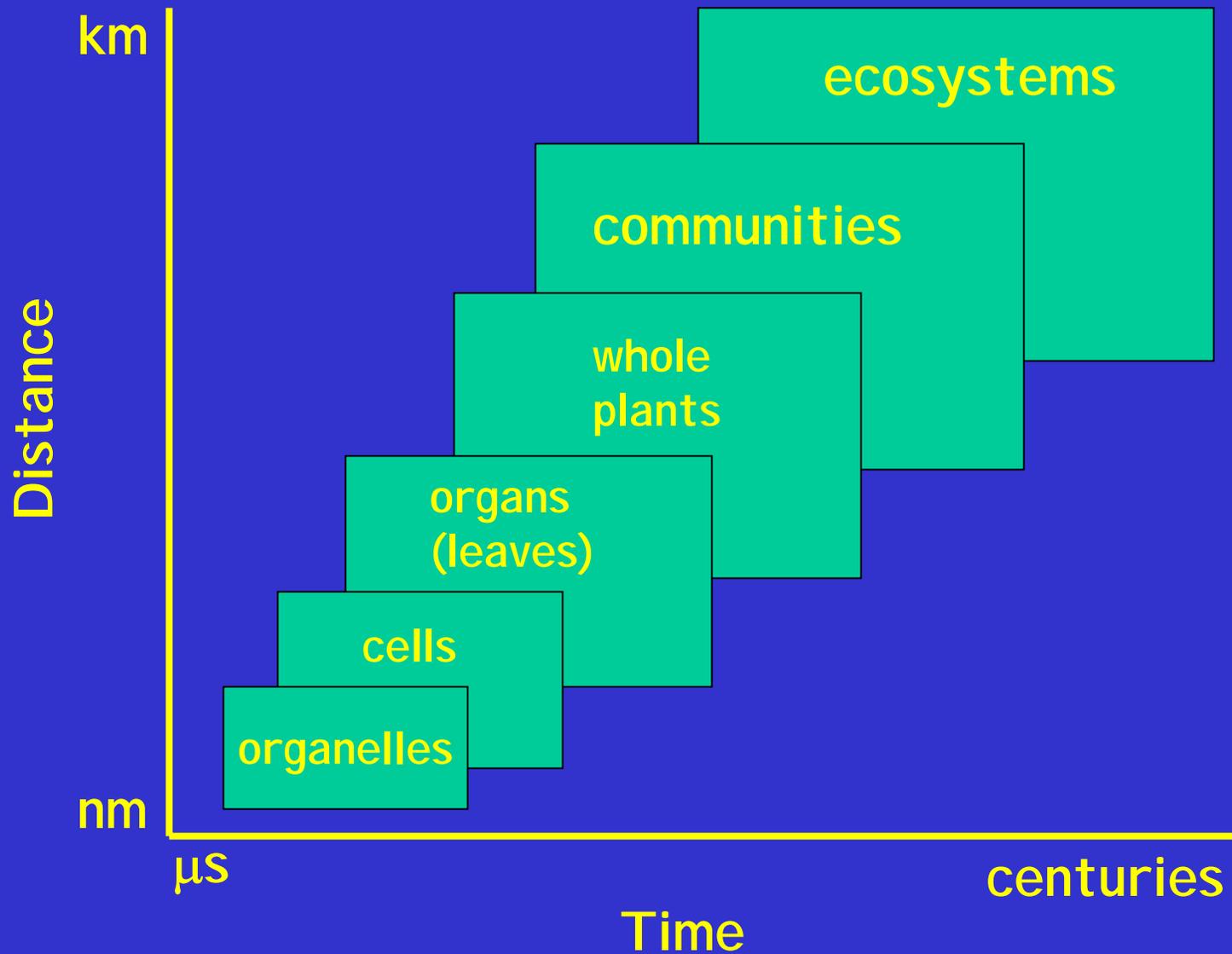
Everything should be  
as simple as possible  
but not simpler.

# Five features of simplicity

Simple environments are:

1. smaller
2. faster
3. cheaper
4. more repeatable
5. lower tech

# Simple studies are smaller and faster



Simple studies often mean using more theory  
and making fewer measurements

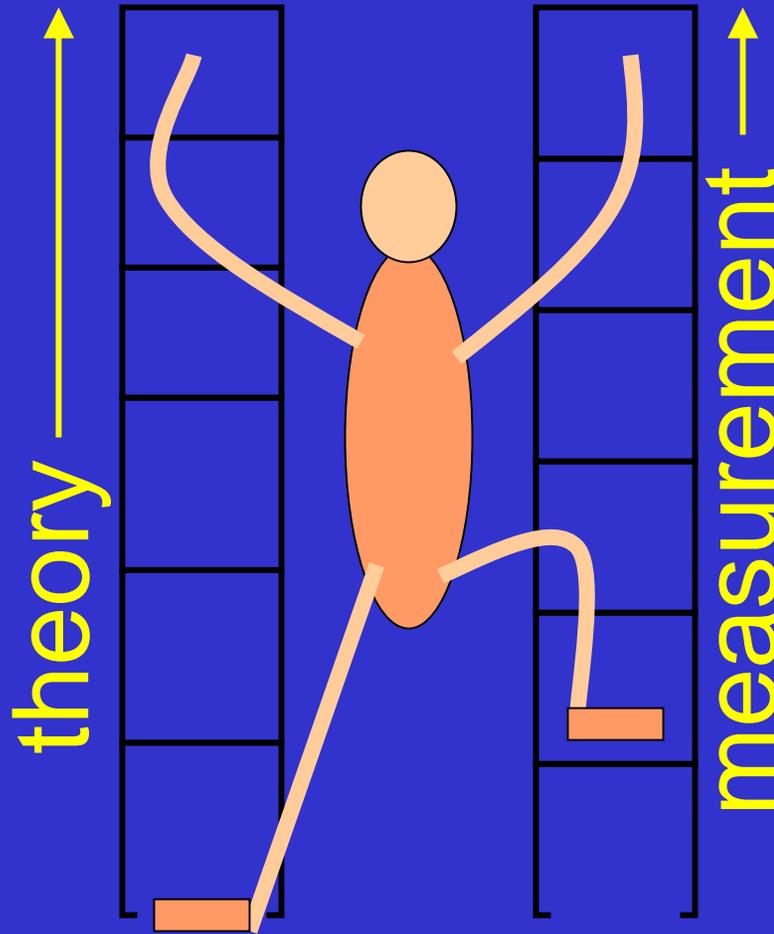
*Many plant biologists would be more productive if they spent more time  
in the library and less time collecting data*

“A month in the lab can save 2 days in the library”.

Francis Bacon

The interaction between theory and knowledge is like having one foot on each of two ladders.

Progress is most efficient if one step at a time is taken on each ladder.



“Simple systems, also called model systems, are a bridge between theory and the real world.”

Kareiva, P. 1989. Renewing the dialogue between theory and experiments in population ecology. *Perspectives in Ecology Theory*. Princeton University Press.

“We must first understand simple systems before we can understand complex ones.”

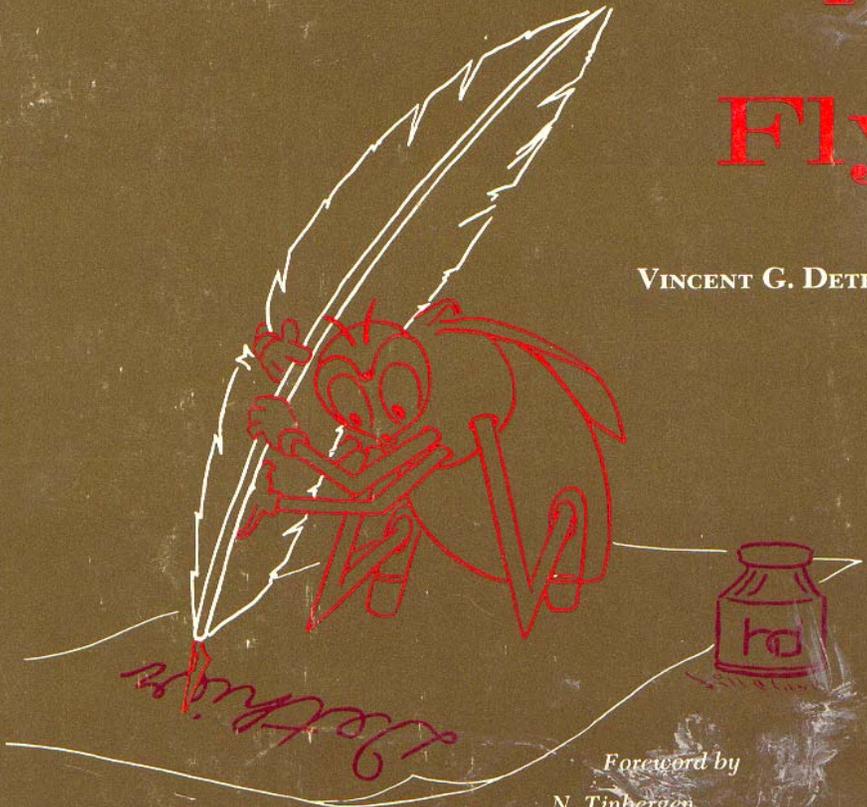
“It is the very complexity of the real world that requires us to conduct simple studies.”

Lawton, John. 1996. The Ecotron Facility at Silwood Park: The value of big bottle experiments. *Ecology* 77:665-669.

BUGPREE

To  
Know  
A  
Fly

VINCENT G. DETHIER



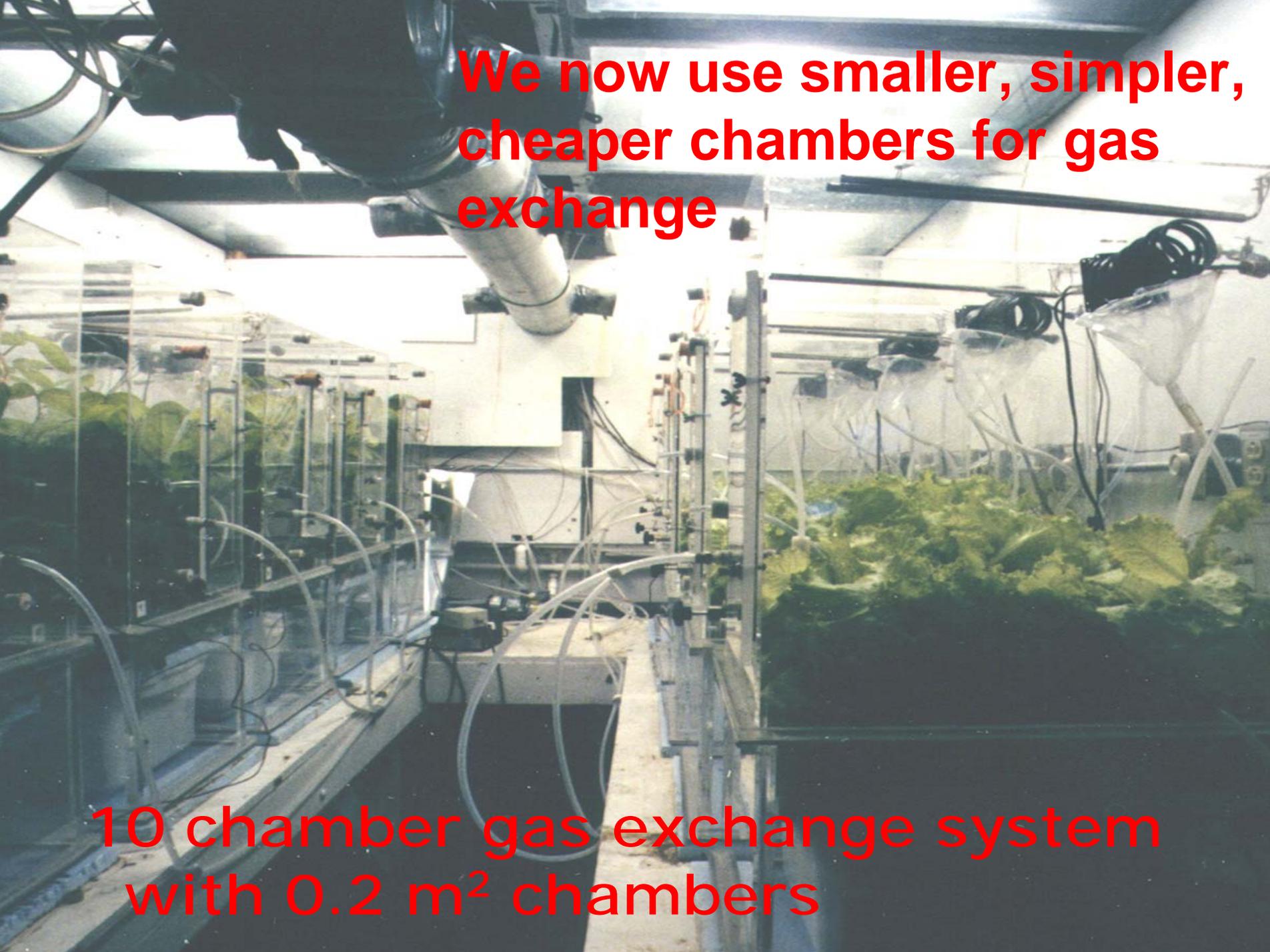
Foreword by  
N. Tinbergen

We learned much of what we know about animal physiology from studying flies in the 1950's and 60's

Vincent Dethier  
1962



We used entire growth chambers as gas-exchange chambers during the 1980's.



