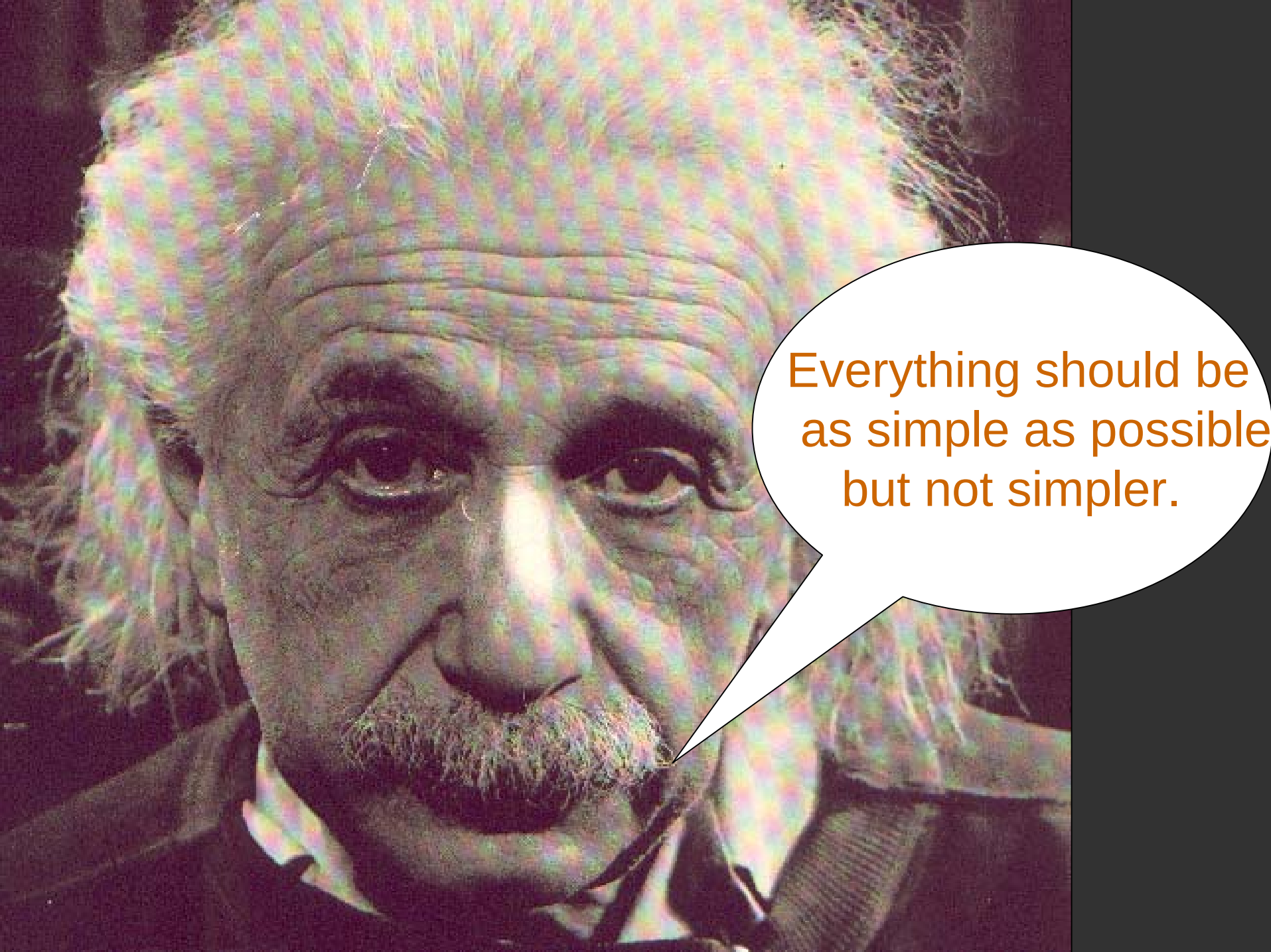
The motion for simplicity

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 11th, 2001*

Bruce Bugbee
Utah State University

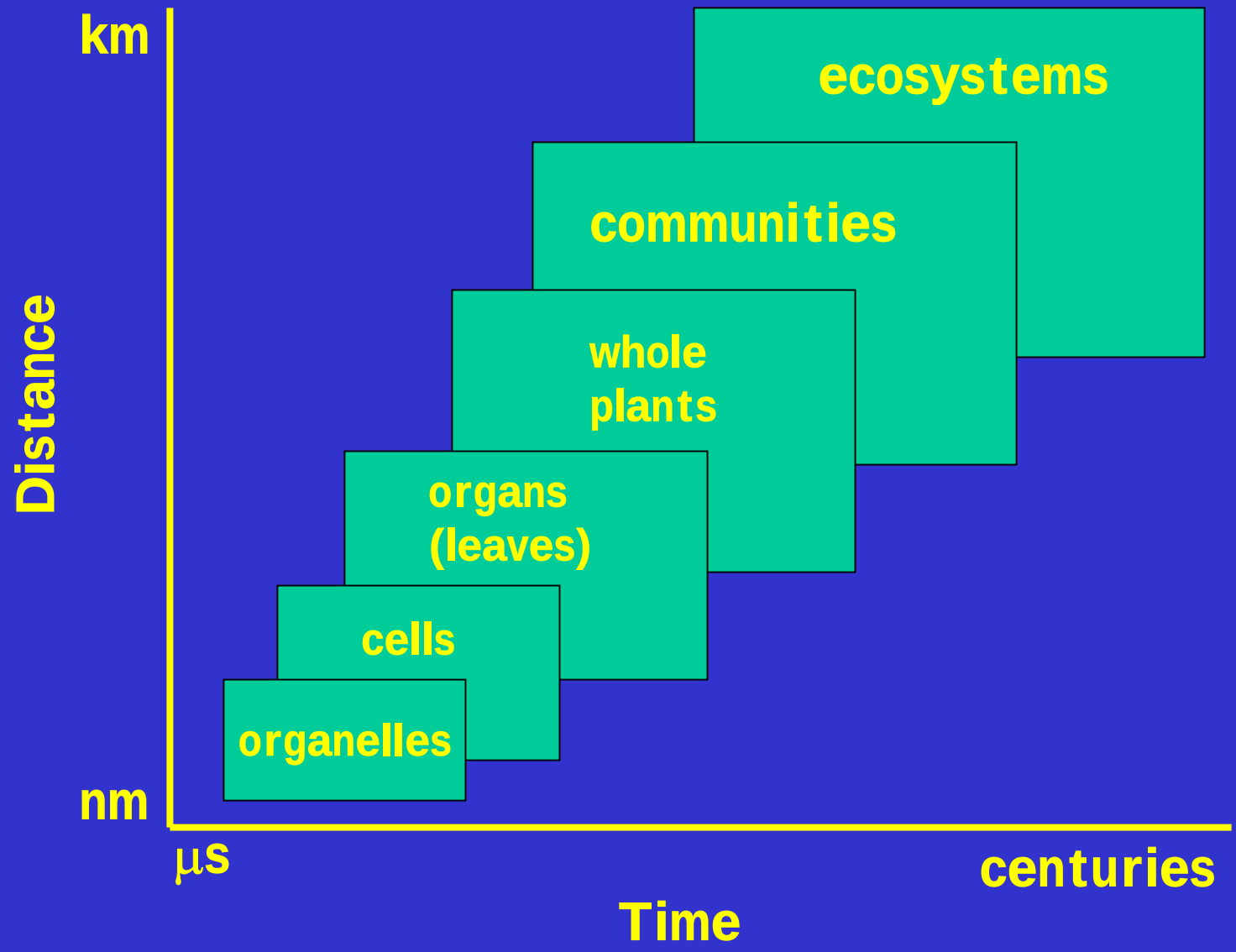

Everything should be
as simple as possible
but not simpler.

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

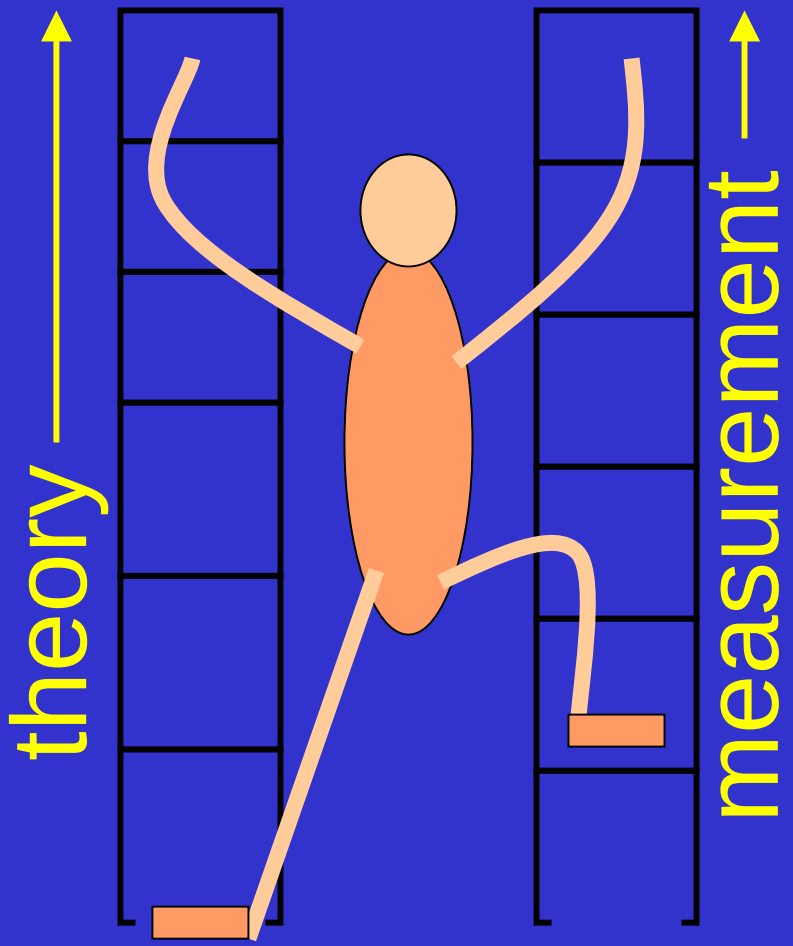
Many plant biologists would be more productive if they spent more time in the library and less time collecting data

“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.



