

The *FT* Gene Controversy

Cory Ellison

Flowering Time and Plants

- Crucial moment in plant life cycle
- Economically important
 - Fruits, pollination, plant-animal interactions
 - Food crops, forestry, biofuels
- IRONY
 - Control of flowering time one of most elusive phenomena in all of plant biology

A Century of Confusion

- 1937
 - Russian scientist, Mikhail Chailakhyan, coins term “florigen”
 - Theoretical plant hormone controlling flowering
 - Grafting experiments
 - Demonstration of a transmissible flowering “signal”
- Decades passed with no success in identifying signal
 - Extremely small quantities of signal
- Florigen described as “Holy Grail” of plant biology

Changes in Plant Biology

- 1980's
 - Onset of molecular techniques to study biological phenomena
- 2000
 - Genome sequencing of *Arabidopsis thaliana* complete
 - Provides genetic tools to investigate previously elusive biological events
 - FLOWERING TIME

Discovery of *FT*

- 3 independent groups identify a gene that controls flowering time
 - FT=Flowering Locus T
 - Each paper published in *Science*
- Detlef Weigel-Max Planck Institute
- Takashi Araki-Kyoto University
- Ove Nilsson-Swedish Agricultural University in Umea

“Florigen” gets more complex

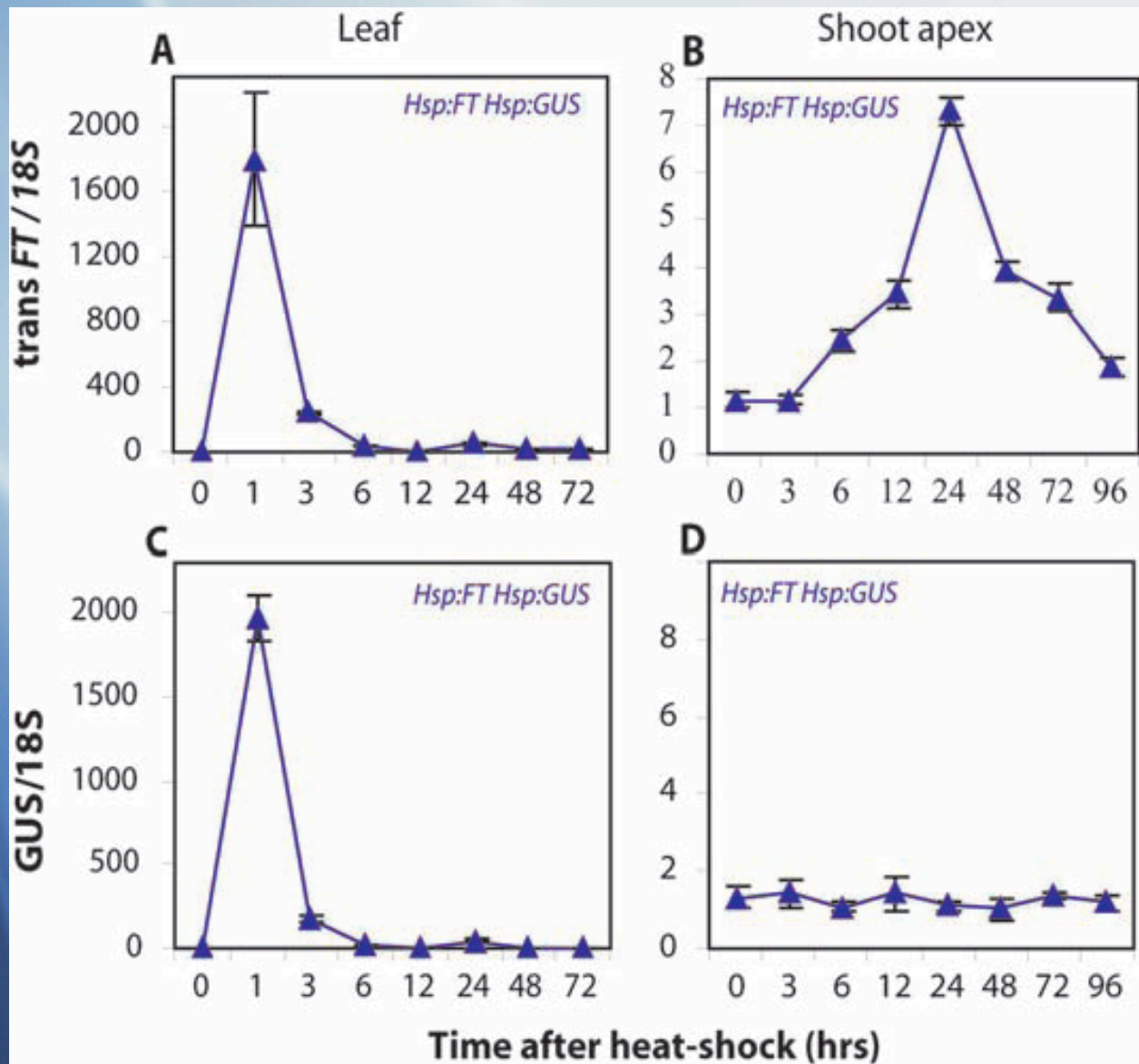
- Mid 2000s
 - Many more genetic components of flowering time identified
 - *FCA*, *SOC1*, *FD*, *CO*, etc...
- Which is the real florigen?
 - Meaning, which is the transmissible signal?

