

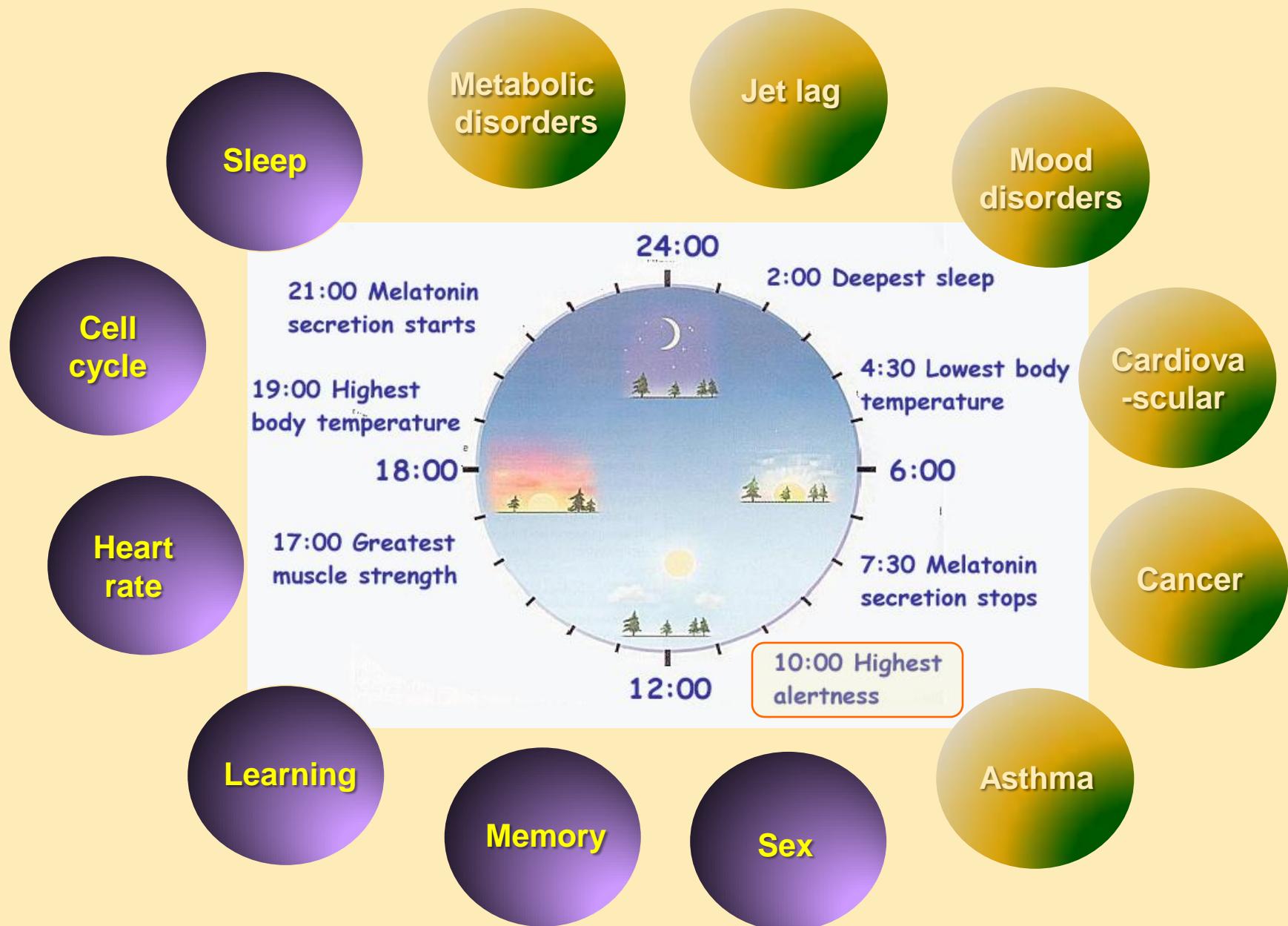
# The social clock of the honeybee

Guy Bloch



**The A. Silberman Institute of Life Sciences  
Department of Ecology, Evolution, and Behavior**

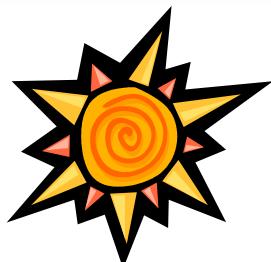
# The circadian system has a central role in human health



# The organization of the circadian system

## Input pathways

Sunlight or other environmental cues



## Clock setting pathway

Sensory receptors

## Core oscillator

Clock mechanism

Pacemaker



## Output pathways

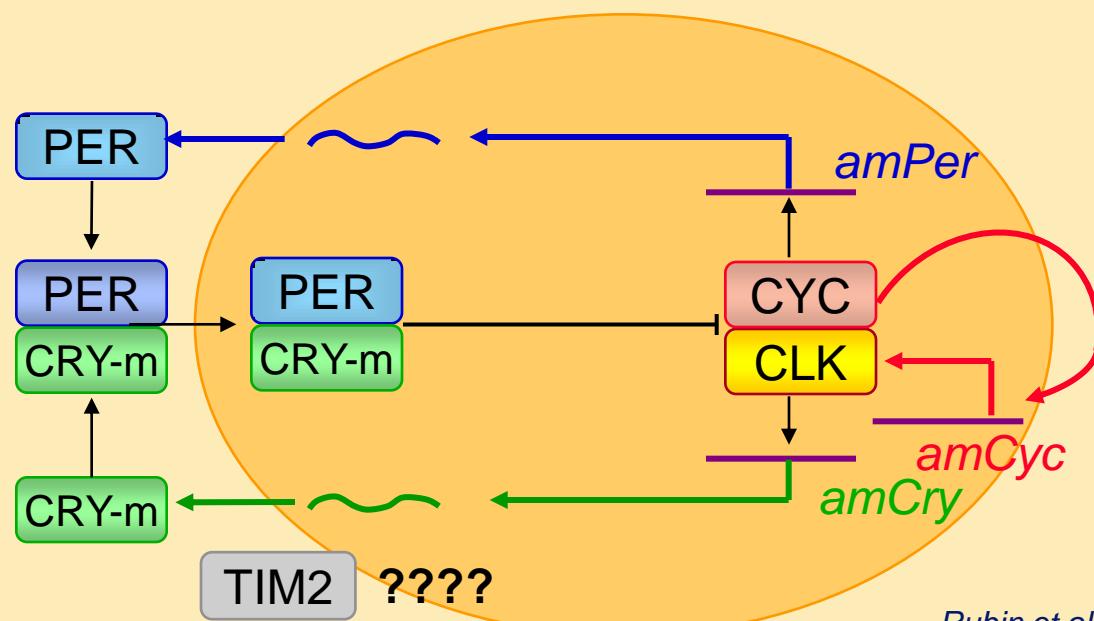
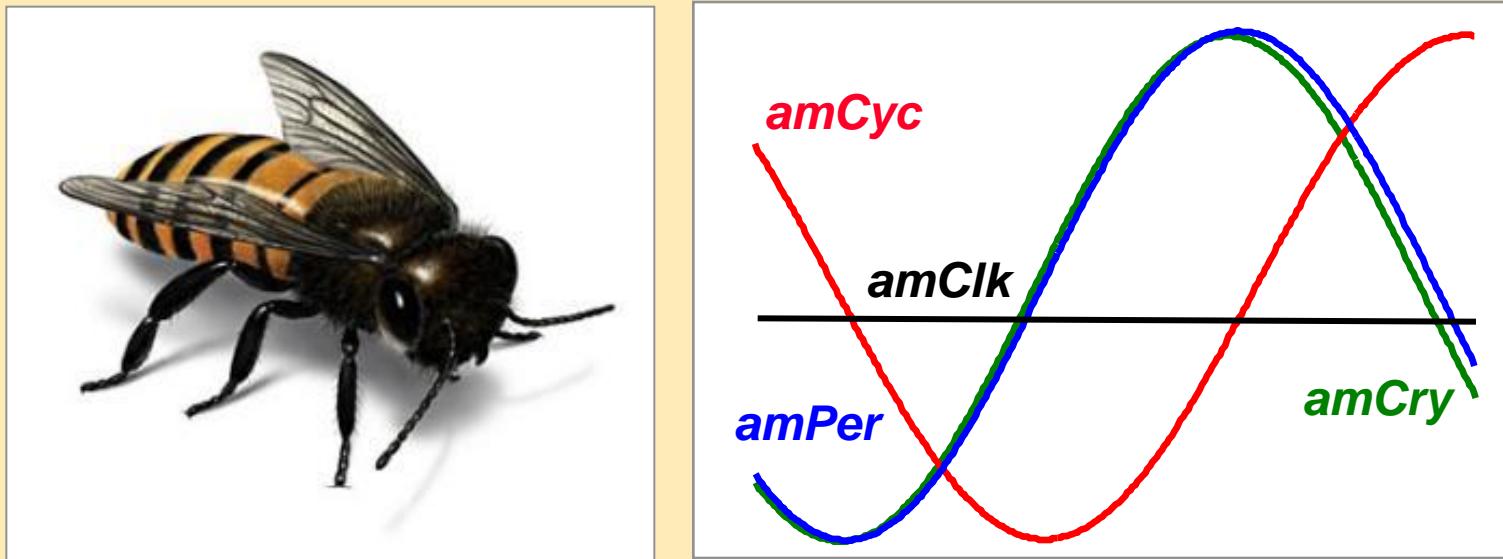
Observed rhythms

Locomotor patterns

Feeding behaviors

Hormone release patterns

Other rhythms



Bloch JBR 2010  
Rubin et al. Genome Res. 2006

# The interplay between the clock and social behavior in bees

- Task-related plasticity in circadian rhythms
- Social entrainment (synchronization)
- Plasticity in circadian rhythms and maternal behavior/physiology in queens
- Social influences on the ontogeny of circadian rhythms



# The interplay between the clock and social behavior in bees

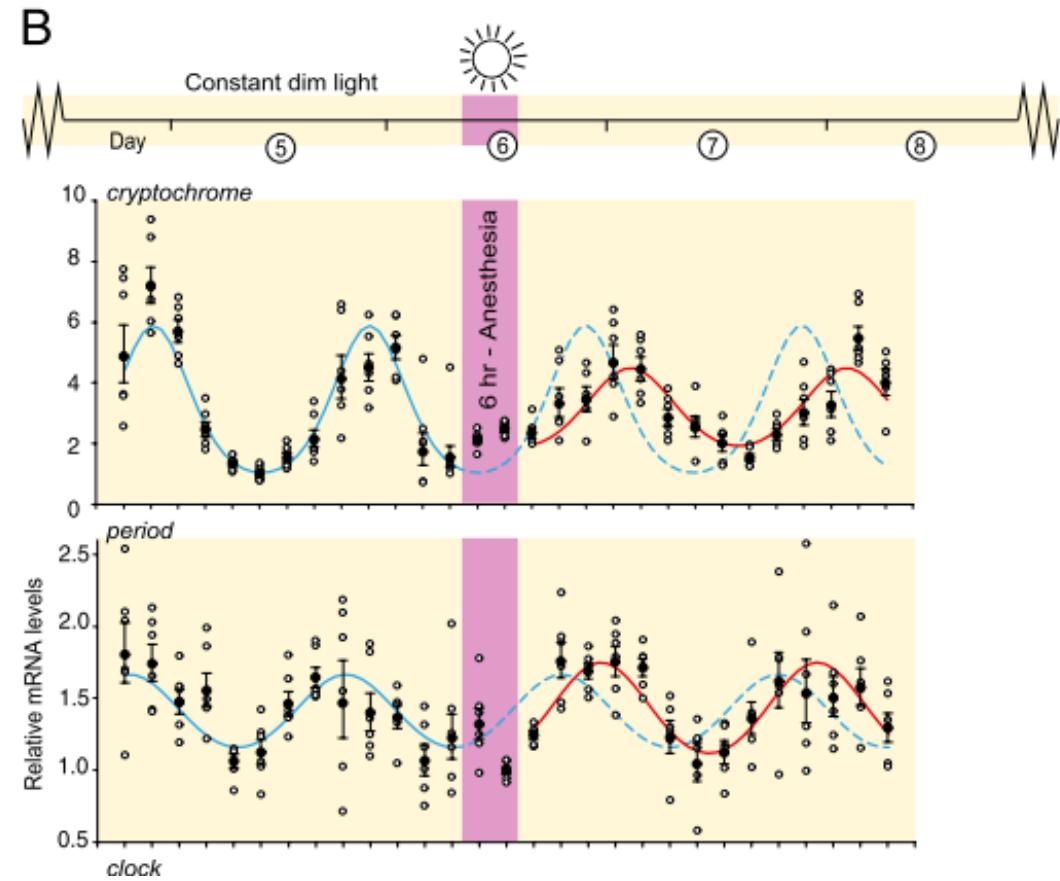
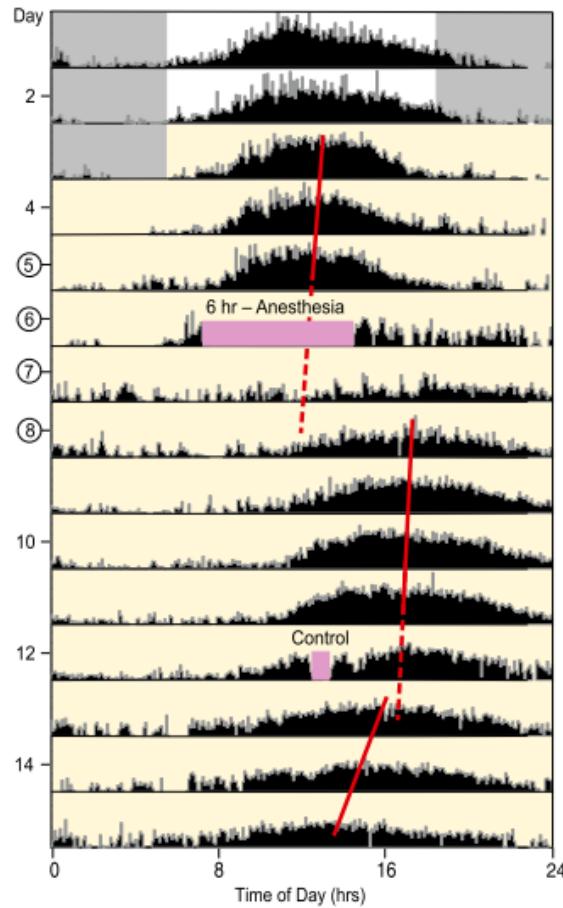
- Task-related plasticity in circadian rhythms
- Social entrainment (synchronization)
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- Social influences on the ontogeny of circadian rhythms