**We now use smaller, simpler,  
cheaper chambers for gas  
exchange**

**10 chamber gas exchange system  
with 0.2 m<sup>2</sup> chambers**

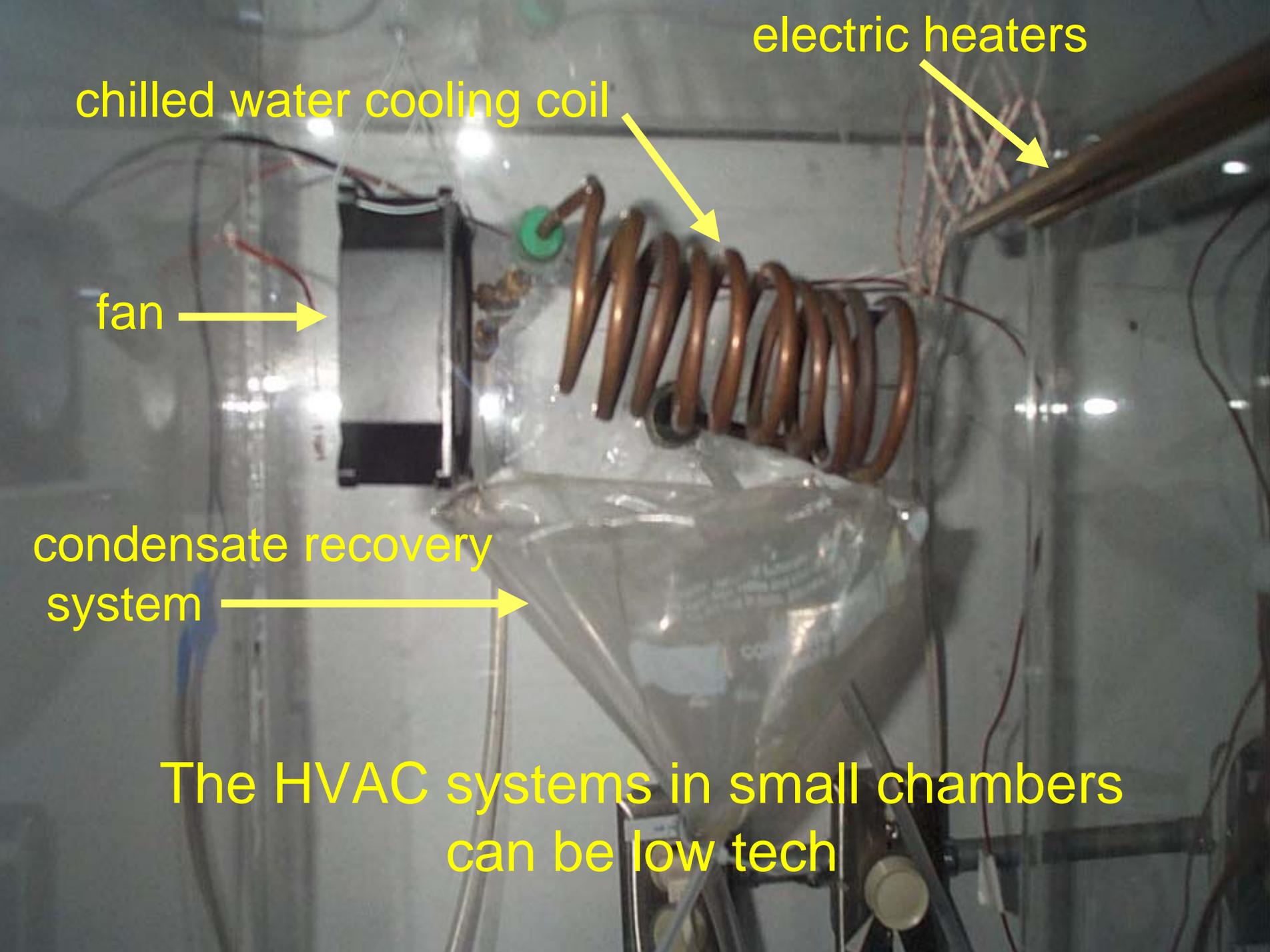
electric heaters

chilled water cooling coil

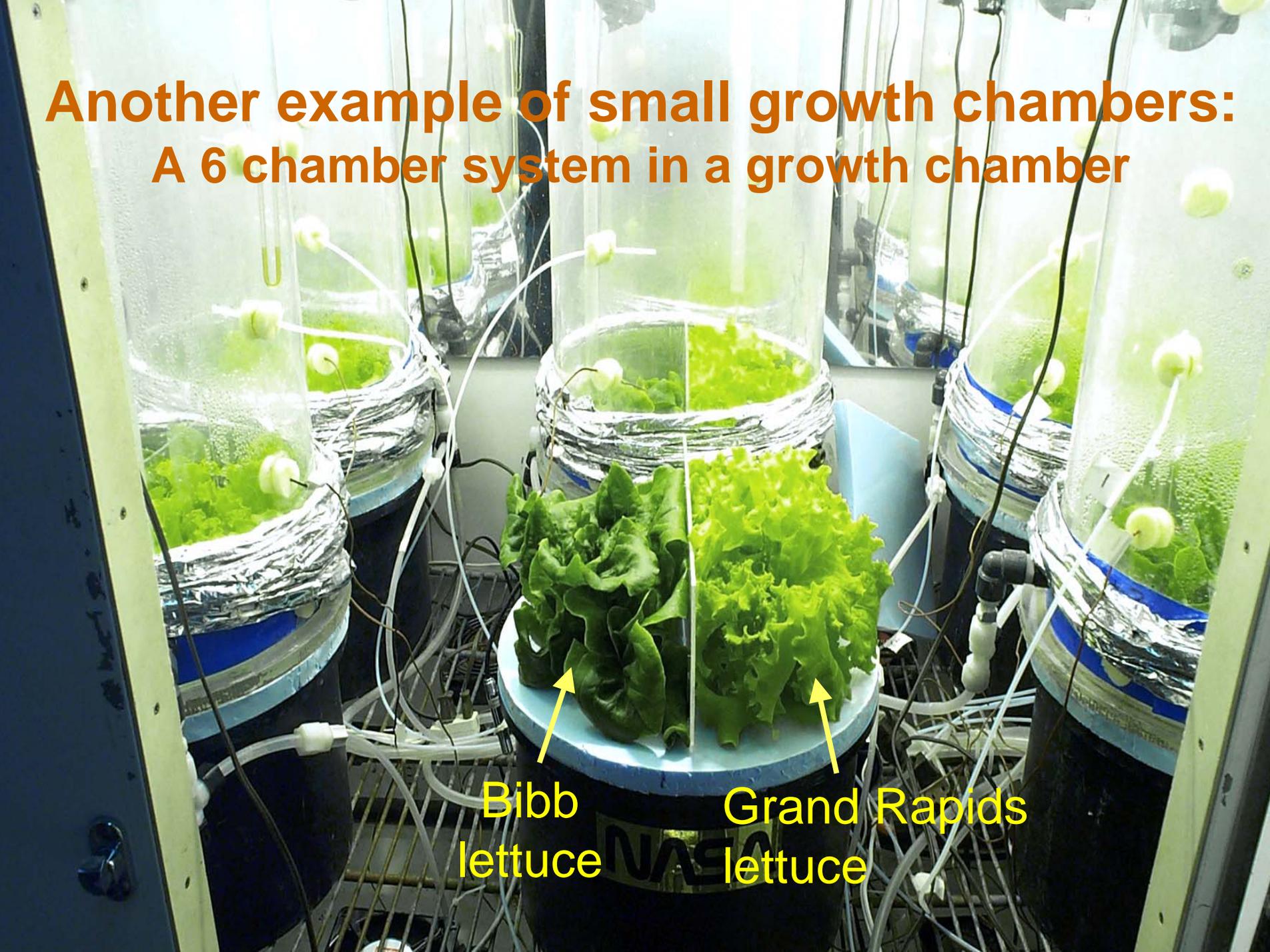
fan

condensate recovery  
system

The HVAC systems in small chambers  
can be low tech



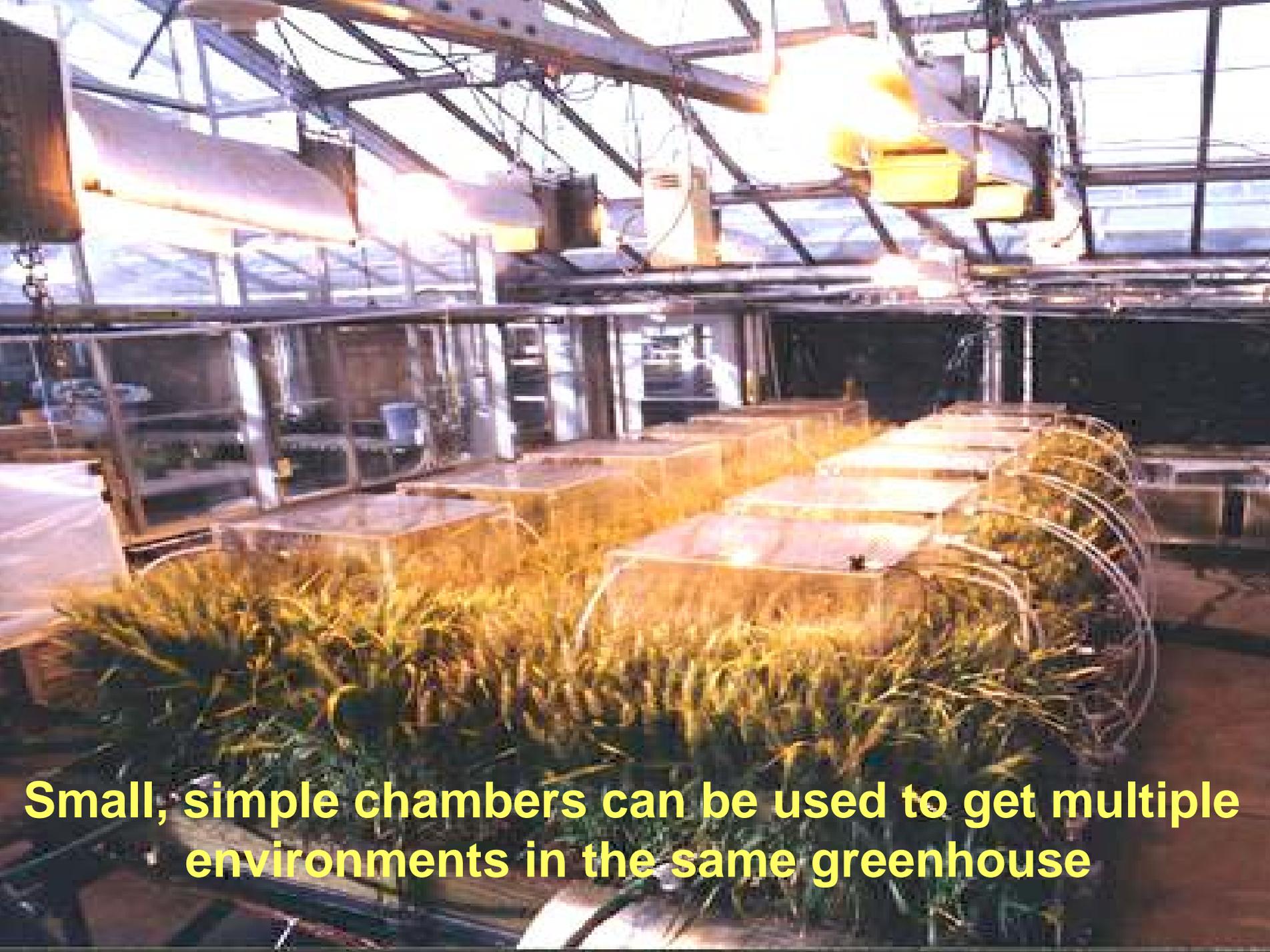
**Another example of small growth chambers:  
A 6 chamber system in a growth chamber**



The image shows a 6-chamber system in a growth chamber. Each chamber is a clear cylindrical container with a blue base, containing a small amount of green lettuce. The chambers are arranged in a row. The central chamber is the largest and contains two types of lettuce: Bibb lettuce on the left and Grand Rapids lettuce on the right. The Bibb lettuce is darker green and has a more rounded, crinkled leaf structure. The Grand Rapids lettuce is lighter green and has a more elongated, crinkled leaf structure. The chambers are connected by a network of white tubes and wires. The background is a dark, metallic surface, likely the interior of the growth chamber.

