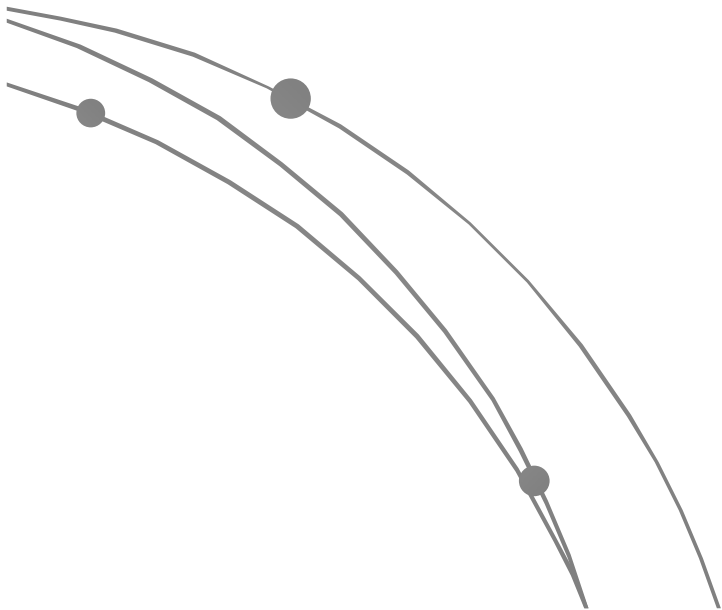


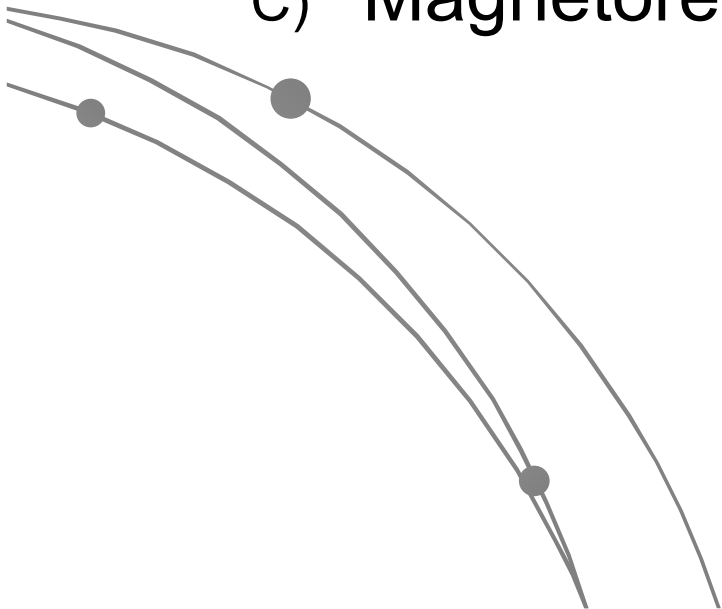
# Bezobratlí v neuroetologii

Martin Vácha



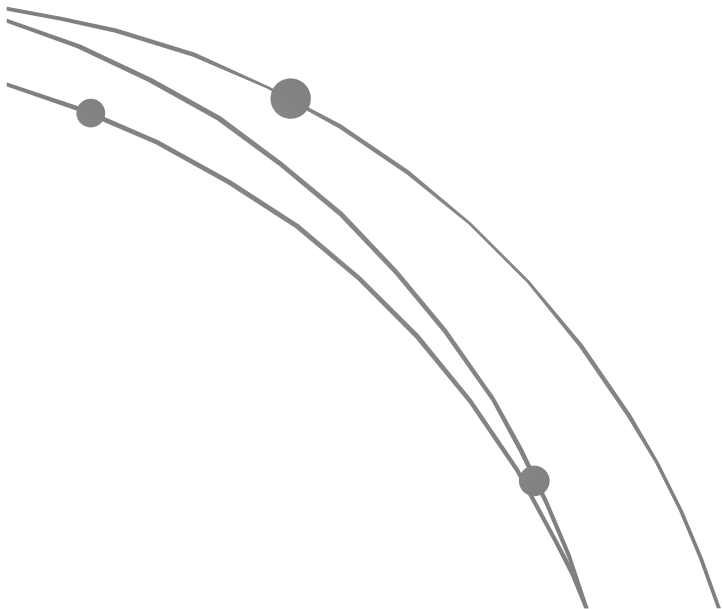
# Bezobratlí v neuroetologii

- A) Bezobratlí jako model neuroetologických experimentů
- B) Podmiňování jako klíč k funkcím NS a smyslů
- c) Magnetorecepce hmyzu



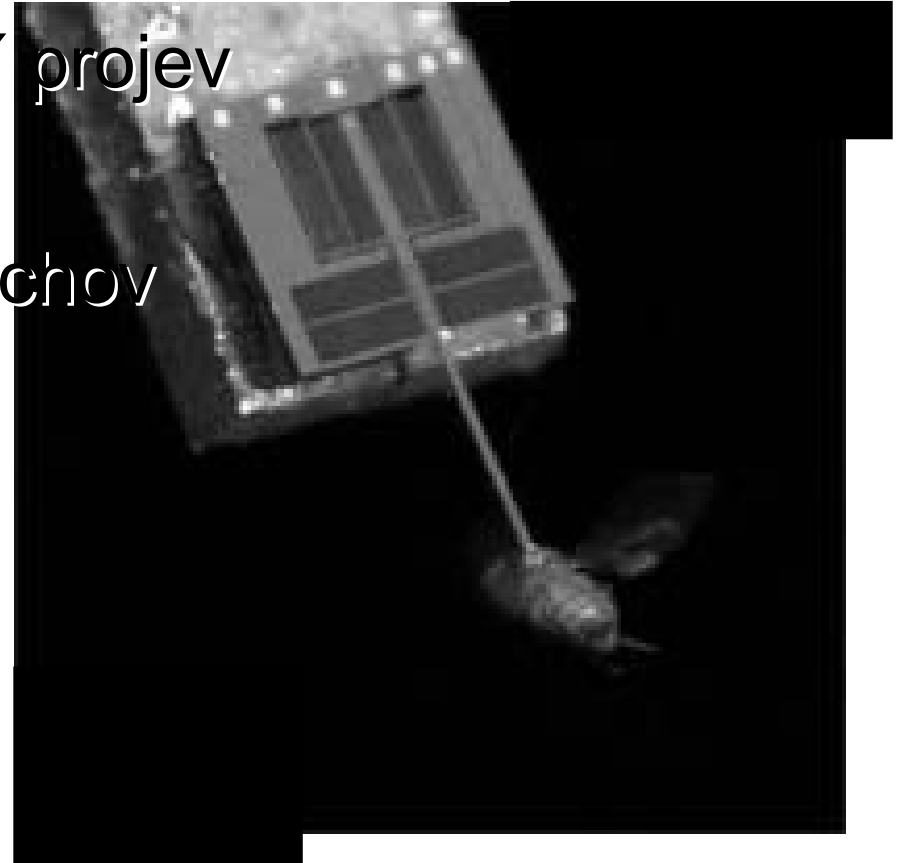
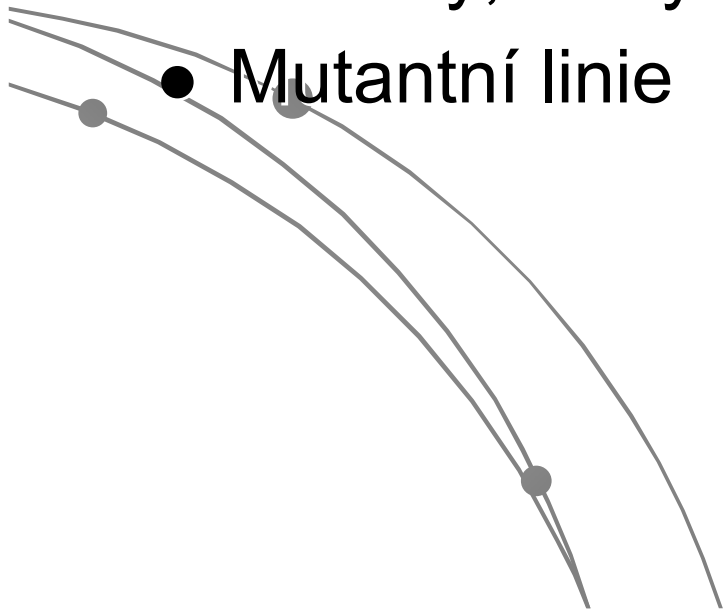
# Neuroetologie (behaviorální neurobiologie):

- Syntéza etologie a neurobiologie (60.I)
- Neurální podstata chování
- Nástroj řešení otázek neurofyzologie



## A) Bezobratlí v neuroetologii:

- Jednoduchý, snadno přístupný nervový systém
- „Robustní“ behaviorální projev
- Laboratorní podmínky
- Snadný, levný a rychlý chov
- Mutantní linie



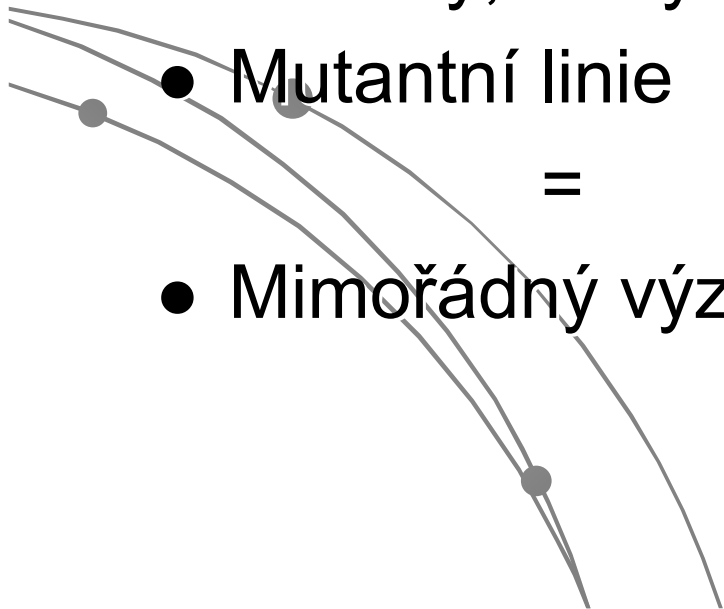
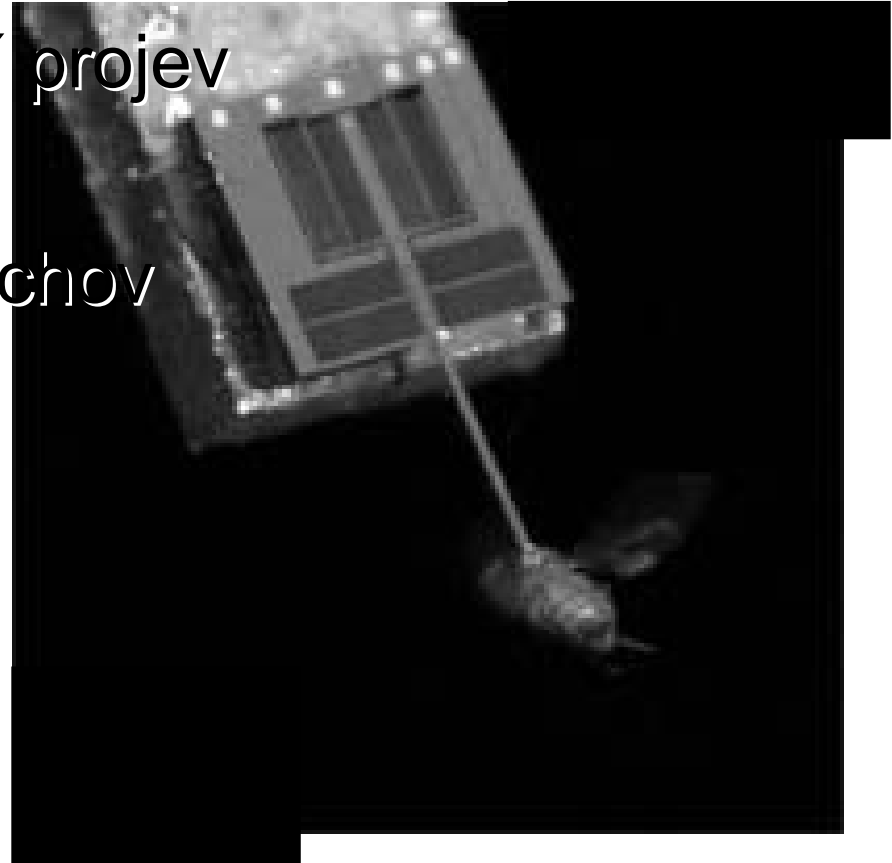
## Bezobratlí v neuroetologii:

- Jednoduchý, snadno přístupný nervový systém
- „Robustní“ behaviorální projev
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- Mutantní linie