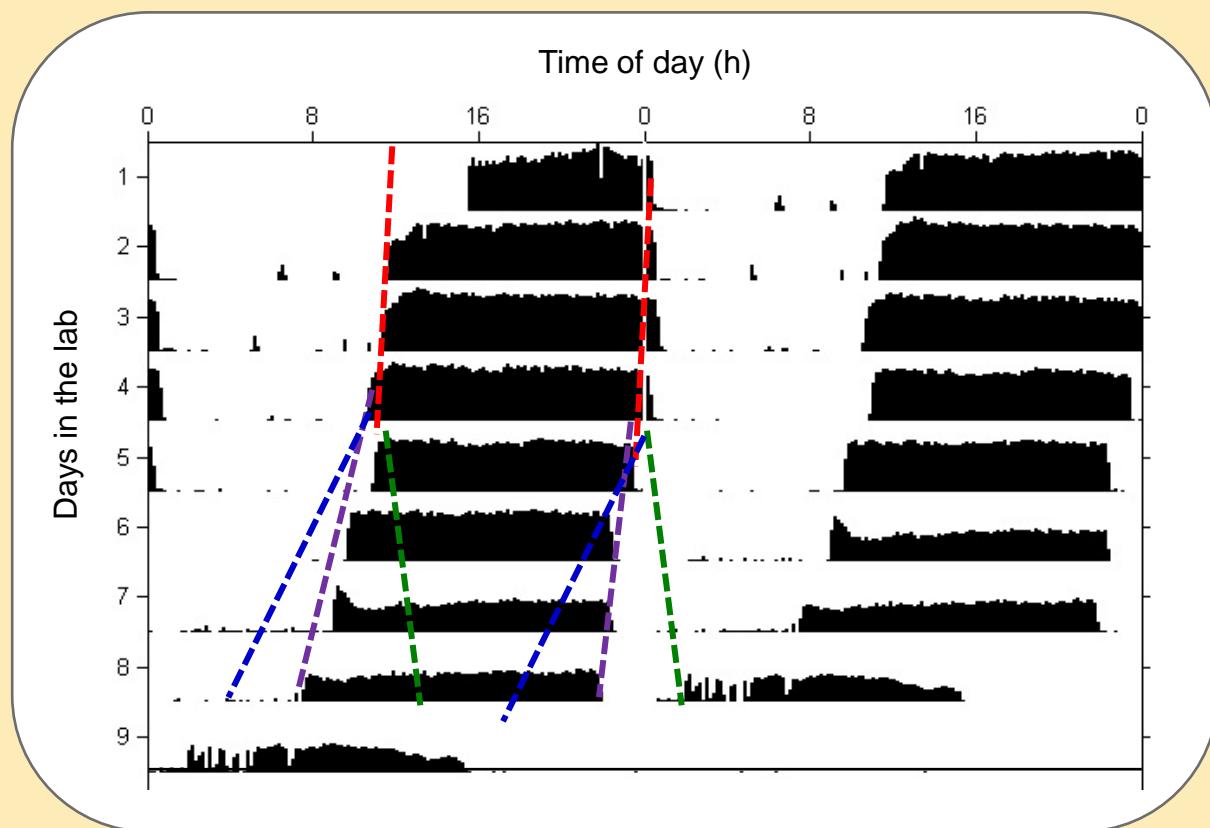
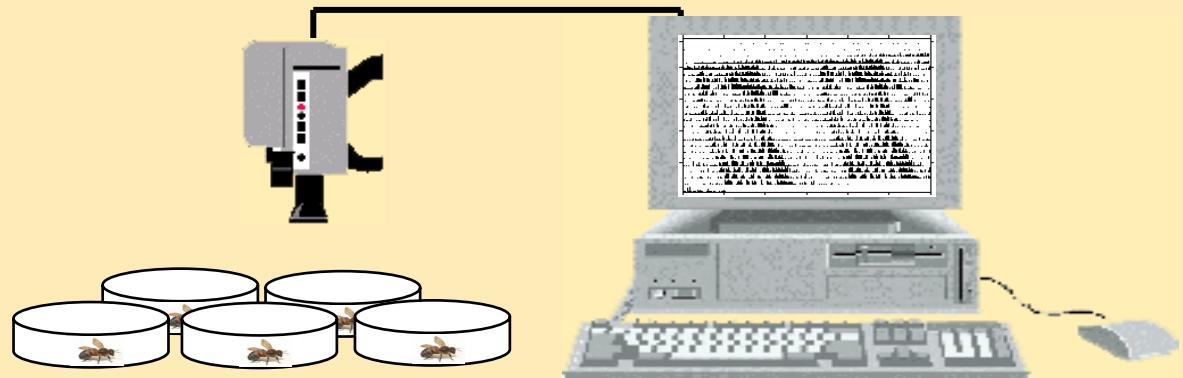


# Social synchronization of activity rhythms



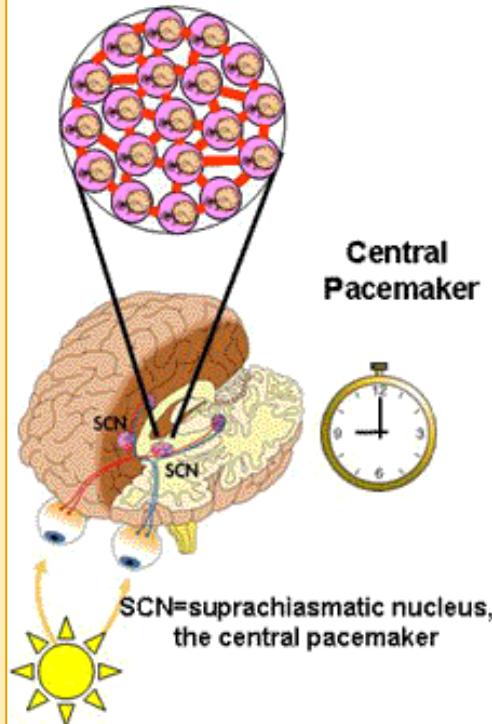
# Hive-activity rhythms and clock gene expression





# How nest bees are synchronized to a common phase?

## MAMMALS



# How bees are synchronized to a common phase?

a.



b.



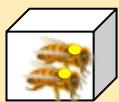
**Foragers**



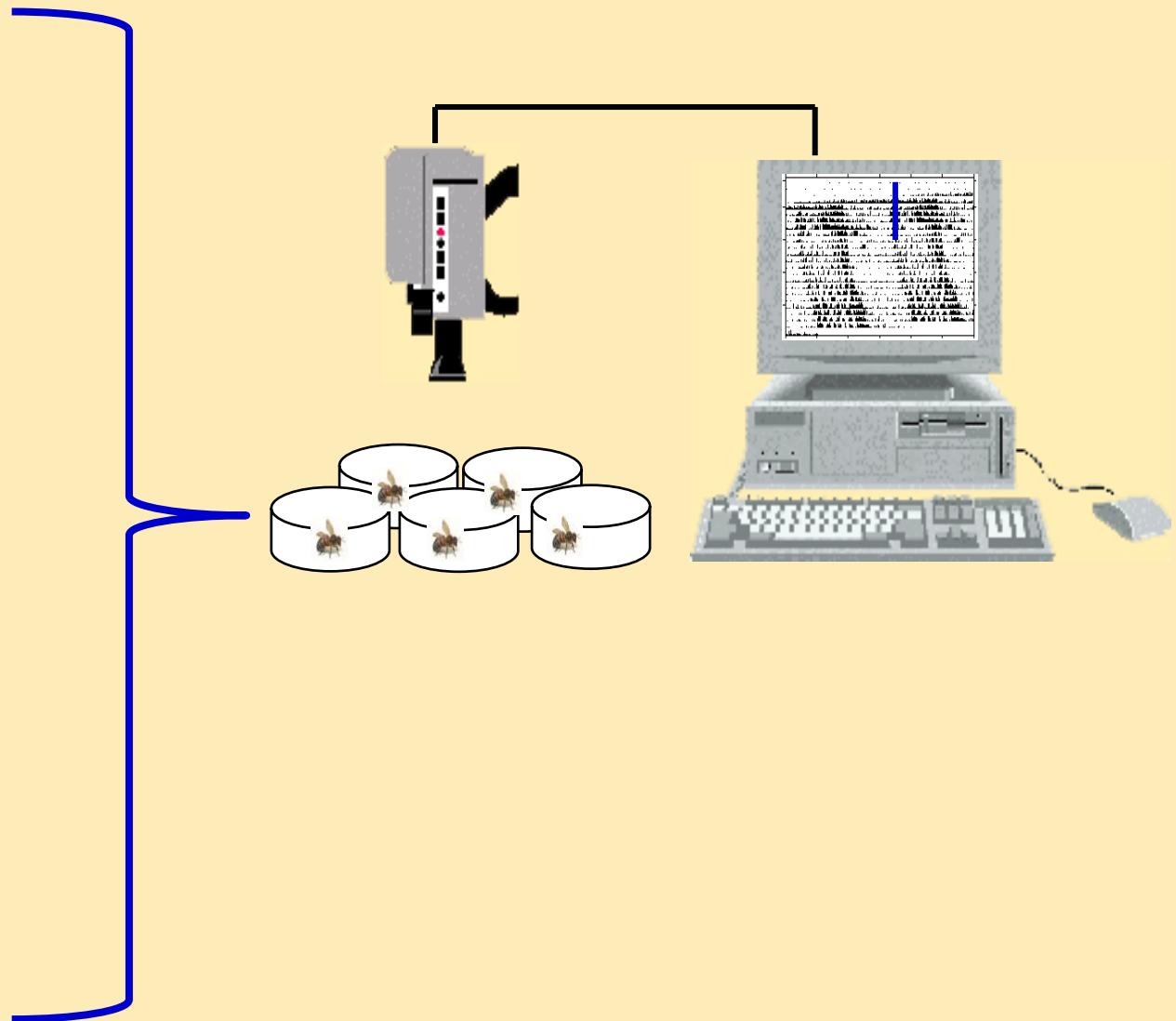
**48h in a colony**



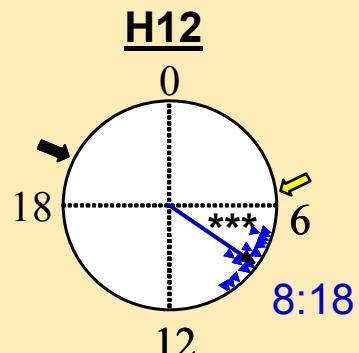
**48h in a cage**



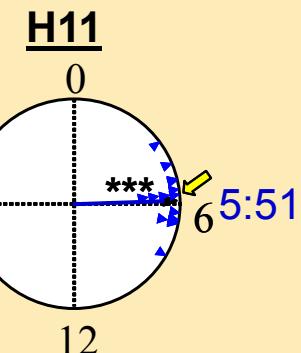
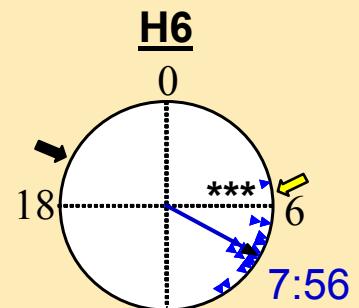
**48h in isolation**



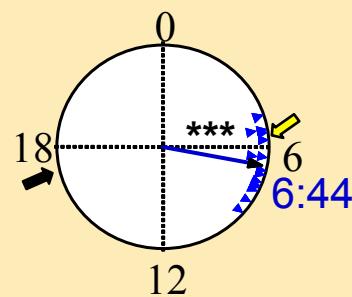
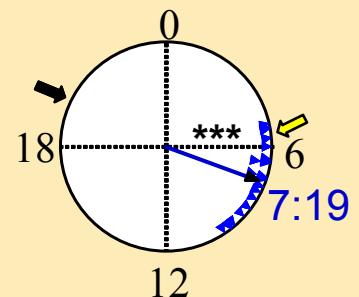
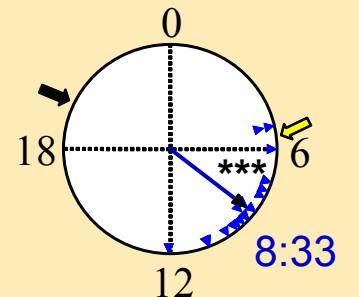
## Colony



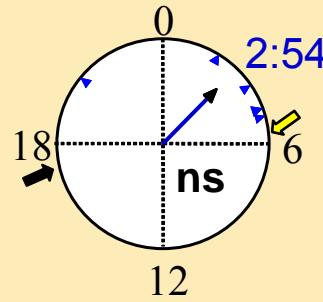
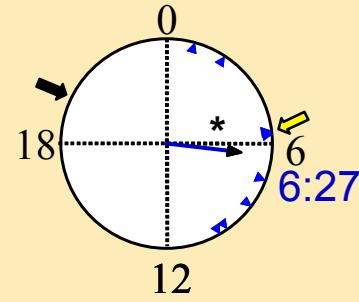
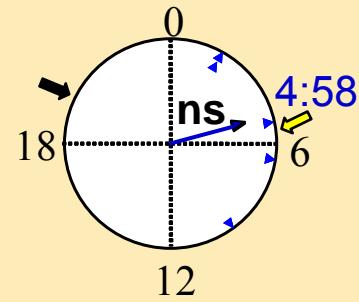
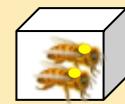
## Foragers



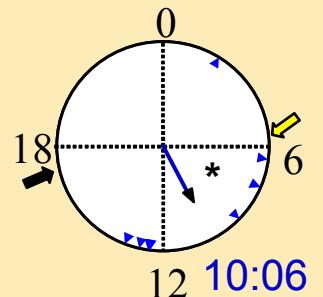
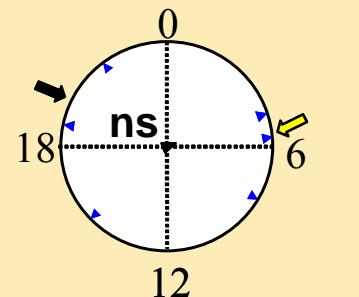
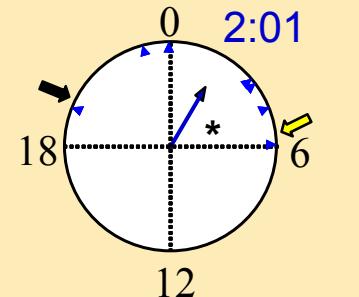
## 48h in a colony