**Bibb  
lettuce**

**Grand Rapids  
lettuce**



**Small, simple chambers can be used to get multiple environments in the same greenhouse**

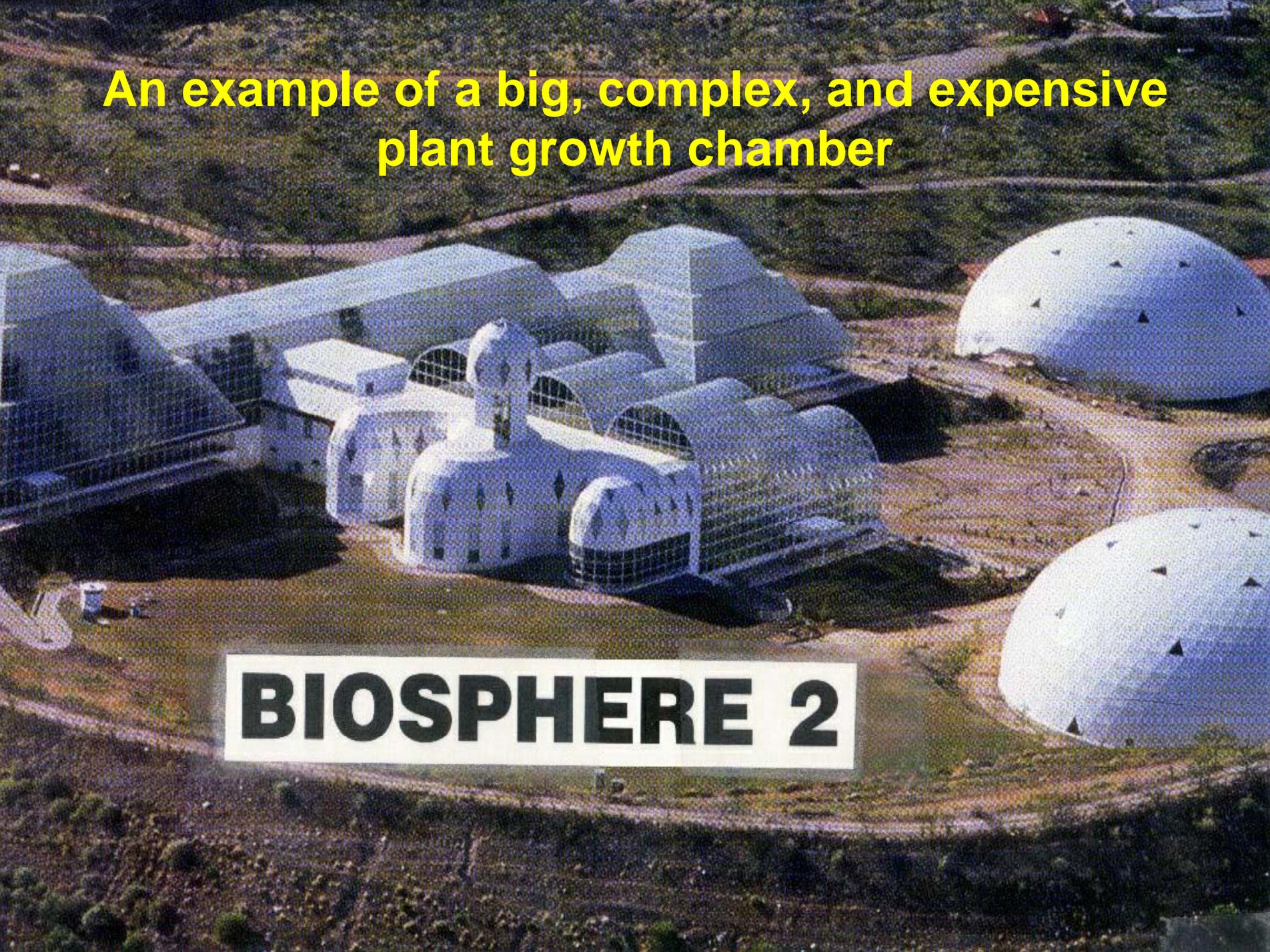
## The NASA 20 foot chamber

In hindsight, might the money and brain power been better utilized with multiple smaller chambers?

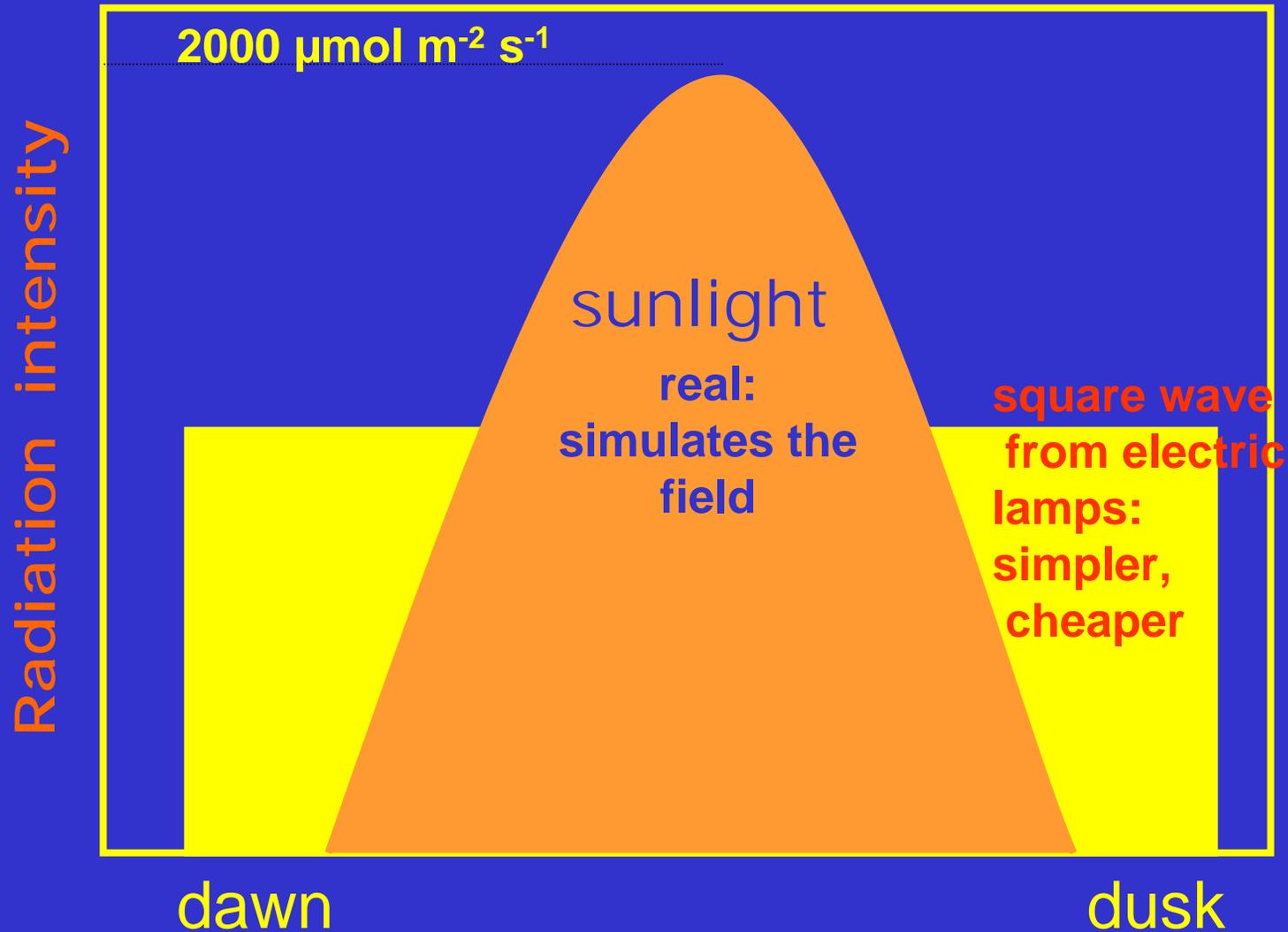


An example of a big, complex, and expensive  
plant growth chamber

**BIOSPHERE 2**

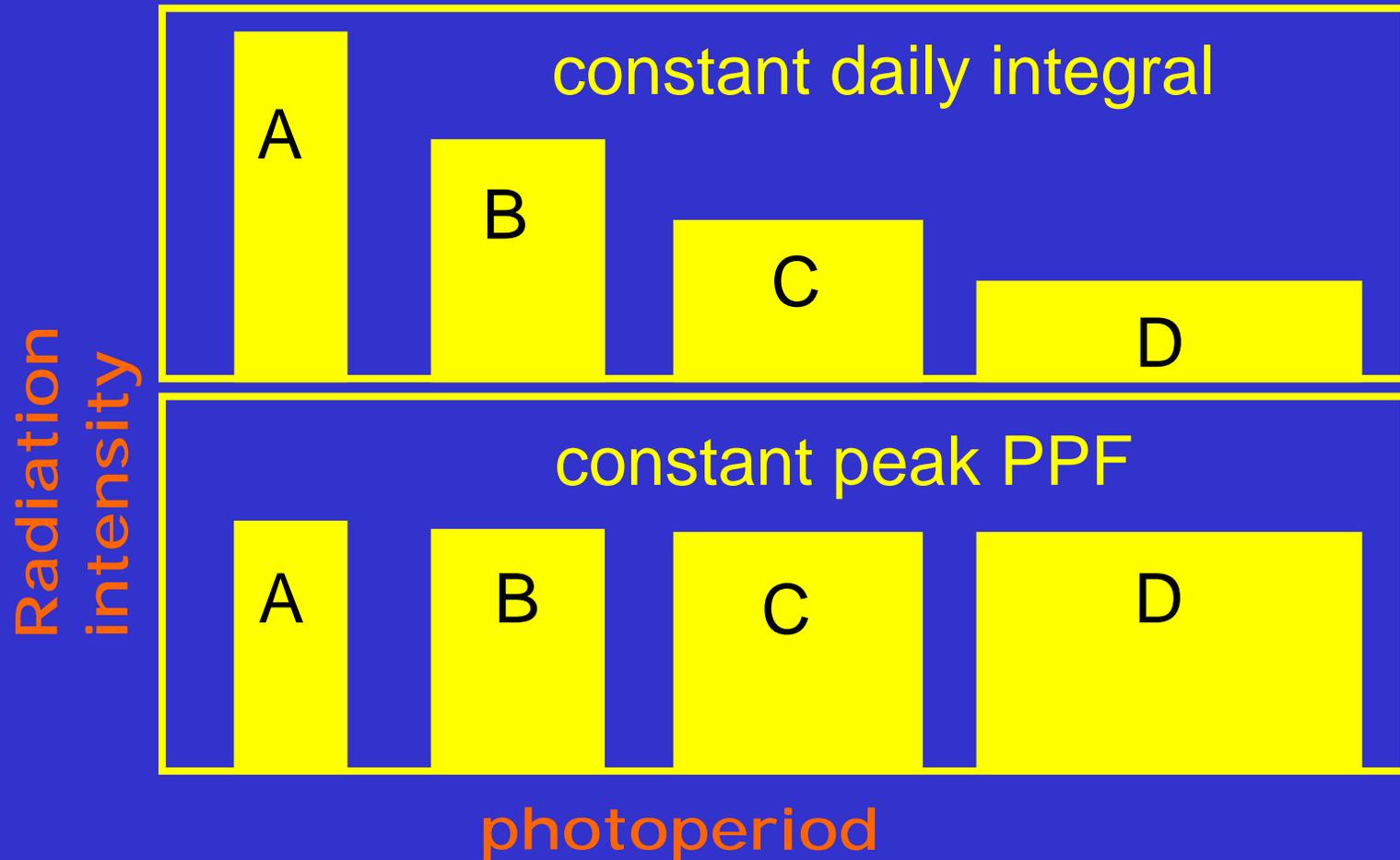
An aerial photograph of Biosphere 2, a large-scale plant growth chamber. The facility consists of several interconnected white, dome-shaped and rectangular structures. The central part features a tall, narrow tower. The entire complex is situated in a cleared, brownish area, possibly a former agricultural field, with some greenery visible in the background. The text 'BIOSPHERE 2' is overlaid in a white box at the bottom center.