=

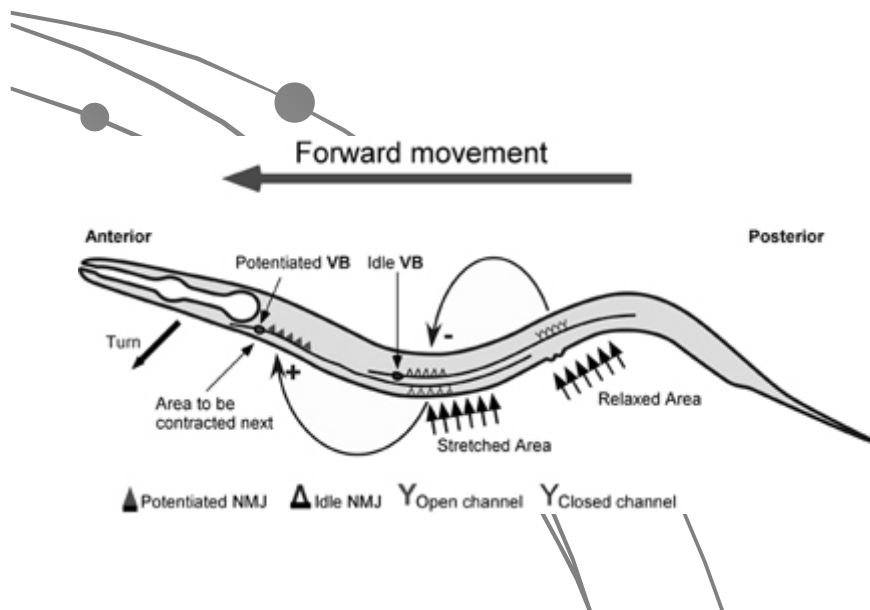
- Mimořádný význam



# Bezobratlí v neuroetologii:

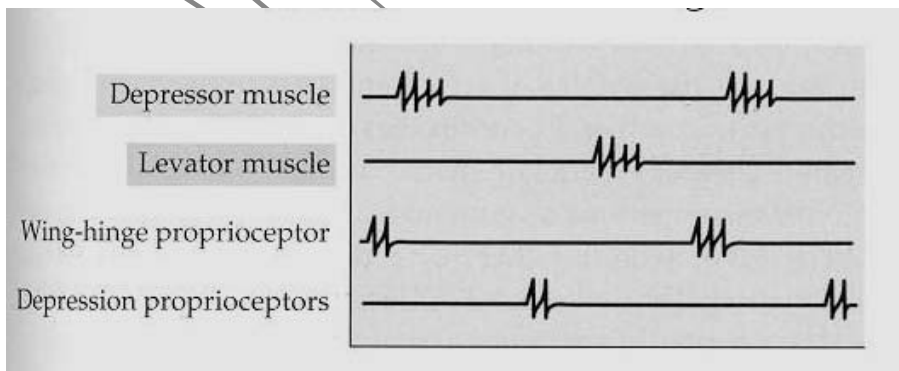
- Sensomotorické reflexy

## Caenorhabditis elegans (hádčátko)



# Bezobratlí v neuroetologii:

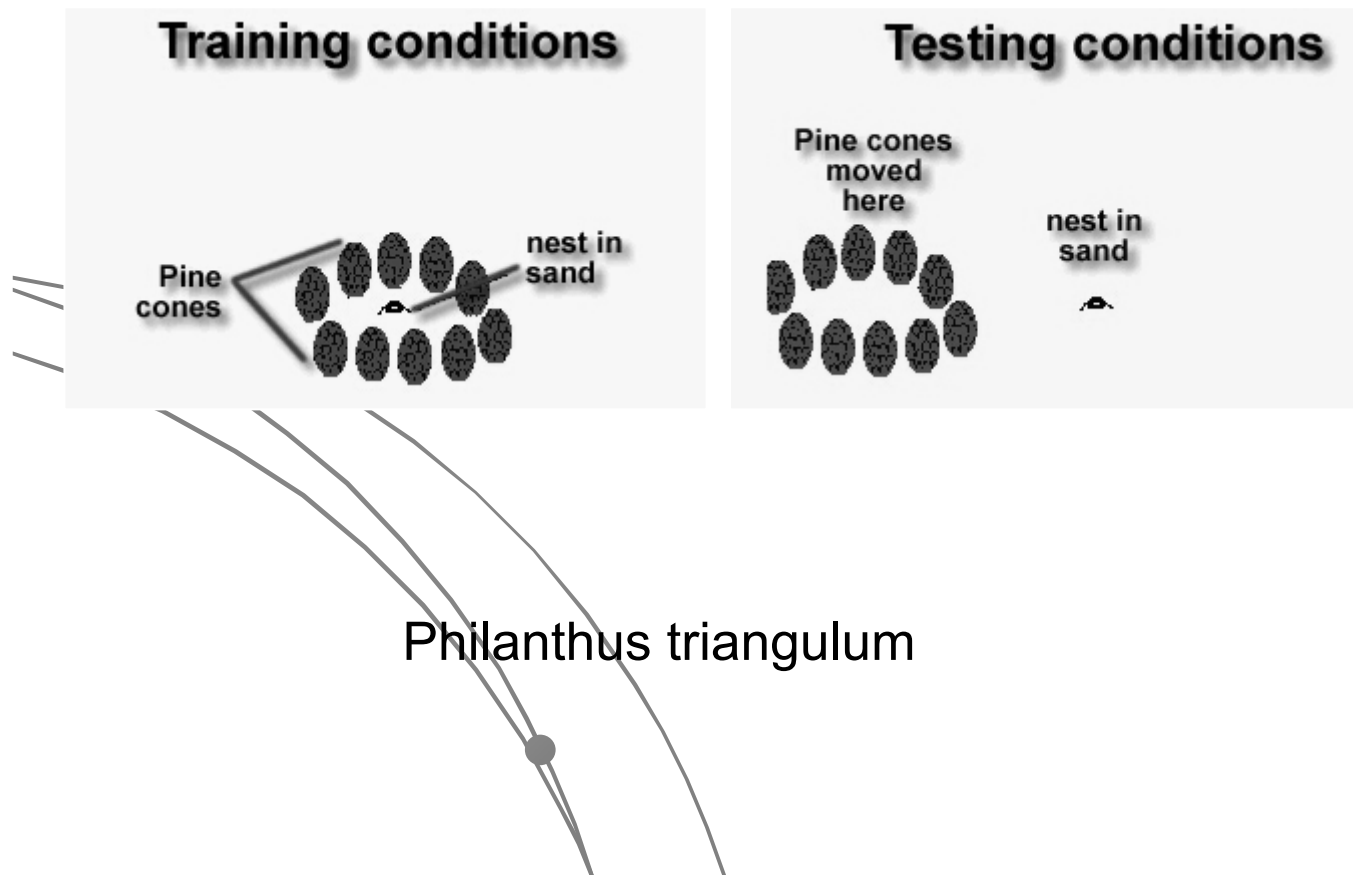
- Sensomotorické reflexy
- Motorické sekvence



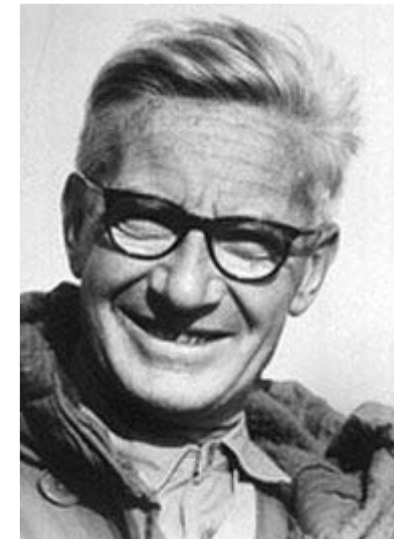
**Clione limacina** (valovka plžovitá)  
„Sea angel“

# Bezobratlí v neuroetologii:

- Sensomotorické reflexy
- Motorické sekvence
- Orientace



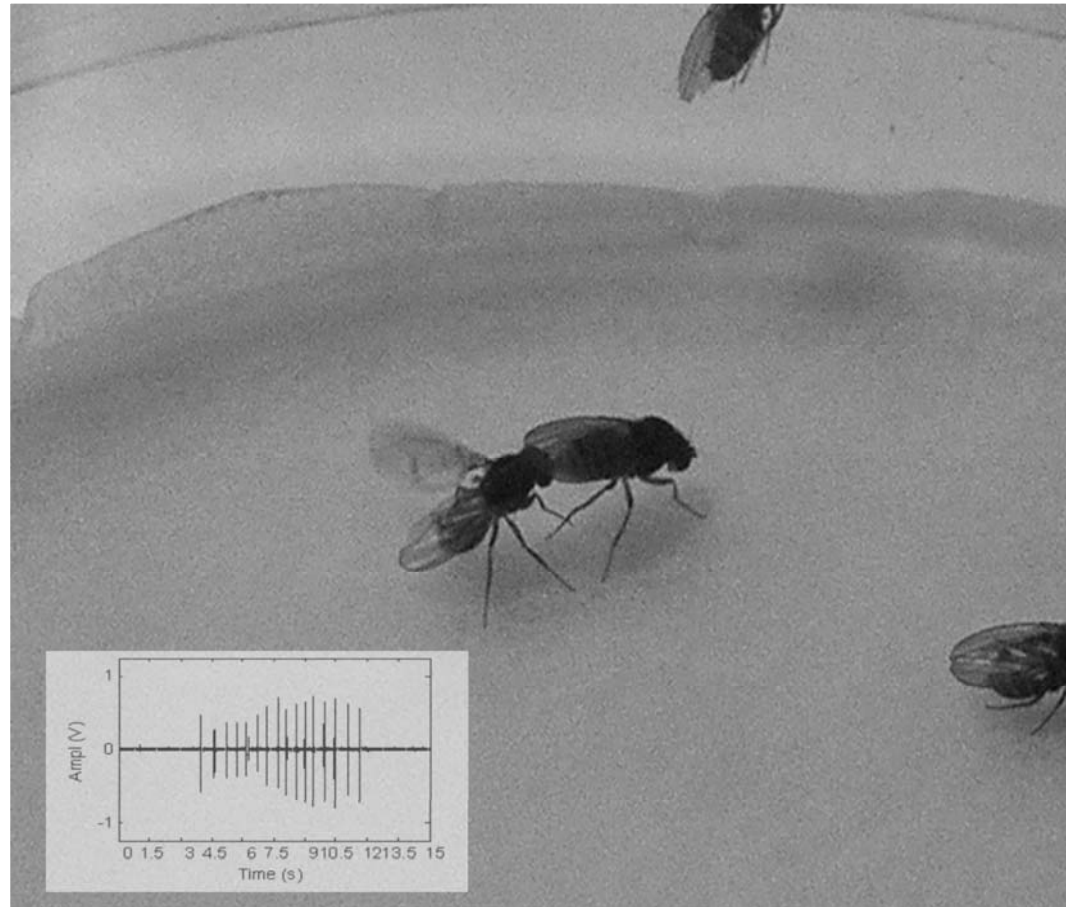
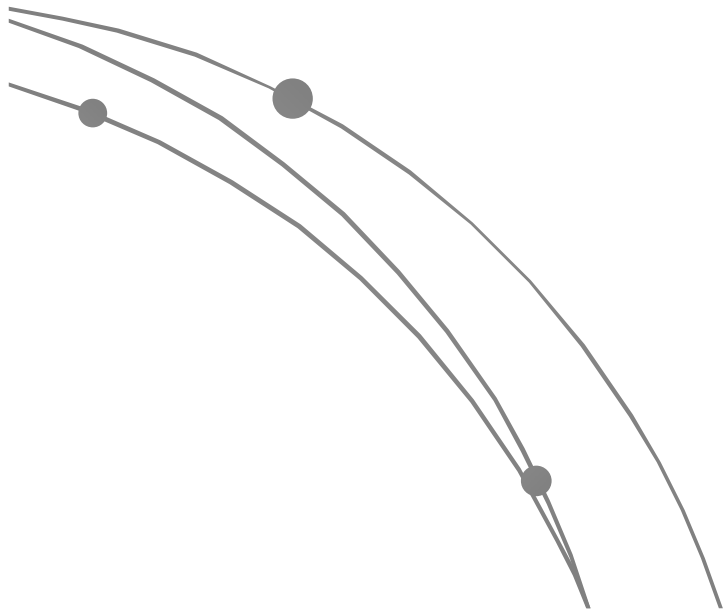
N. Tinbergen  
Nobelova cena 1973





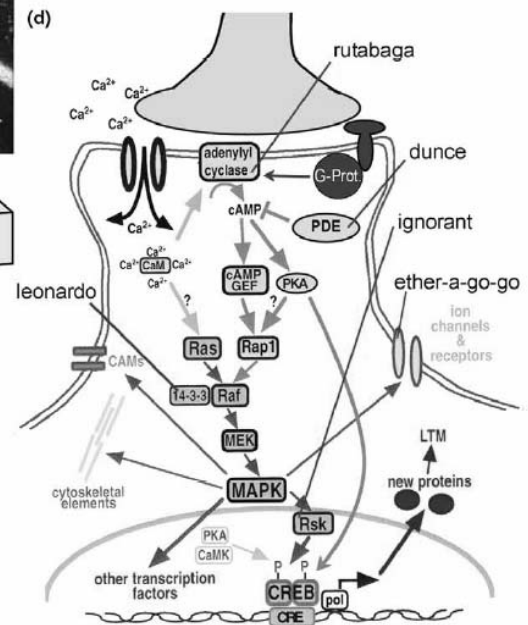
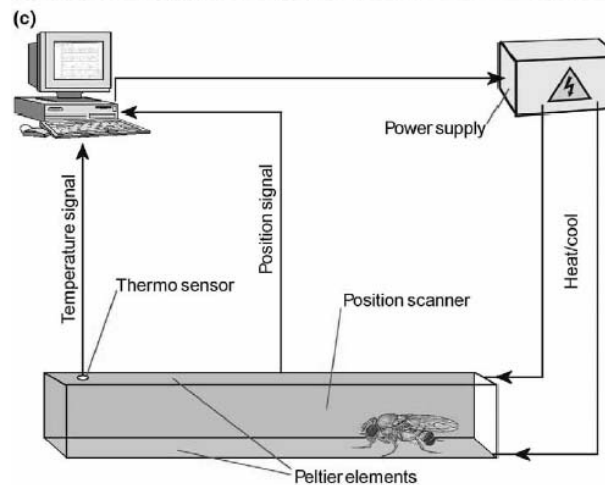
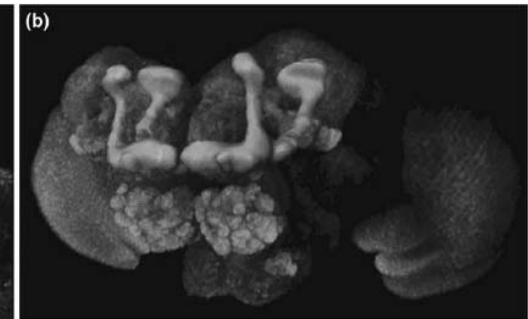
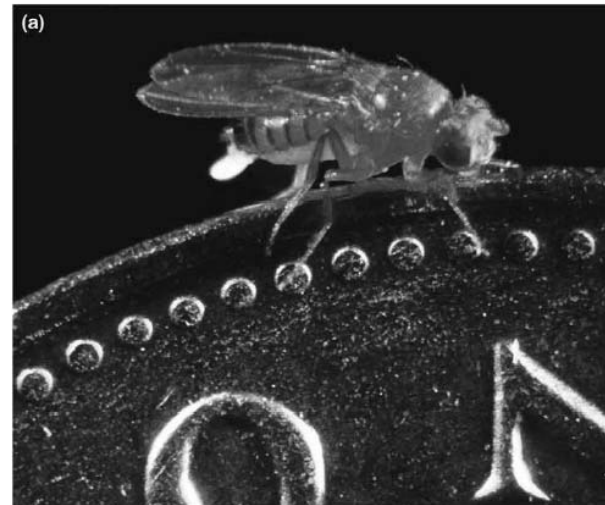
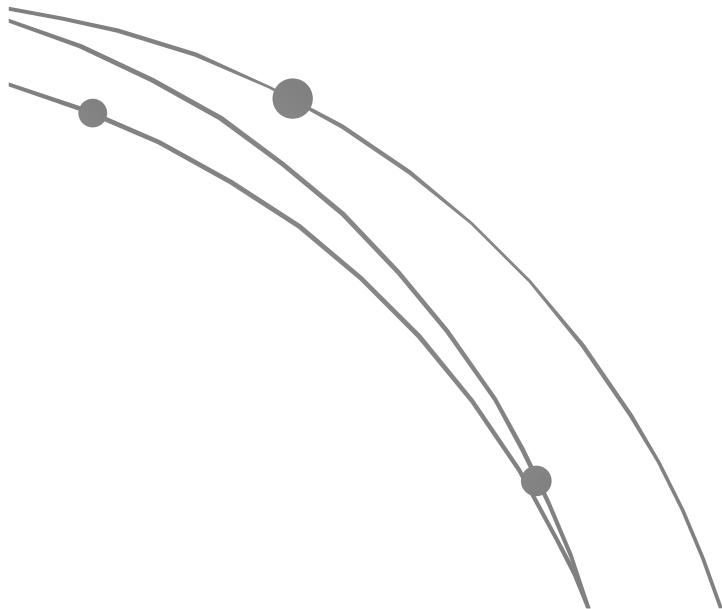
# Bezobratlí v neuroetologii:

- Sensomotorické reflexy
- Motorické sekvence
- Orientace
- Komunikace



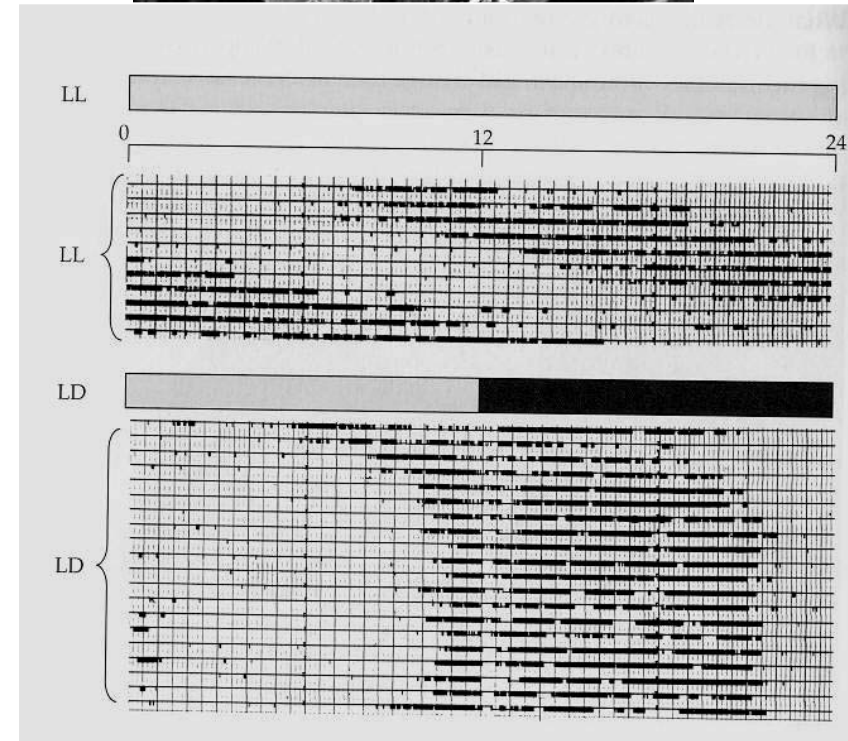
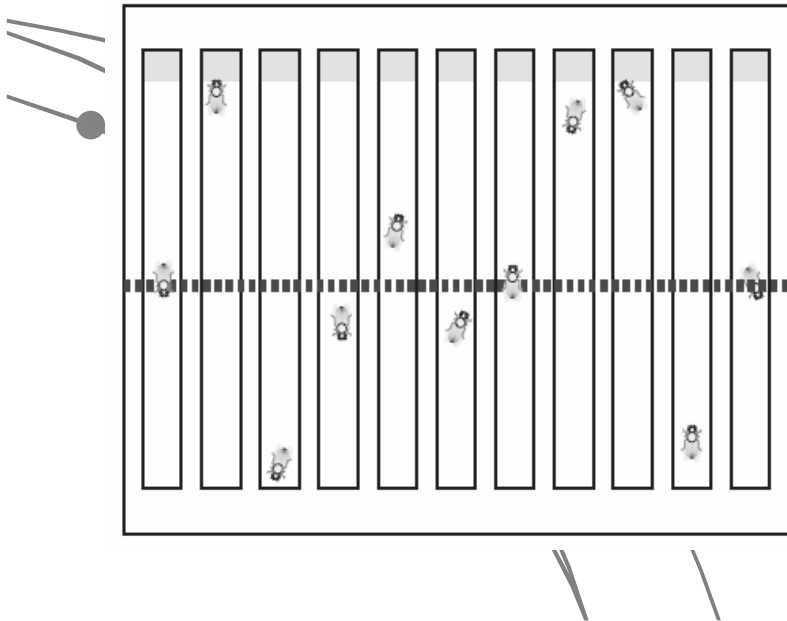
# Bezobratlí v neuroetologii:

- Sensomotorické reflexy
- Motorické sekvence
- Orientace
- Komunikace
- Učení a paměť



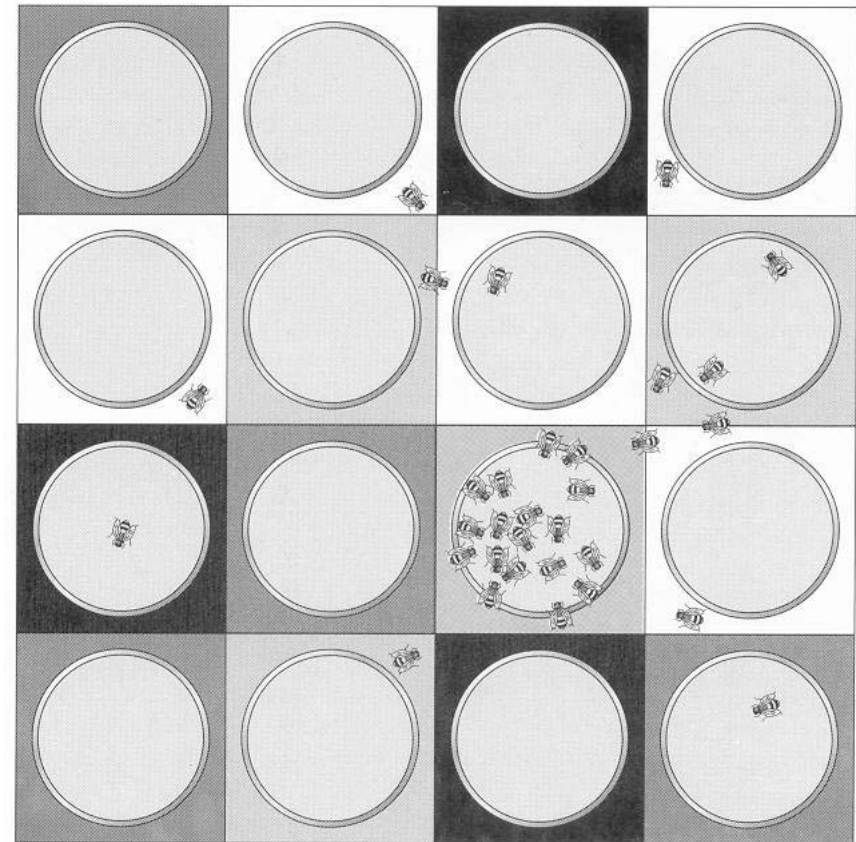
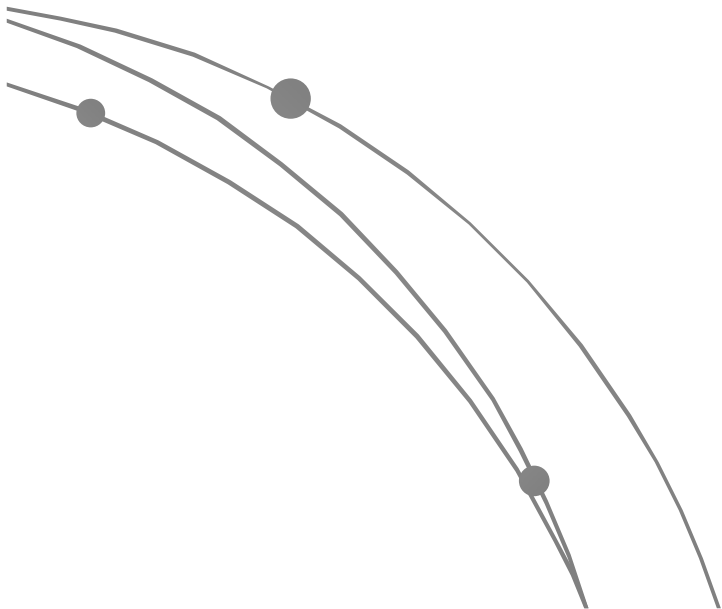
# Bezobratlí v neuroetologii:

- Sensomotorické reflexy
- Motorické sekvence
- Orientace
- Komunikace
- Učení a paměť
- Circadiální rytmy



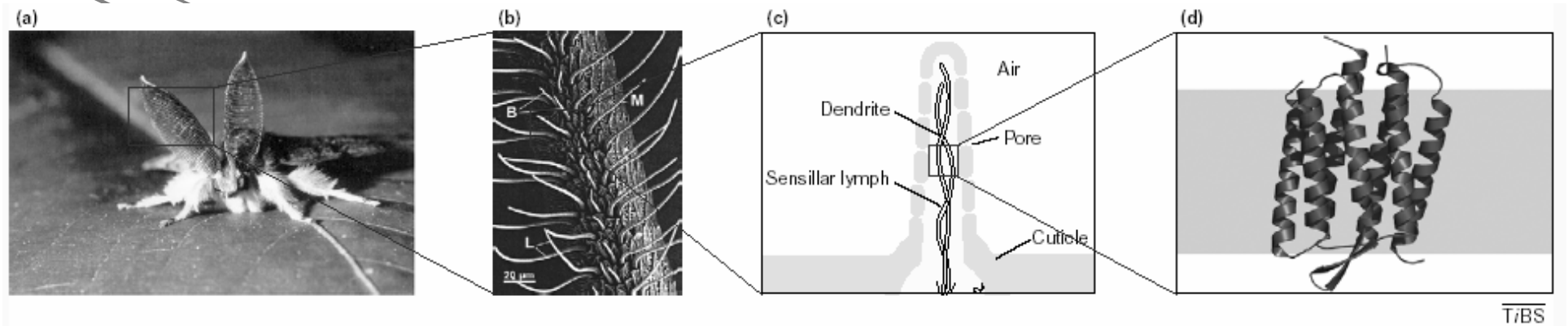
# Bezobratlí v neuroetologii:

- Sensomotorické reflexy
- Motorické sekvence
- Orientace
- Komunikace
- Učení a paměť
- Circadiánní rytmy
- Smyslové schopnosti



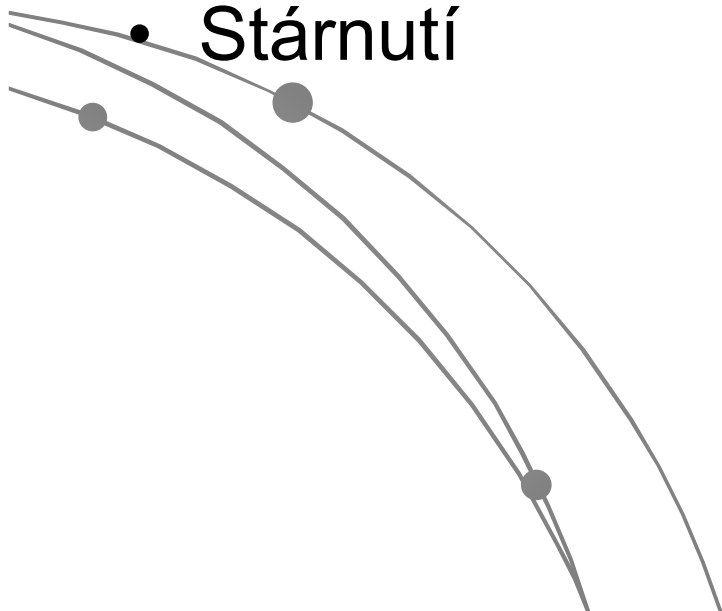
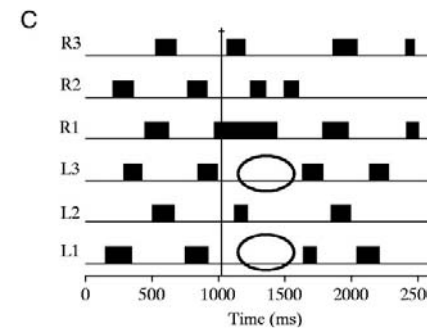
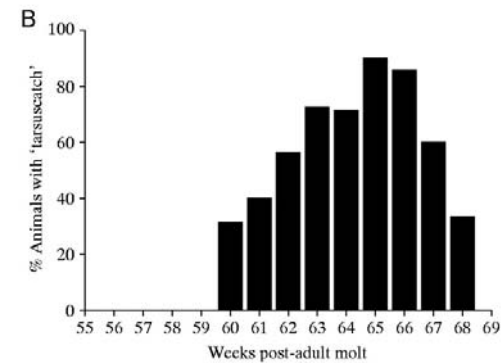
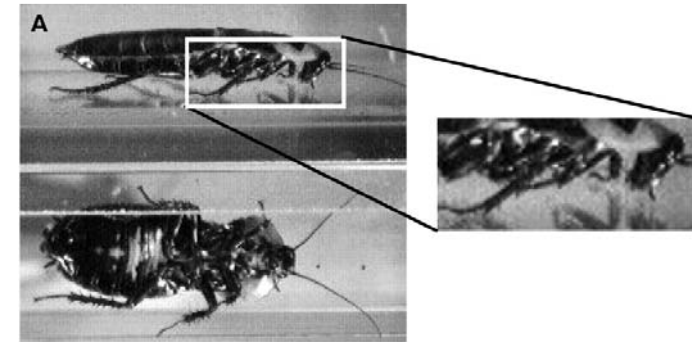
# Bezobratlí v neuroetologii:

- Sensomotorické reflexy
- Motorické sekvence
- Orientace
- Komunikace
- Učení a paměť
- Circadiální rytmy
- Smyslové schopnosti



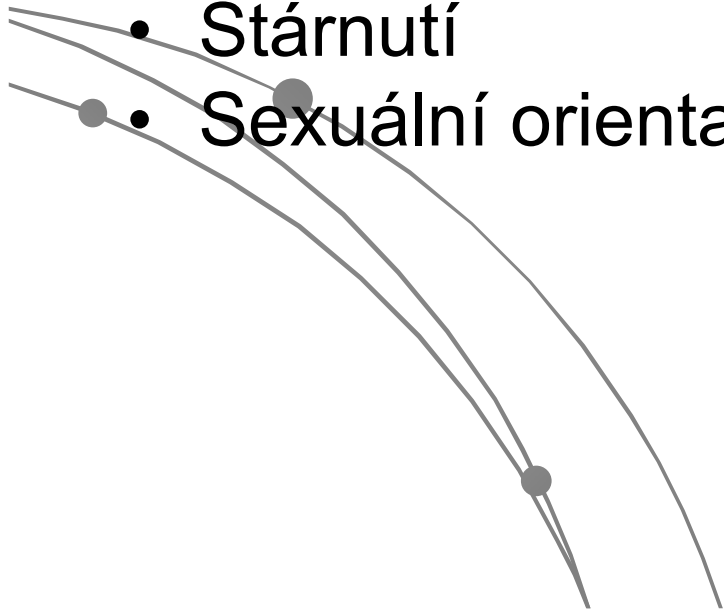
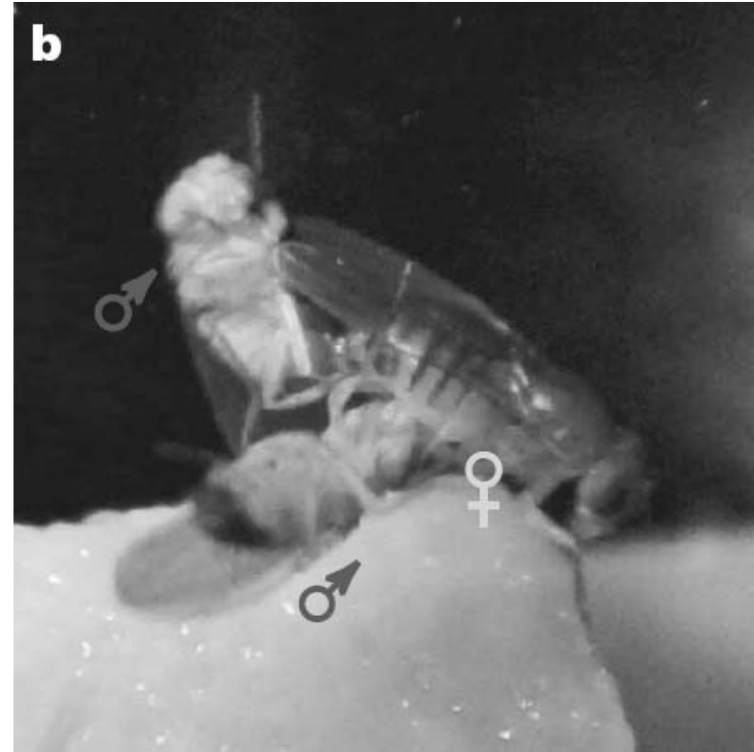
# Bezobratlí v neuroetologii:

- Sensomotorické reflexy
- Motorické sekvence
- Orientace
- Komunikace
- Učení a paměť
- Circadiánní rymy
- Smyslové schopnosti a dráhy
- Stárnutí



# Bezobratlí v neuroetologii:

- Sensomotorické reflexy
- Motorické sekvence
- Orientace
- Komunikace
- Učení a paměť
- Circadiánní rytmy
- Smyslové schopnosti
- Stárnutí
- Sexuální orientace



# Bezobratlí v neuroetologii:

- Sensomotorické reflexy
- Motorické sekvence
- Orientace
- Komunikace
- Učení a paměť
- Circadiánní rytmy
- Smyslové schopnosti
- Stárnutí
- Sexuální orientace
- Agresivita





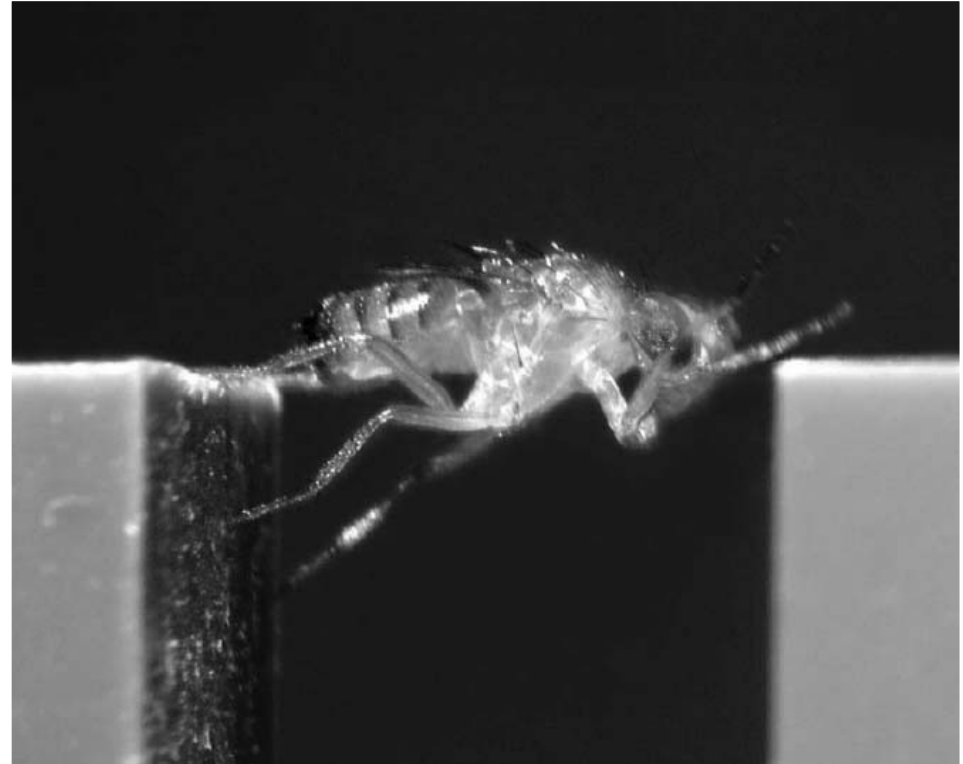
# Bezobratlí v neuroetologii:

- Sensomotorické reflexy
- Motorické sekvence
- Orientace
- Komunikace
- Učení a paměť
- Circadiánní rytmy
- Smyslové schopnosti a dráhy
- Stárnutí
- Sexuální orientace
- Agresivita
- Působení drog a farmak