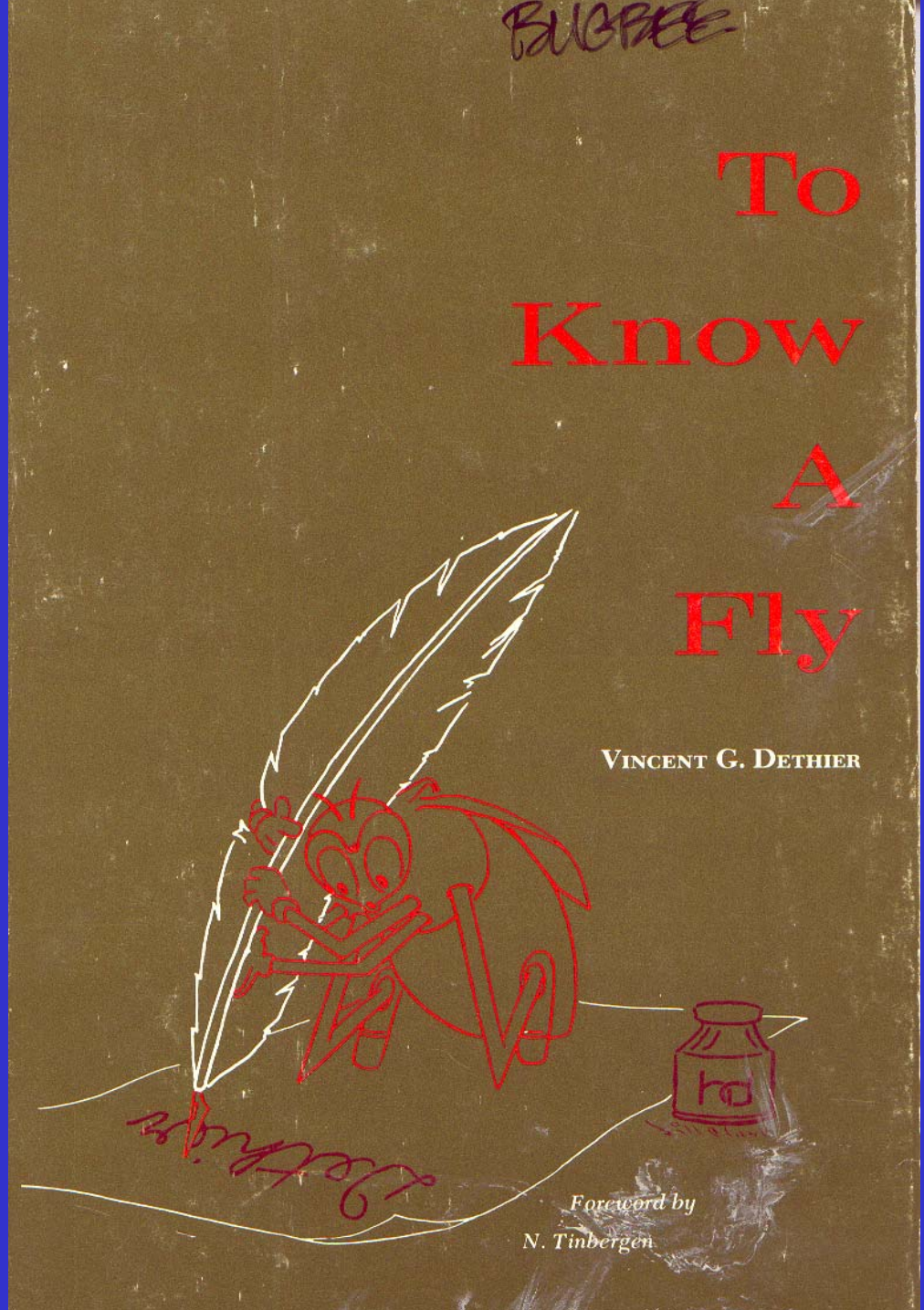
"Simple systems, also called model systems, are a bridge between theory and the real world."

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.”

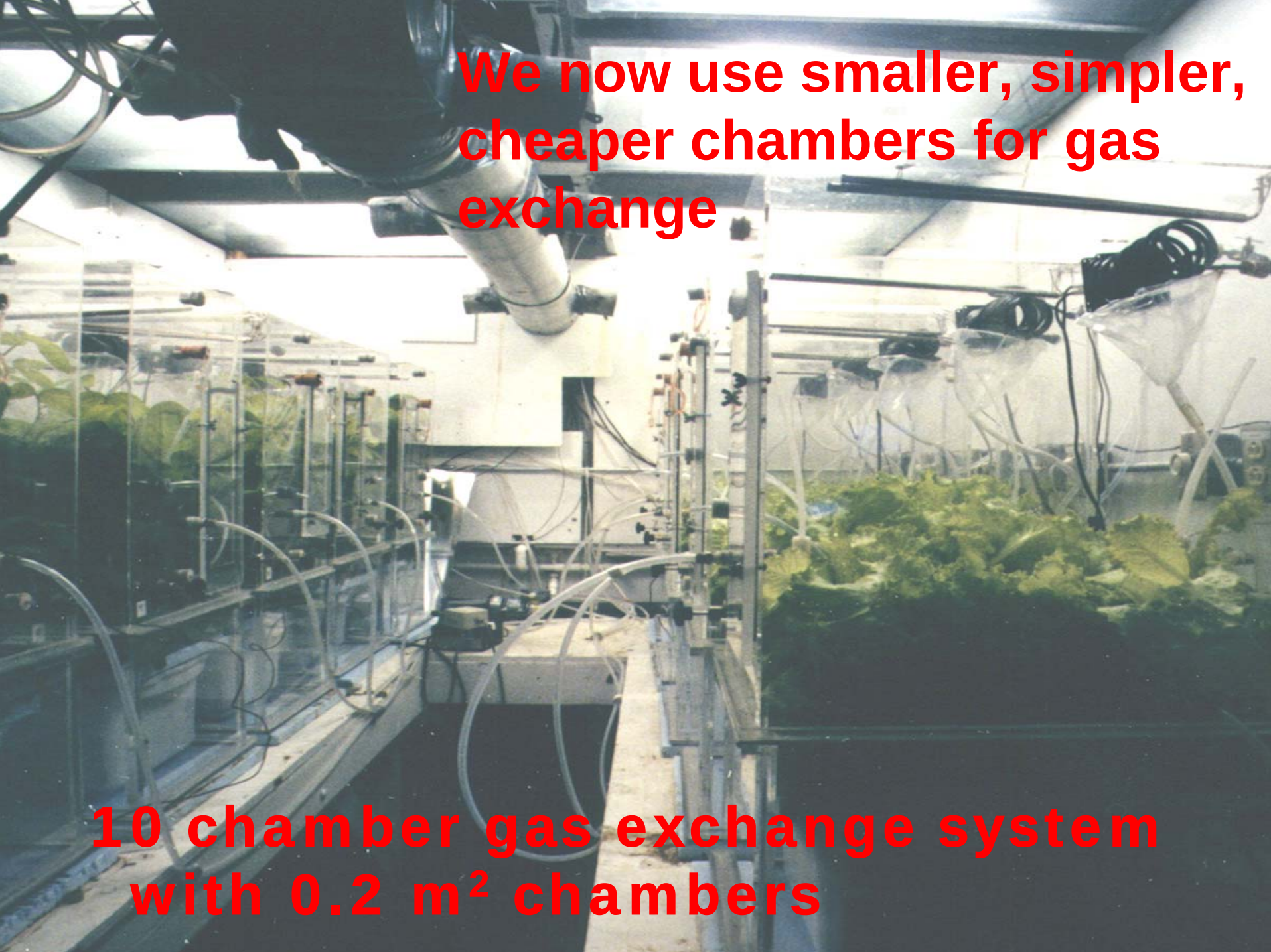
Lawton, John. 1996. The Ecotron Facility at Silwood Park: The value of big bottle experiments. Ecology 77:665-669.

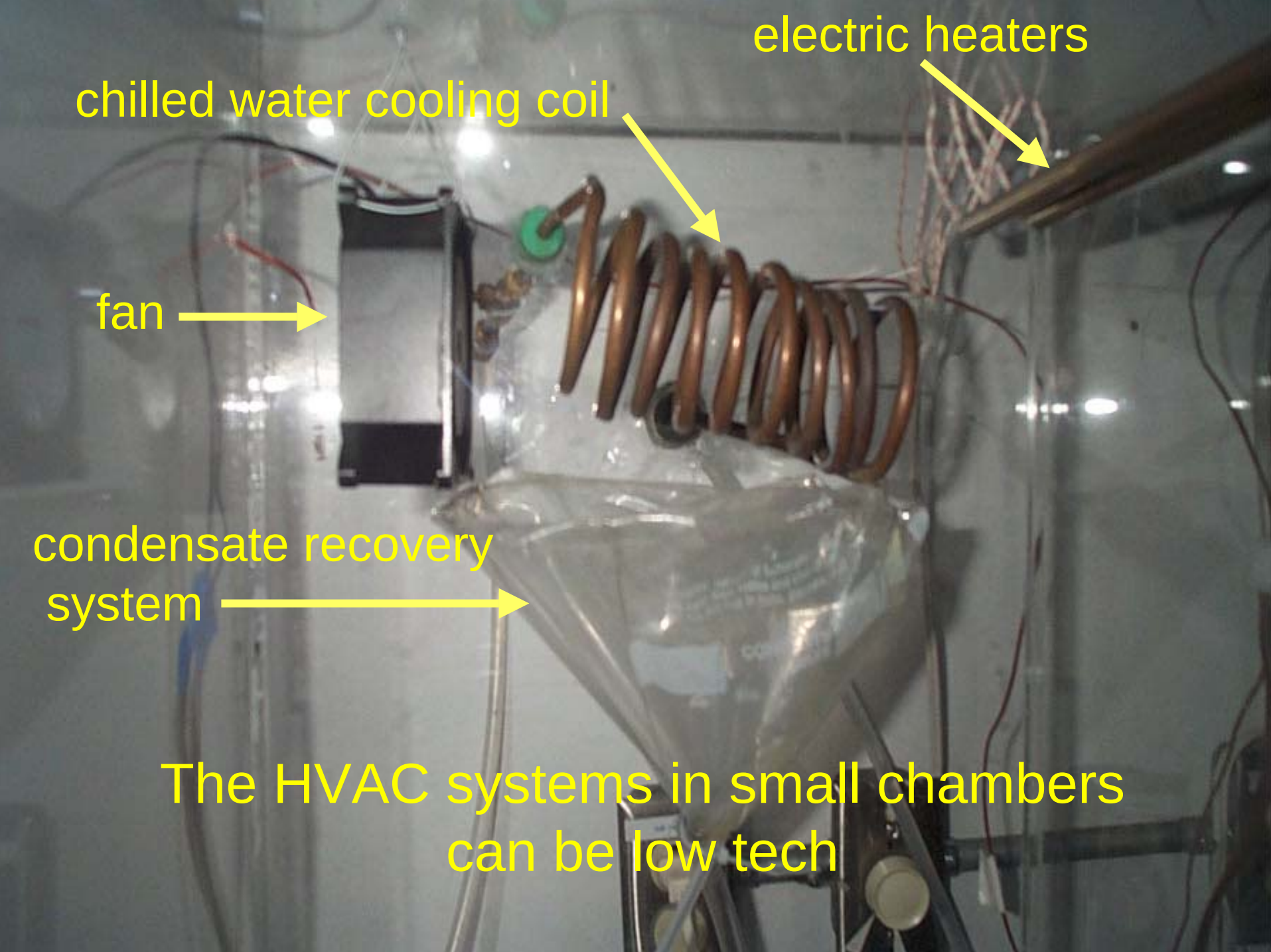


We learned much of what we know about animal physiology from studying flies in the 1950's and 60's