Do we need to simulate the diurnal pattern of radiation from the sun?



Answer: NO!

Plant growth is determined by the daily light total,  
not the peak light level.

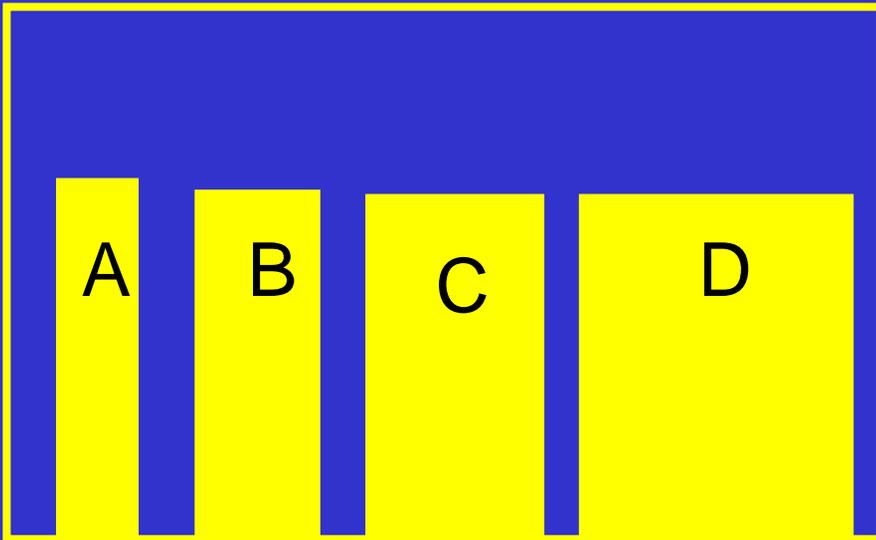
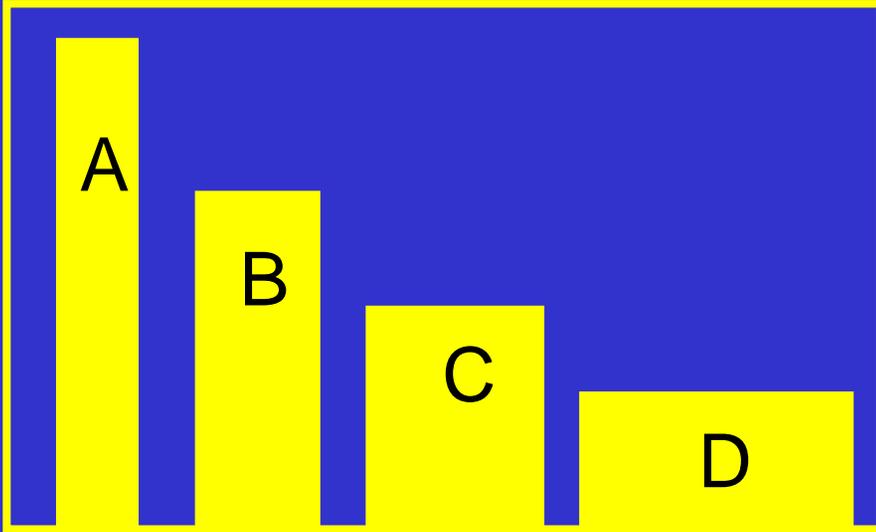


Chabot, et. al. 1979. Influence of Instantaneous and Integrated  
Light-Flux Density on Leaf Anatomy and  
Photosynthesis. Amer. J. Bot. 66: 940-945.

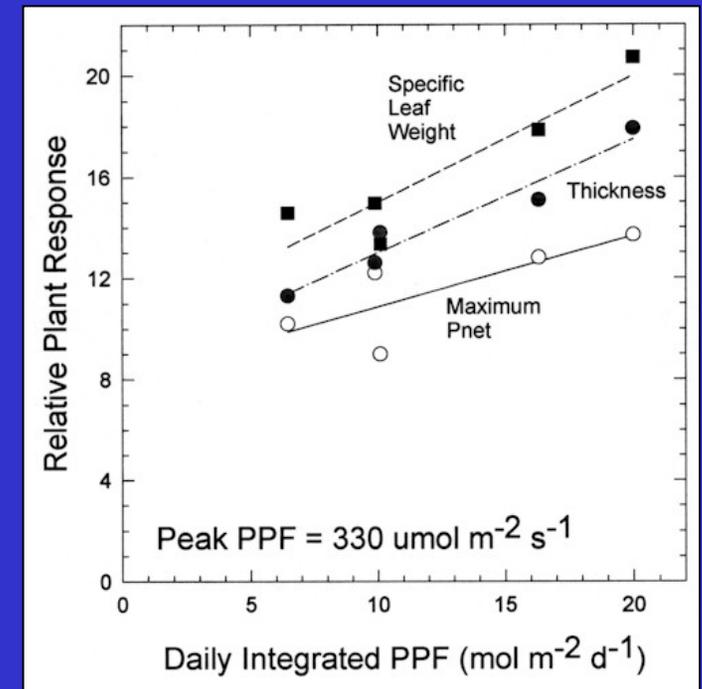
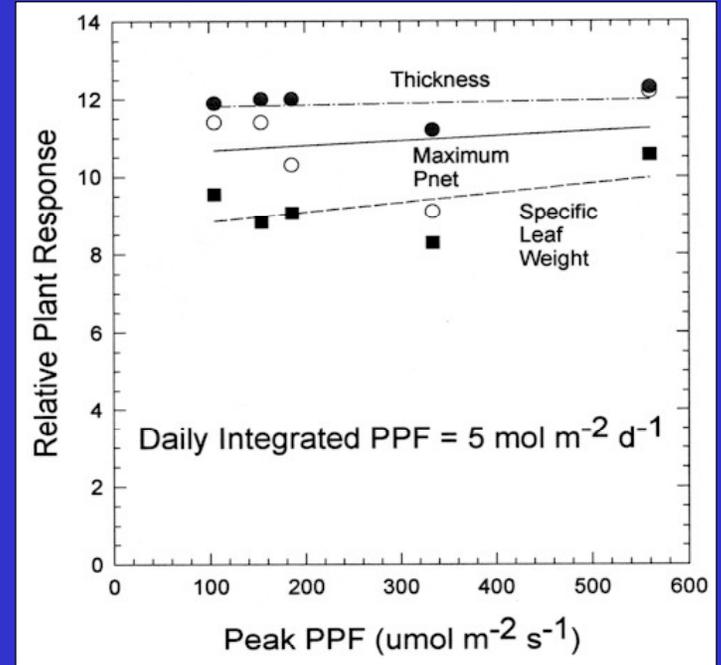
Chabot, et. al. 1979.

Amer. J. Bot. 66: 940-945.