# Bezobratlí v neuroetologii:

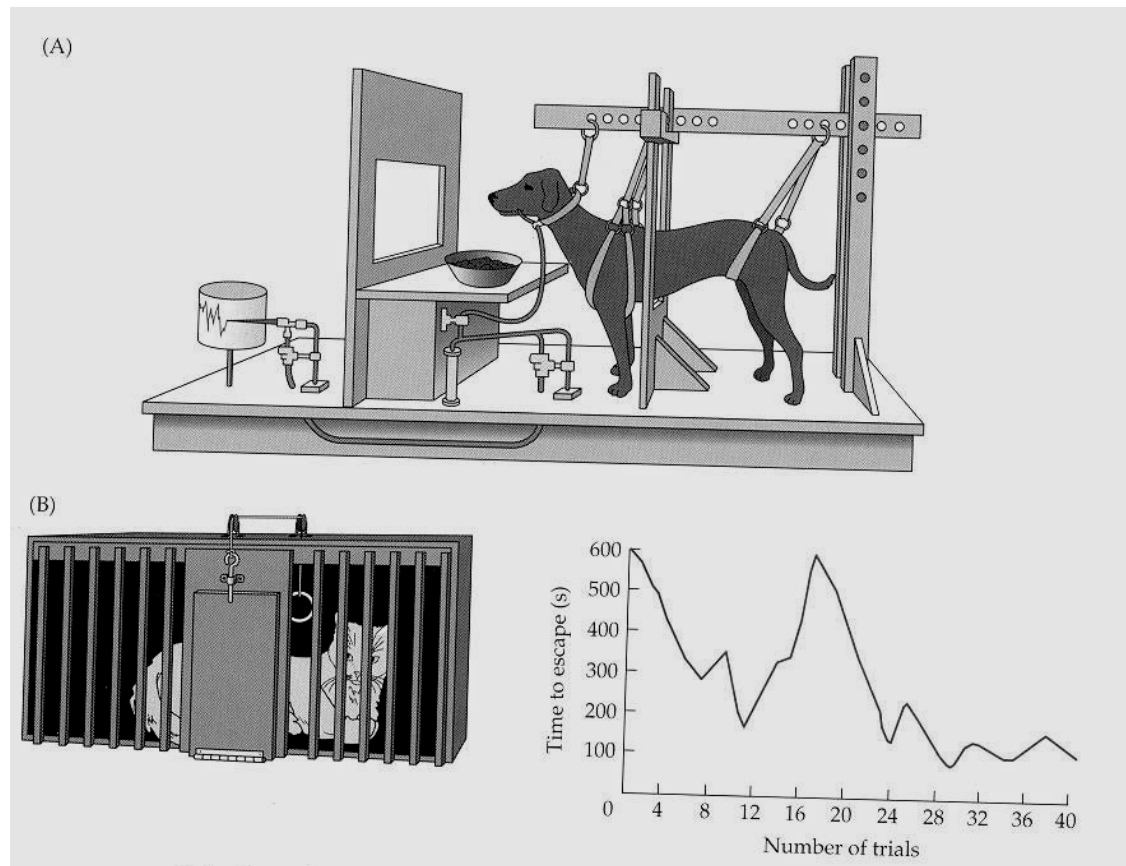
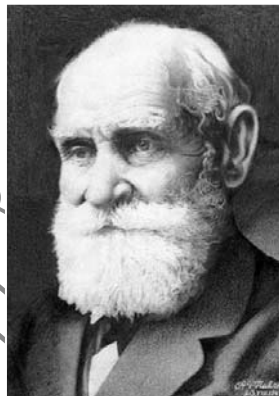
- Sensomotorické reflexy
- Motorické sekvence
- Orientace
- Komunikace
- Učení a paměť
- Circadiální rytmy
- Smyslové schopnosti
- Stárnutí
- Sexuální orientace
- Agresivita
- Působení drog a farmak
- Ochota riskovat, emoce atd...



# B) Podmiňování jako klíč k funkci NS a smyslů

Vytvoření podmíněného spojení je důkazem plasticity NS a základem paměti a učení.

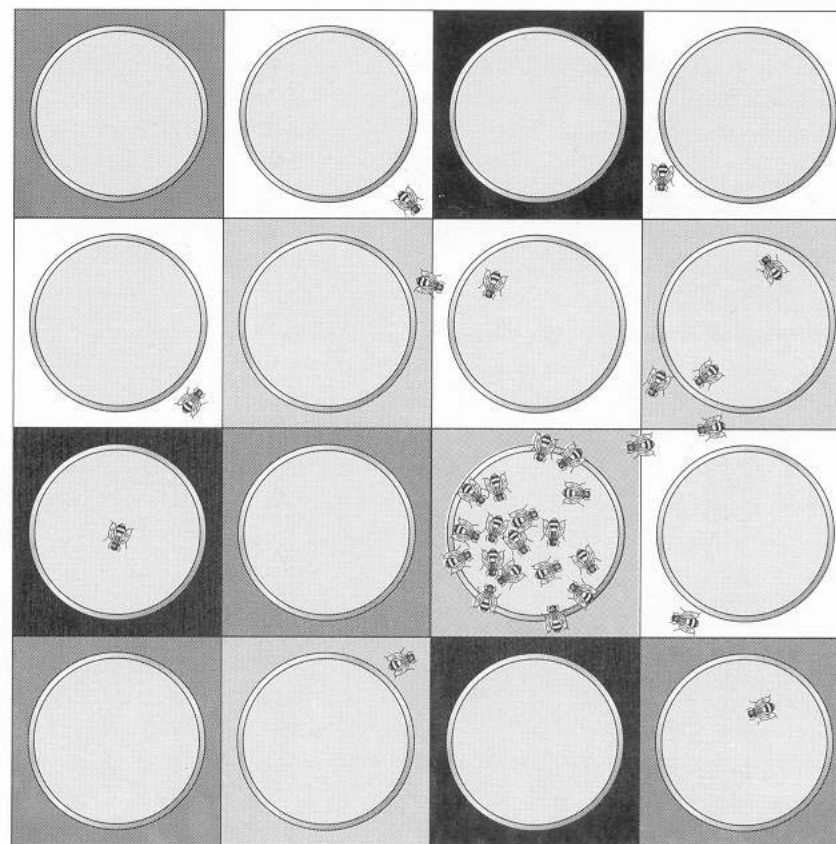
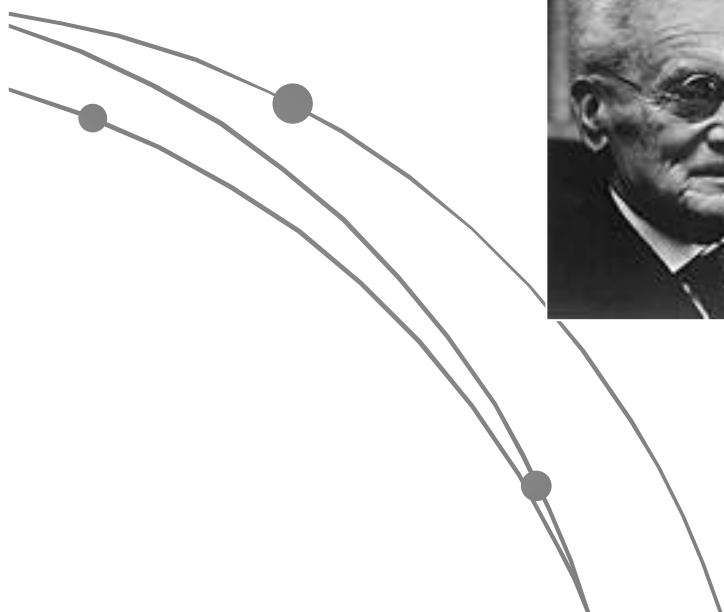
Pavlov



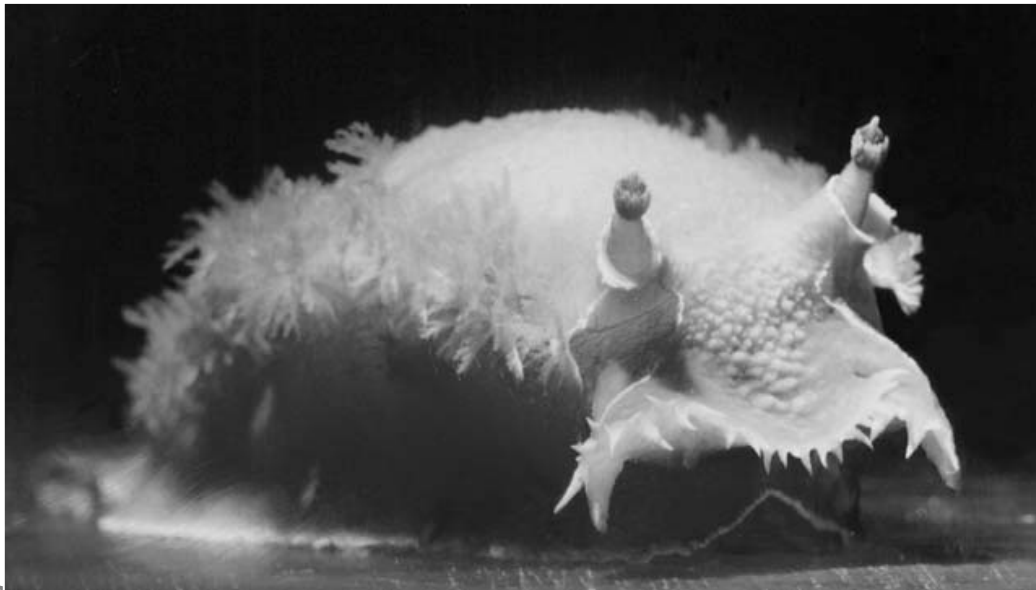
# Podmiňování jako klíč k funkci NS a smyslů

Vytvoření podmíněného spojení je důkazem plasticity NS a základem paměti a učení.

von Frish

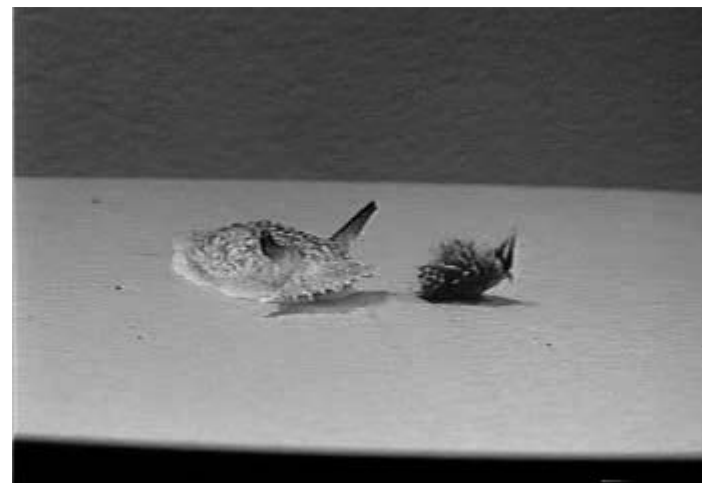


Vytvoření podmíněného spojení může být:  
cílem výzkumu paměti a učení



Tritonia diomedea

I měkkýši se učí



Vytvoření podmíněného spojení může být:  
cílem výzkumu paměti a učení



Aplysia – zej  
„mořský zajíc“

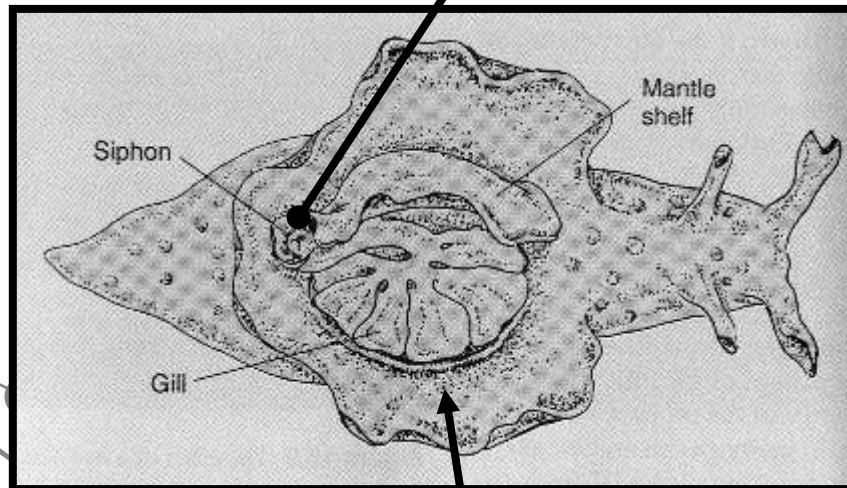
Aplysia

Eric Kandel  
Nobelova cena 2000



Vytvoření podmíněného spojení může být:  
cílem výzkumu paměti a učení

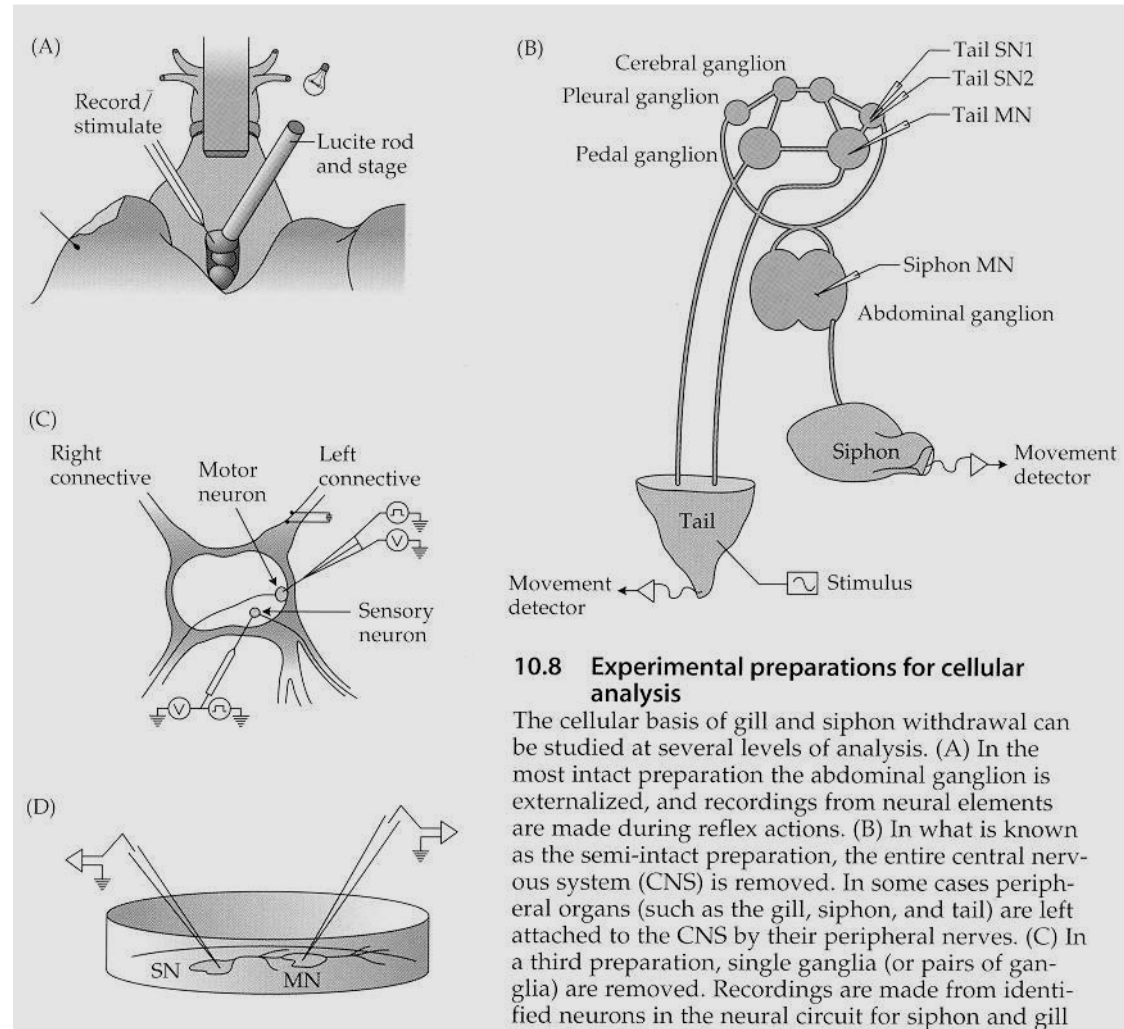
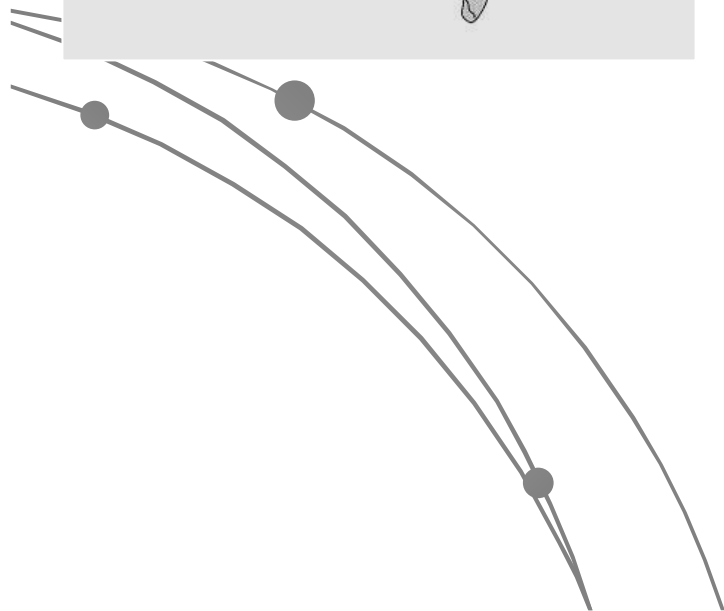
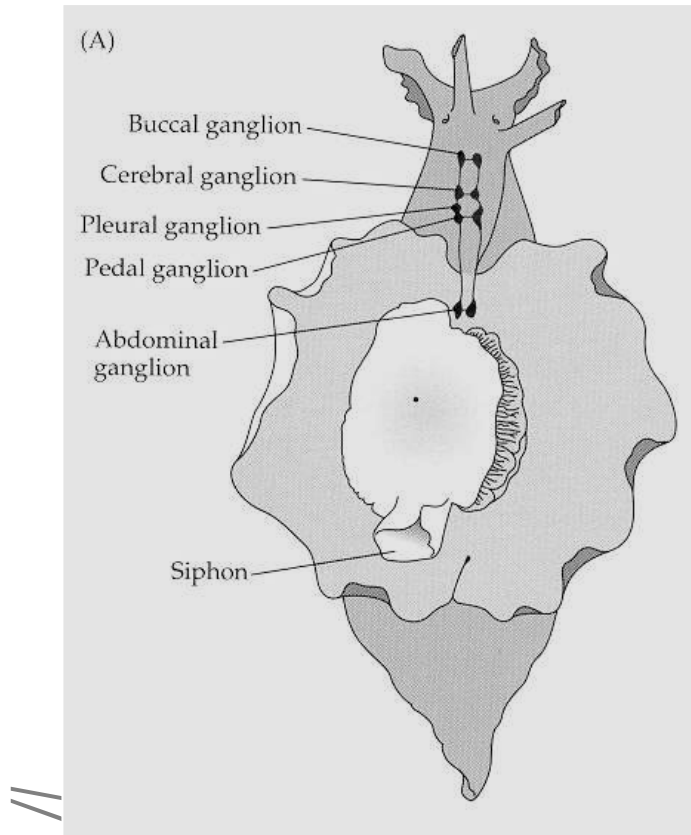
Dotek na sifon...