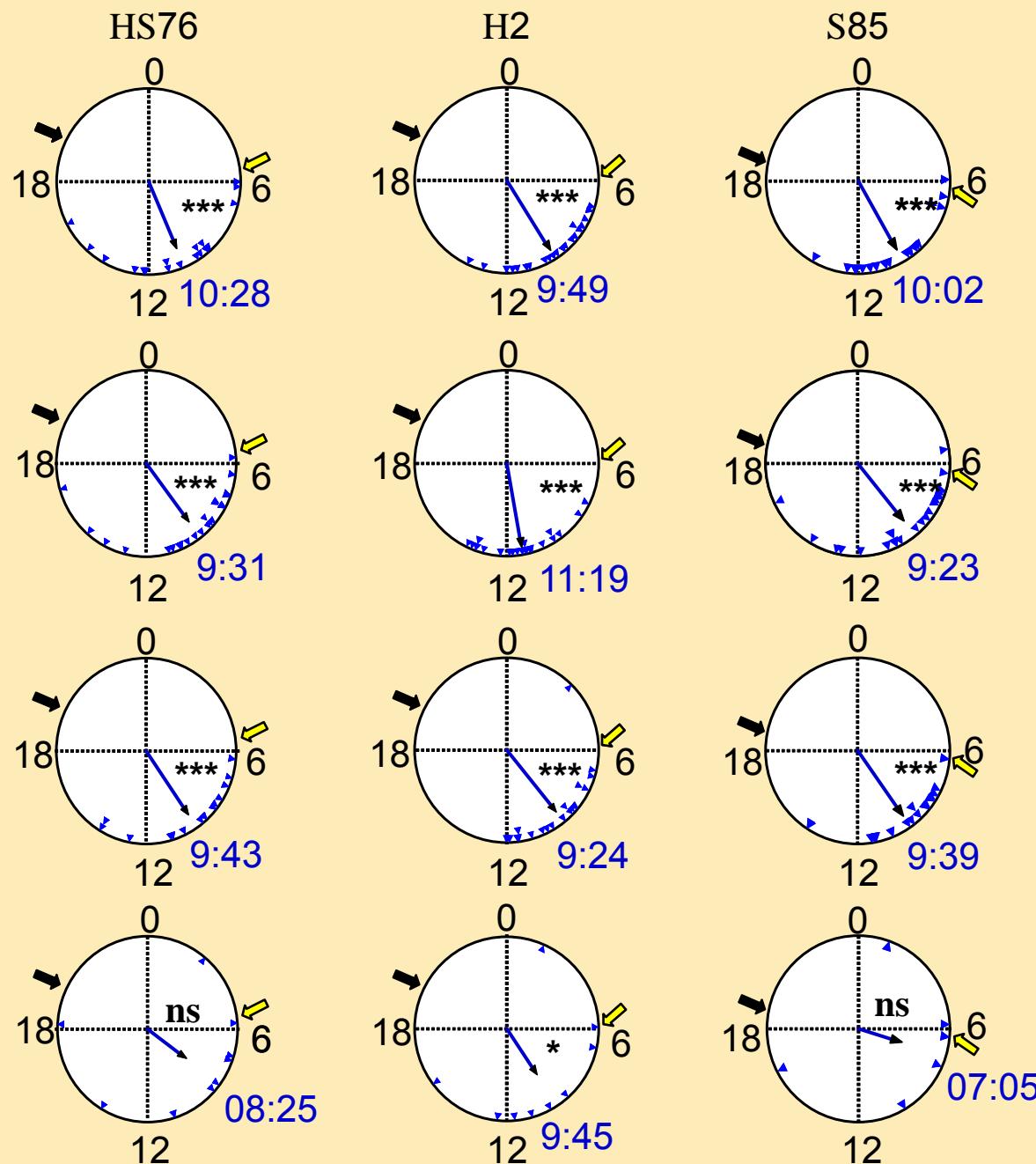
## 48h in a cage

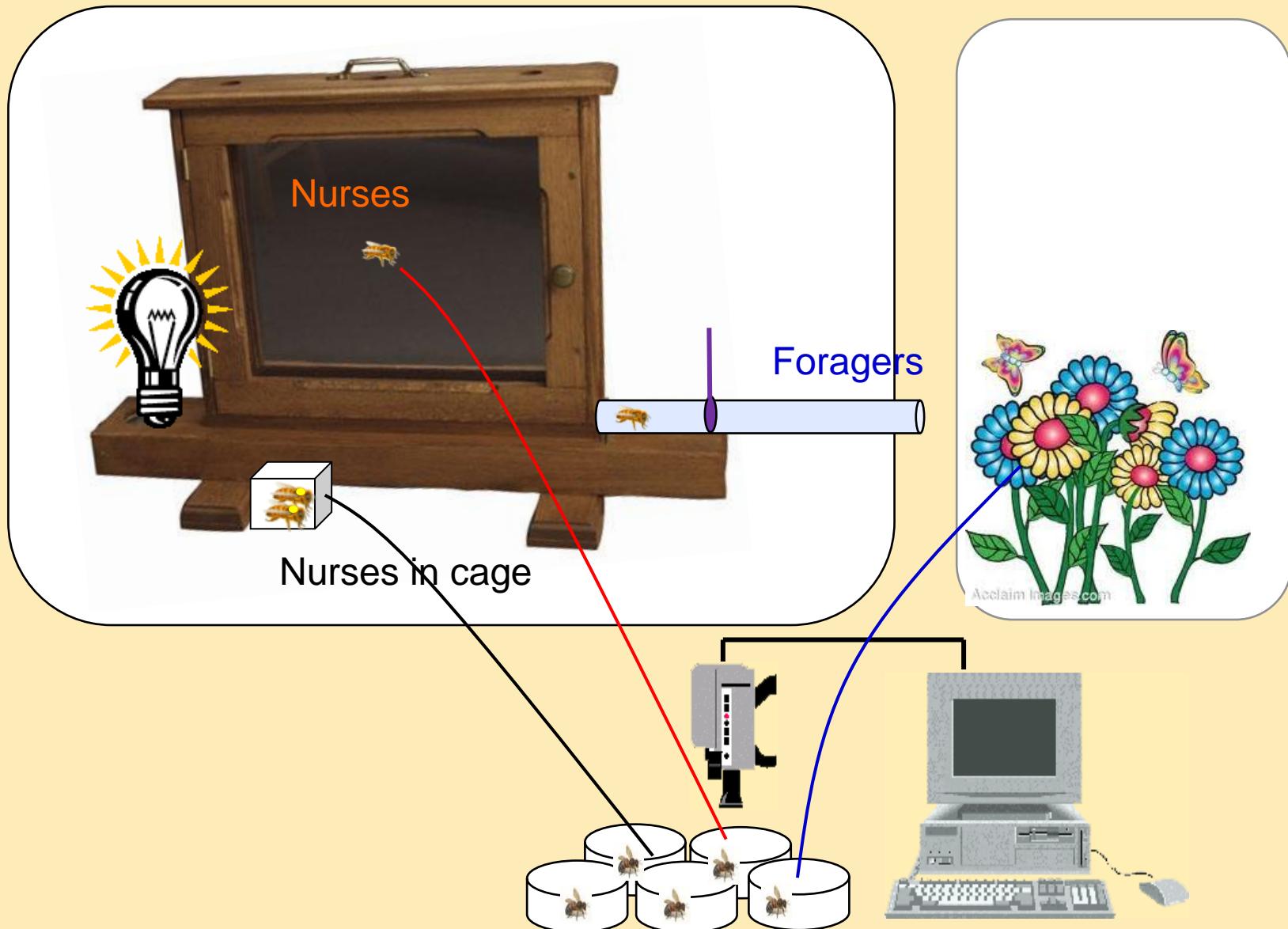


## 48h in isolation



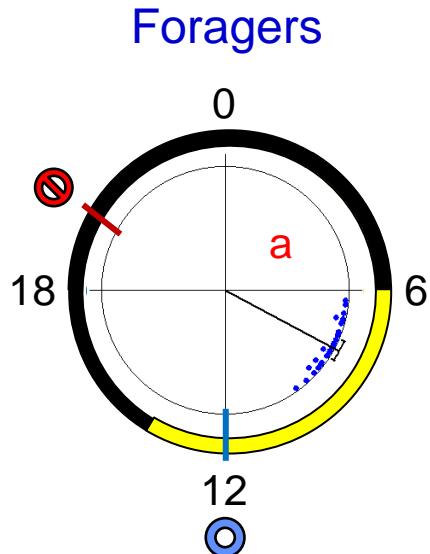
# Colony



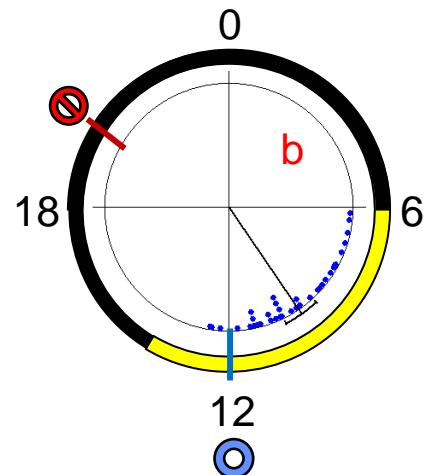


Fuchikawa, Nagari, and Bloch, unpublished

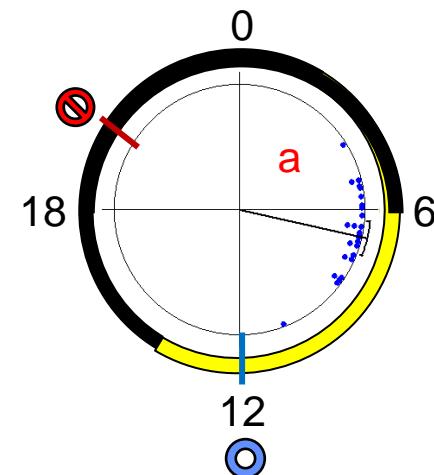
**Onset**



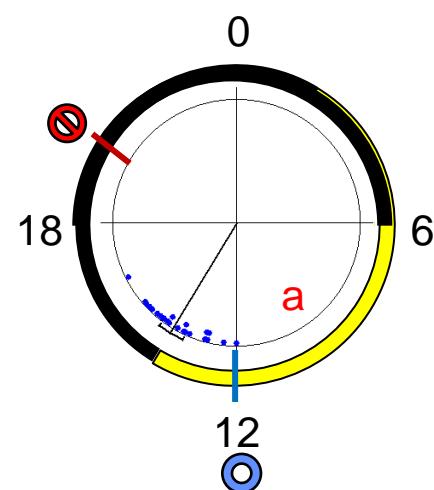
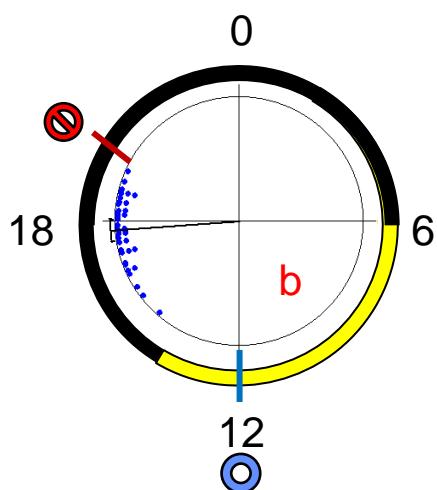
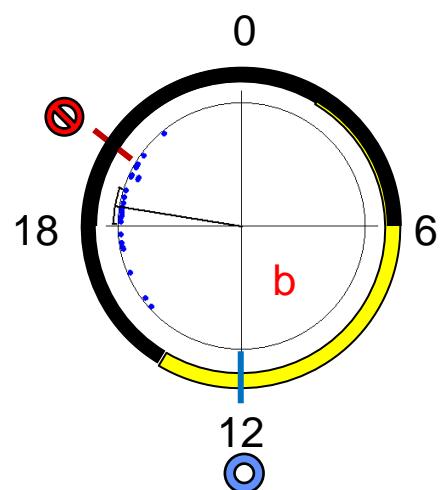
**Nurses**



**Nurses in cage**



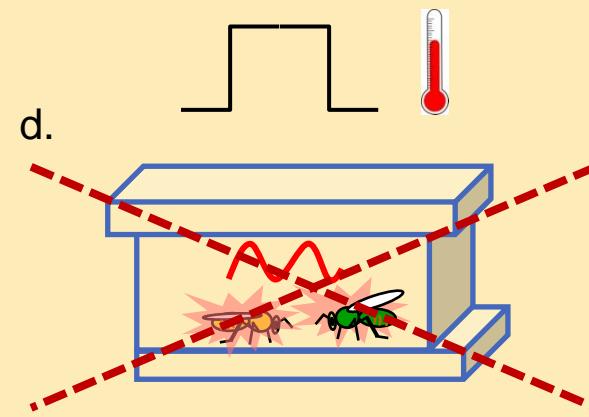
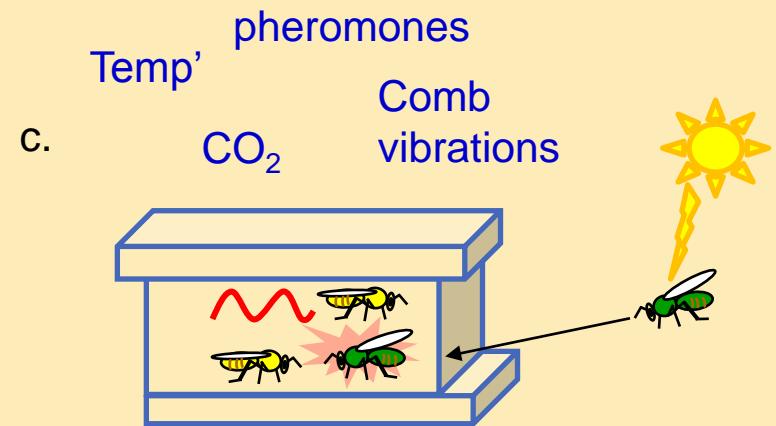
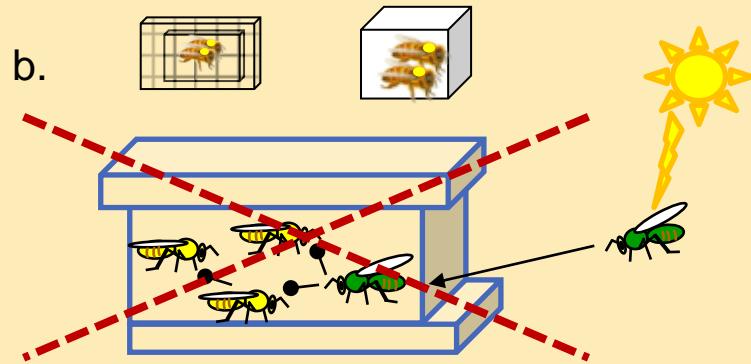
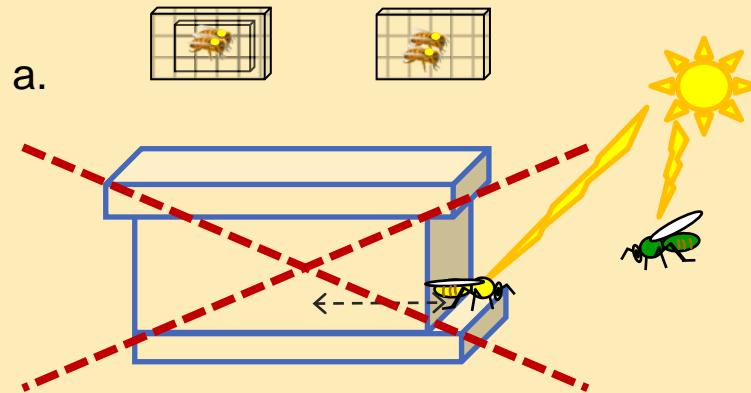
**Offset**