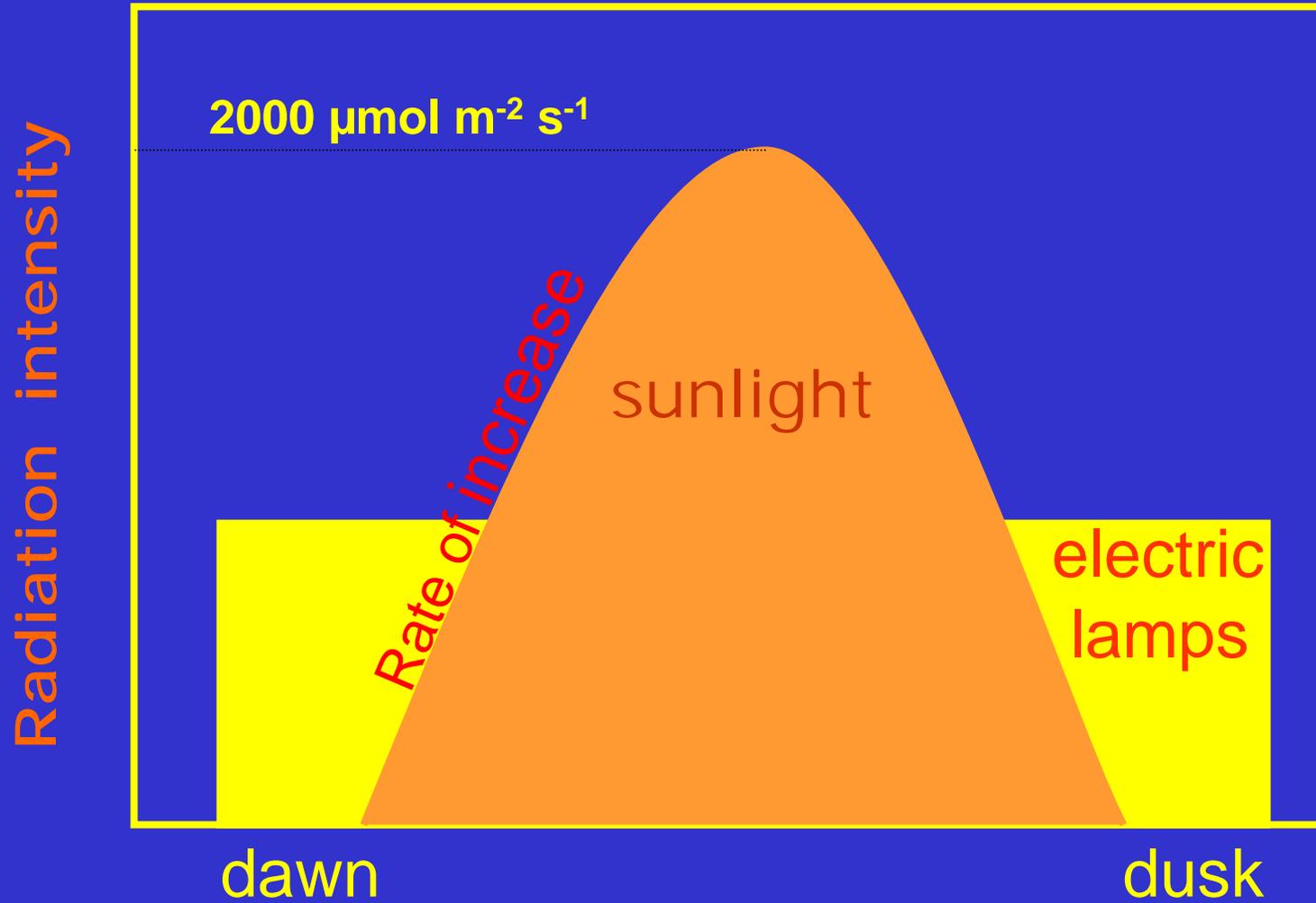
Radiation intensity



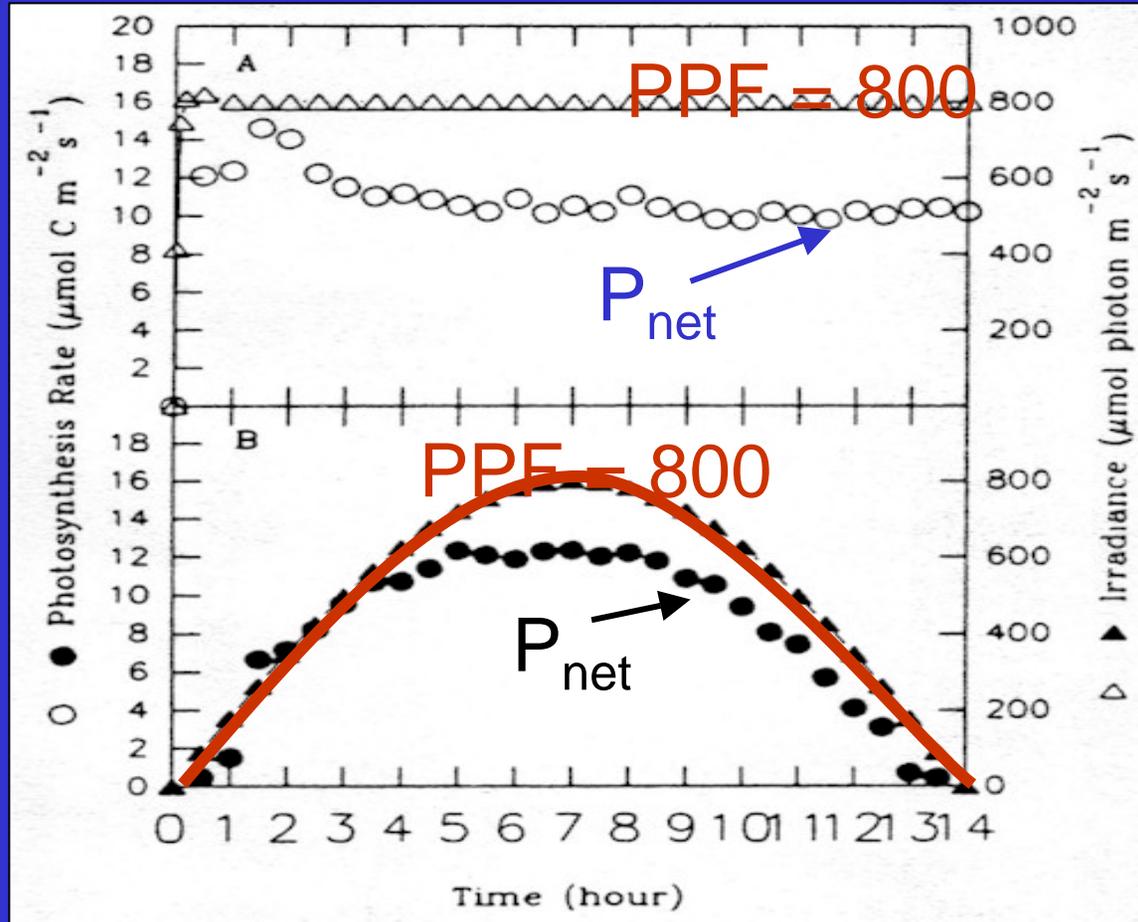
photoperiod



Is it important to slowly increase the radiation in the morning,  
like the field?



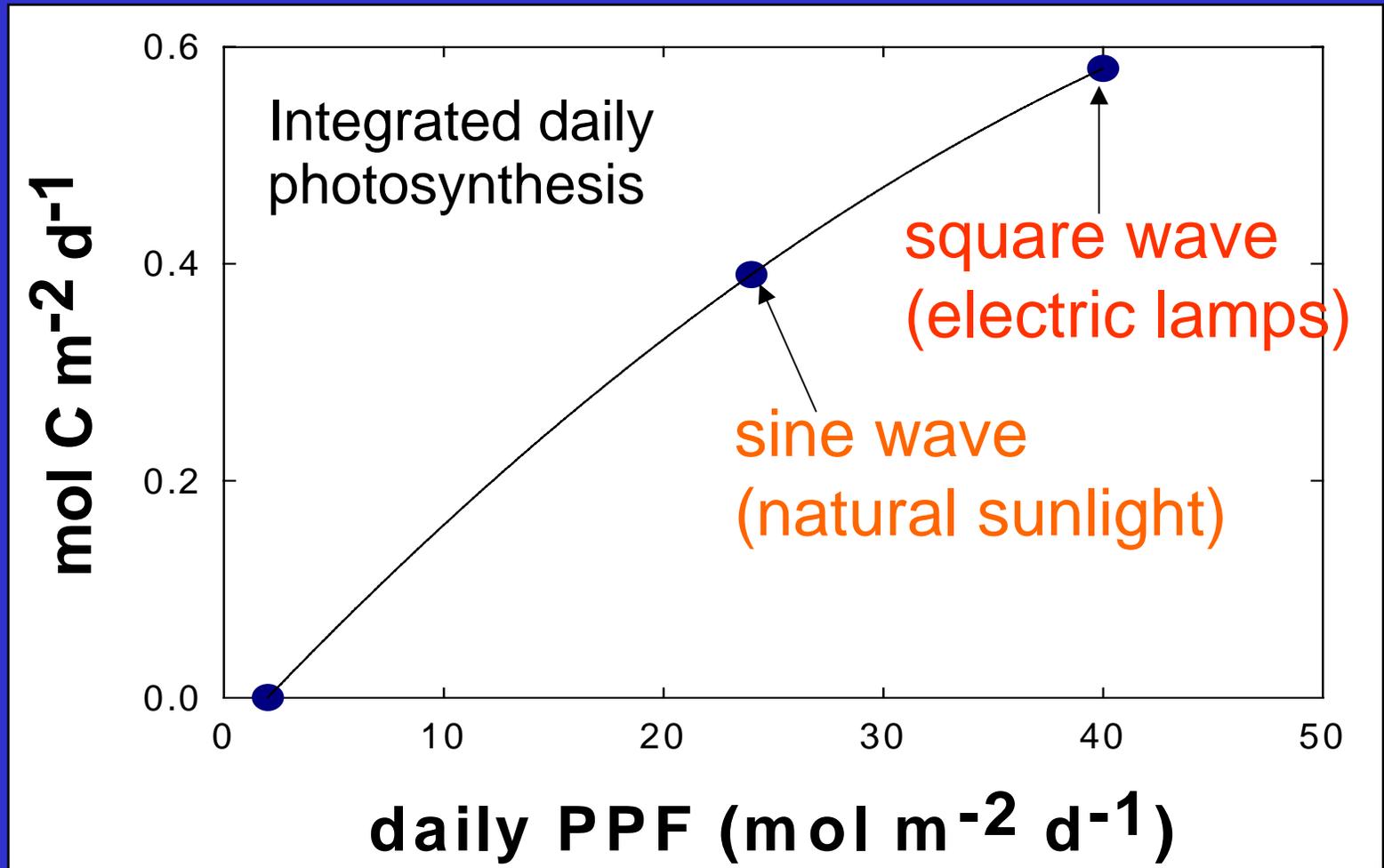
Don Geiger et al. examined this in 1991



Geiger, et. al. 1991. Carbon Assimilation and Leaf Water Status in Sugar Beet Leaves during a Simulated Natural Light Regimen. *Plant Physiol.* 97:1103-1108.

**Answer: NO**

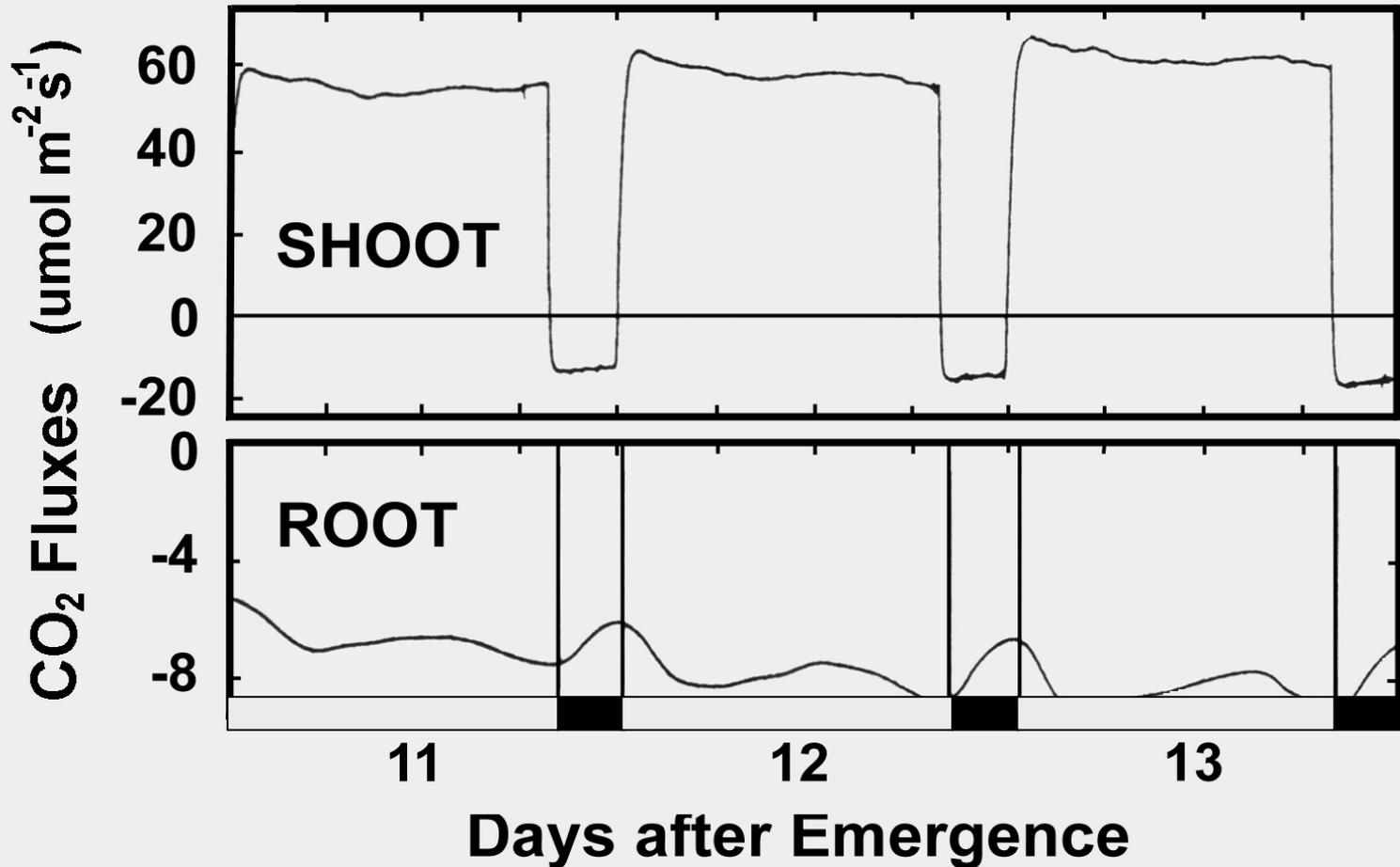
**Supplying the light as a square wave, with sharp on and off end points, did not reduce growth**