Vincent Dethier
1962

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

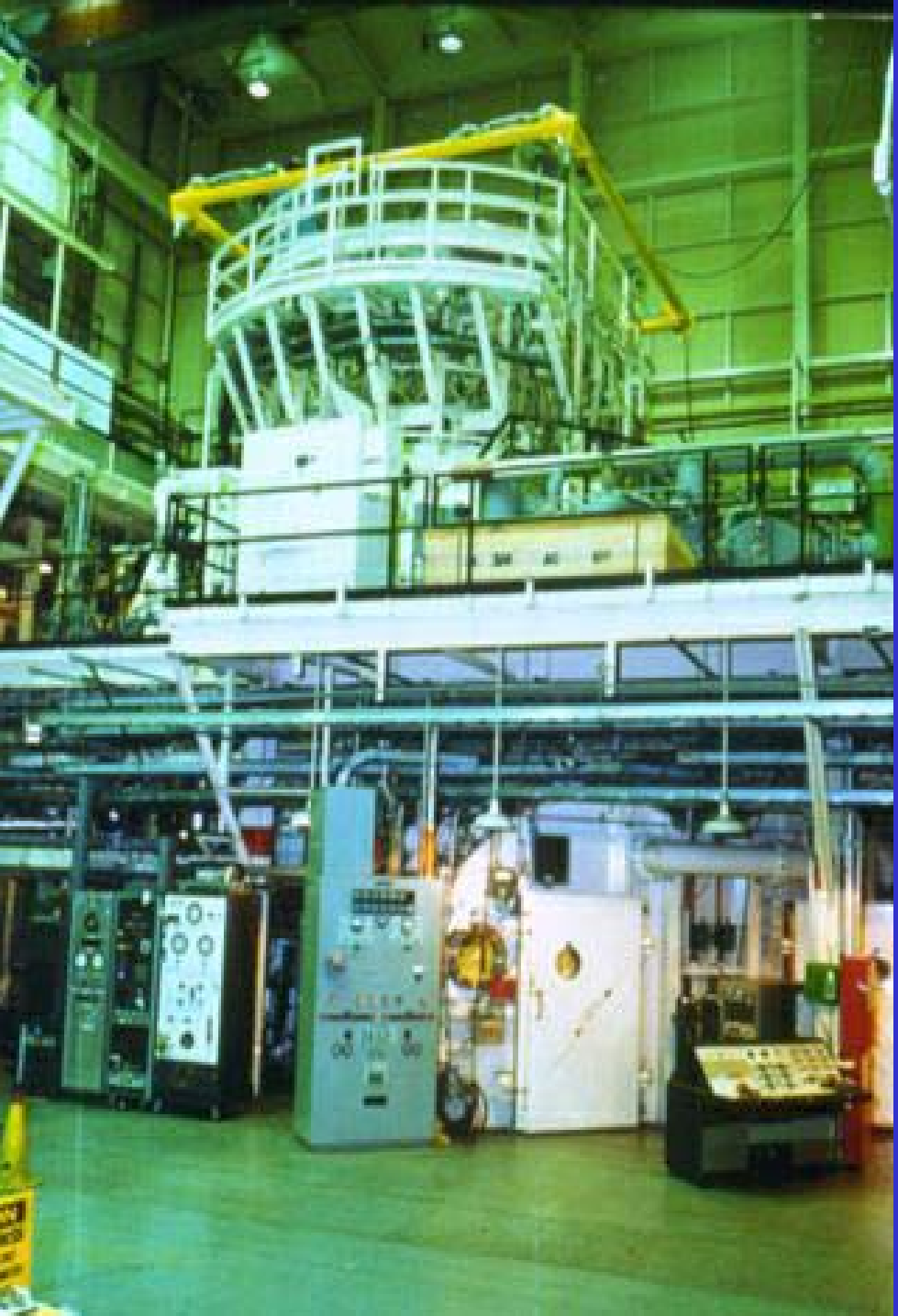

We now use smaller, simpler, cheaper chambers for gas exchange
10 chamber gas exchange system with 0.2 m² chambers



The HVAC systems in small chambers can be low tech

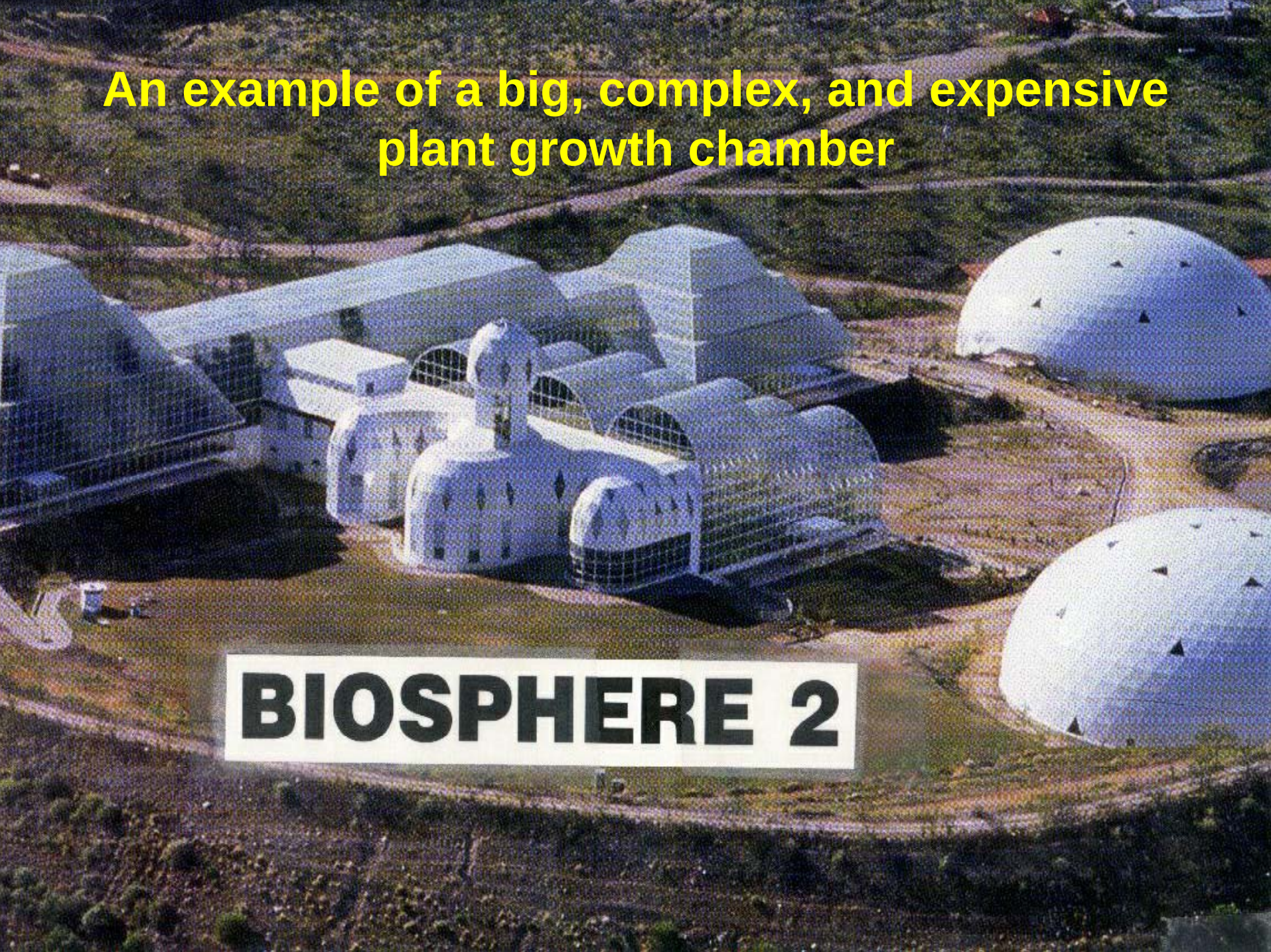
Another example of small growth chambers:
A 6 chamber system in a growth chamber