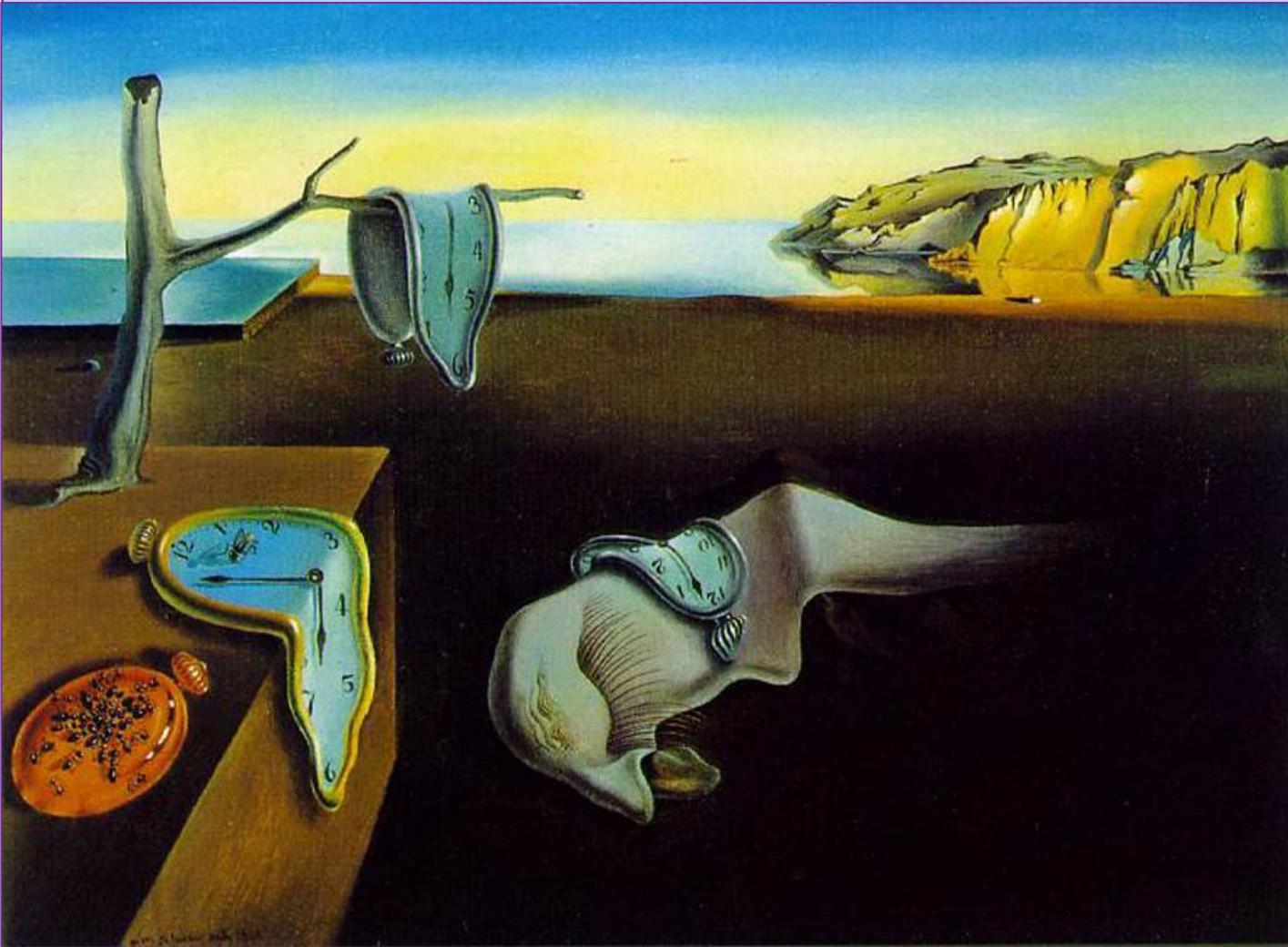
○ \ ( ) Open\ close hive entrance

[yellow] [black] light: dark

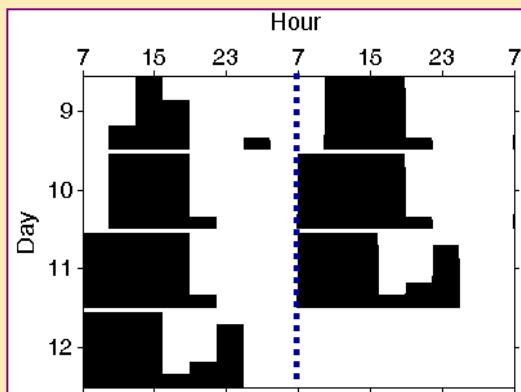
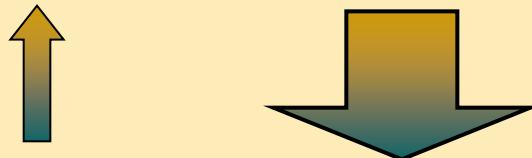
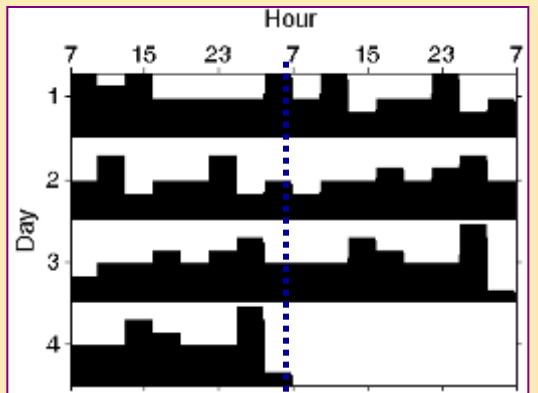
# How bees are synchronized to a common phase?



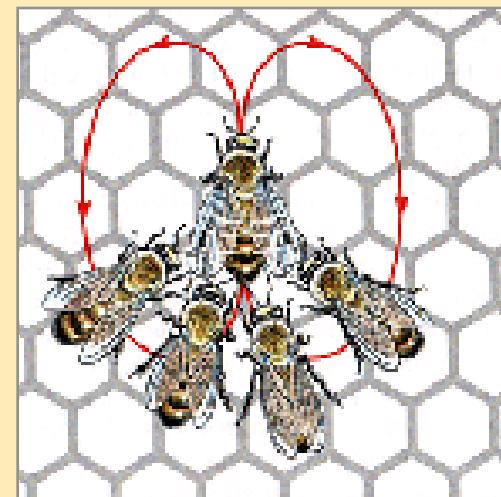
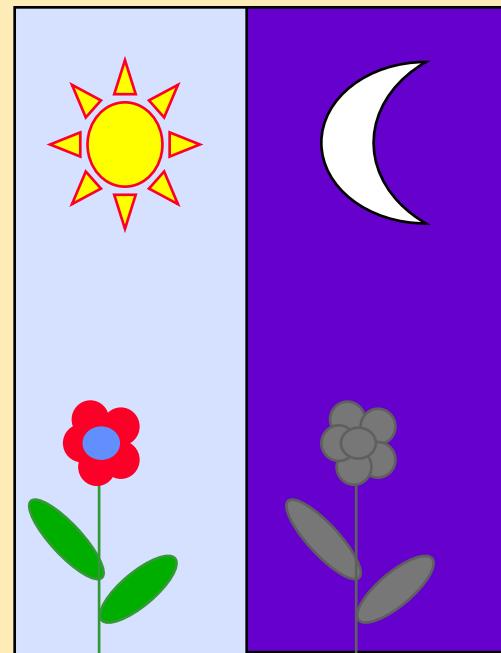
# Socially regulated plasticity in circadian rhythms



# Division of labor and plasticity in circadian rhythms



Moore et al. 1998; Bloch and Robinson 2001





Jong and Lee, 2008



*Polyrhachis dives*

Ingram et al. 2012

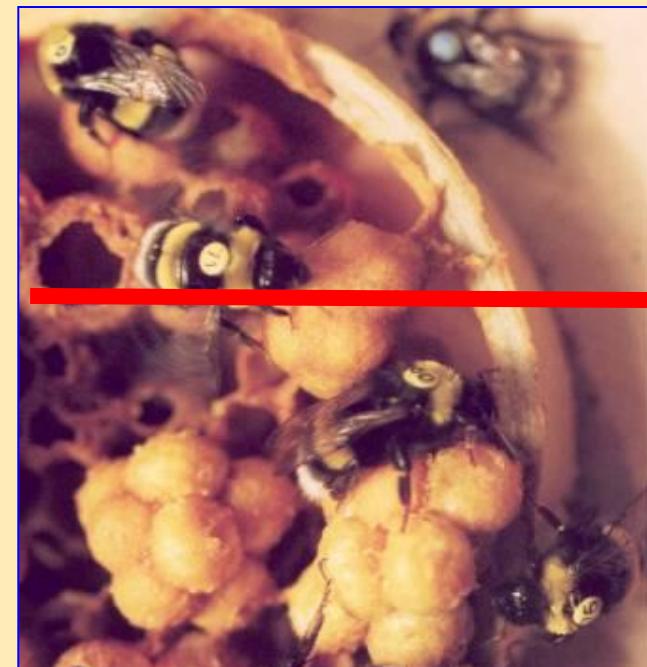
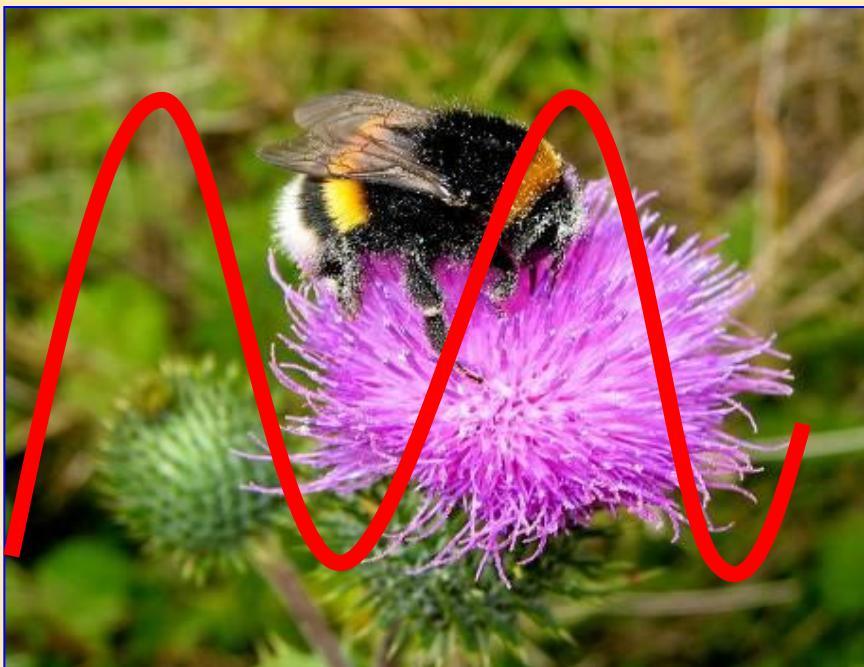