...a žábra se stáhnou

• Habituační u *Aplysia*

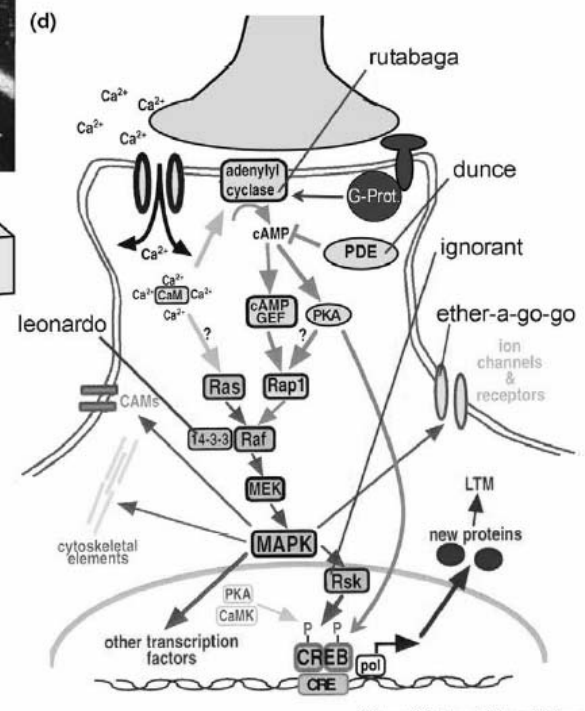
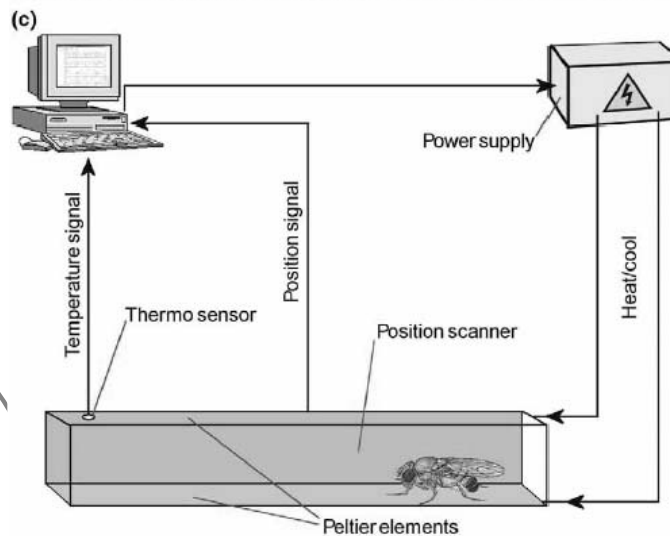
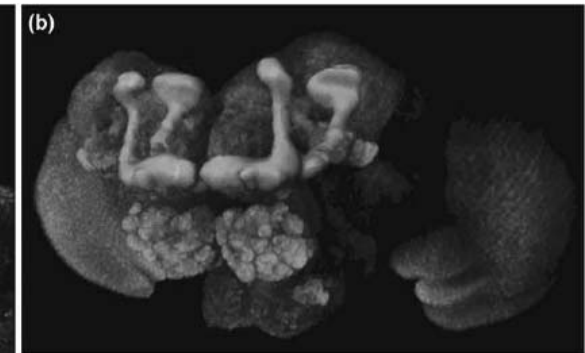
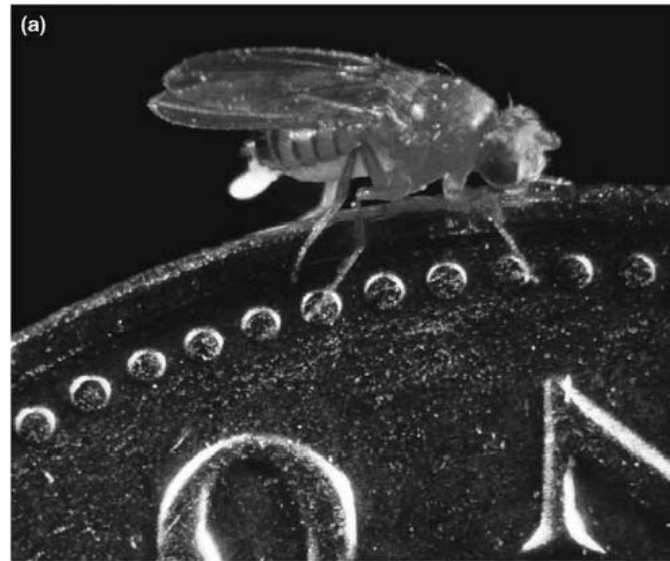
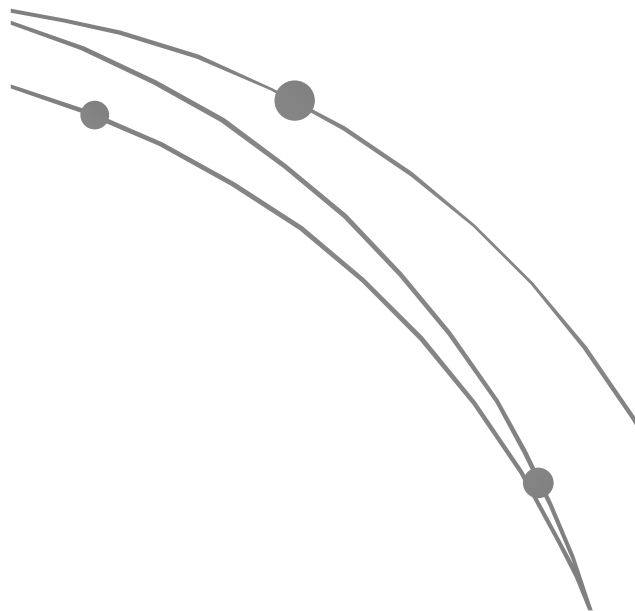
# Plasticita nervového spojení i na izolovaných gangliích





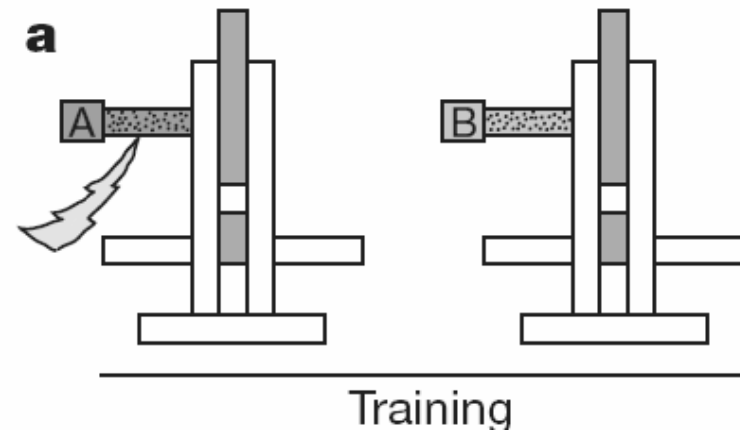
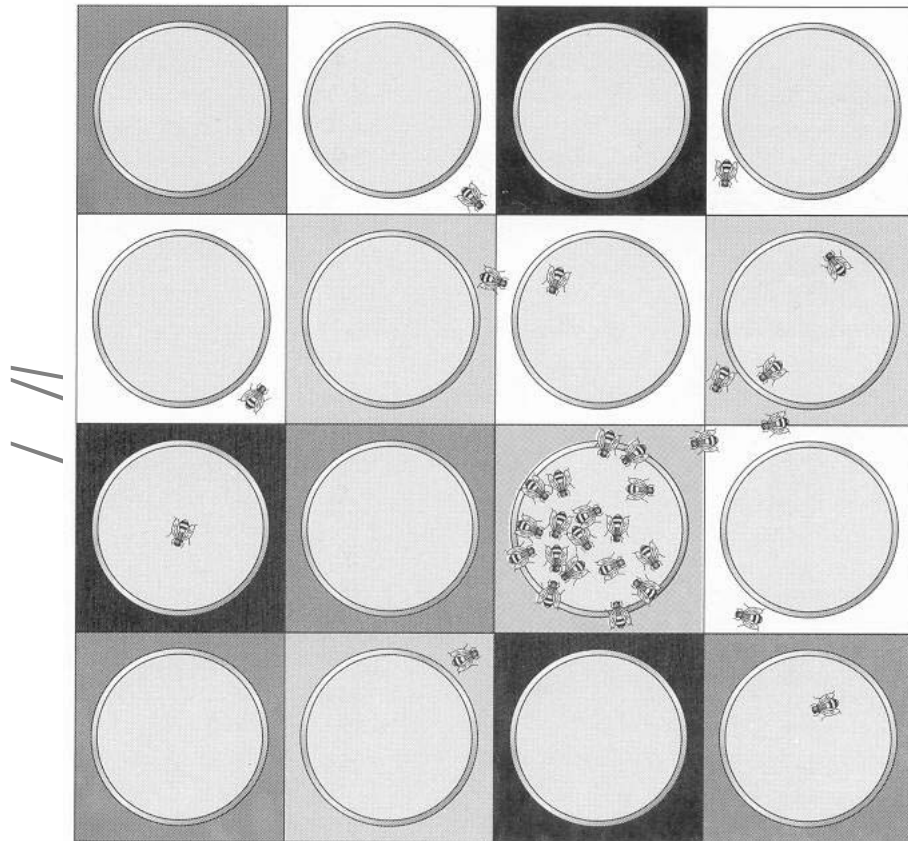
# Vytvoření podmíněného spojení může být: cílem výzkumu paměti a učení

## Trénink a test



Vytvoření podmíněného spojení může být:  
nástrojem výzkumu smyslových schopností

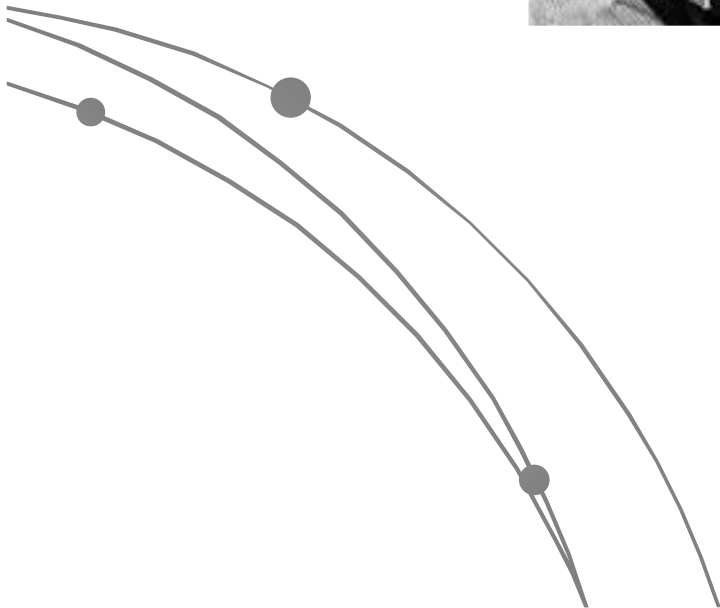
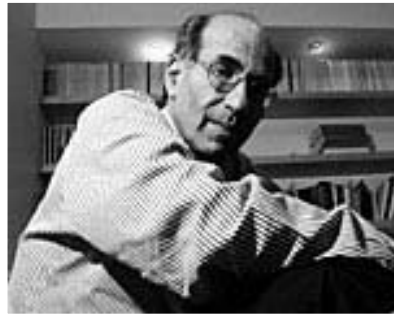
Odměna nebo trest při tréninku



# Vytvoření podmíněného spojení může být: nástrojem výzkumu smyslových schopností

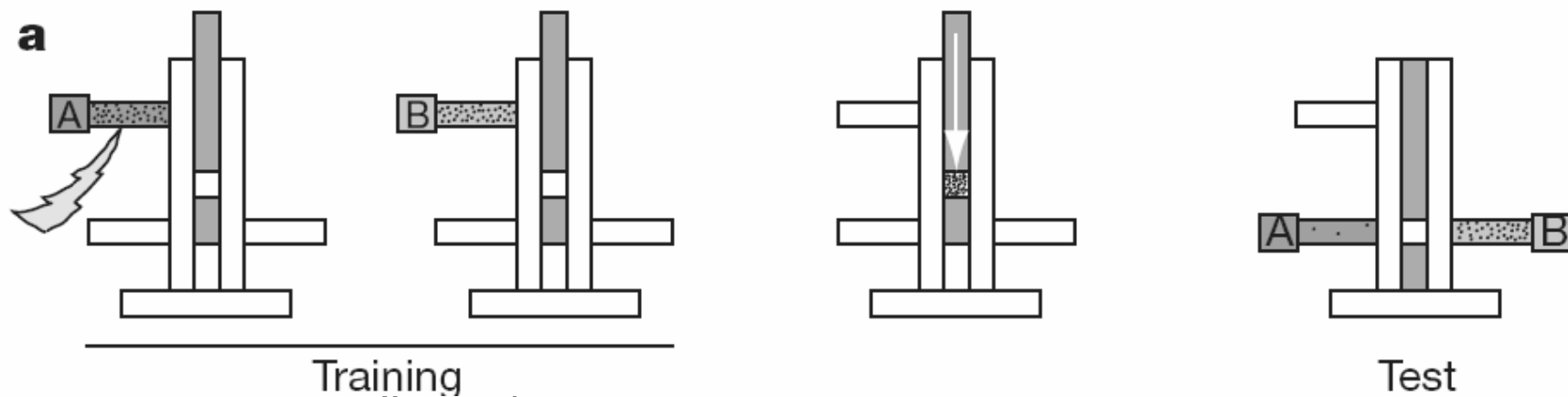
Richard Axel

Nobelova cena 2004 za objevy podstaty čichu



# Vytvoření podmíněného spojení může být: nástrojem výzkumu smyslových schopností

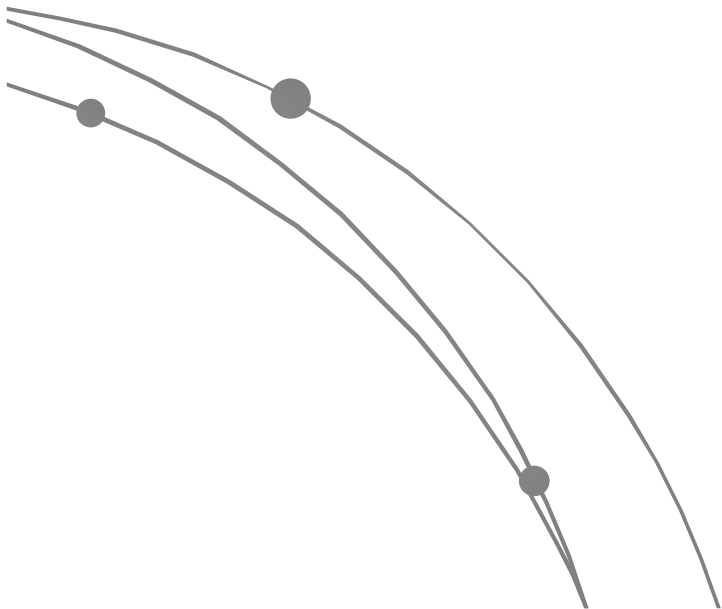
Richard Axel  
Nobelova cena 2004 za objevy podstaty čichu