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

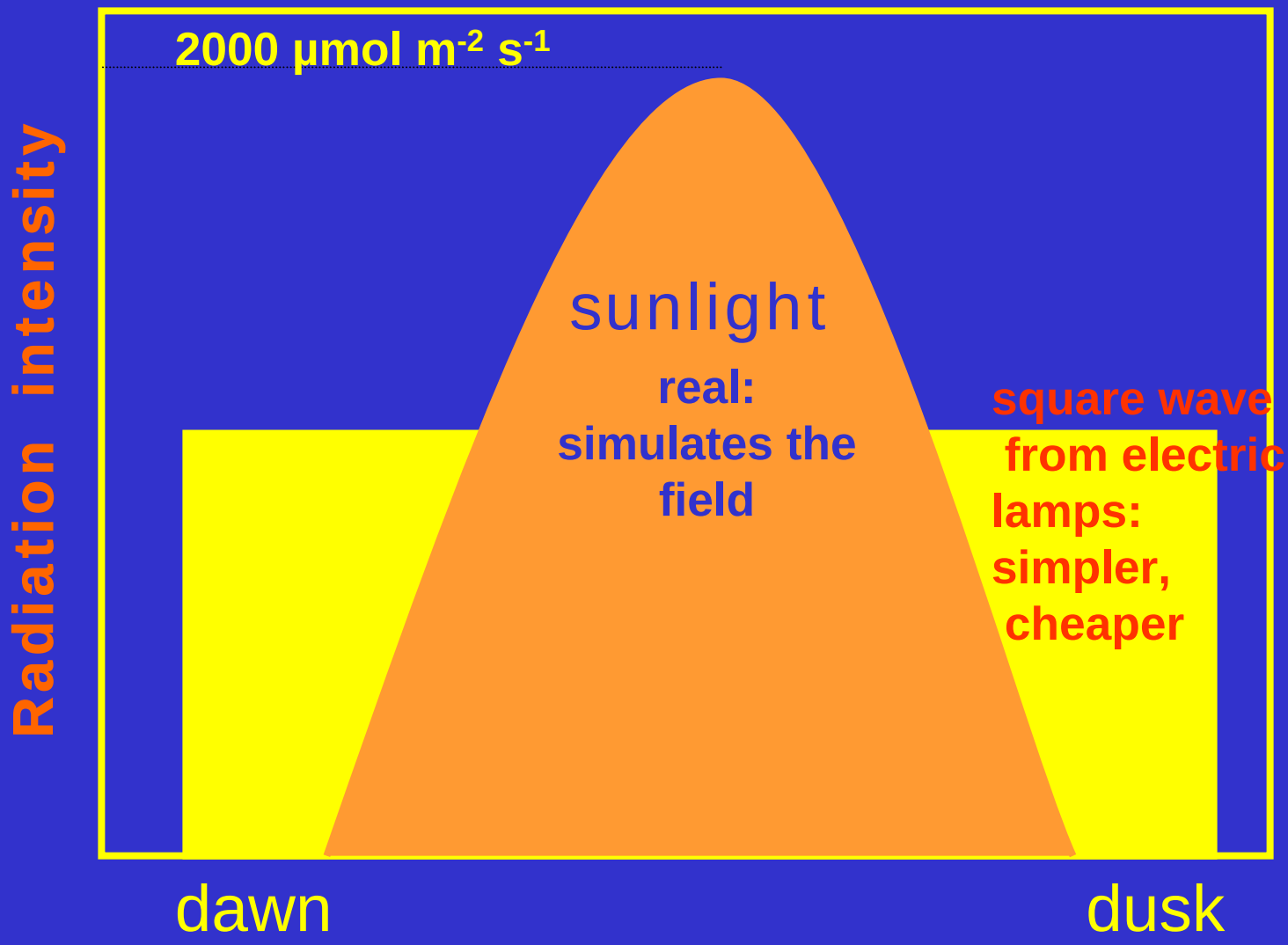


The NASA 20 foot chamber

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

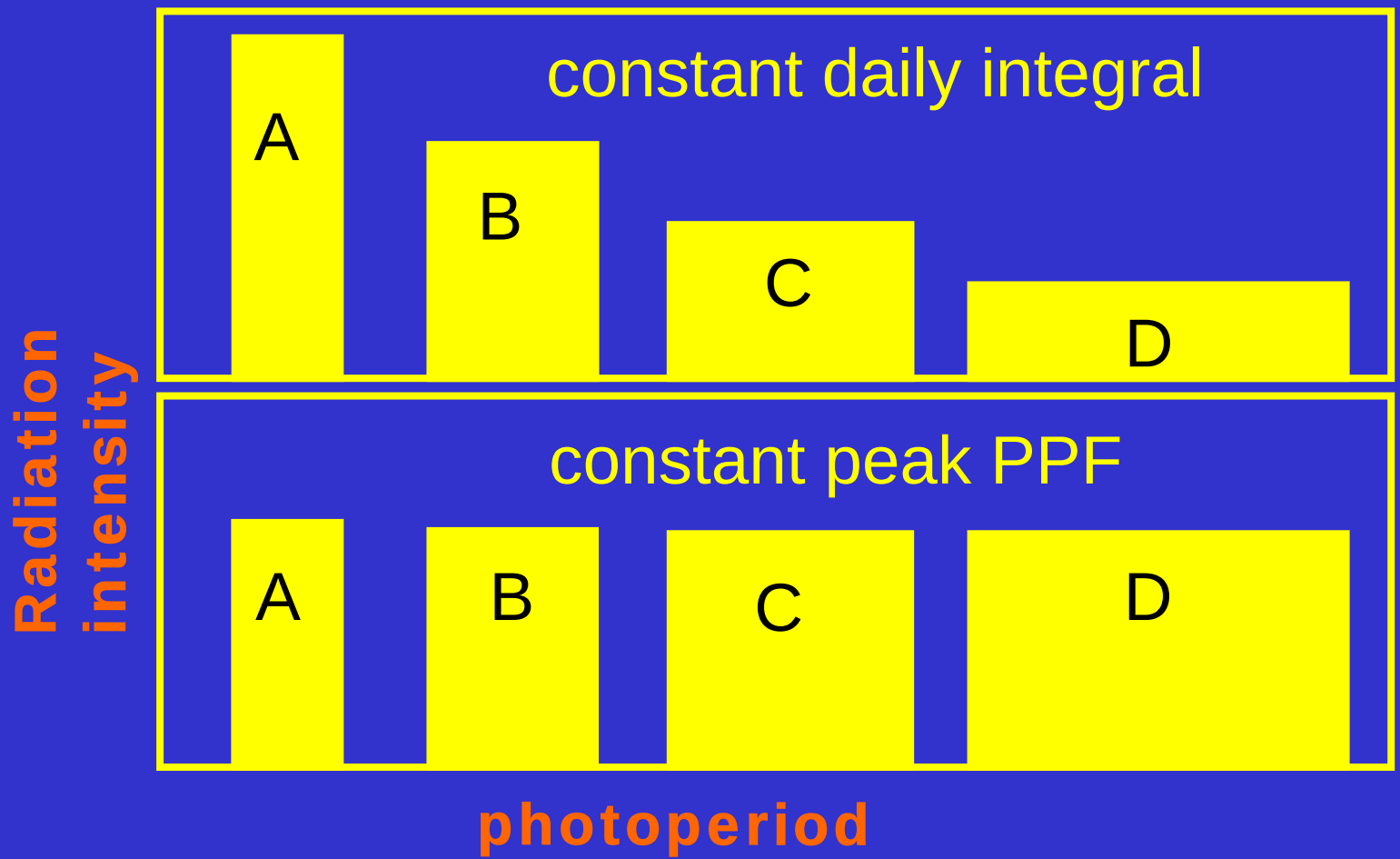

An example of a big, complex, and expensive plant growth chamber
BIOSPHERE 2

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.

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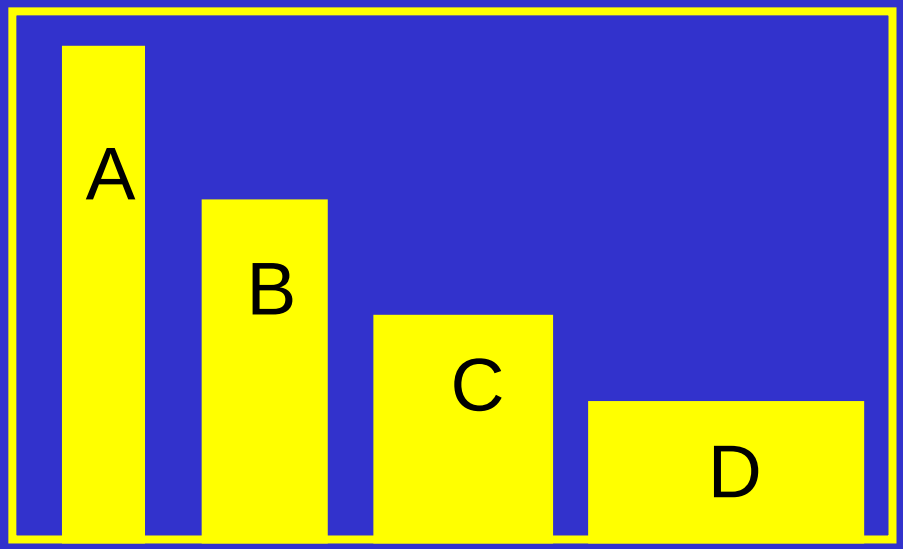
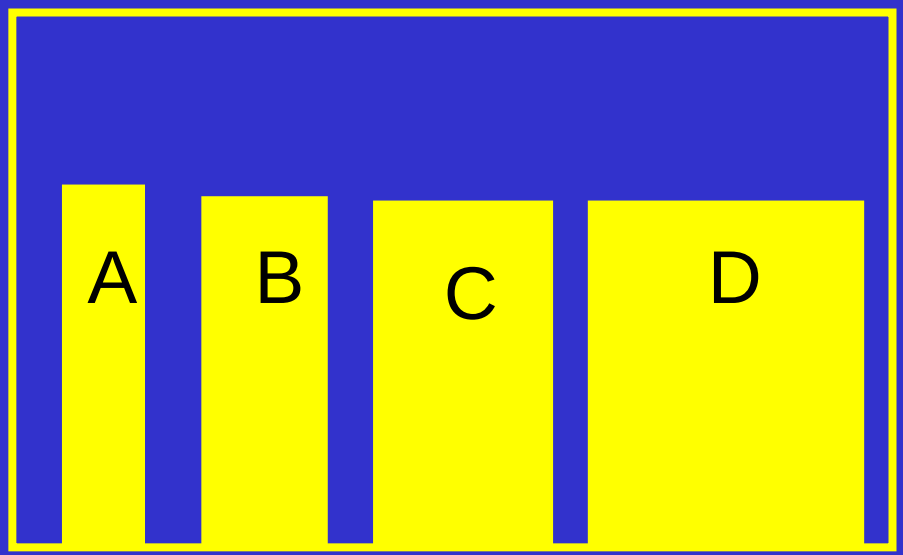
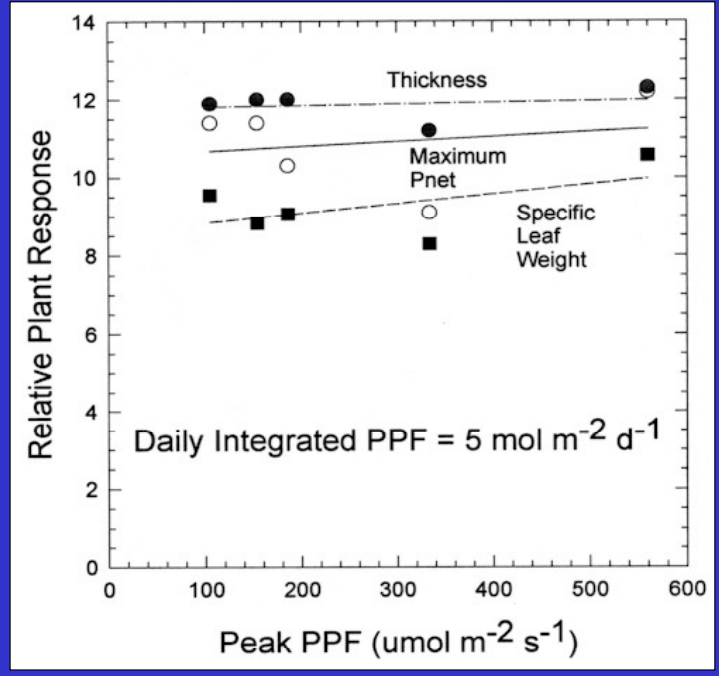
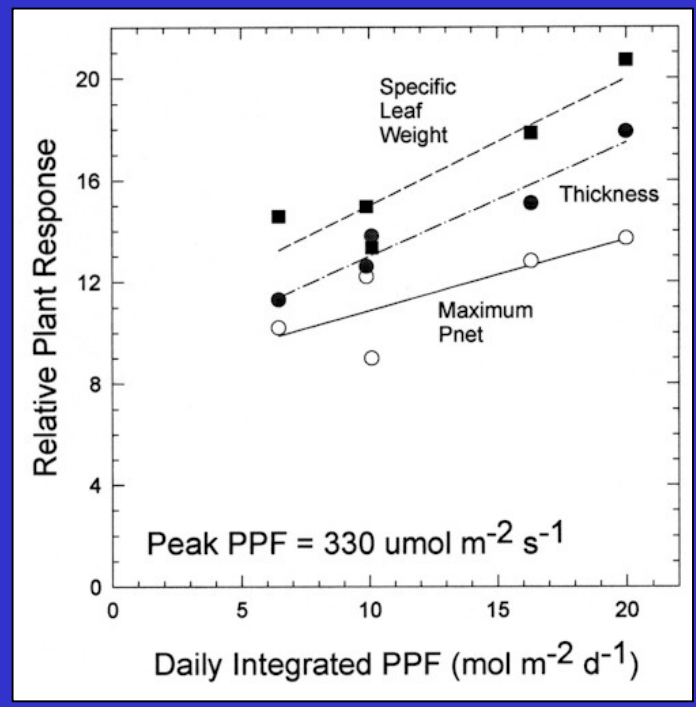