*Solenopsis invicta*

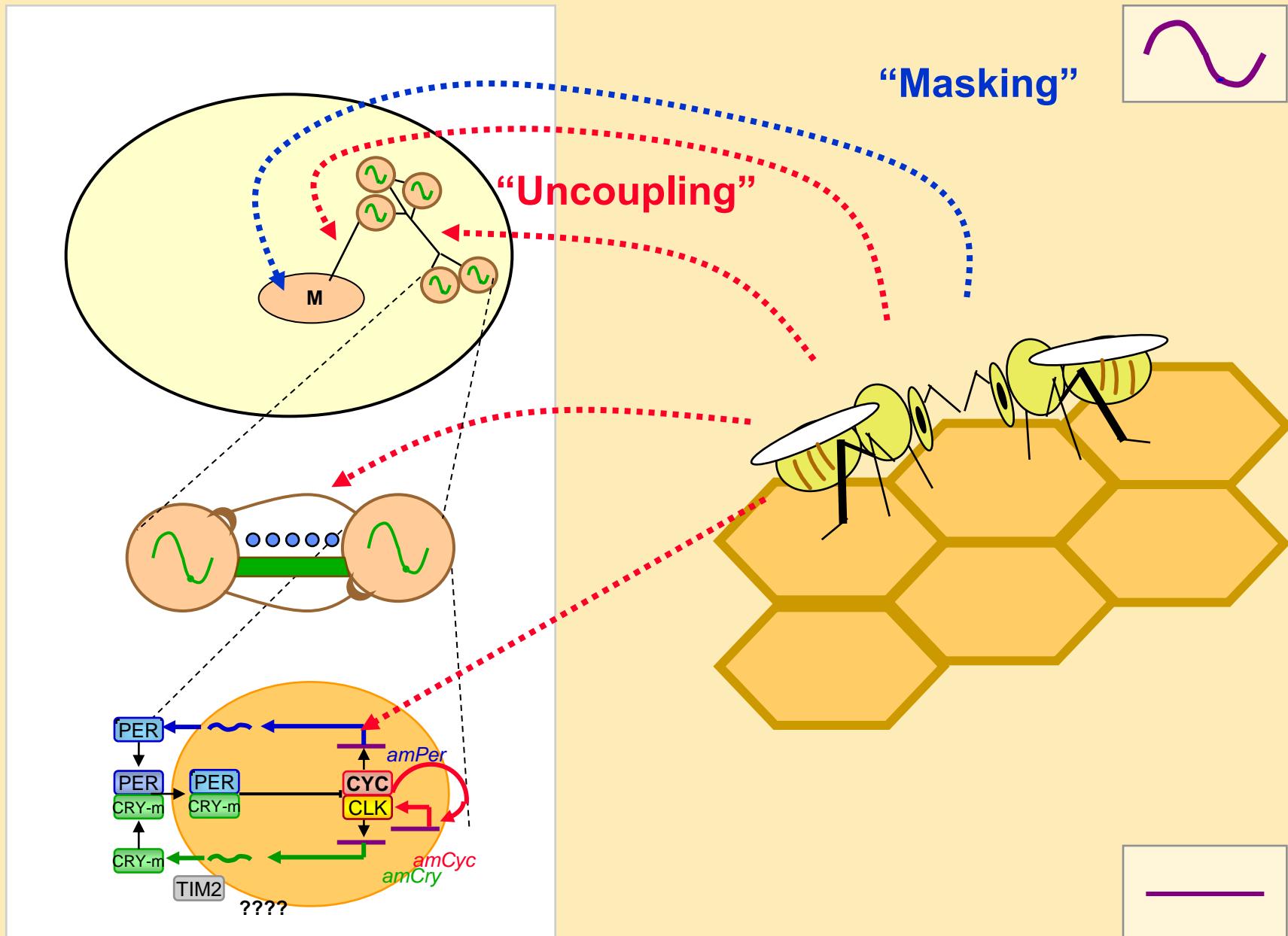
Ingram et al. 2009

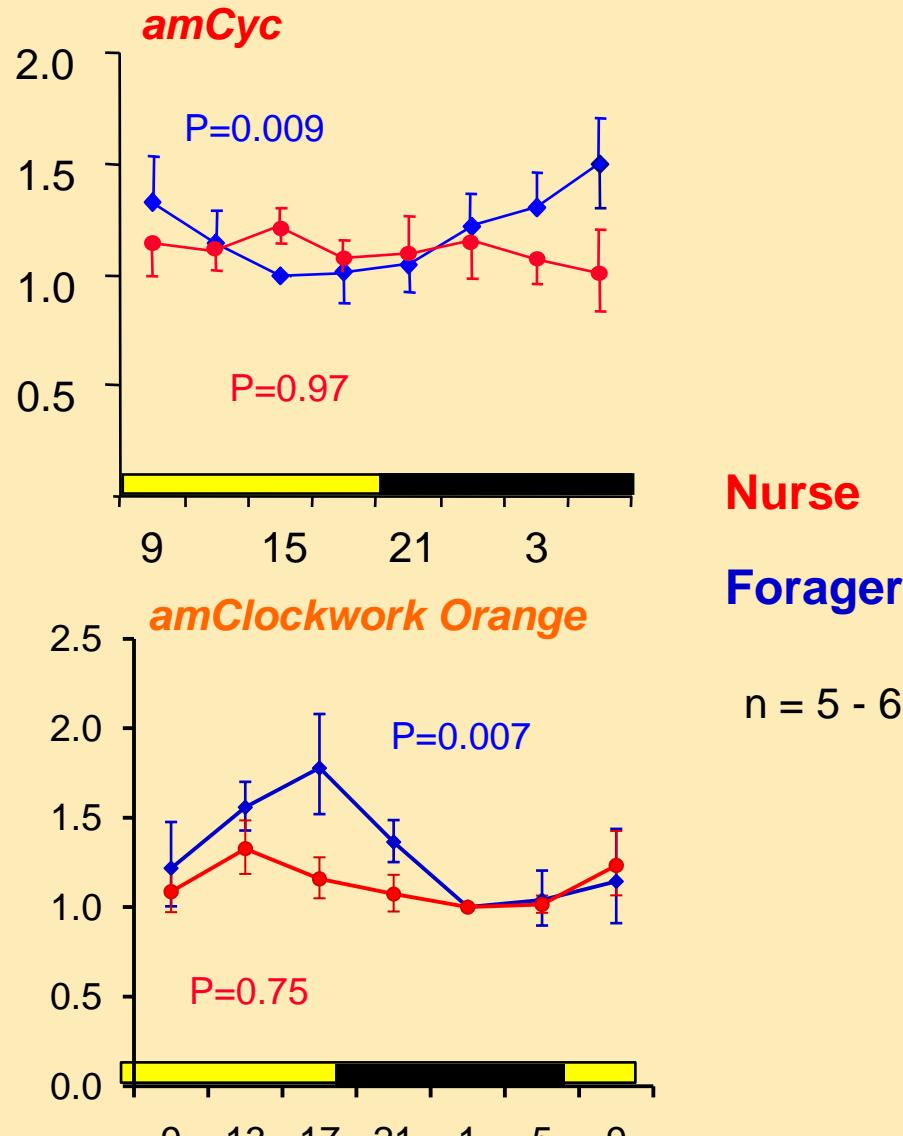
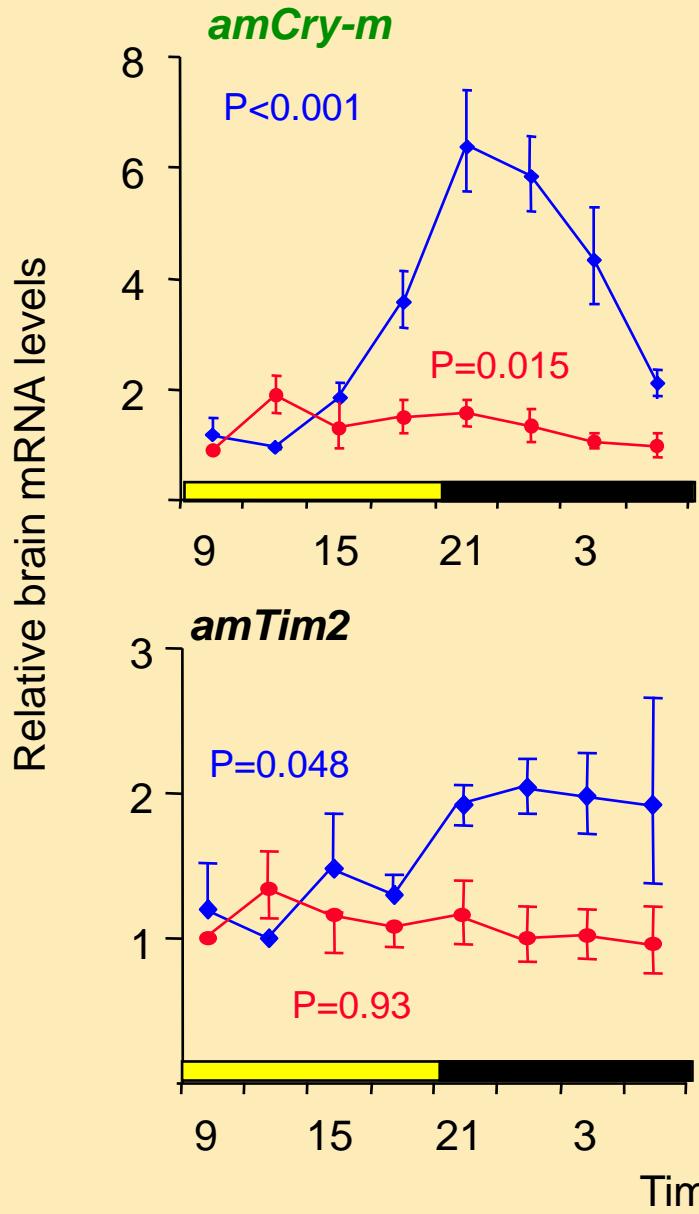


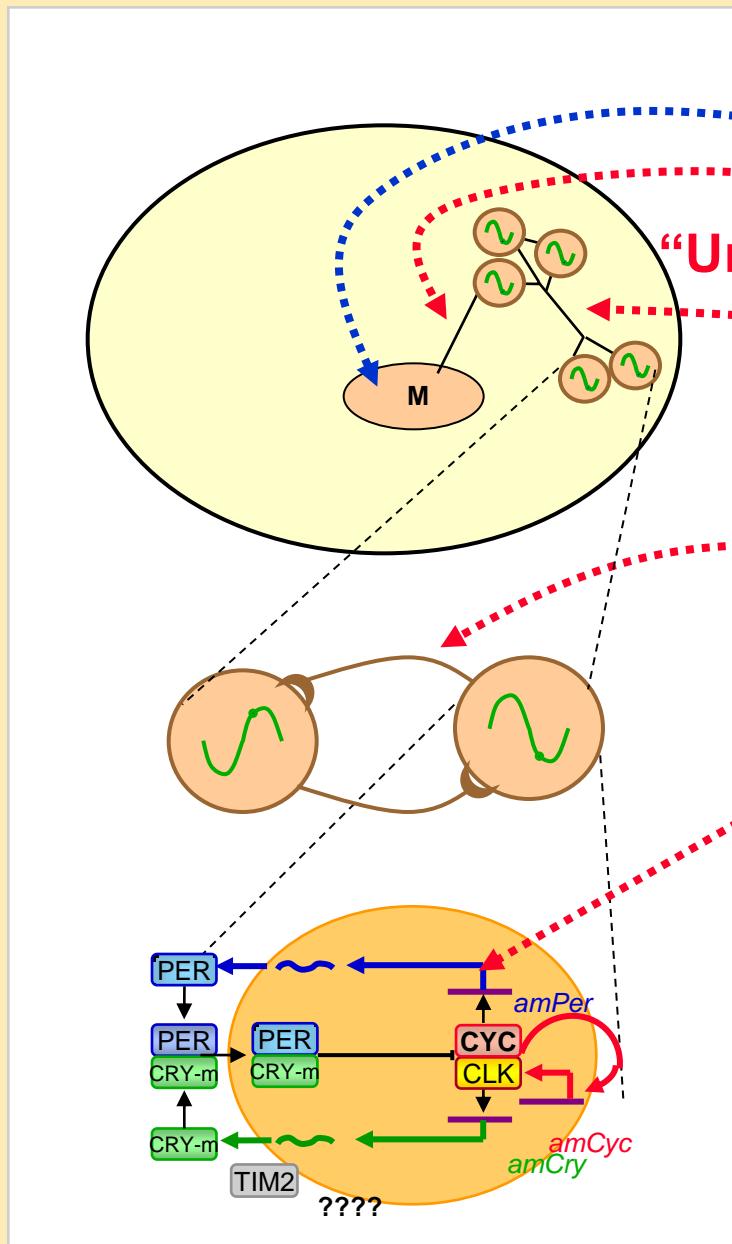
*Pogonomyrmex occidentalis*



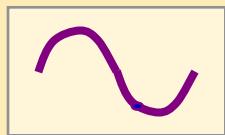
Yerushalmi et al., JEB 2006



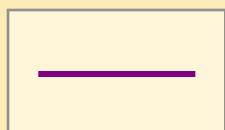
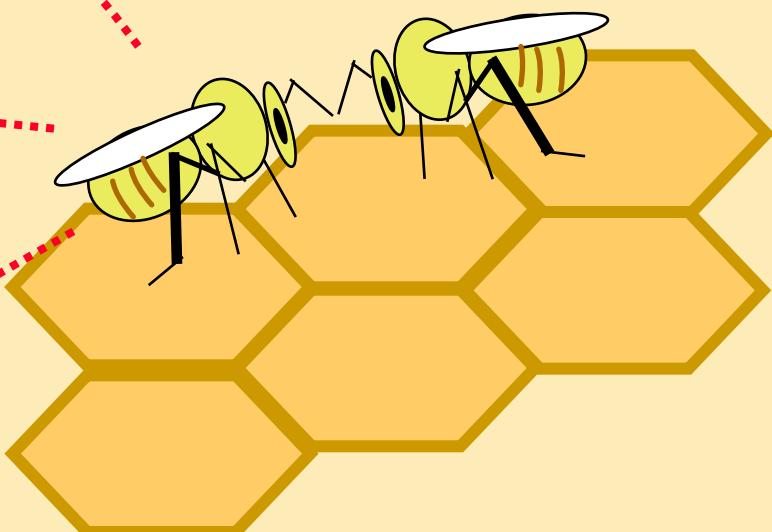


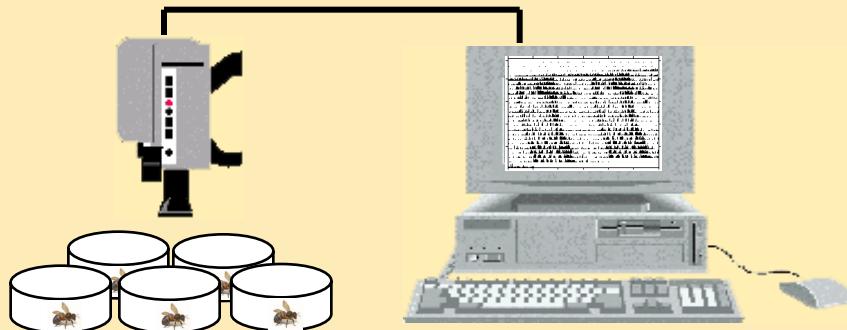


**“Masking”**

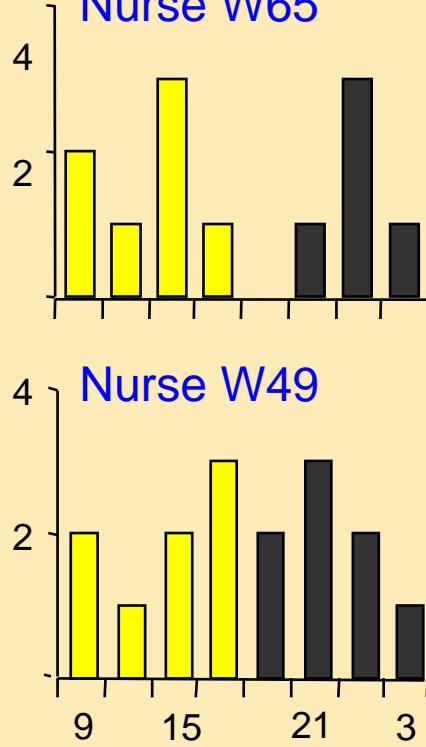


**“Uncoupling”**

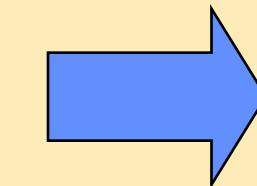
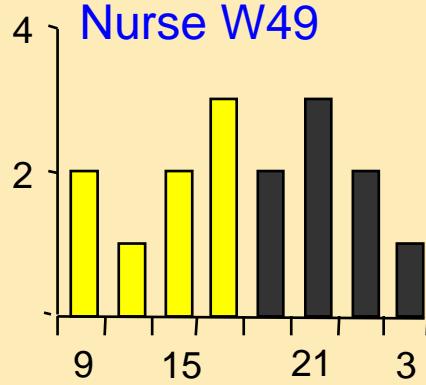




Nurse W65

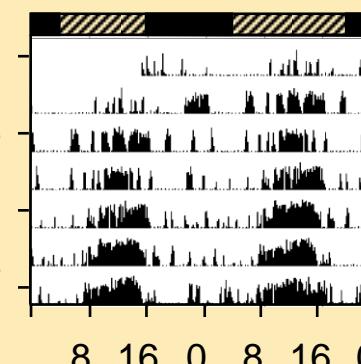
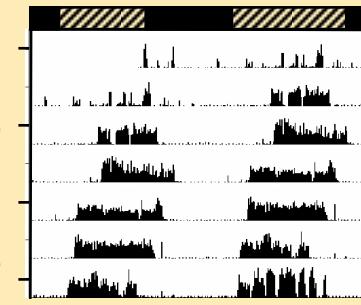
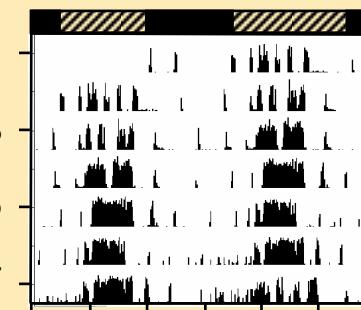


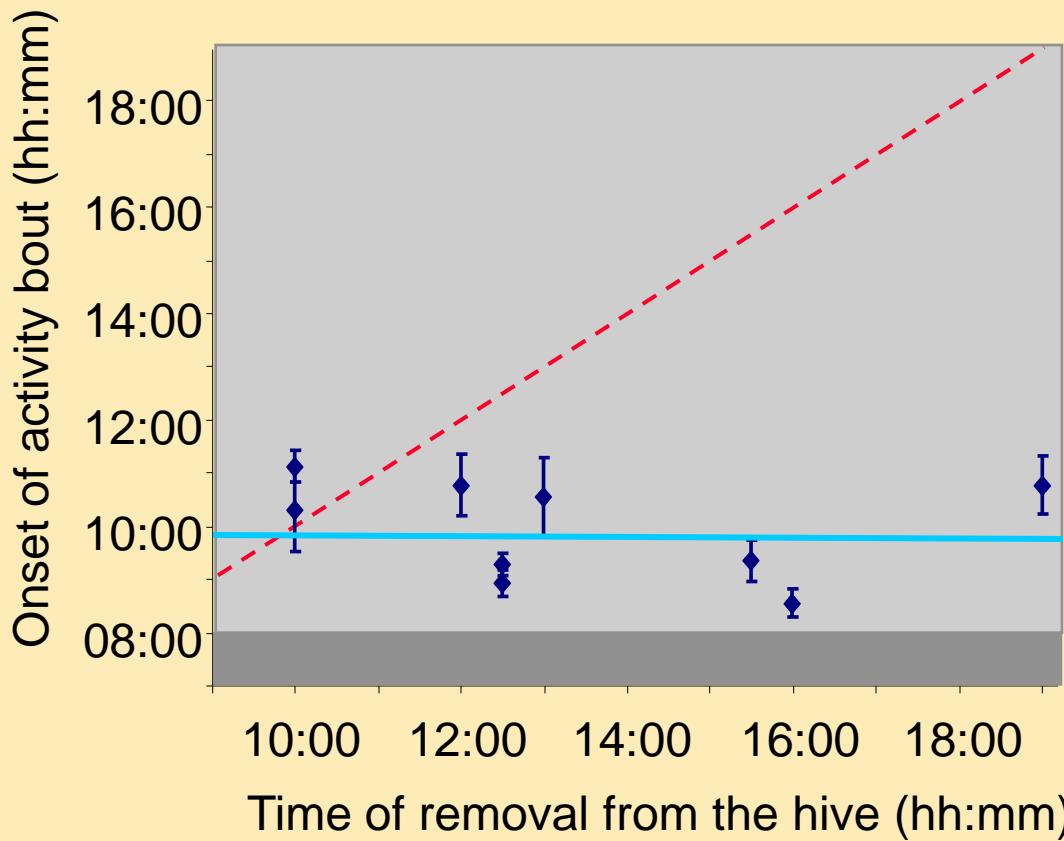
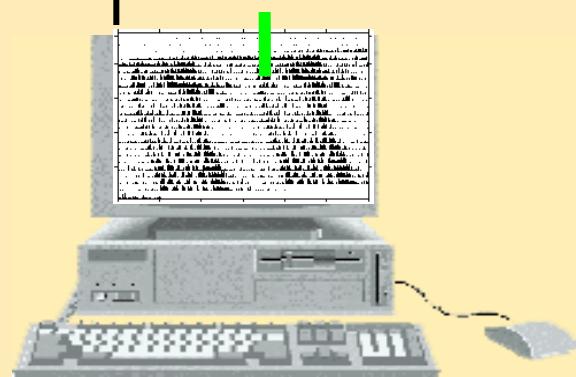
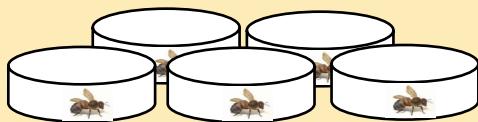
Nurse W49