# Podmiňování jako klíč k funkci NS a smyslů

Vytvoření podmíněného spojení může být:

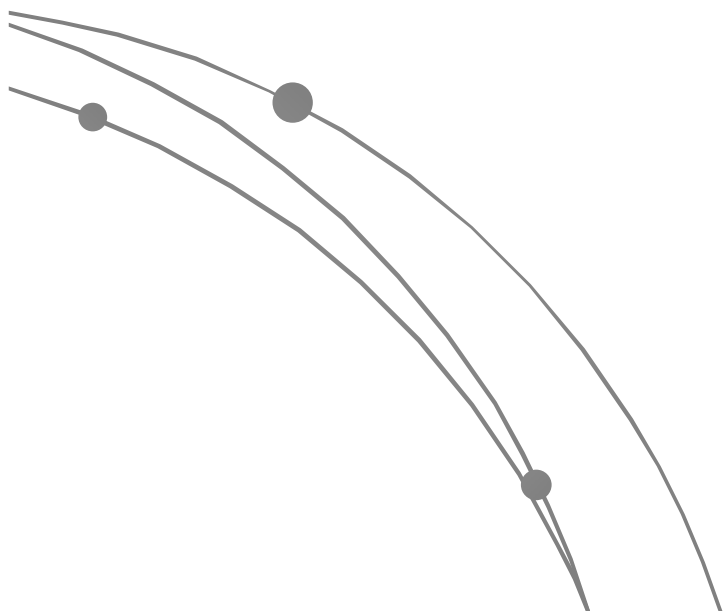
- cílem výzkumu paměti a učení



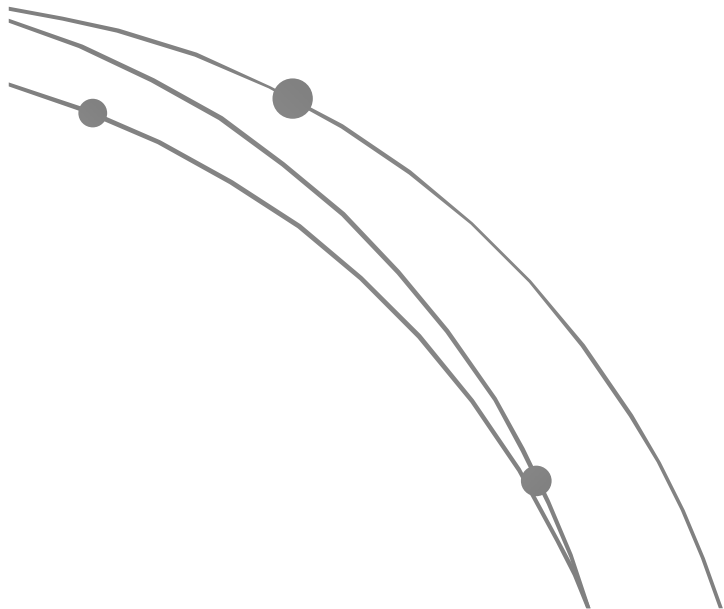
# Podmiňování jako klíč k funkci NS a smyslů

Vytvoření podmíněného spojení může být:

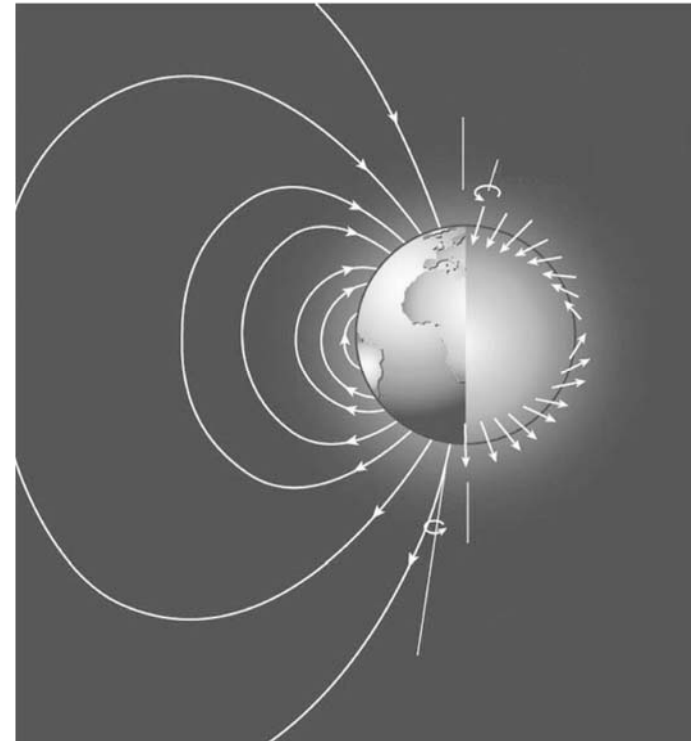
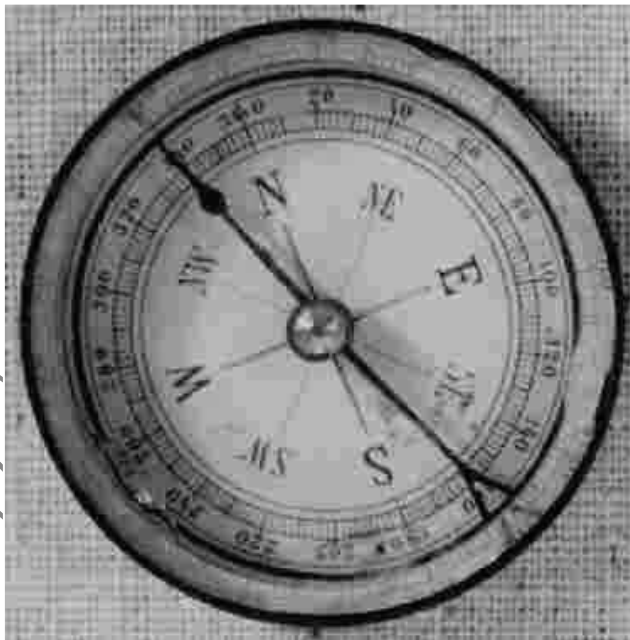
- nebo nástrojem výzkumu smyslových schopností



## C) Magnetorecepce – výzva smyslové fyziologii

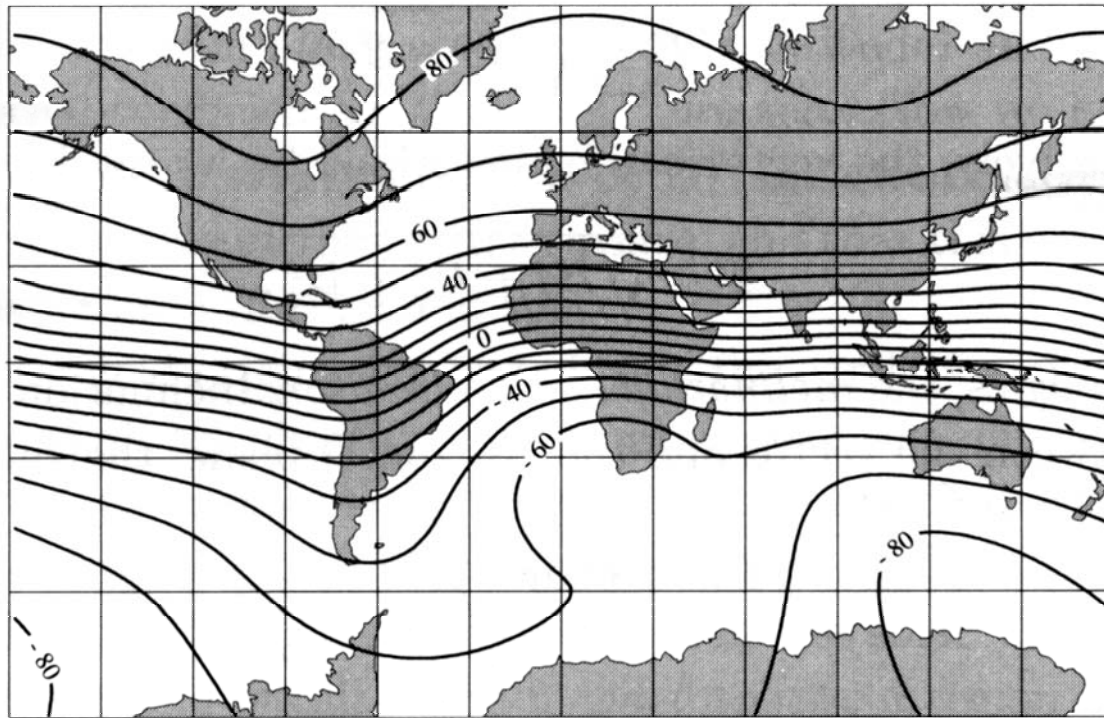


# Kompas: Všudypřítomné vodítko

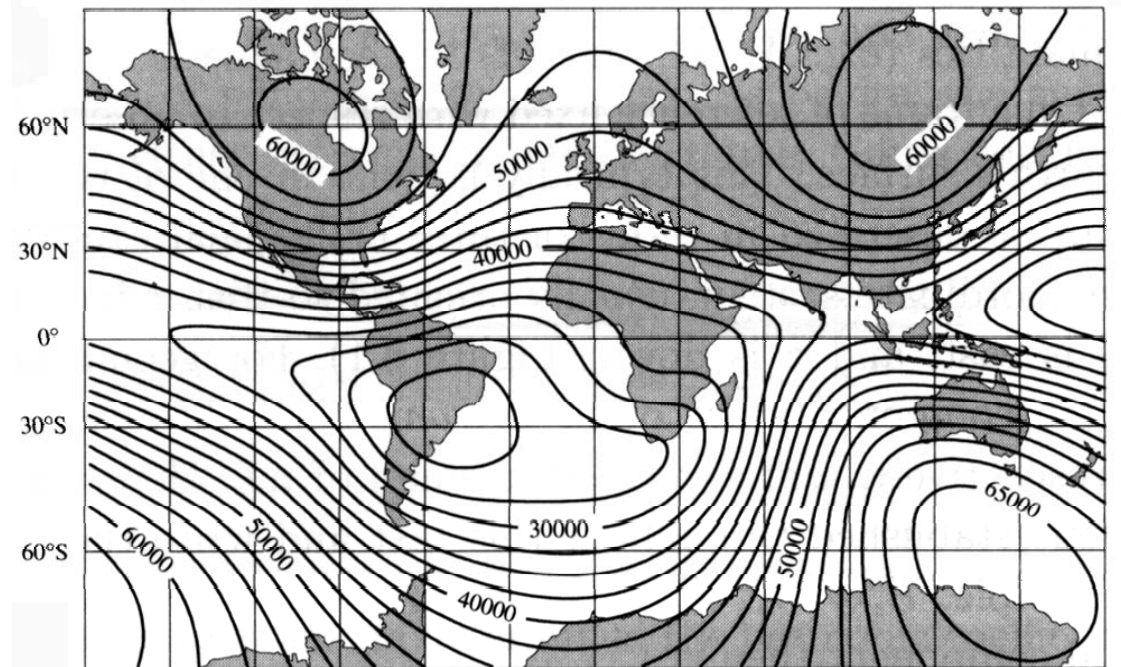
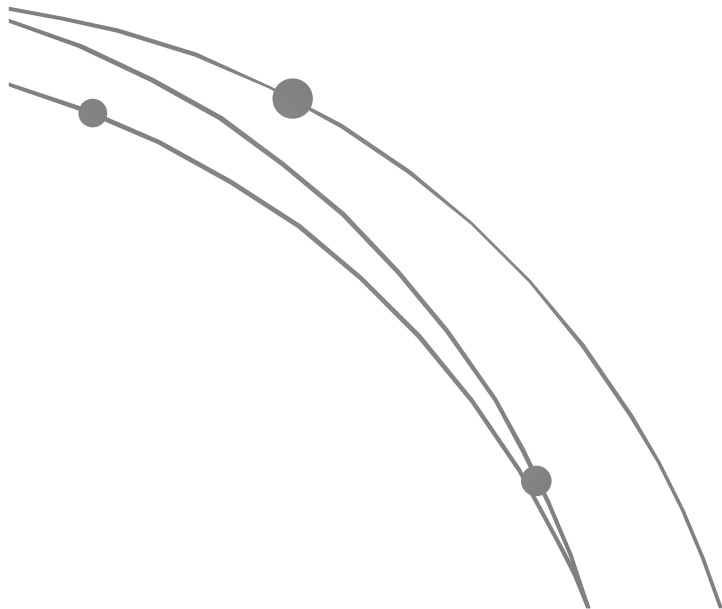




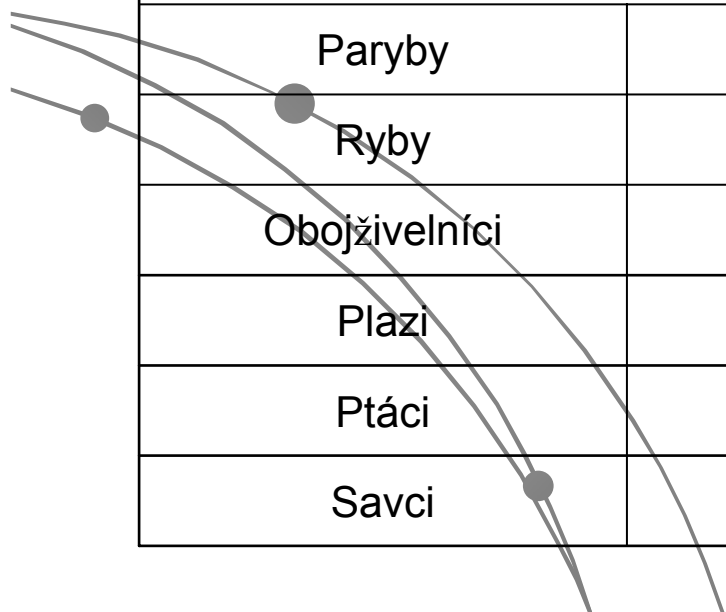
# Mapa – „GPS“



180°W 120°W 60°W 0° 60°E 120°E 180°E



| Magnetická kompasová orientace nalezena u těchto živočišných skupin: |           |          | Typ kompasu           |
|--|-----------|----------|-----------------------|
| <b>Měkkýši</b>   |           |          |                       |
| Plži   | 1 čeleď   | 1 druh   | ???                   |
| <b>Členovci</b>  |           |          |                       |
| Korýši   | 3 čeledě  | 5 druhů  | Polaritní, inklináční |
| Hmyz   | 7 čeledě  | 9 druhů  | Polaritní (?)         |
| <b>Obratlovci</b>  |           |          |                       |
| Paryby   | 1 čeleď   | 1 druh   | ???                   |
| Ryby   | 2 čeledě  | 4 druhy  | Polaritní (?)         |
| Obojživelníci  | 2 čeledě  | 2 druhy  | Polaritní, inklináční |
| Plazi  | 2 čeledě  | 2 druhy  | Inklináční            |
| Ptáci  | 11 čeledí | 19 druhů | Inklináční            |
| Savci  | 2 čeledě  | 3 druhy  | Polaritní             |