Radiation intensity

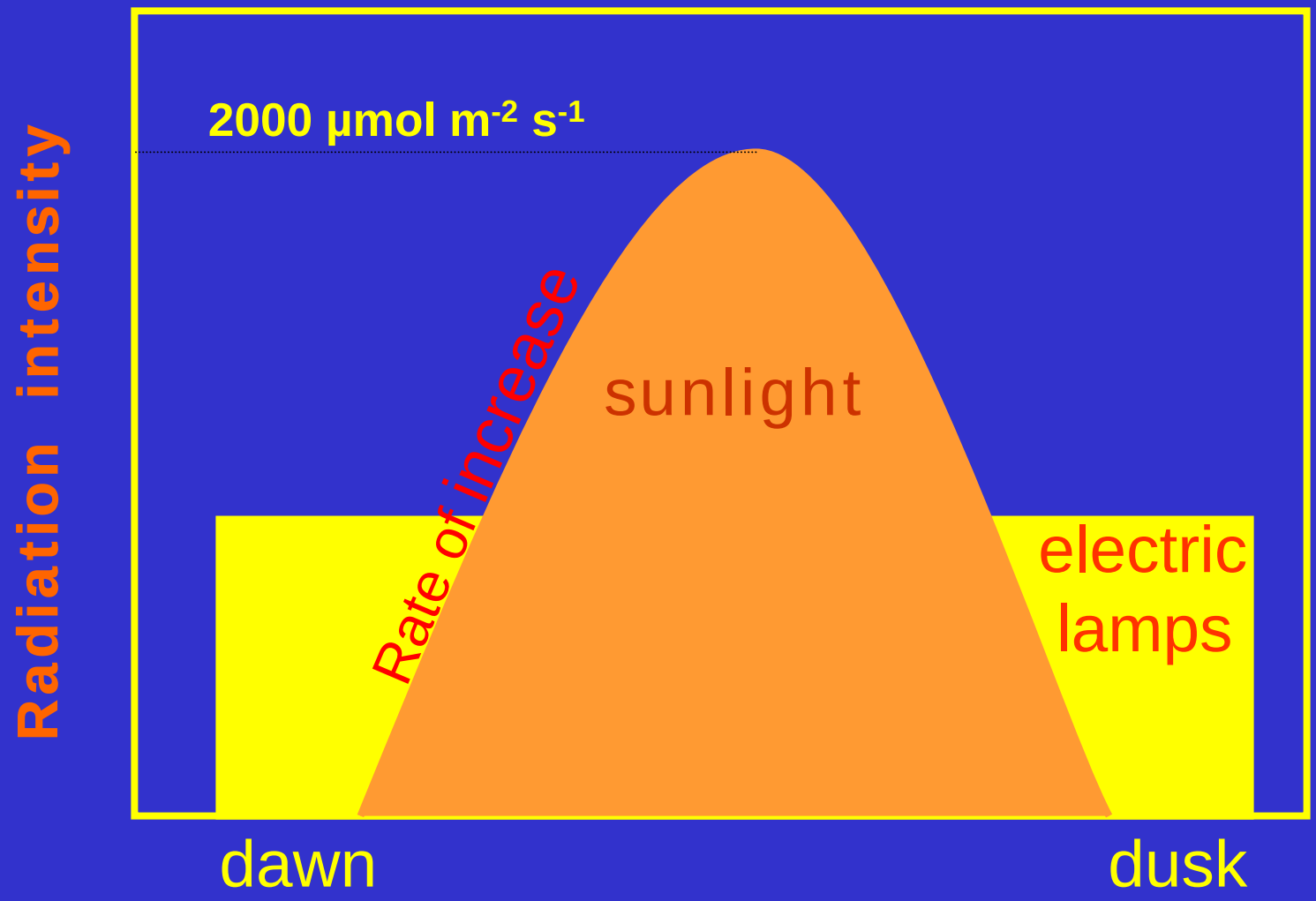


photoperiod

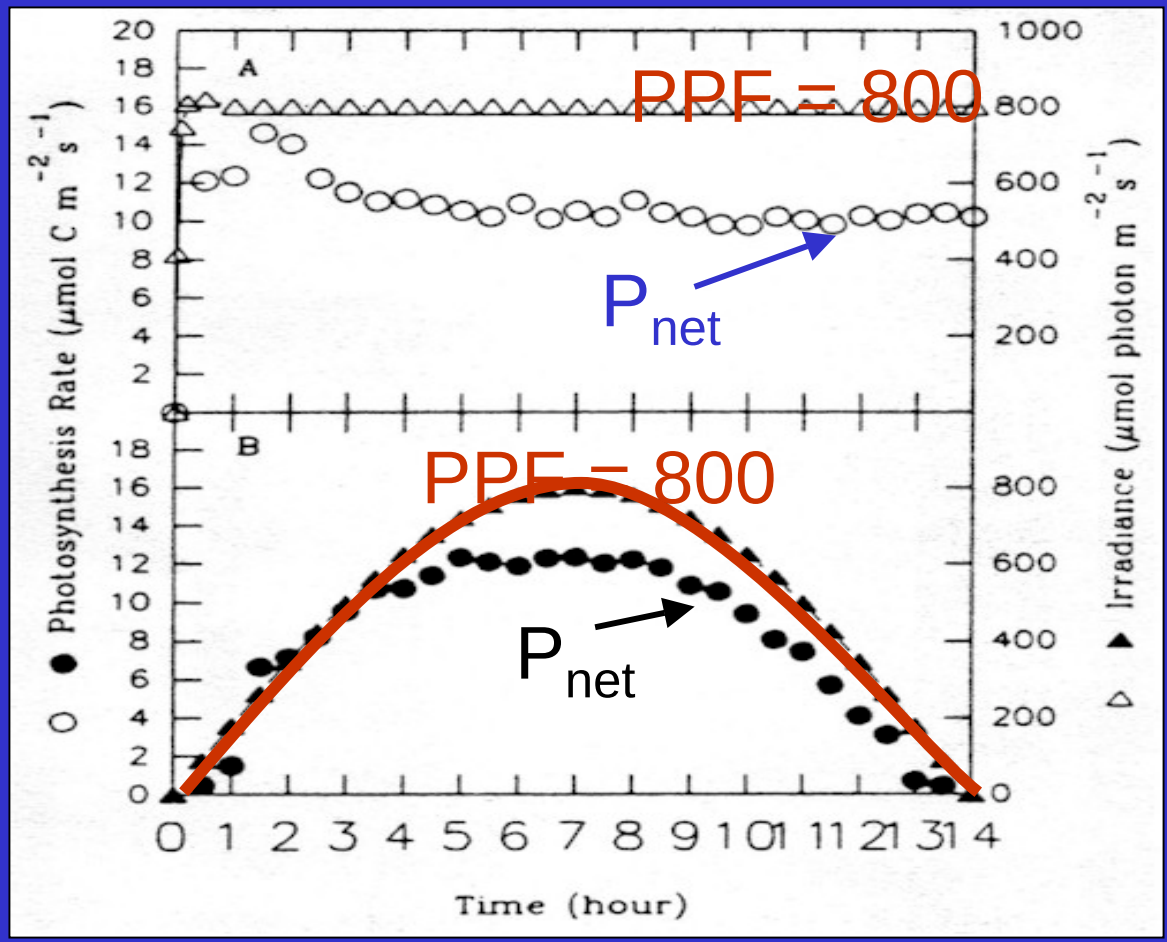




Is it important to slowly increase the radiation in the morning, like the field?



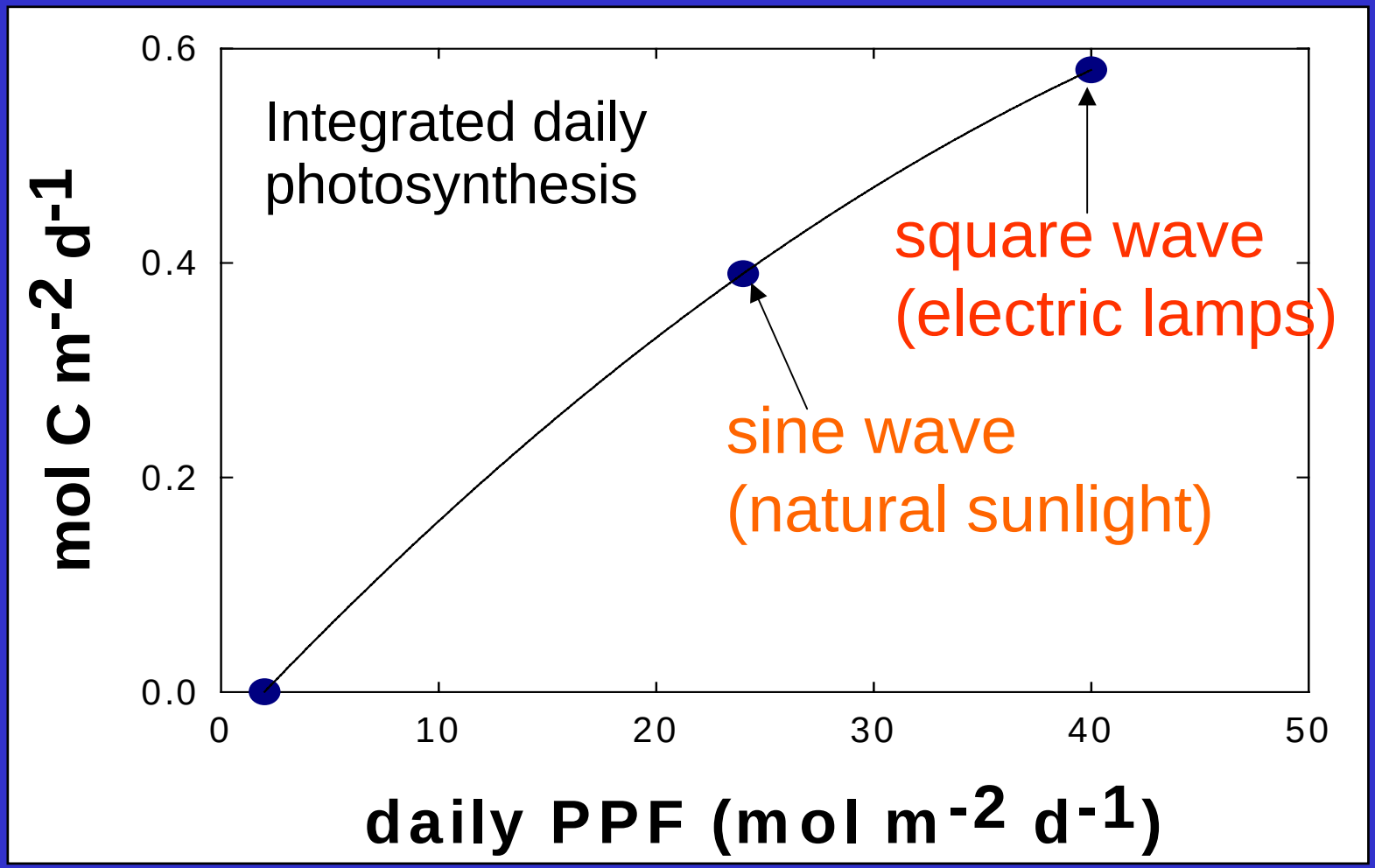
Don Geiger et al. examined this in 1991



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

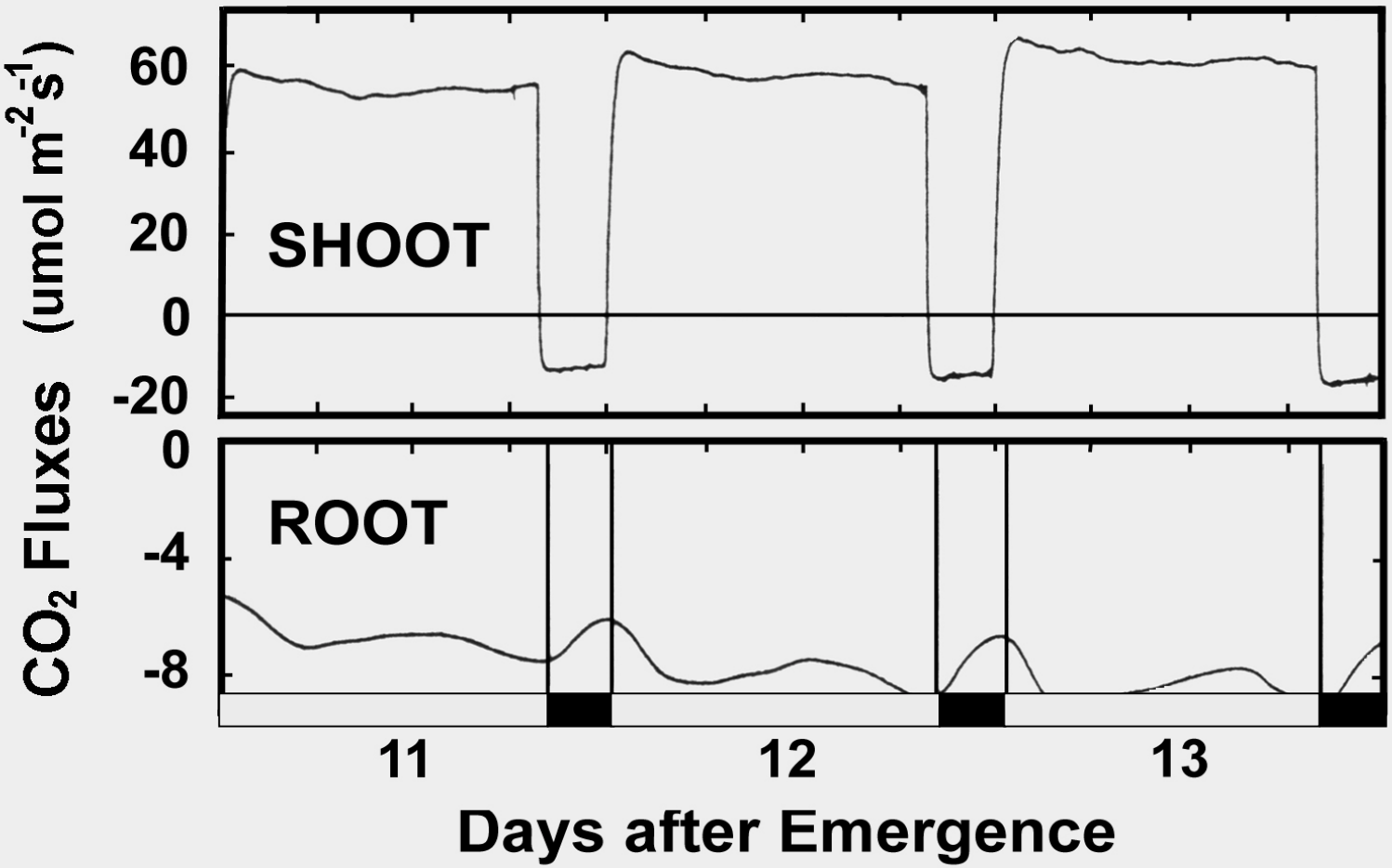
Supplying the light as a square wave, with sharp on and off end points, did not reduce growth