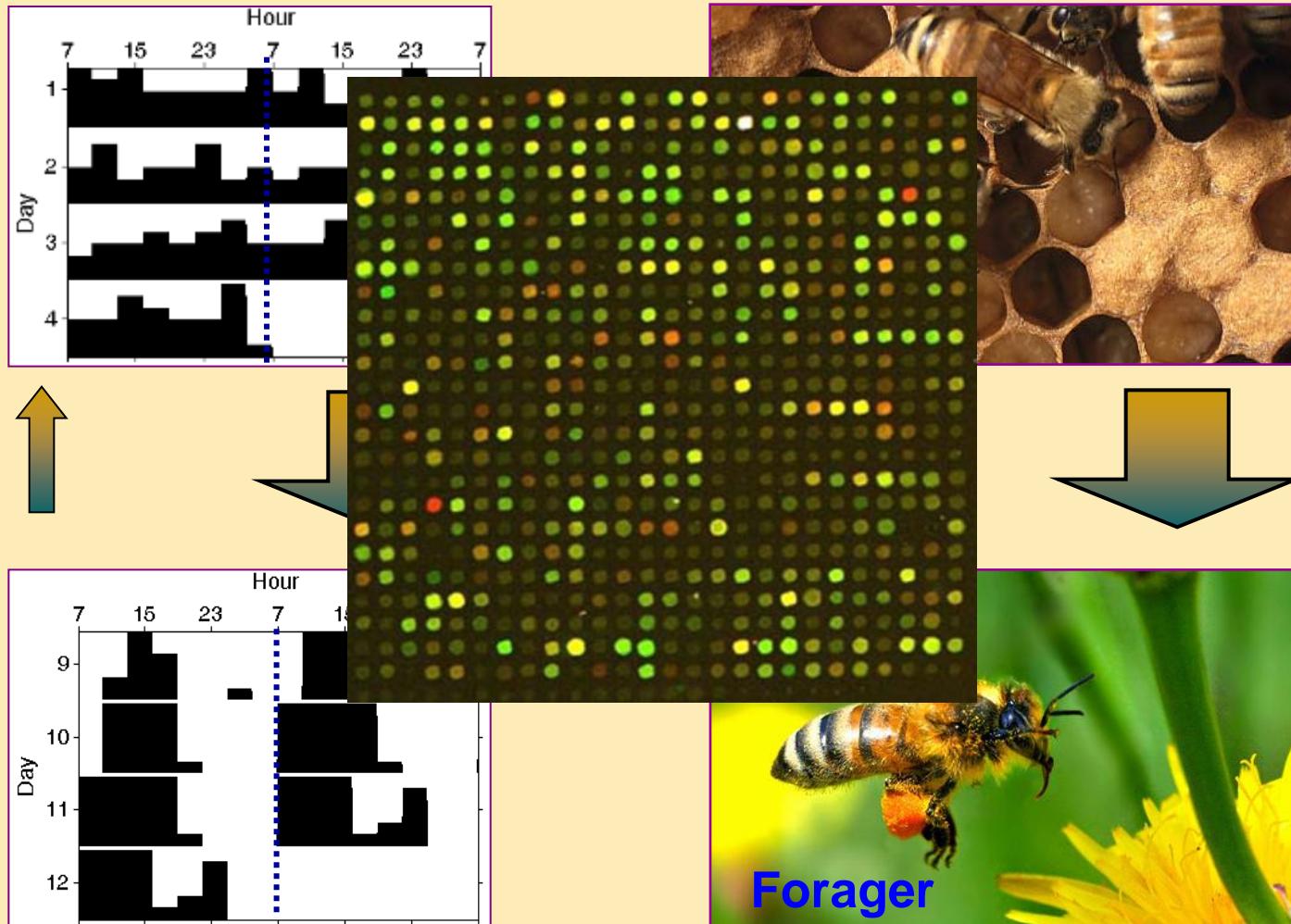
Time of day (h)

Forager

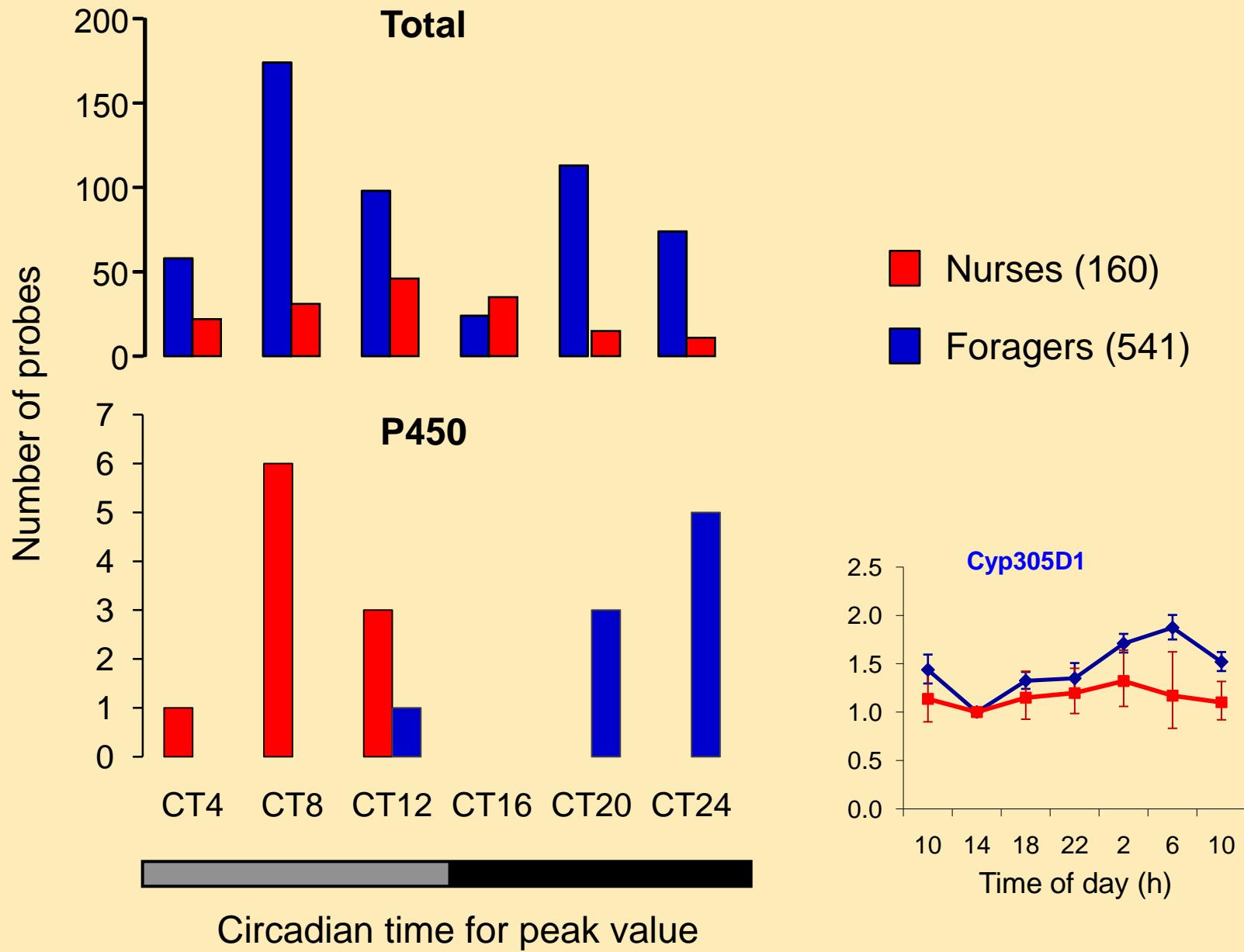




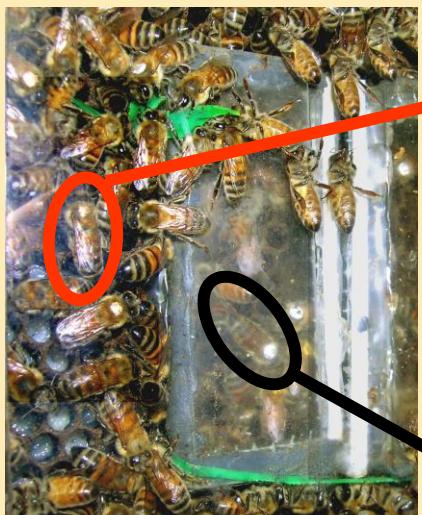
# Division of labor and plasticity in circadian rhythms



Moore et al. 1998; Bloch and Robinson 2001

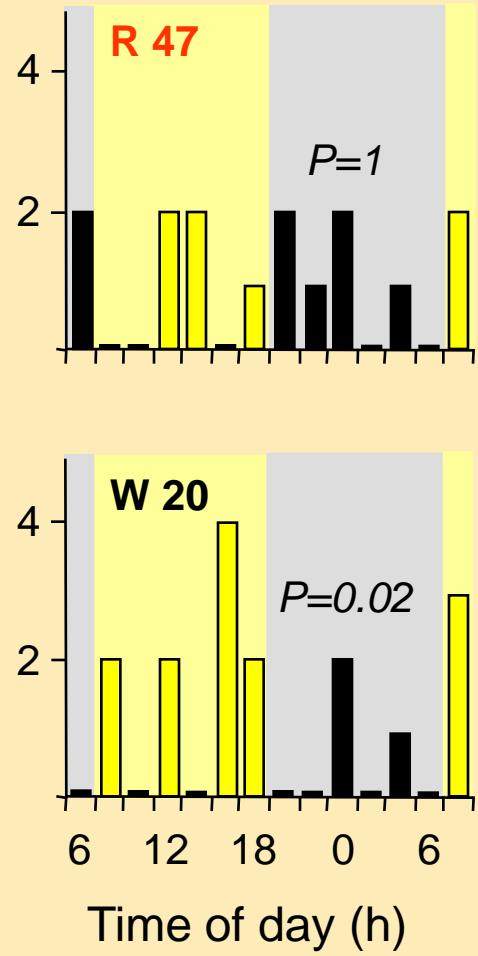




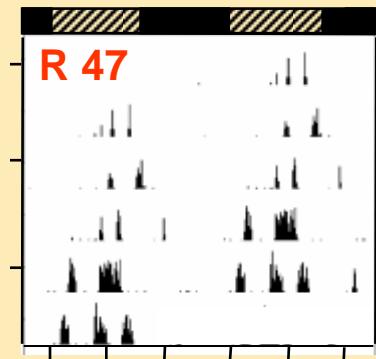


$P < 0.001$

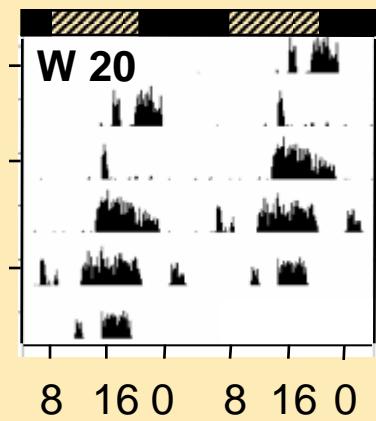
No. scans active (walking >3 sec)



Days in DD



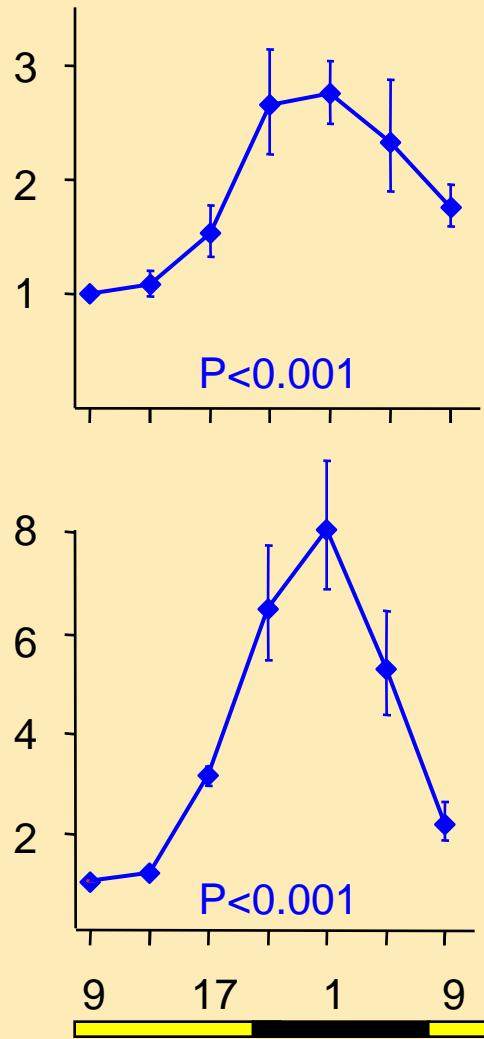
Days in DD



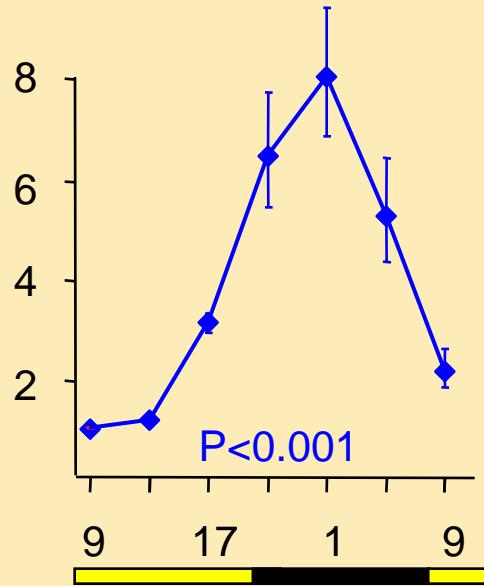
Time of day (h)