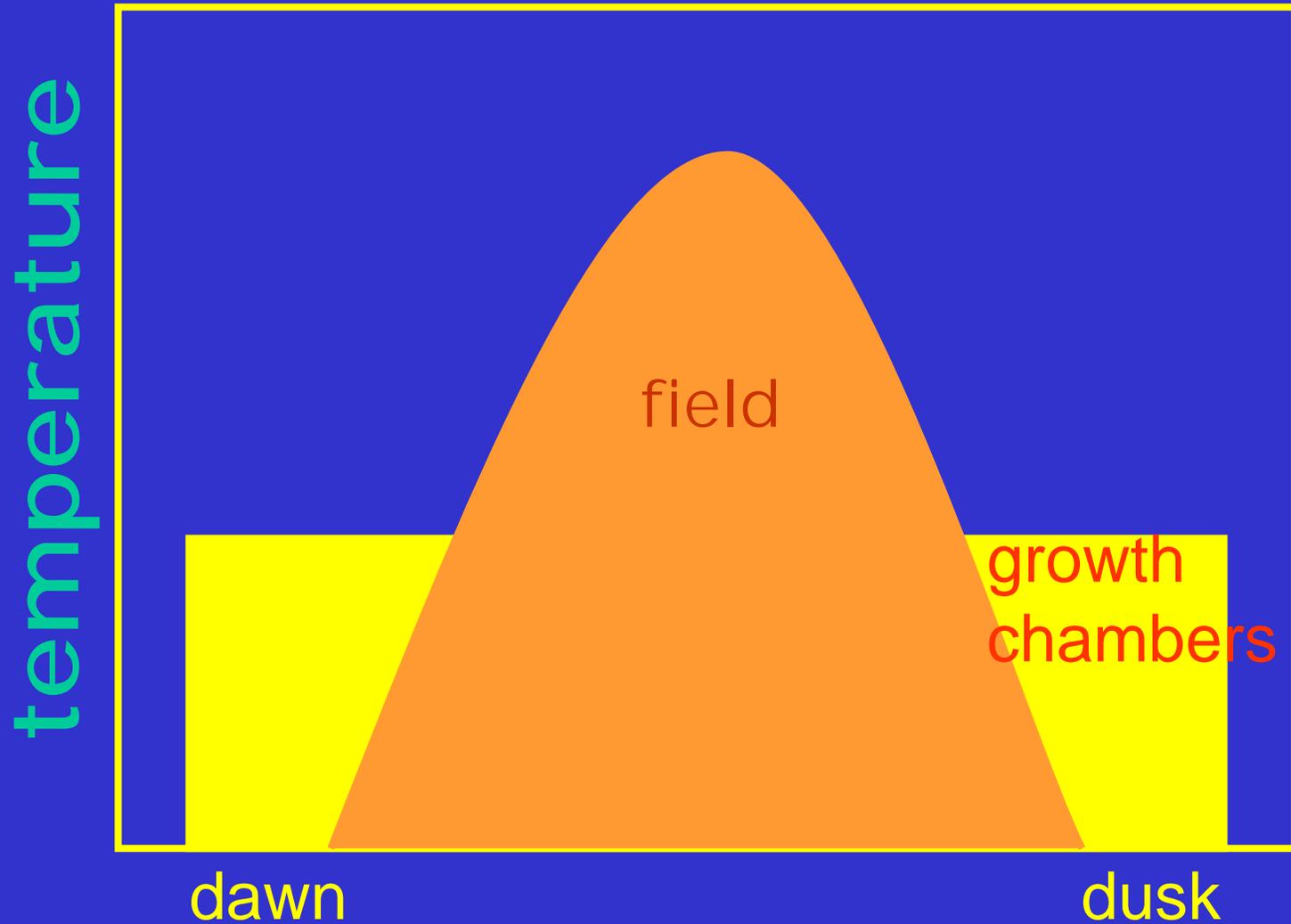
**Geiger et al. 1991. Simulated natural light. . .**

Photosynthetic rate increases rapidly in the morning  
as the light reach full output.

There is no evidence of the need to ramp the lights up gradually



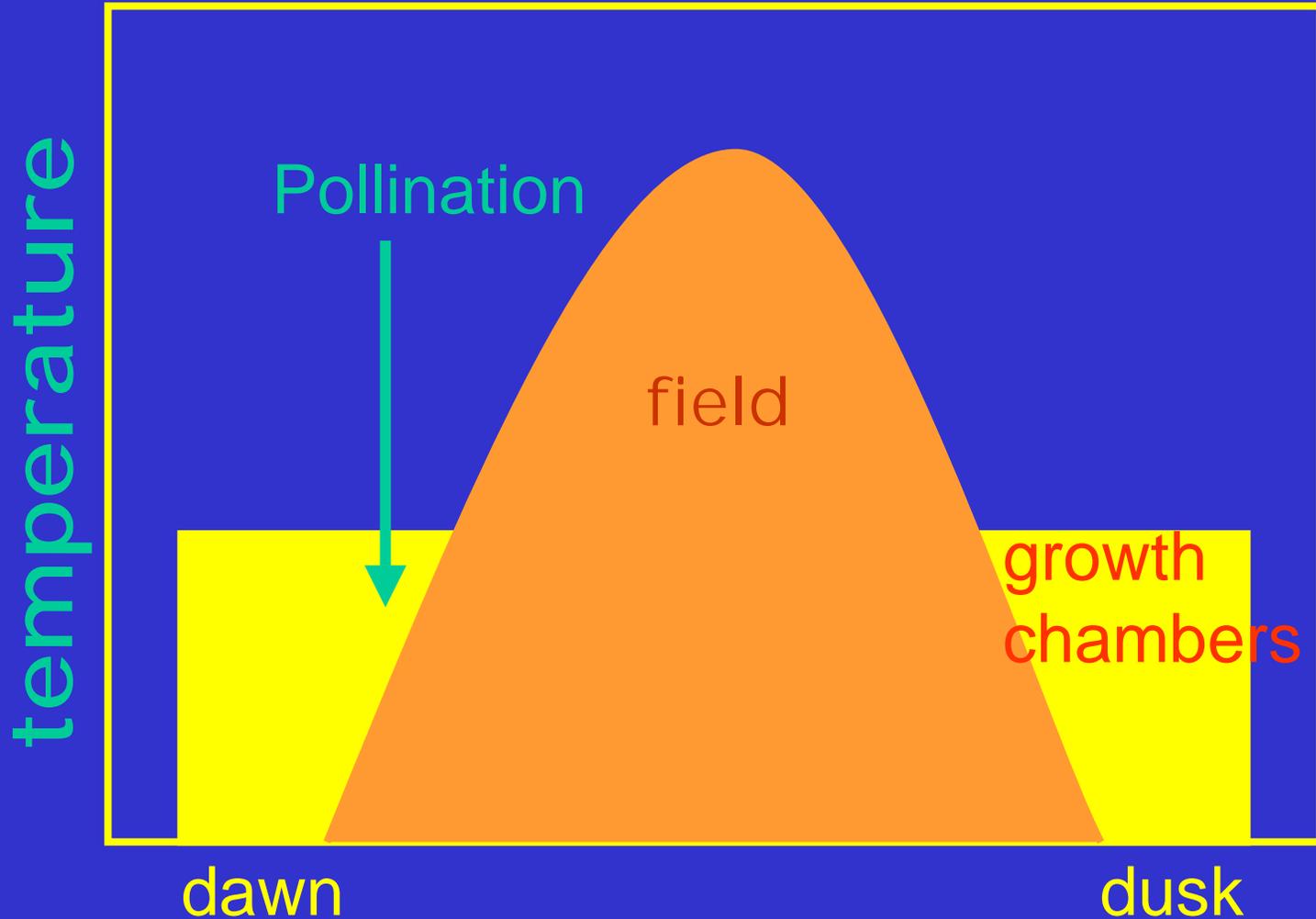
Do we need to gradually increase the temperature in growth chambers, like the slow increase after dawn in the field?



Answer: yes, in some unique cases.

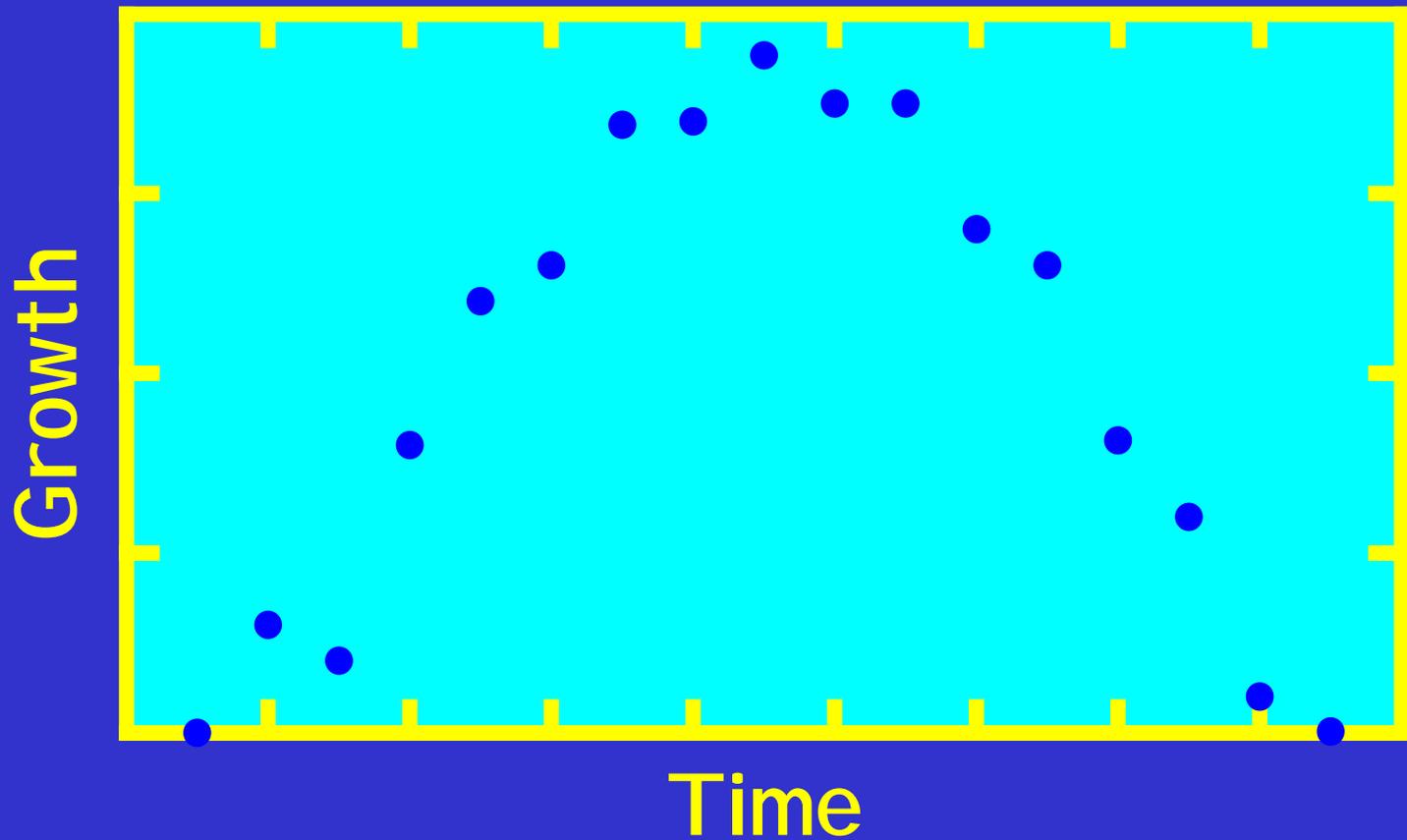
Pollination in most crops occurs a few hours after dawn, when the temperature is still cool. Pollination, fertilization, and seed set can be reduced if the temperature increases too high, too fast.

This is mostly a problem in high temperature stress studies.