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

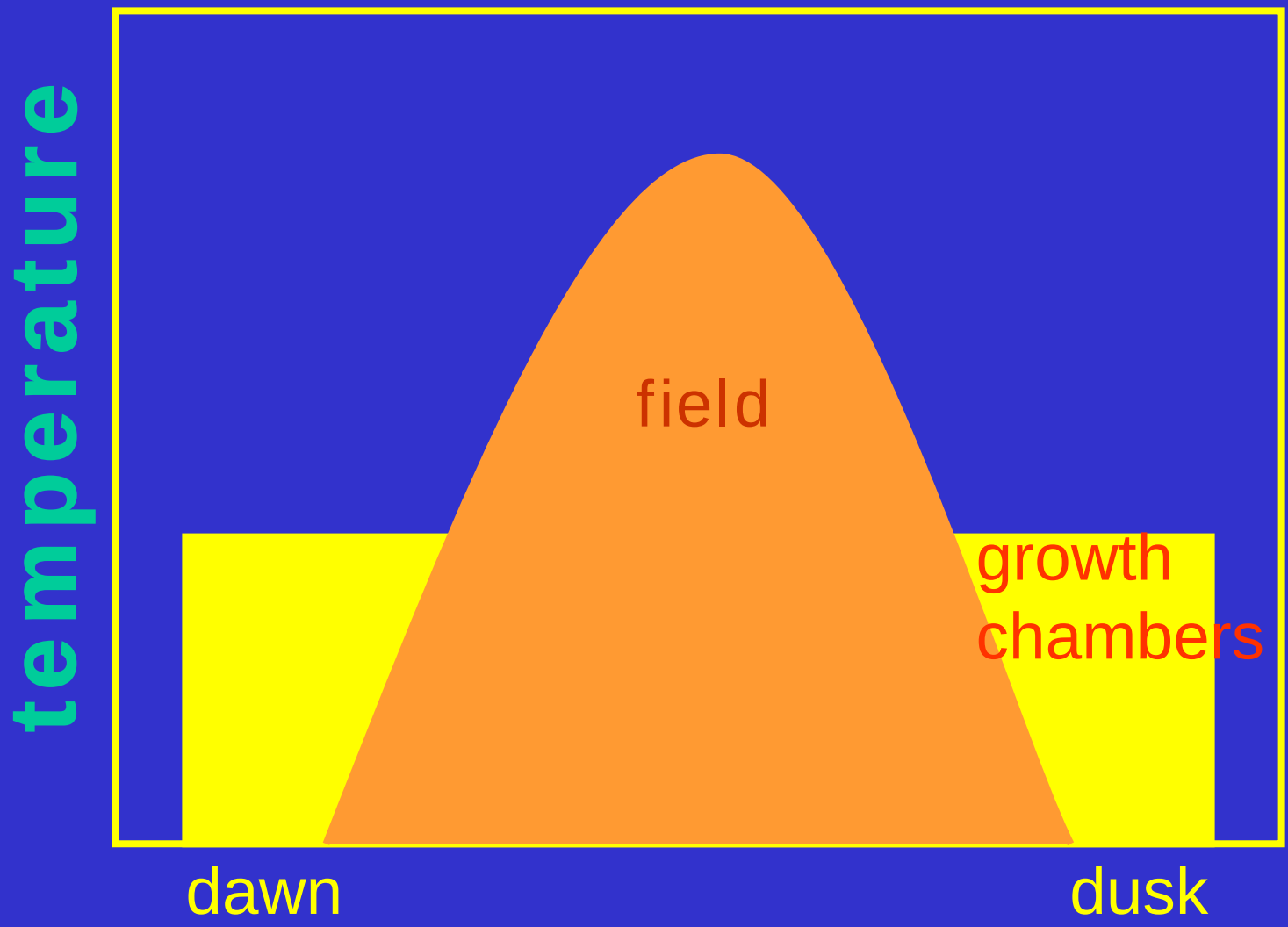
Photosynthetic rate increases rapidly in the morning as the light reach full output.

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



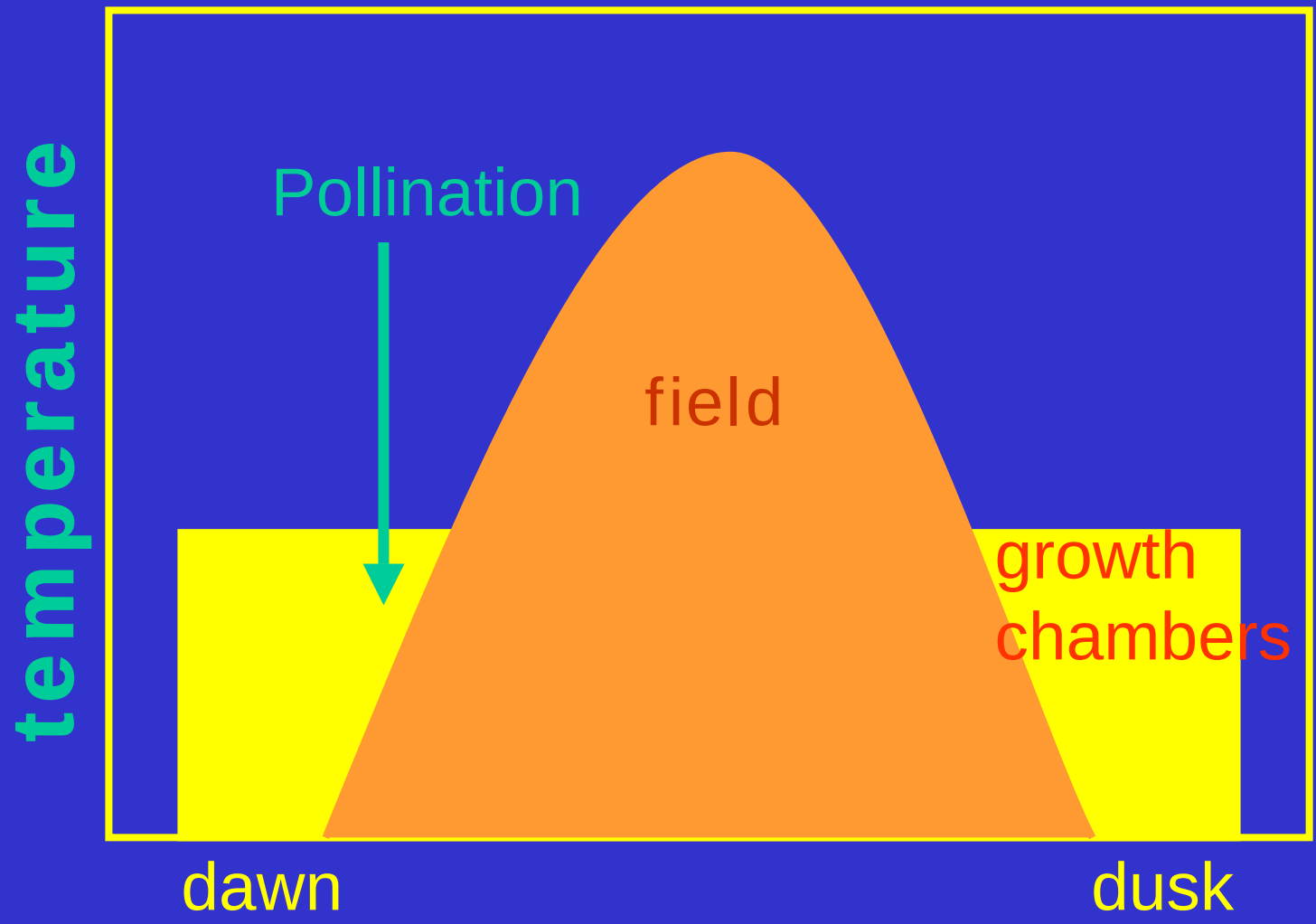
Monje and Bugbee, 1996. Acta Hort. 440:123-126.

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



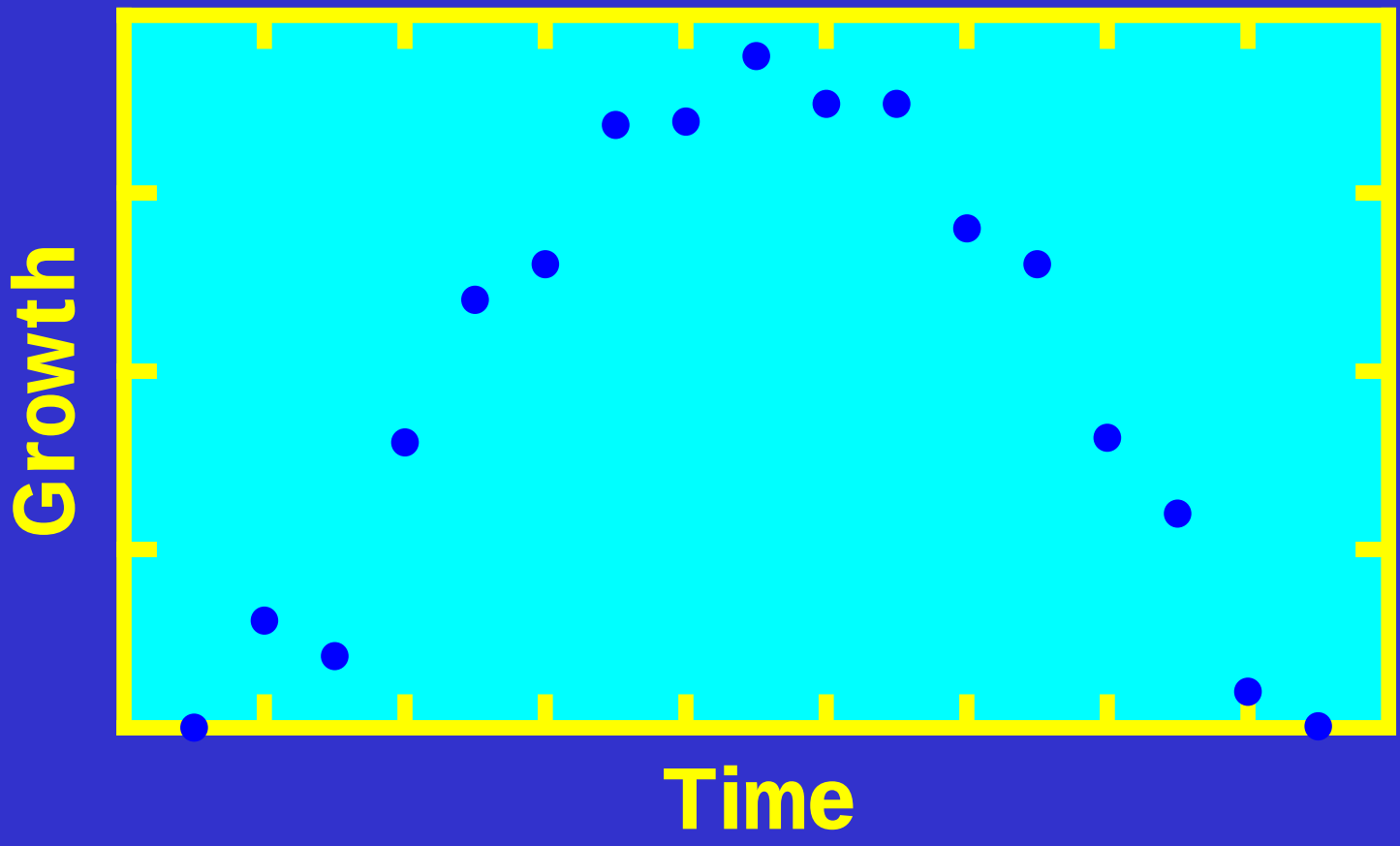
Answer: yes, in some unique cases.

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.