### Colony S 77

Relative brain *Per*  
mRNA levels



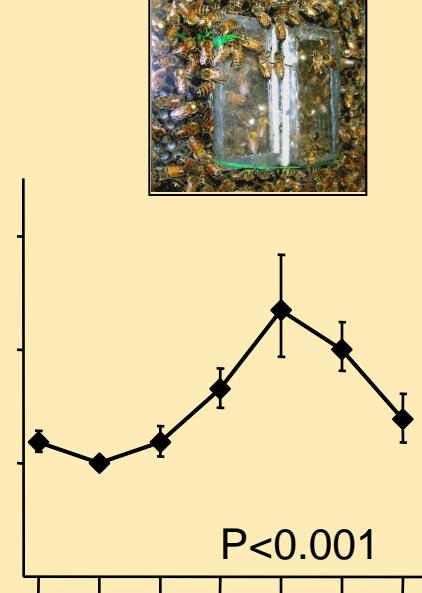
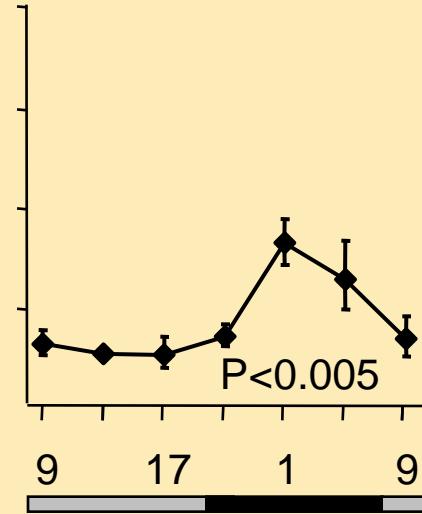
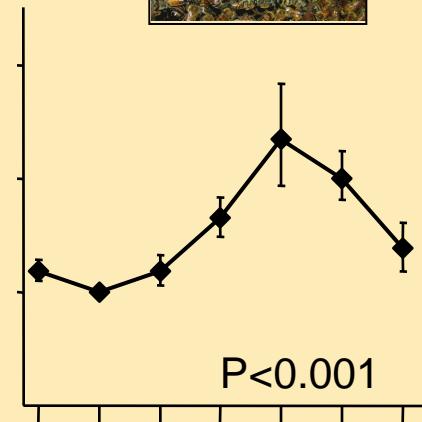
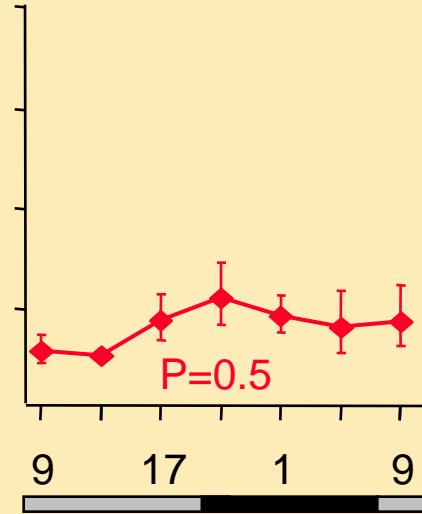
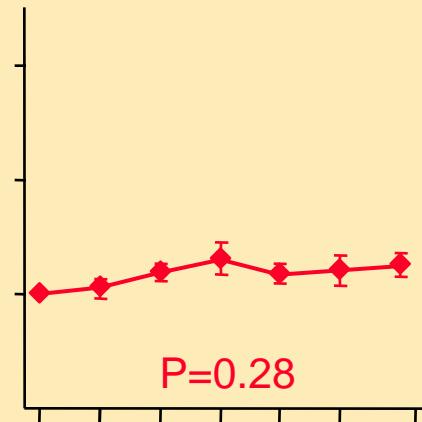
Relative brain *Cry*  
mRNA levels



$N=5$

Time of day (h)

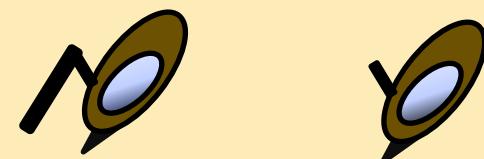
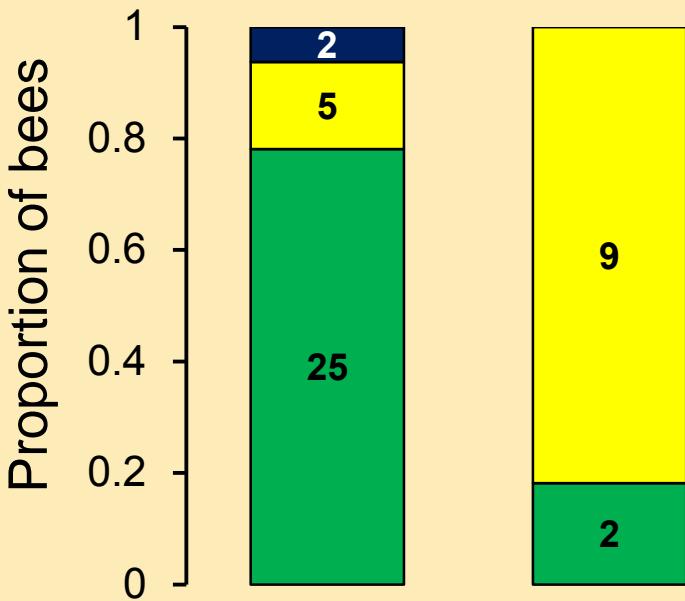
Shemesh et al. J. Neuroscience 2010





**Trial-1**

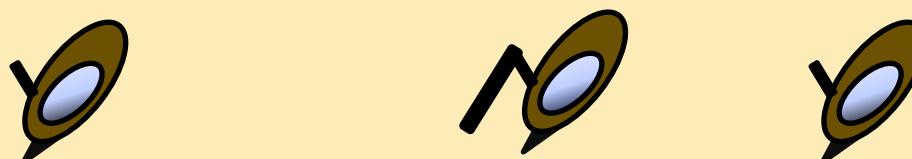
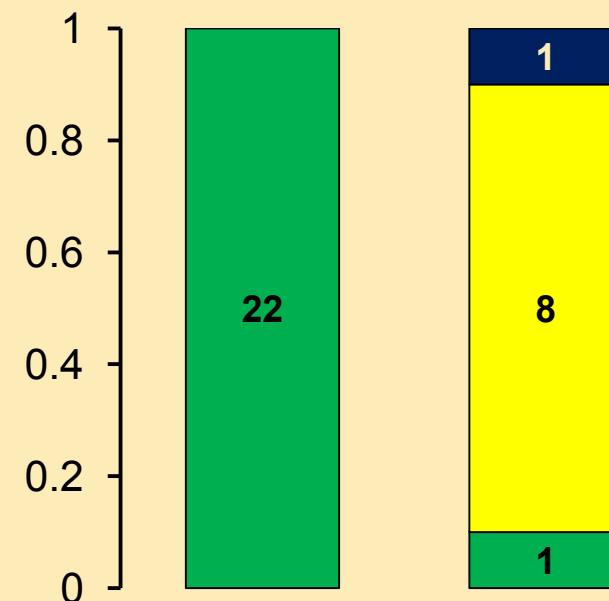
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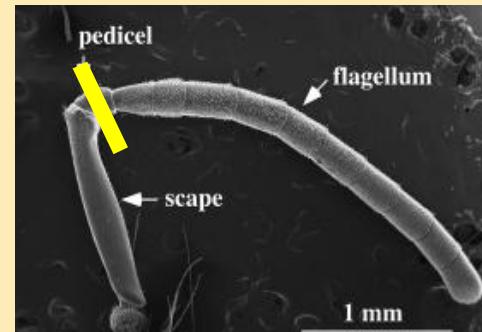
3X2 Fisher Exact test

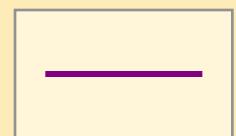
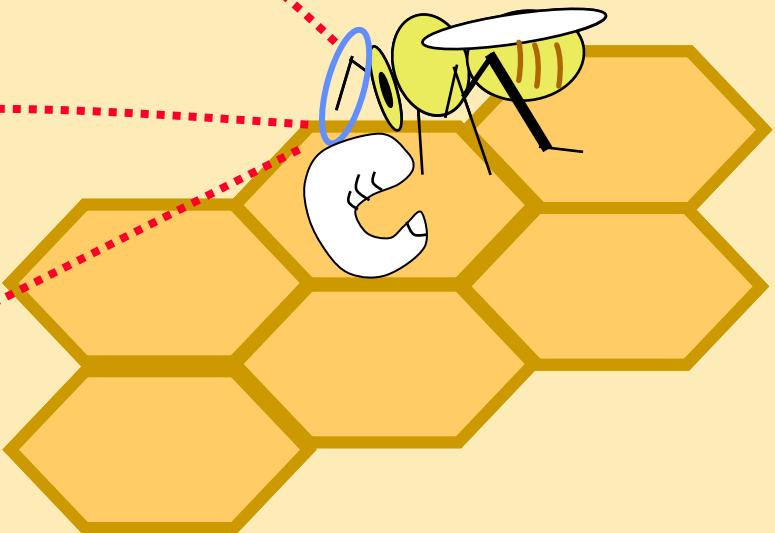
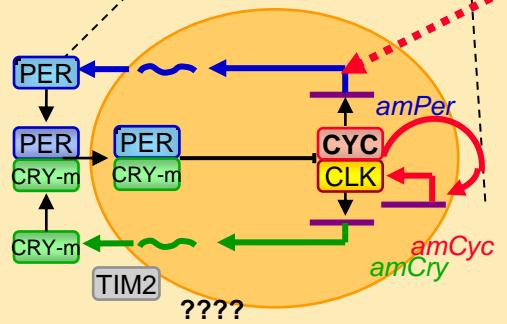
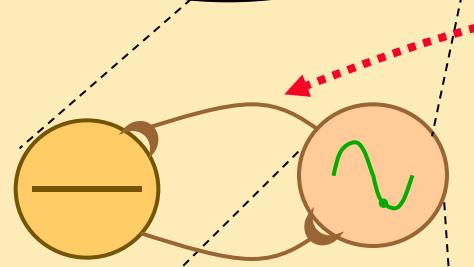
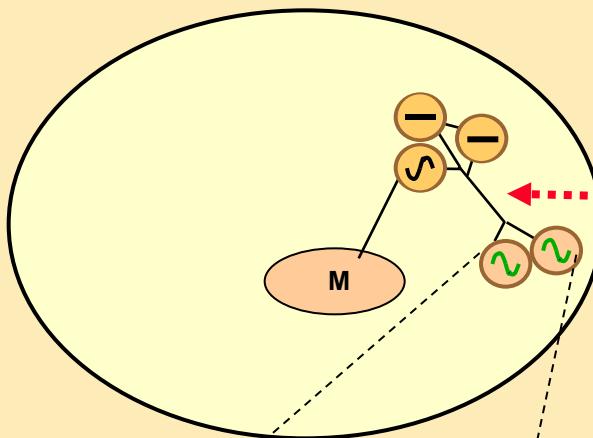
**Trial-2**

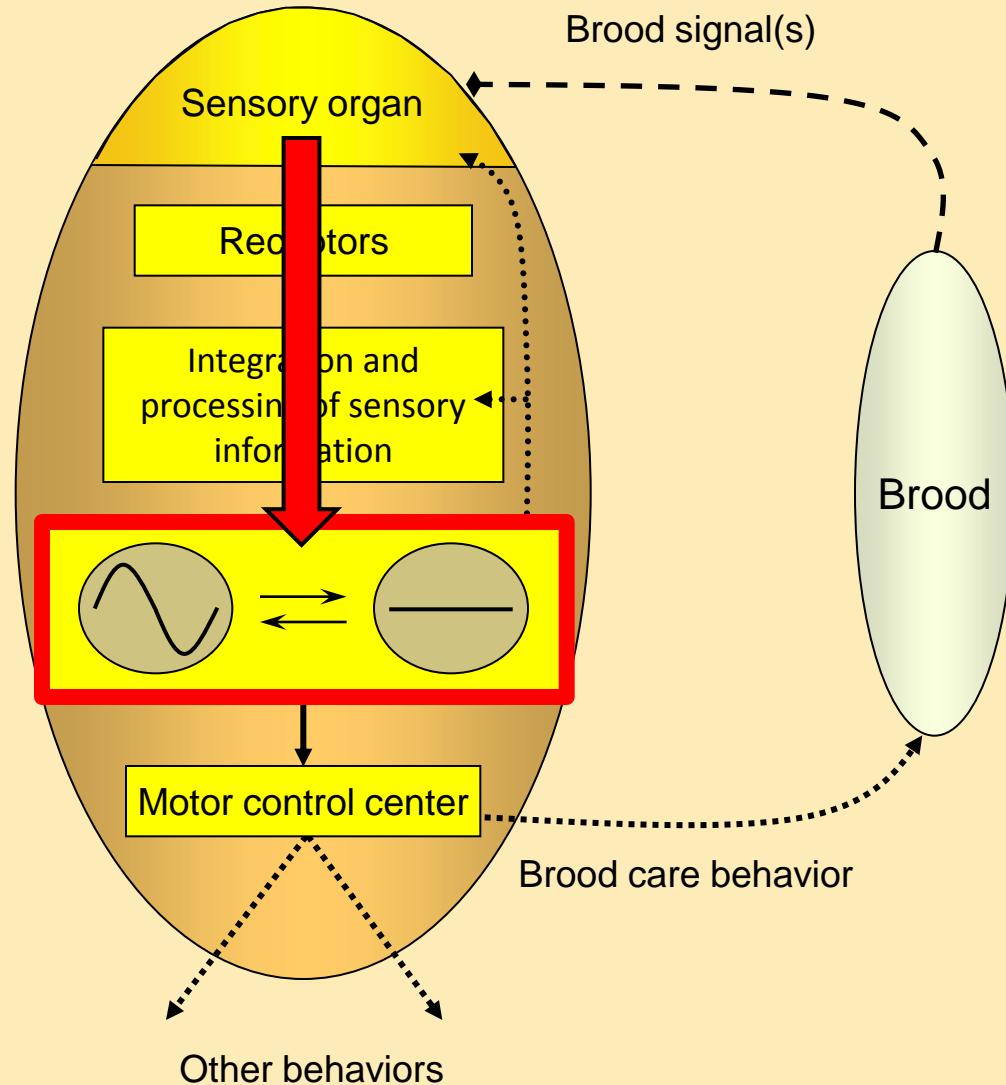
p<0.001



*Nagari and Bloch, JIP 2012*







**HUJI**

**Yair Shemesh**  
Ada Eban-Rothschild

**Elad Rubin**

**Avital Kayam**  
**Shi Yerushalmi**

**Additional  
Graduate and  
undergraduate  
students**

**Raphael Nir**  
**Mira Cohen**

**Taro Fuchikawa**  
**Muki Nagari**

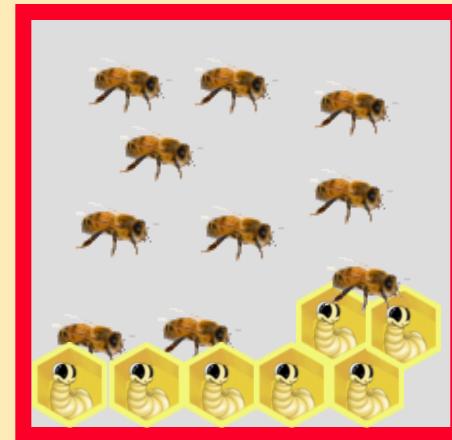
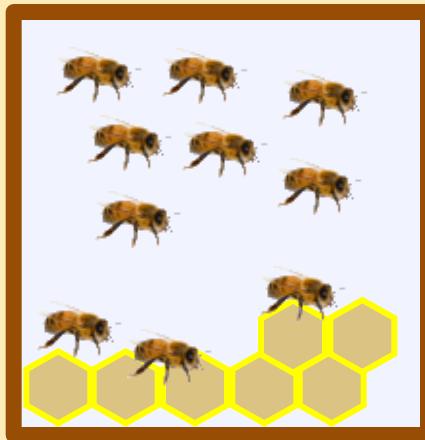
**UIUC**  
**Gene E. Robinson**  
**Sandra Rodriguez-Zas**  
**Hugh M. Robertson**