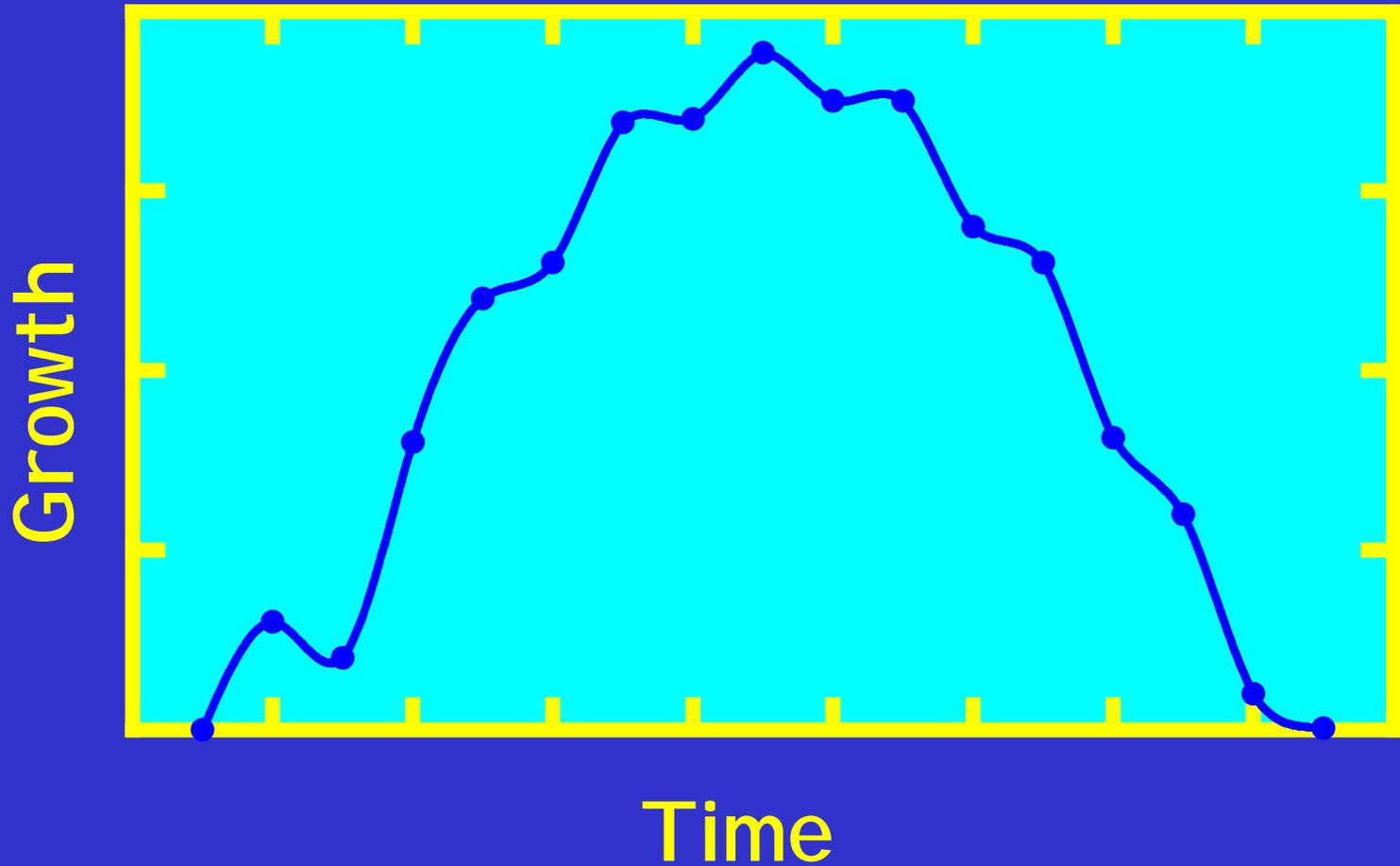


Our statistics  
should also be as  
simple as possible

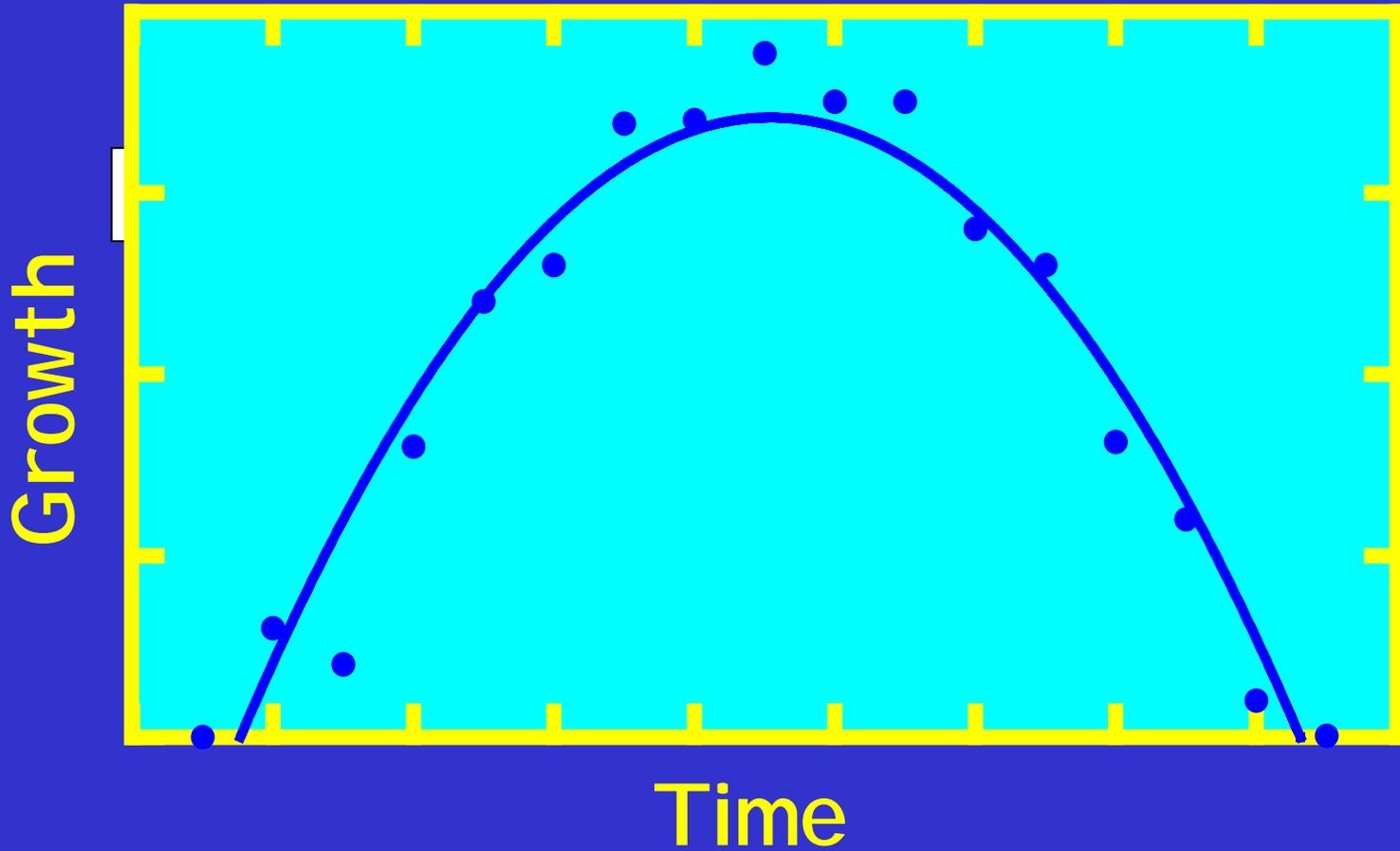
Our statistics should also be as simple as possible



An example of an *inappropriate* curve fit.  
The curve follows the experimental error in the data



An example of an *appropriate* curve fit.  
The curve follows the trend in the data  
with a much simpler equation.



Variable	Grain yield
Planting date (PD)	*
Foliar fungicide (FF)	**
PD X FF	NS
Cultivar (C)	**
PD X C	**
FF X C	NS
PD X FF C	NS
Year (Yr)	**
PD X Yr	**
FF X Yr	**
PD X FF X Yr	**
C X Yr	**
PD X C X Yr	**
FF X C X Yr	**
PD X FF X C X Yr	**

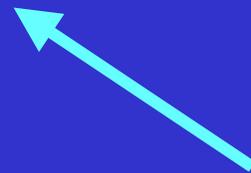
\* Significant at the 0.05 probability.

\*\* Significant at the 0.01 probability level.

NS = not significant

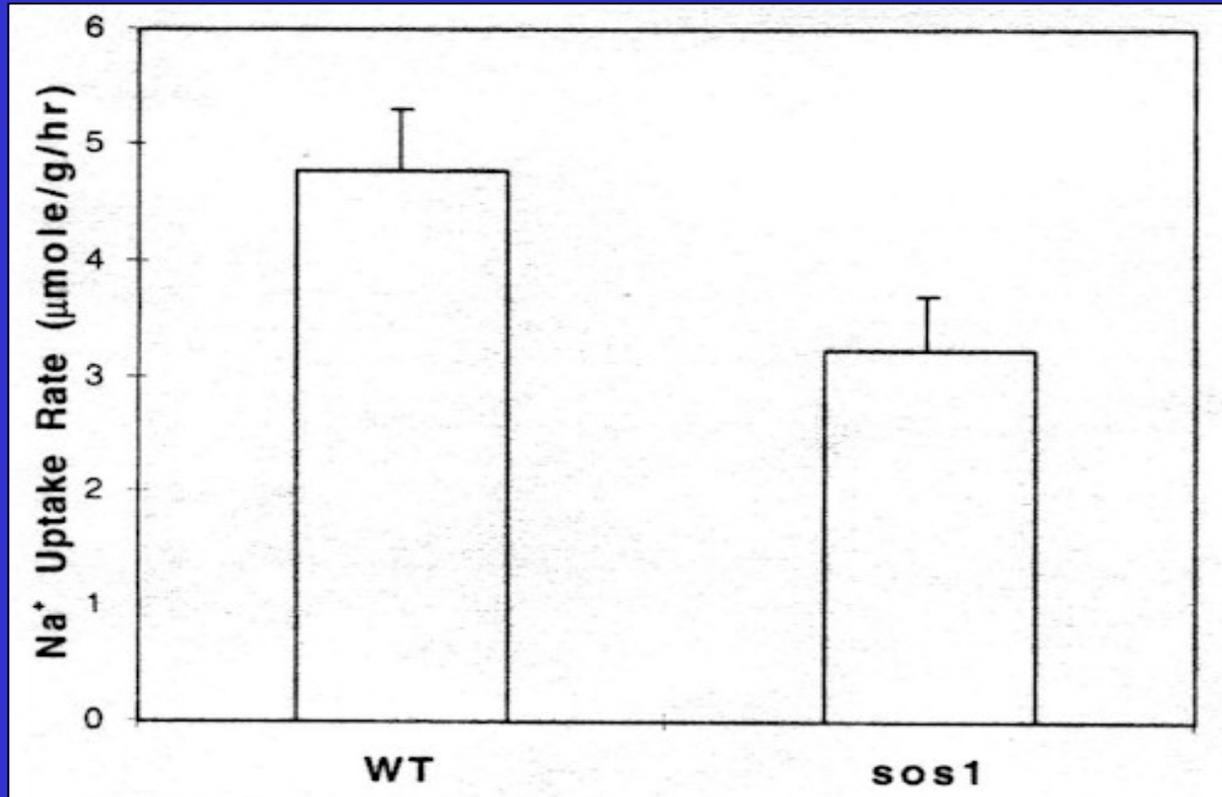
Complex experimental designs do not mean better research. In fact, they often mean the authors do not understand the underlying mechanisms in their study.

From the most recent issue of Agronomy Journal



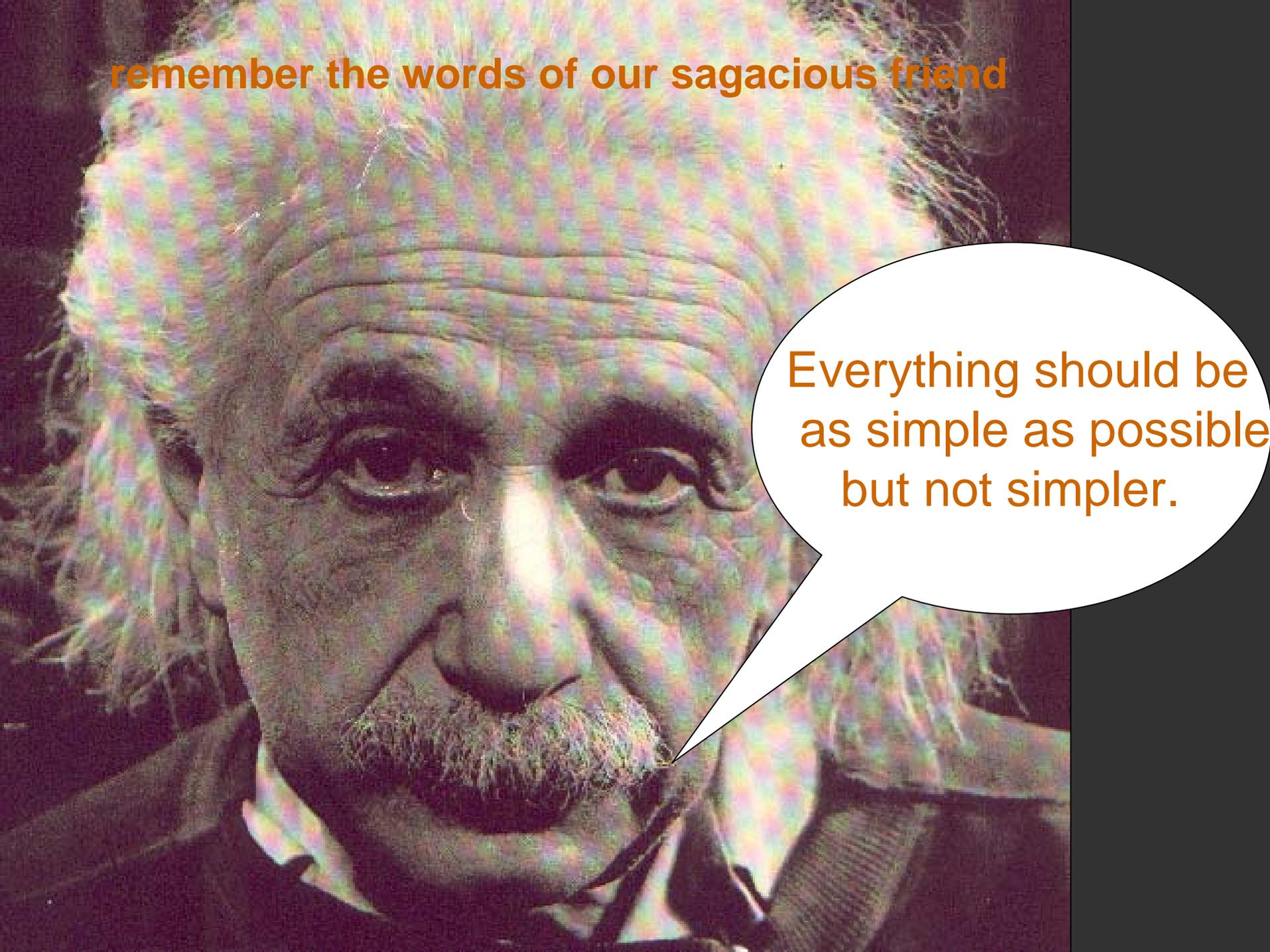
Simple statistics are all that is necessary if one understands the underlying mechanism.