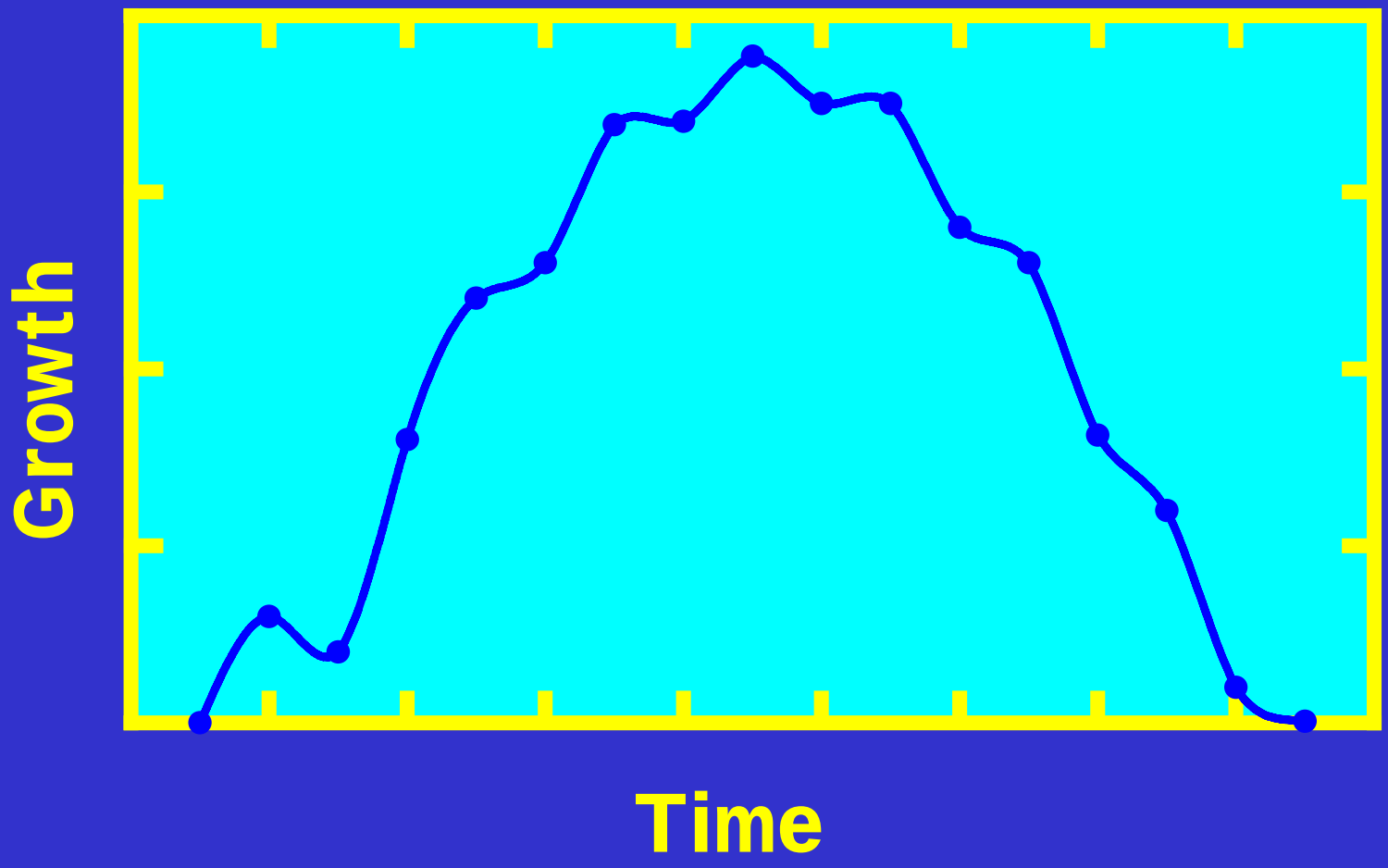


Our statistics
should also be as
simple as possible

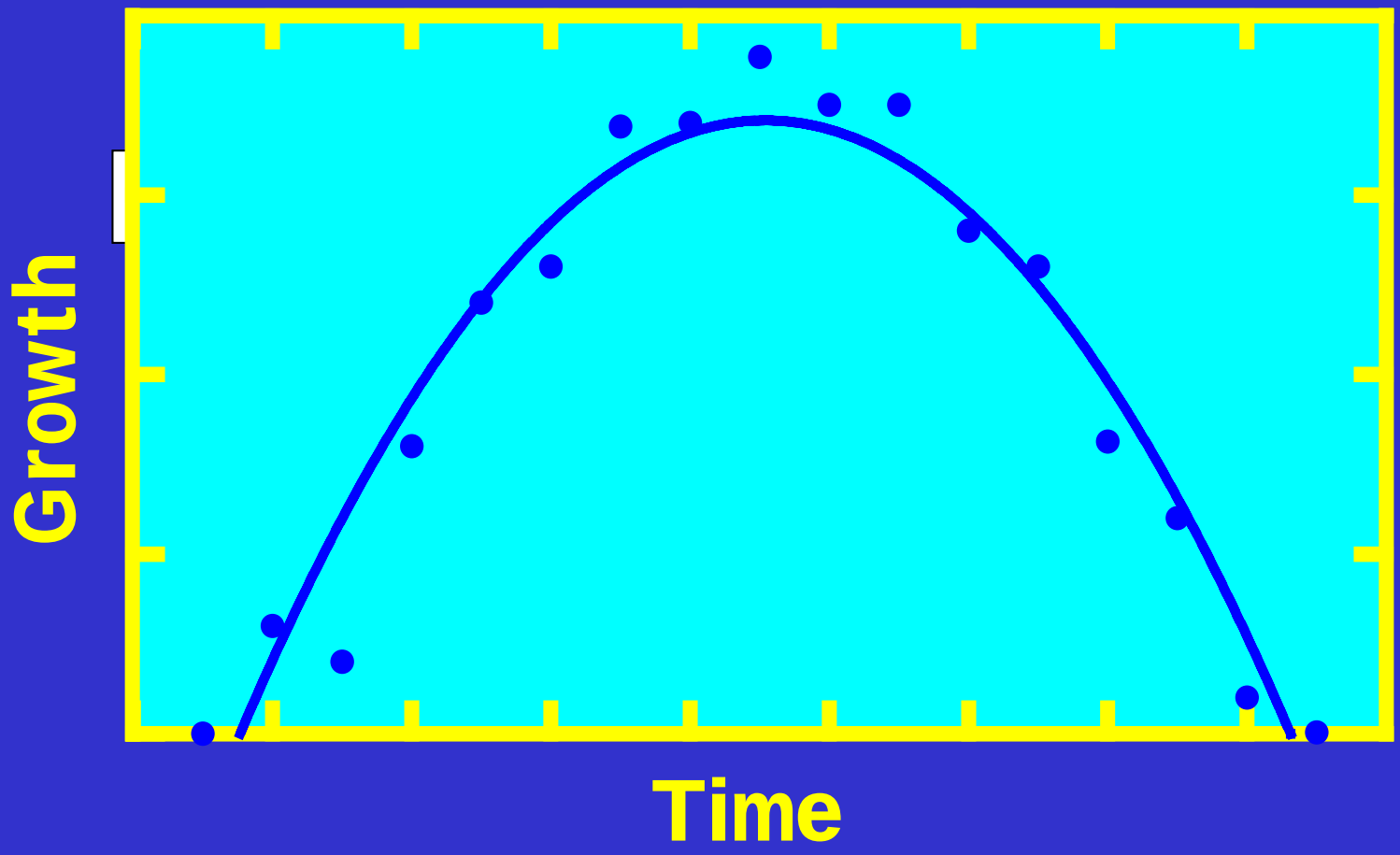
Our statistics should also be as simple as possible



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.

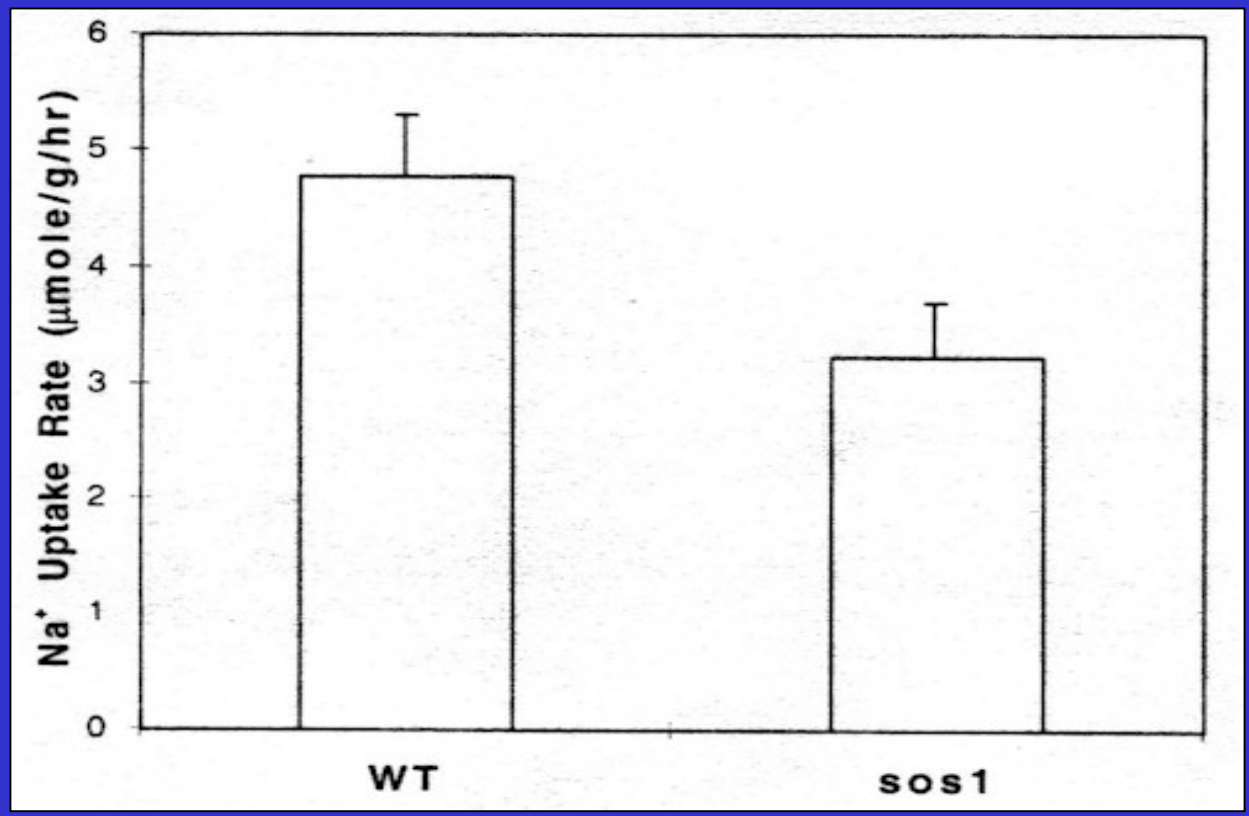
NS = not significant

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.