**Financial support**



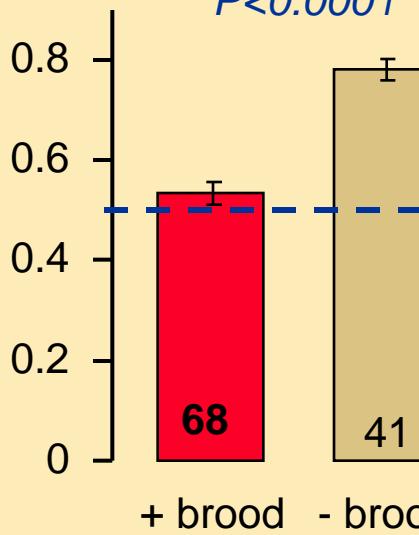
**Joseph and Belle  
Braun Senior  
Lecturership**



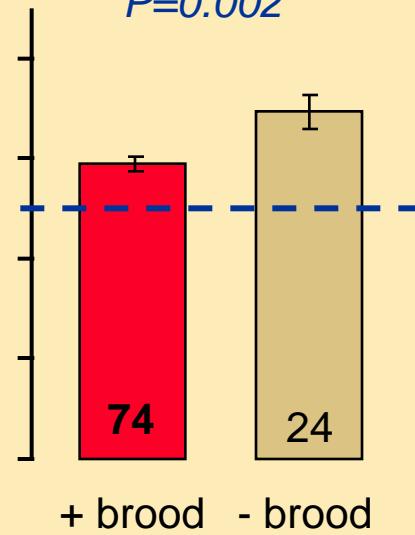


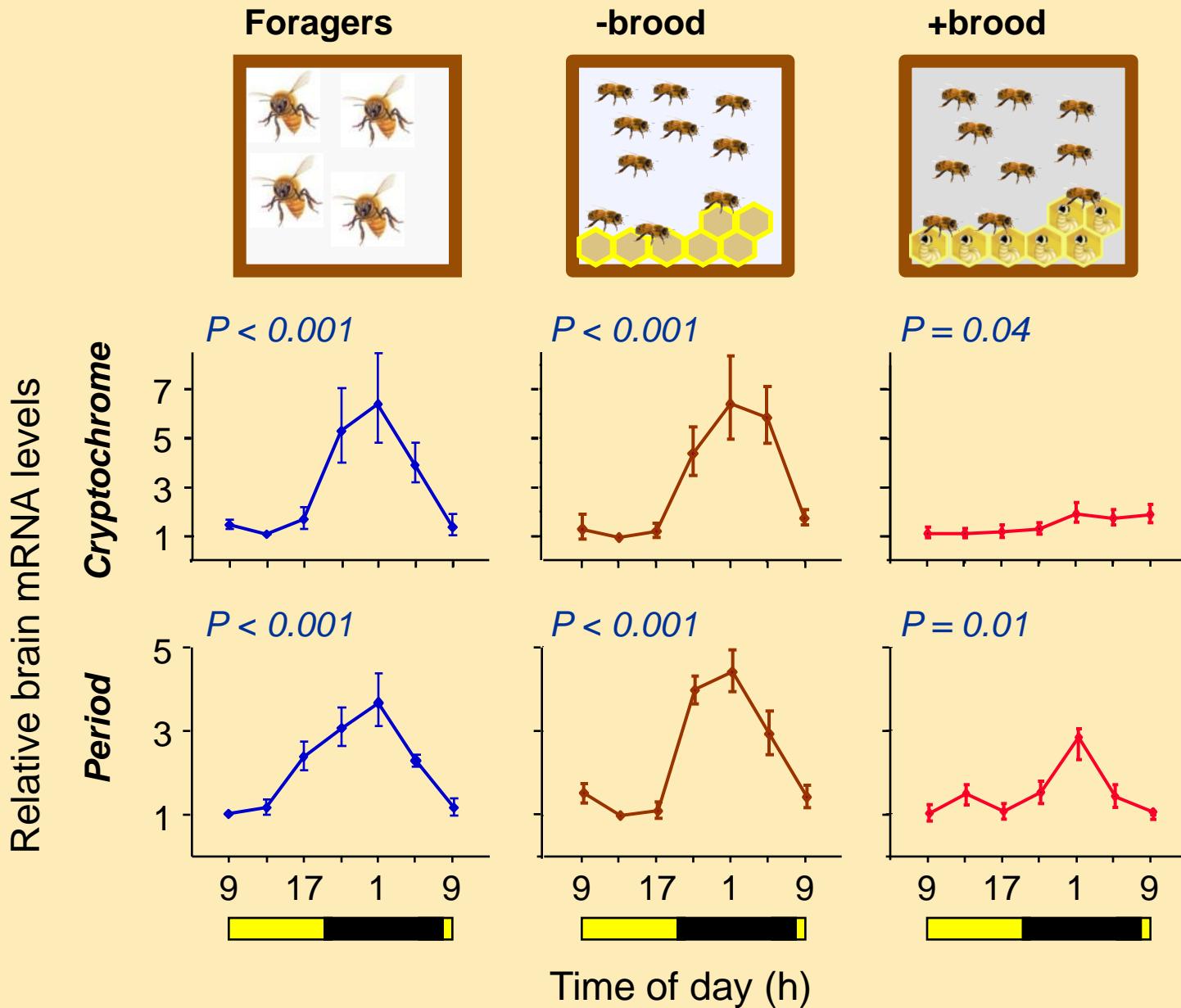
Activity during the light phase/  
activity during the entire day

Colony S85  
*P<0.0001*

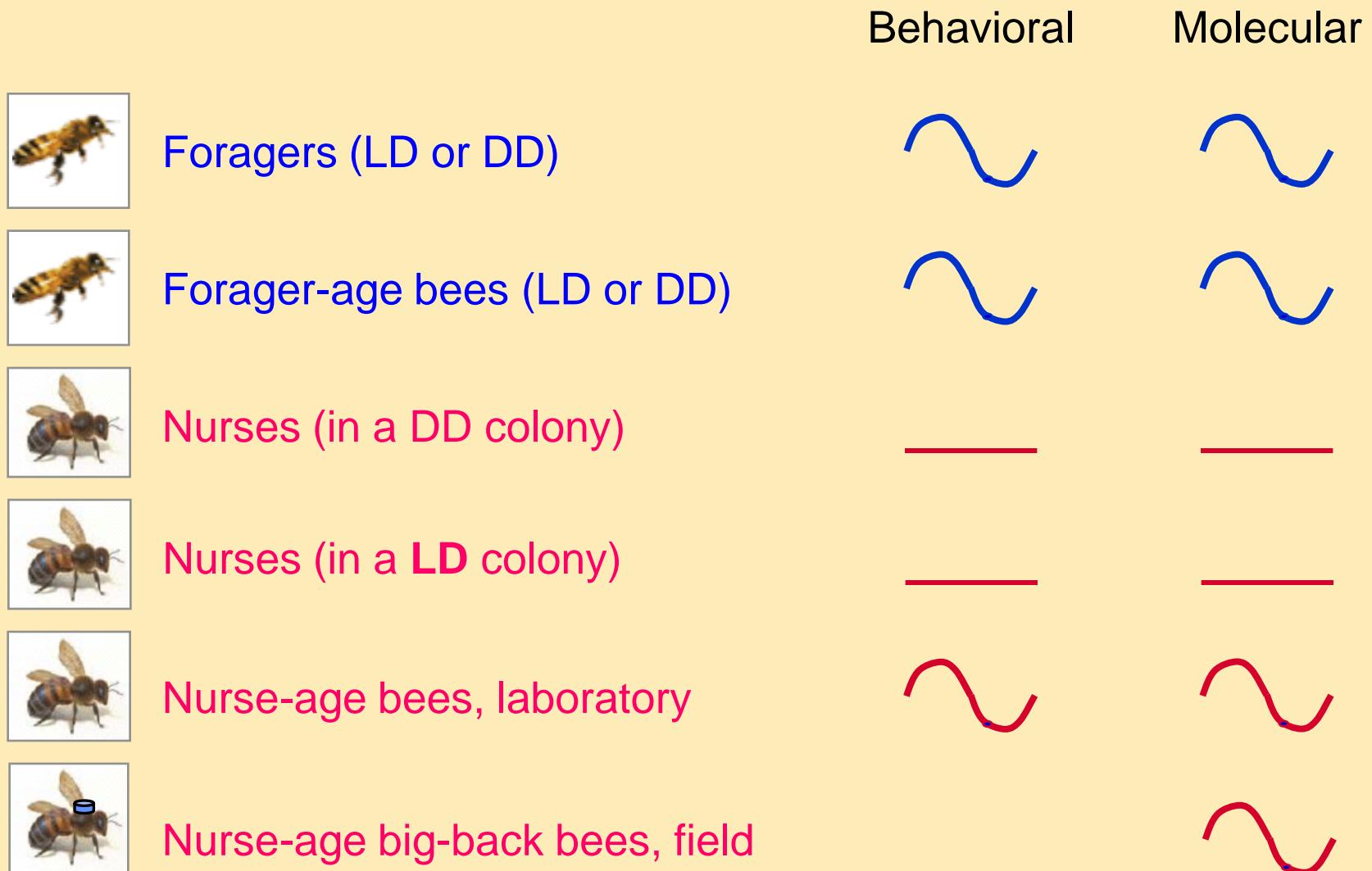


Colony H7  
*P=0.002*





# Division of labor and plasticity in the behavioral and molecular circadian rhythms

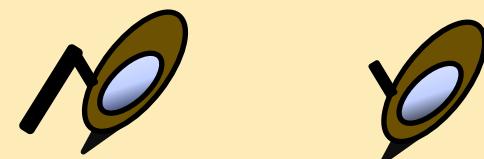
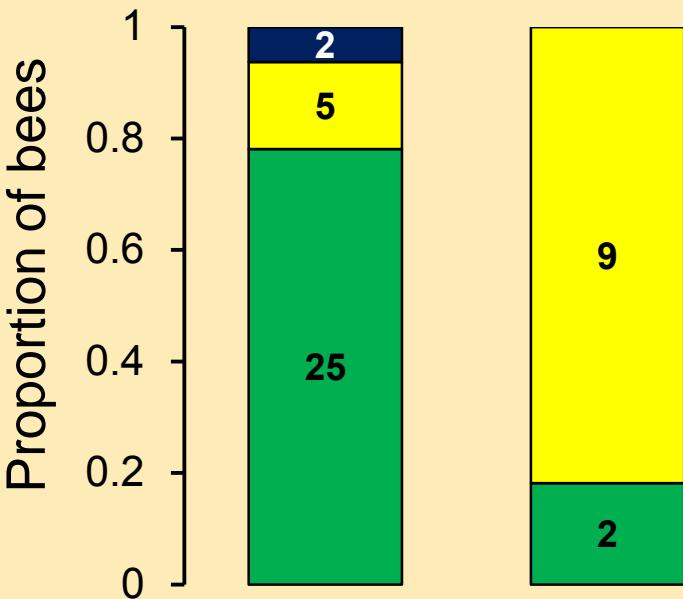


Toma et al. 2000; Bloch et al. 2001, 2004, Shemesh et al. 2007, 2010



**Trial-1**

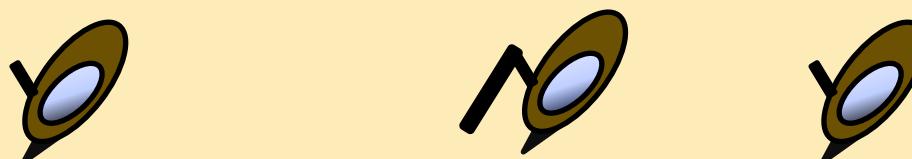
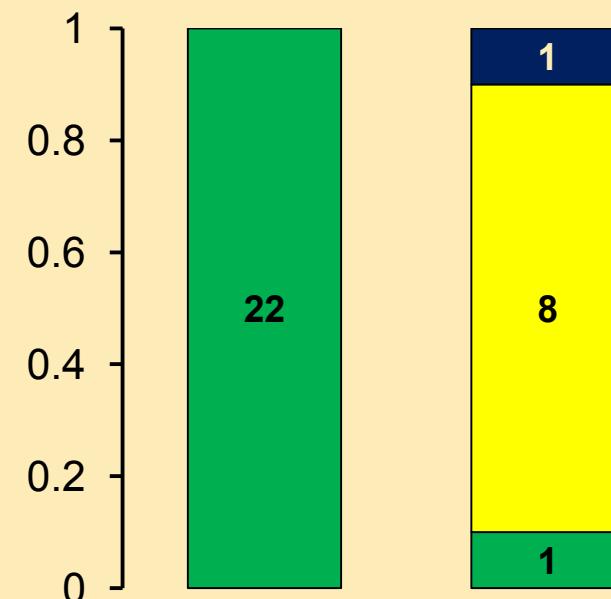
p<0.001



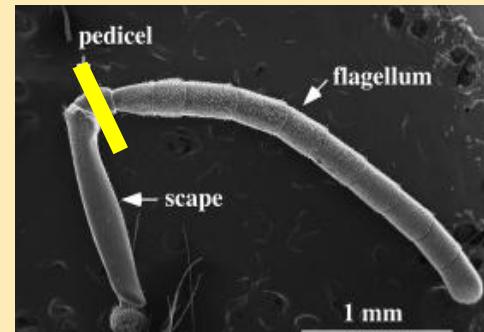
3X2 Fisher Exact test

**Trial-2**

p<0.001



*Nagari and Bloch, unpublished*





Brood  
care

Brood

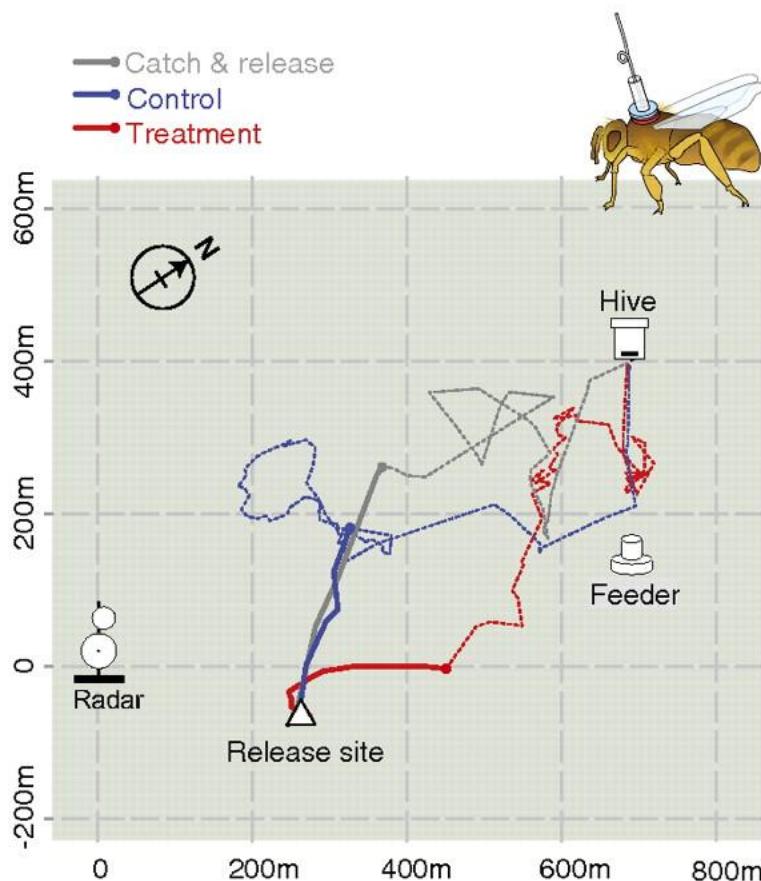
A caged  
bee

Mesh



# Flight paths of individual bees tracked by harmonic radar

A



B