An  $r^2$  of 0.99 in experimental physics means that the study should be done over to get a more clear answer.



from the most recent issue of *Plant Physiology*  
the only statistics are standard deviations

remember the words of our sagacious friend

A close-up portrait of Albert Einstein, showing his characteristic wild, white hair and a mustache. He is wearing a dark suit jacket, a white shirt, and a dark tie. A white speech bubble with a black outline is positioned on the right side of the image, containing text. The background is dark and out of focus.

Everything should be  
as simple as possible  
but not simpler.

*William of Occam understood the need for simplicity  
several centuries ago*

## Occam's Razor

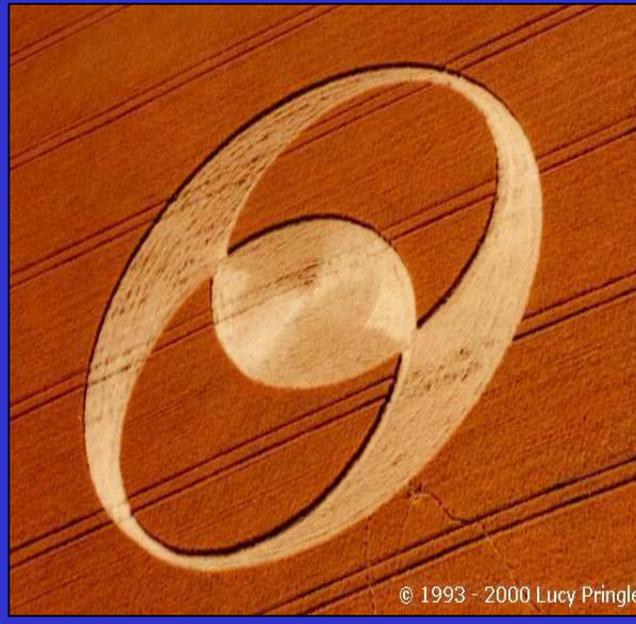
One should not increase, beyond what is necessary, the number of entities required to explain anything.

William of Occam

*Where is William of Occam when we need him?*

## Is this the most simple explanation for Crop circles?

“Scientific analysis has been carried out on plant samples taken from the crop circles. The work done by US biophysicist Dr William Levengood seems to suggest that some sort of **microwave energy** effect is involved in the circle making process. Crop circle researchers are increasingly being asked to use creative and innovative thought as part of their investigative process.”



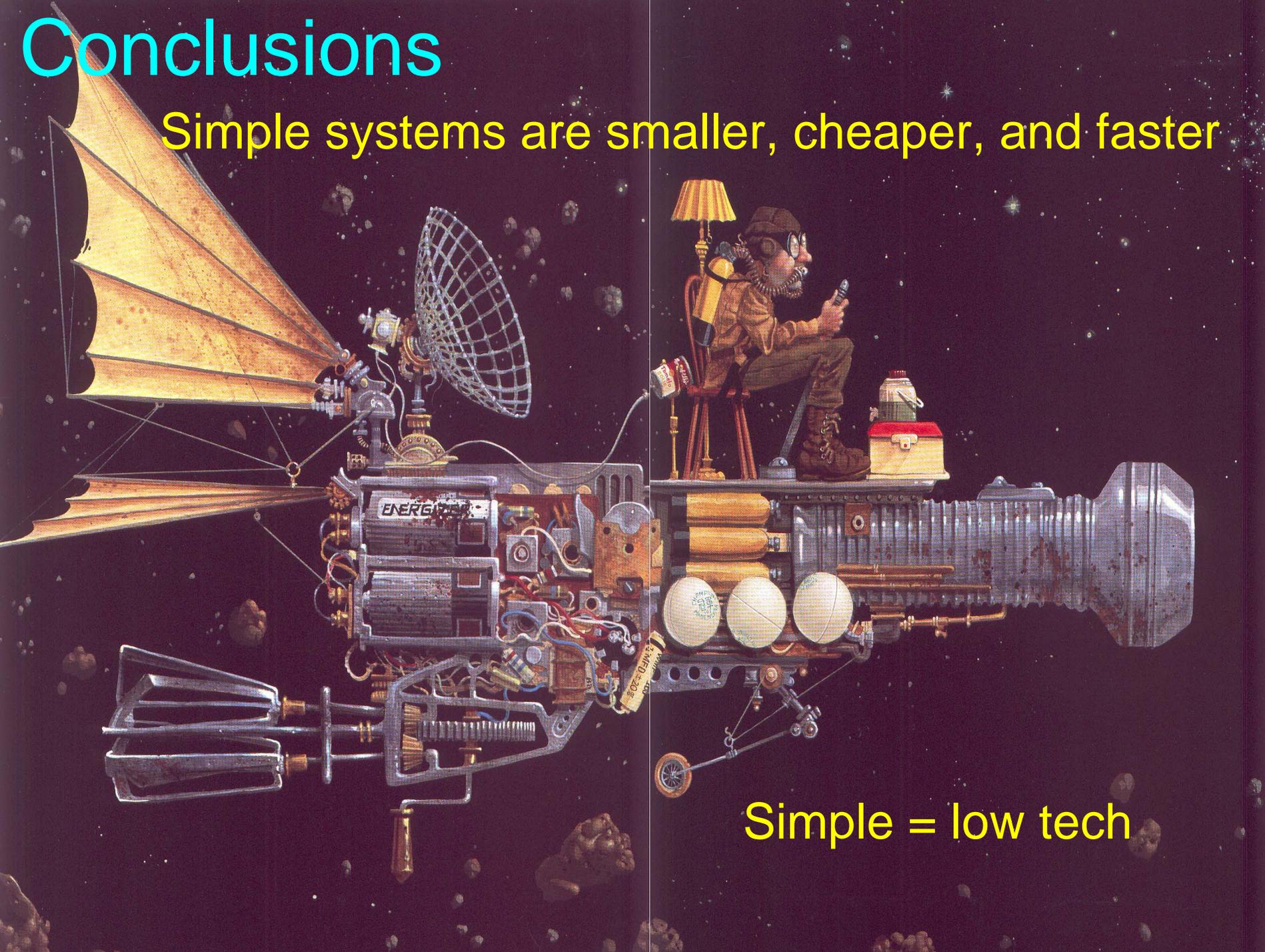
© 1993 - 2000 Lucy Pringle



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# Conclusions

Simple systems are smaller, cheaper, and faster



Simple = low tech

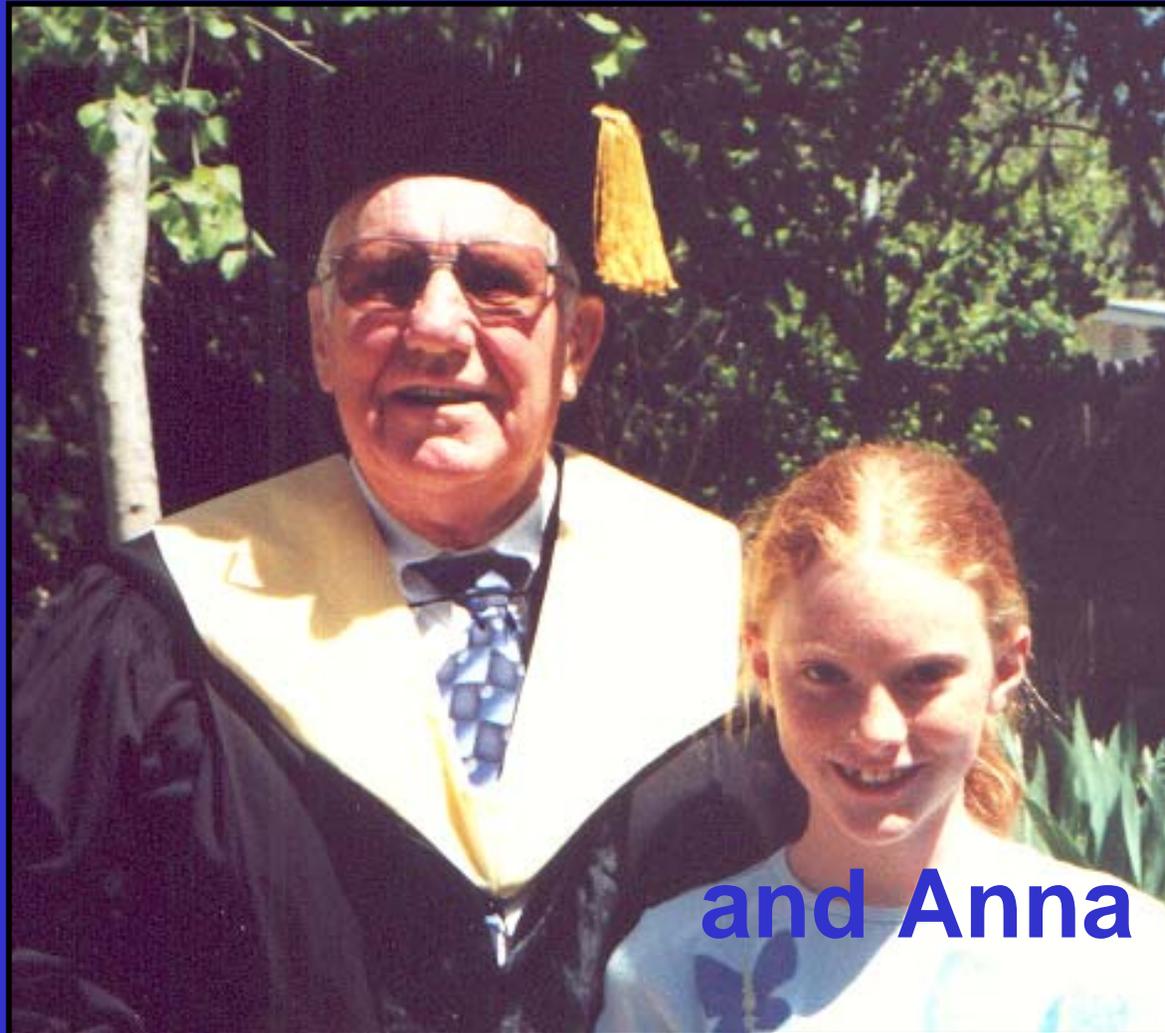
# Conclusions

1. Conclusions from simple systems are broadly applicable
2. Simple systems mean that knowledge must be substituted for the cost of hardware.
3. The use of simple systems requires a thorough understanding of scaling principles so that results can be extrapolated to larger systems

**I dedicate this talk to my father,  
who never got the chance to finish college.**



and to my daughter, may she grow to see people's hearts  
. . . like her grandpa.



**and Anna**

*smaller..... cheaper..... faster*