2005-The “Answer” Arrives...

The mRNA of the *Arabidopsis* Gene *FT* Moves from Leaf to Shoot Apex and Induces Flowering

**Tao Huang,¹ Henrik Böhlenius,¹ Sven Eriksson,¹
François Parcy,² Ove Nilsson^{1*}**

Day length controls flowering time in many plants. The day-length signal is perceived in the leaf, but how this signal is transduced to the shoot apex, where floral initiation occurs, is not known. In *Arabidopsis*, the day-length response depends on the induction of the *FLOWERING LOCUS T* (*FT*) gene. We show here that local induction of *FT* in a single *Arabidopsis* leaf is sufficient to trigger flowering. The *FT* messenger RNA is transported to the shoot apex, where downstream genes are activated. These data suggest that the *FT* mRNA is an important component of the elusive “florigen” signal that moves from leaf to shoot apex.



Ove Nilsson's Group Praised

- Paper widely accepted in plant biology community
- “An enormously exciting breakthrough” -Colin Turnbull
- Florigen finally discovered



Ove Nilsson

2006

- Coupland's group finds evidence that FT mRNA is not moving
- April 2006
 - Eliezer Lifschitz-Israel Institute of Technology
 - PNAS Publication
 - FT mRNA in tomatoes does not induce flowering in flowering shoots of tomato
- Plant Bio community gets suspicious

Shock of the Decade

- April 20th, 2007
 - Ove Nilsson announces retraction of the FT mRNA paper from *Science*
 - Paper accepted as scientifically valid for 1.5 years
- Only 4 out of 5 authors agreed to and signed retraction
 - Exception=Tao Huang (lead author)

Why the Retraction?

- Explanation
 - Re-analysis of data revealed multiple “anomalies”
 - Data points removed
 - Data points differentially weighted
 - Re-do of statistical analysis yields null results- none of experiments repeatable or statistically significant
 - Ove states that Tao manipulated the data

What About Tao Huang?

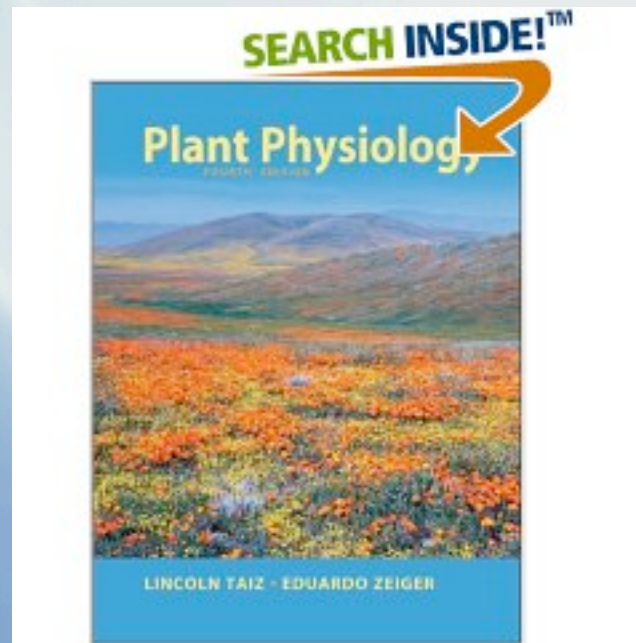
- Left Umea shortly after FT publication
 - Joined Xiamen U. in China
- Refuses to accept retraction
 - Believes data omissions were valid
 - “I think the retraction for this paper should not happen, and was at least immature.”
 - Claims certain data were “irrelevant to the experiment”

Immediately Following Retraction

- Umea University issued an internal and external investigation
- External investigator-Lars Rask
 - “As far as we can tell, [Huang] realized that there were potential problems in the experiments carried out.”
- Investigations still ongoing
- Fate of Tao Huang not determined

Consequences of “Florigen”

- Work was cited in 54 scientific publications
- Results had already made their way into biology textbooks



Story Isn't Over...

- *Science* has 2 papers in press
 - Coupland and Shimamoto groups have evidence that FT protein, not mRNA, is the mobile signal
- What's the problem?
 - Coupland's group has come under heavy fire regarding their experimental methods
 - Possible that this paper will be retracted as soon as it is published

“Florigen has a long history of
disappointing people!”

Brian Ayre, University of North
Texas

Who is at Fault?

- Too early to tell
- Tao Huang likely central culprit
- Some agreement that reviewing process was faulty
 - Obvious statistical errors in original manuscript
- Chicago-July 2007
 - Editorial Board of *The Plant Cell* discussing changes in reviewing process
 - Possible changes=reviewers sign their names to reviews