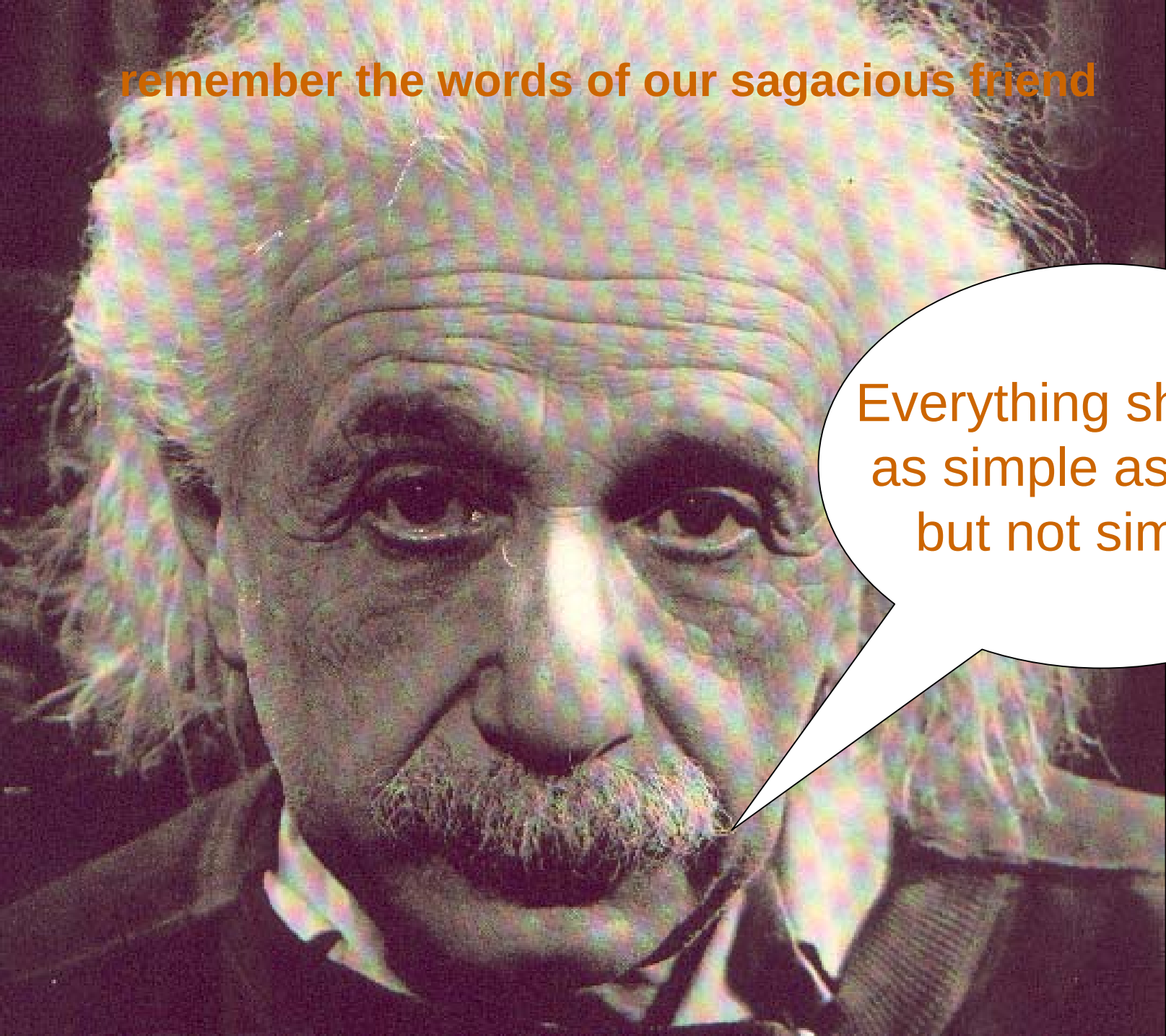
An r^2 of 0.99 in experimental physics means that the study should be done over to get a more clear answer.



from the most recent issue of Plant Physiology

the only statistics are standard deviations

remember the words of our sagacious friend



William of Occam understood the need for simplicity several centuries ago

Occam's Razor

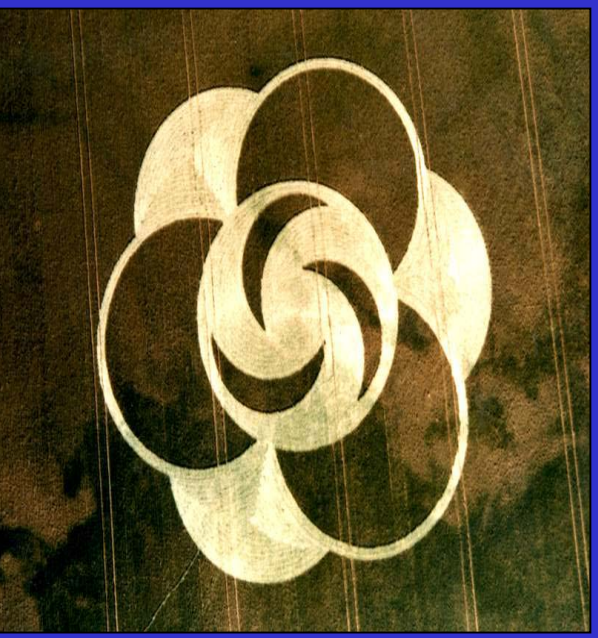
One should not increase, beyond what is necessary, the number of entities required to explain anything.

William of Occam

Where is William of Occam when we need him?

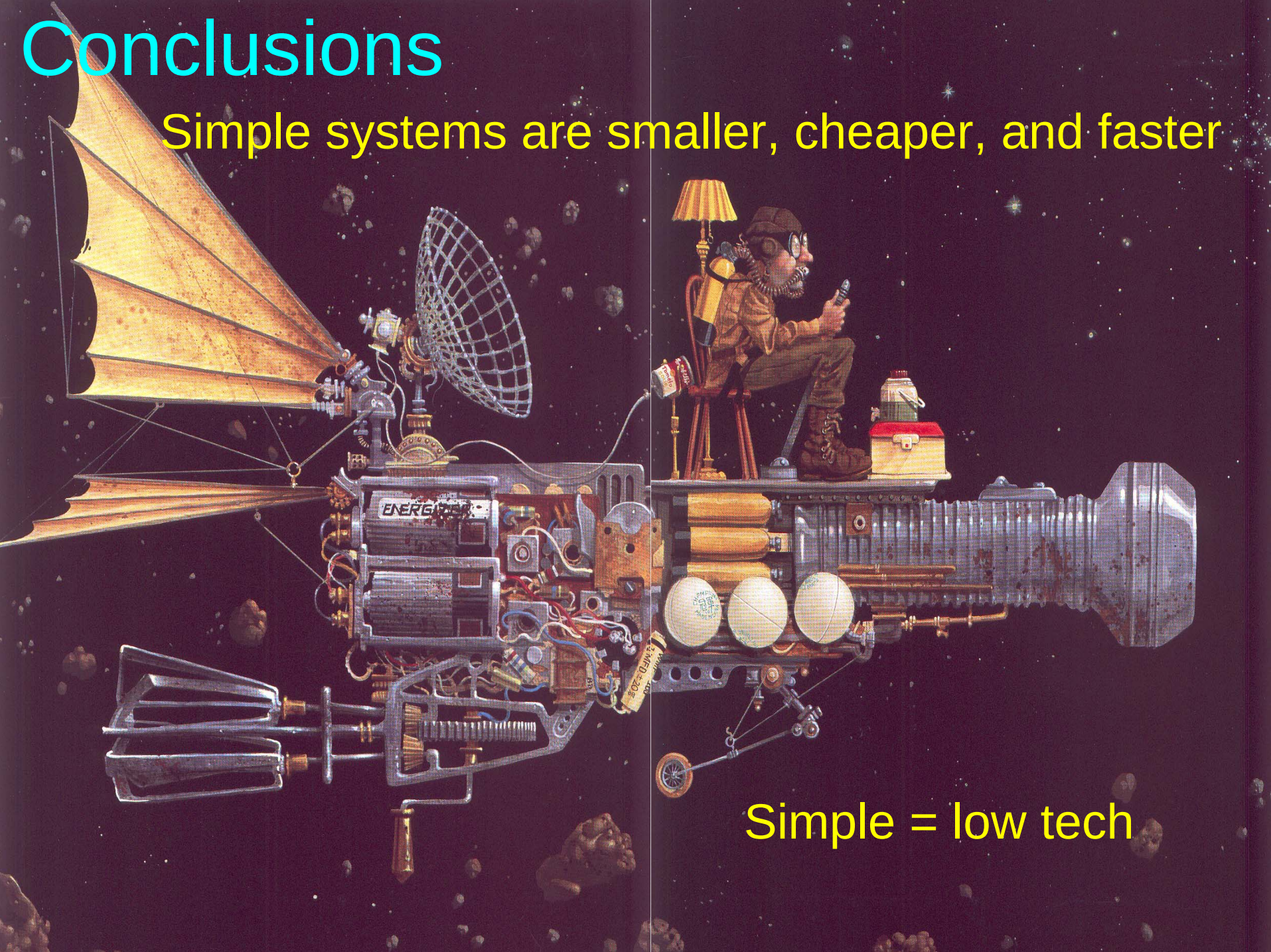
Is this the most simple explanation for Crop circles?

"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."



Conclusions

Simple systems are smaller, cheaper, and faster



Simple = low tech

Conclusions

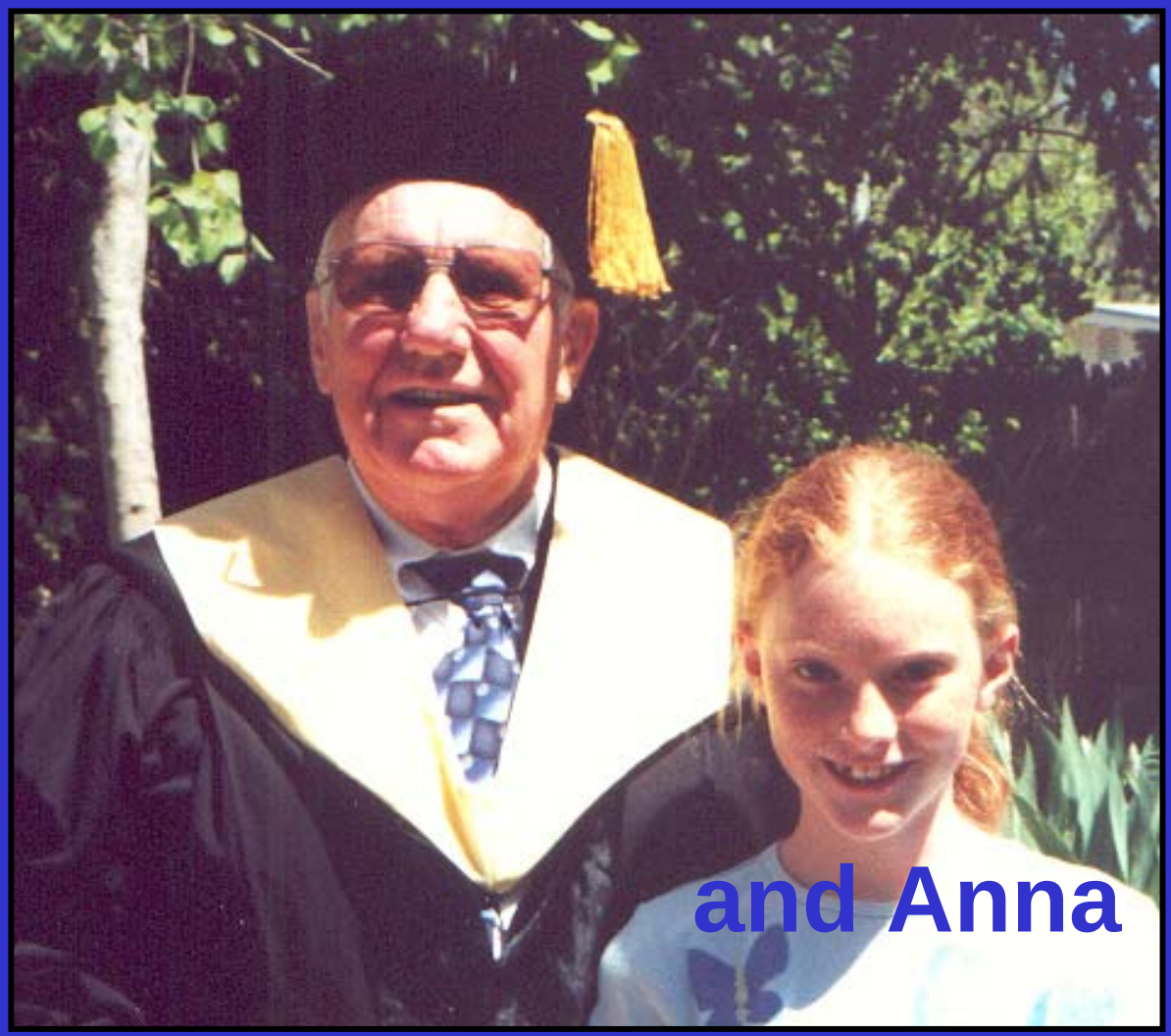
1. Conclusions from simple systems are broadly applicable

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.




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