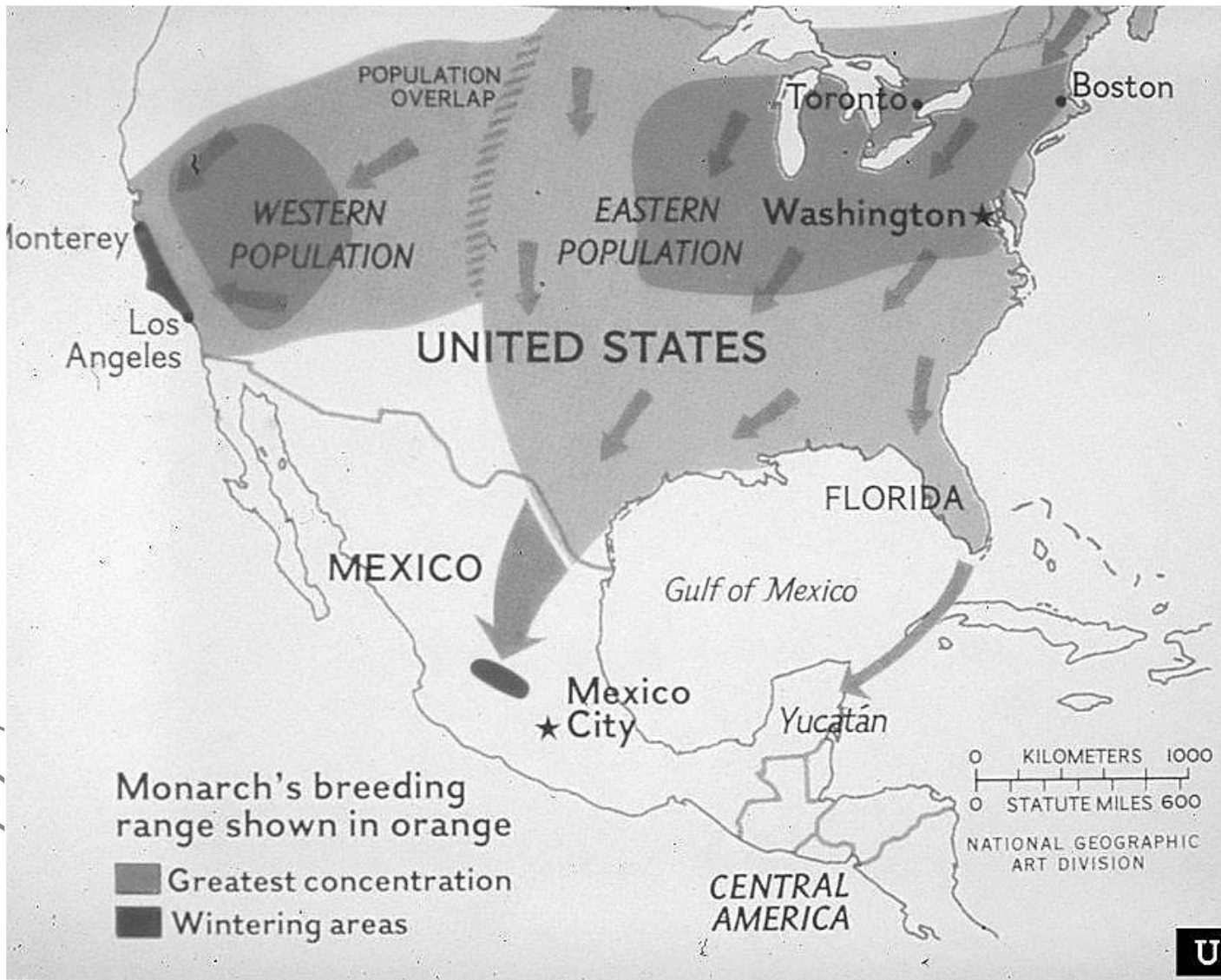


# Orientace hmyzu

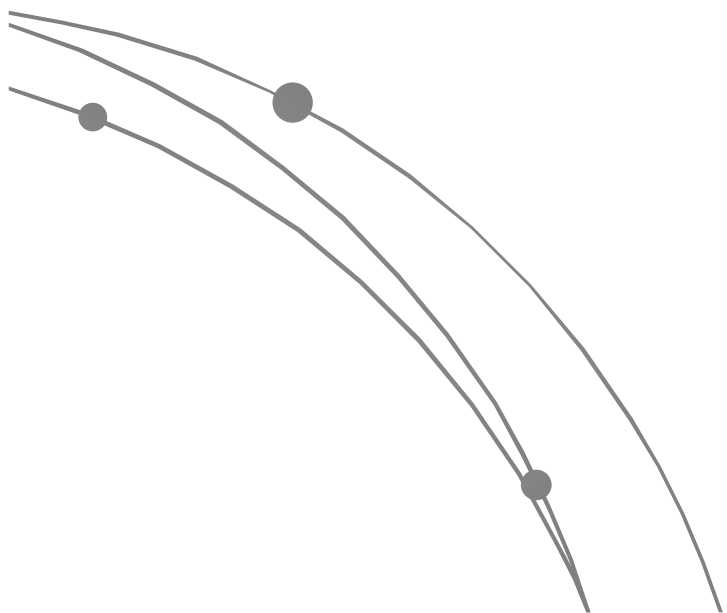


Migrující hmyz:

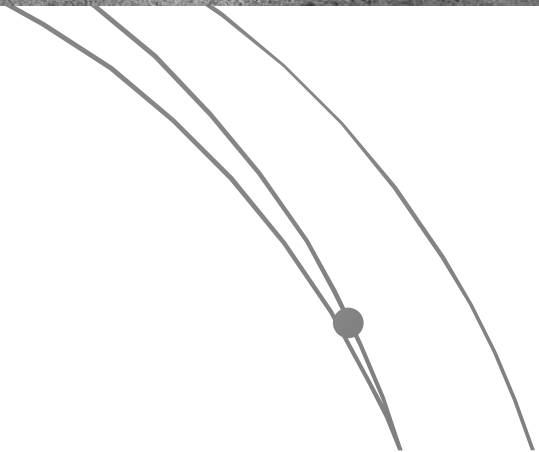
monarcha stěhovavý



# Metody výzkumu





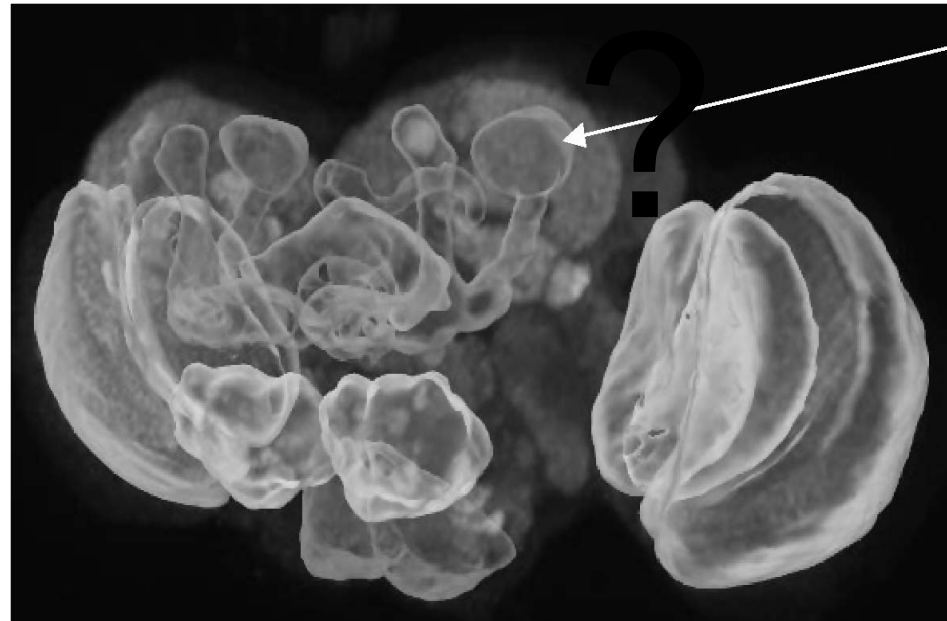
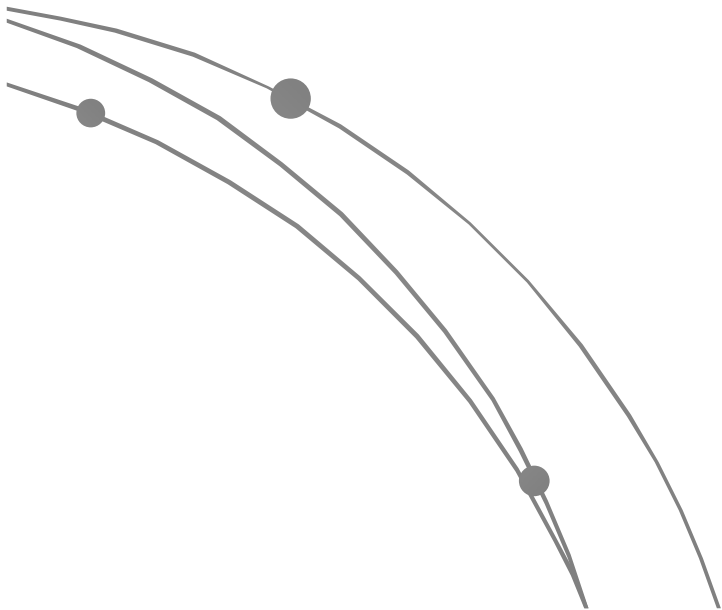




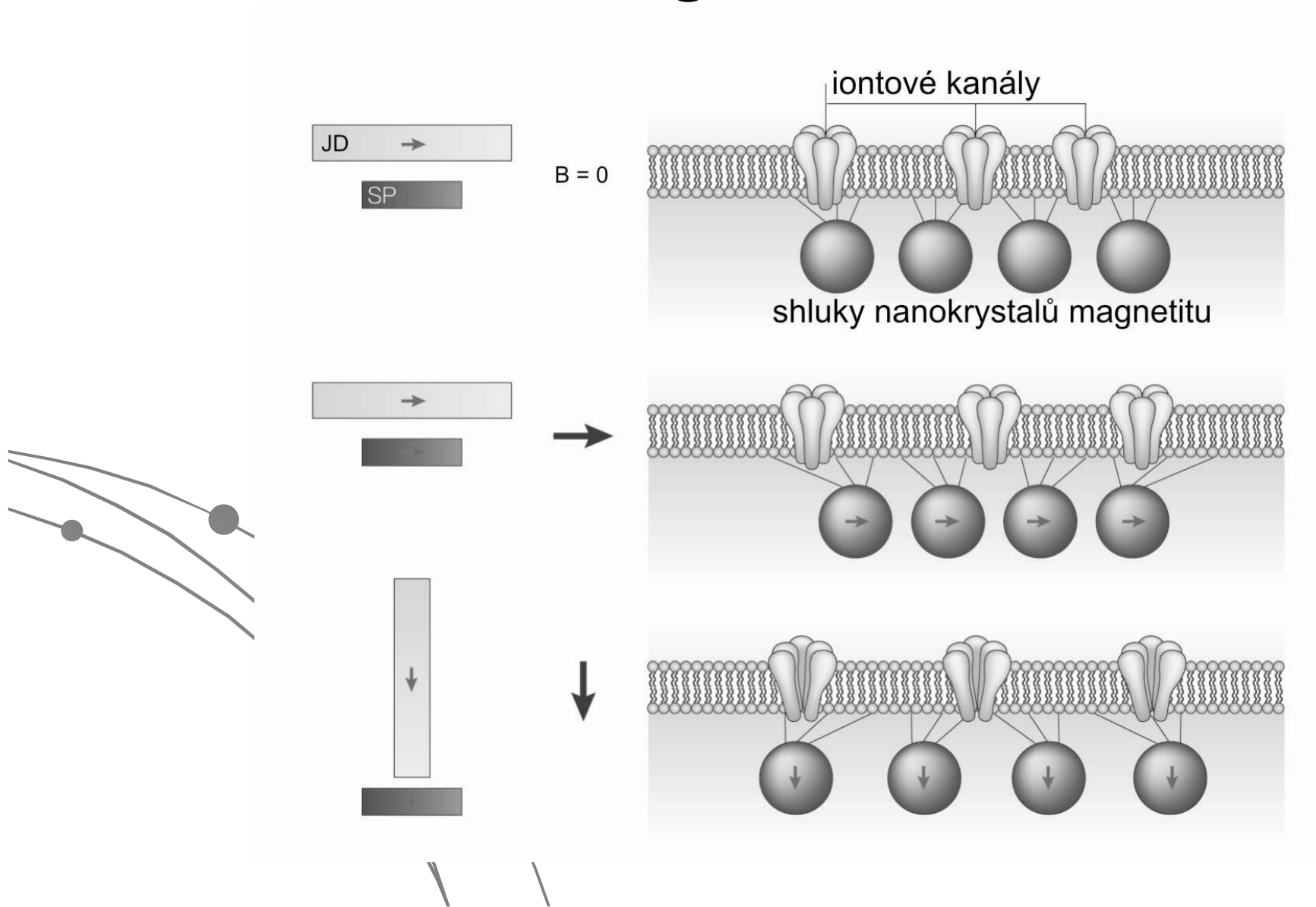


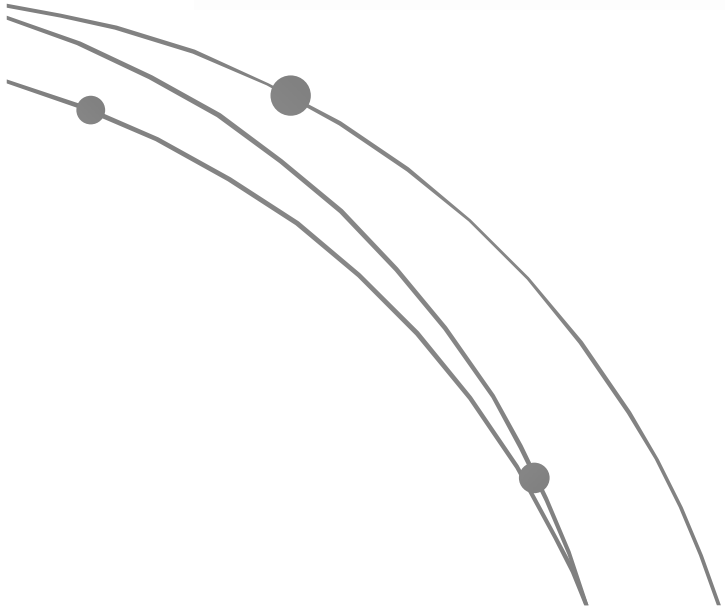
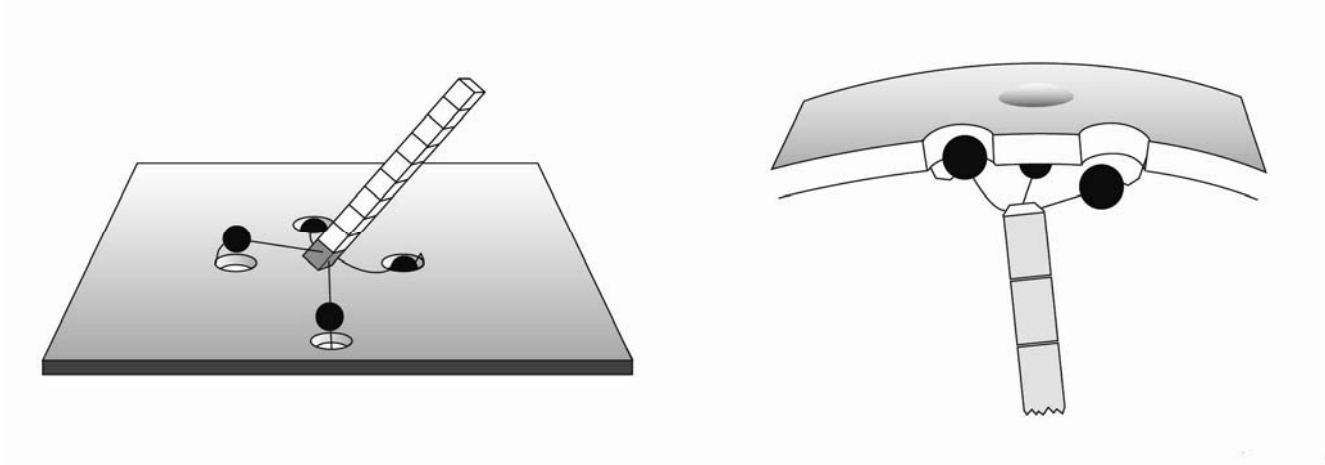
# Neznáme:

- Mechanismus recepce
- Lokalizaci receptoru
- Adaptivní význam

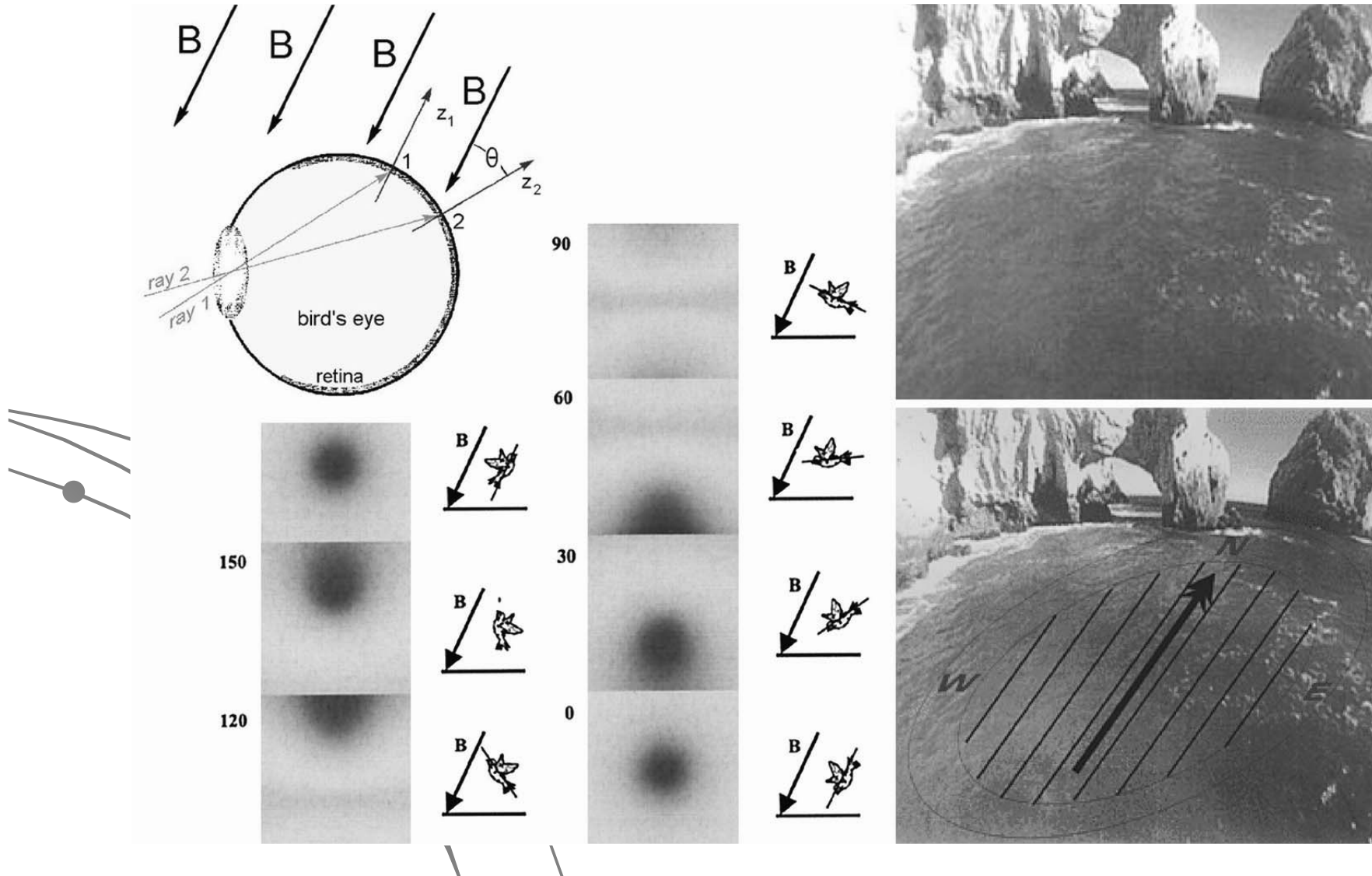


# Magnetit?



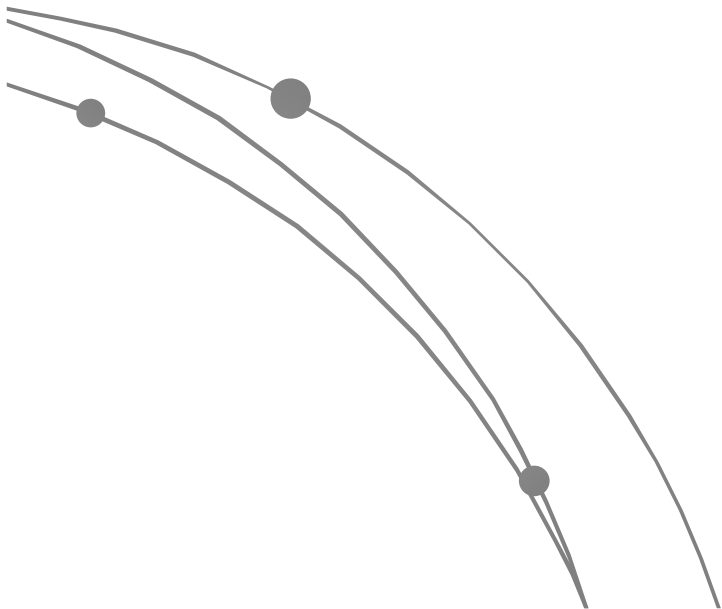


# Modifikace zraku?



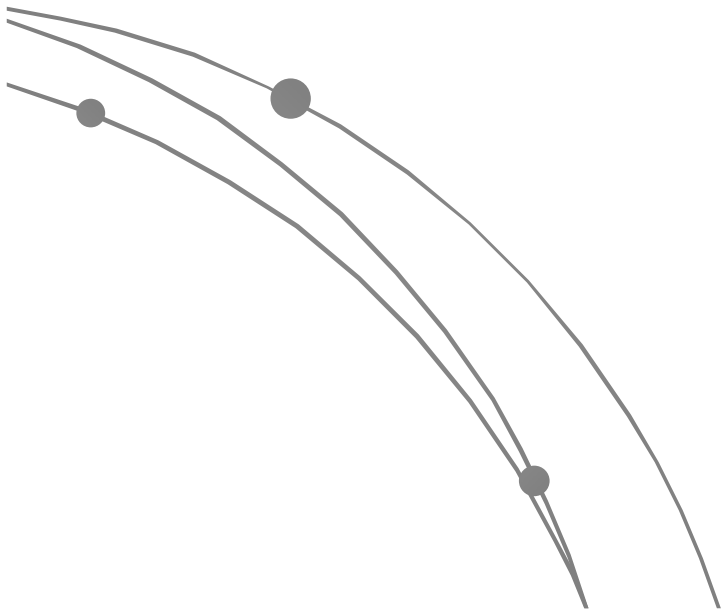
# Neuroetologické metody smyslové fyziologie

Podmiňování a spontánní reakce



# Neuroetologické metody smyslové fyziologie

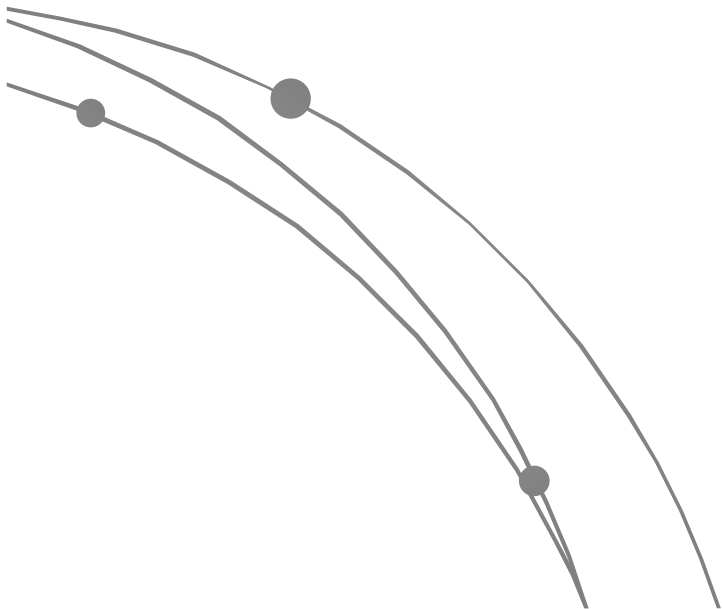
Podmiňování: Trénink a test



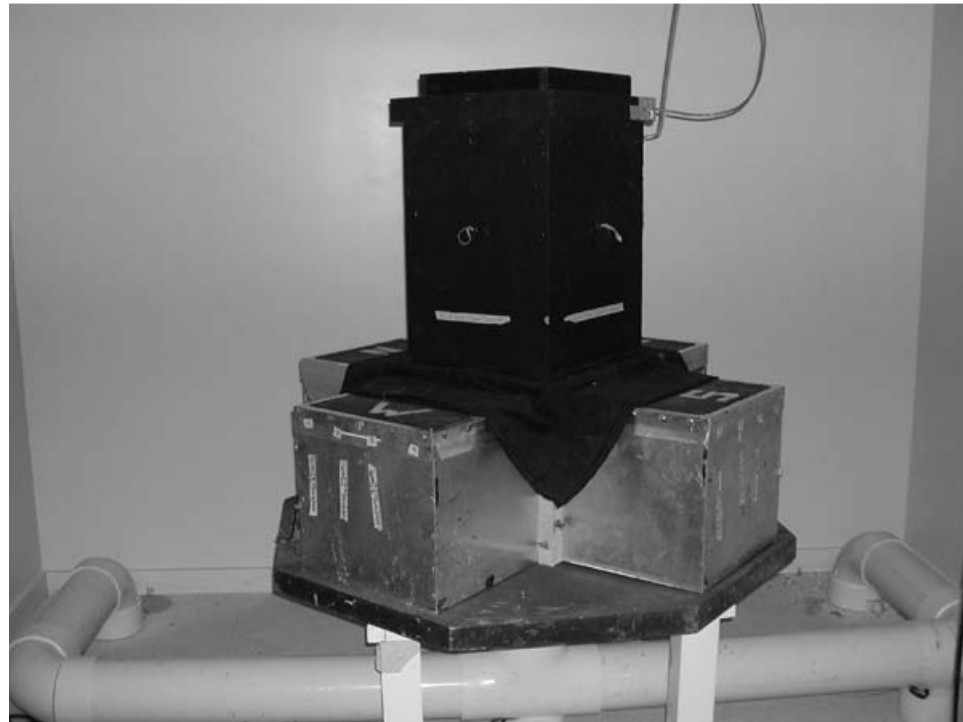
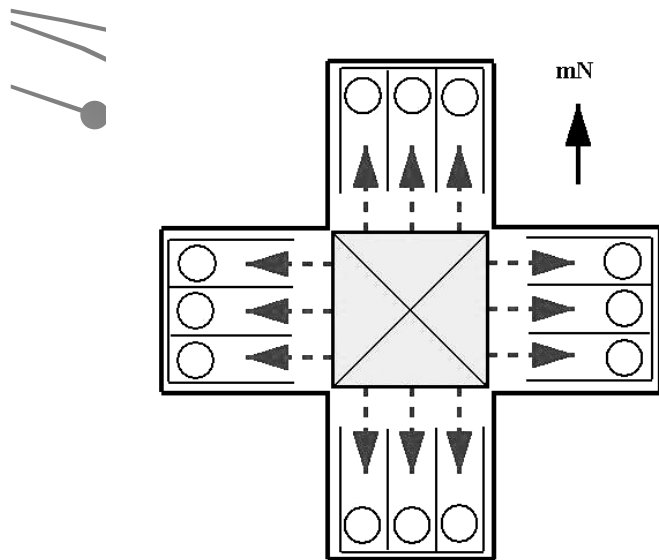
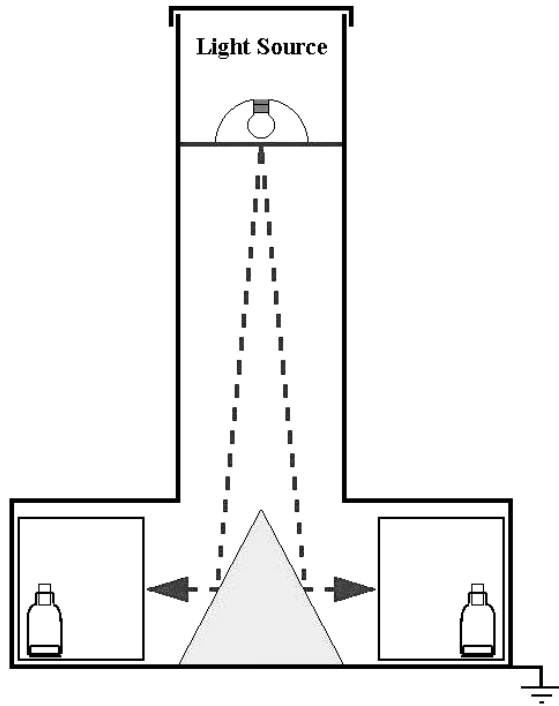
# Neuroetologické metody smyslové fyziologie

Podmiňování: Trénink a test

Trénink: Odměna nebo trest

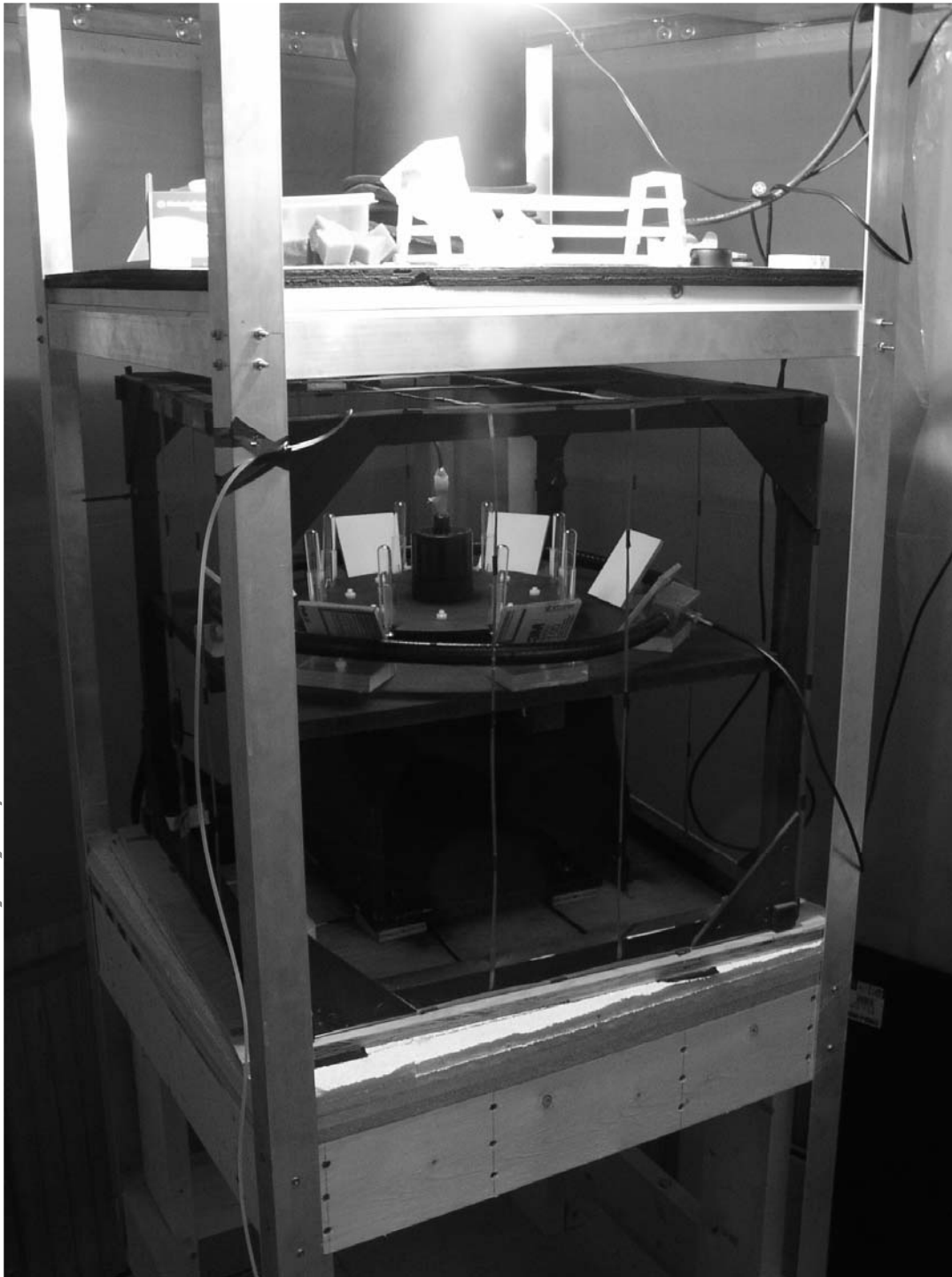


# Trénink Drosophila Světlo jako atraktivní stimul

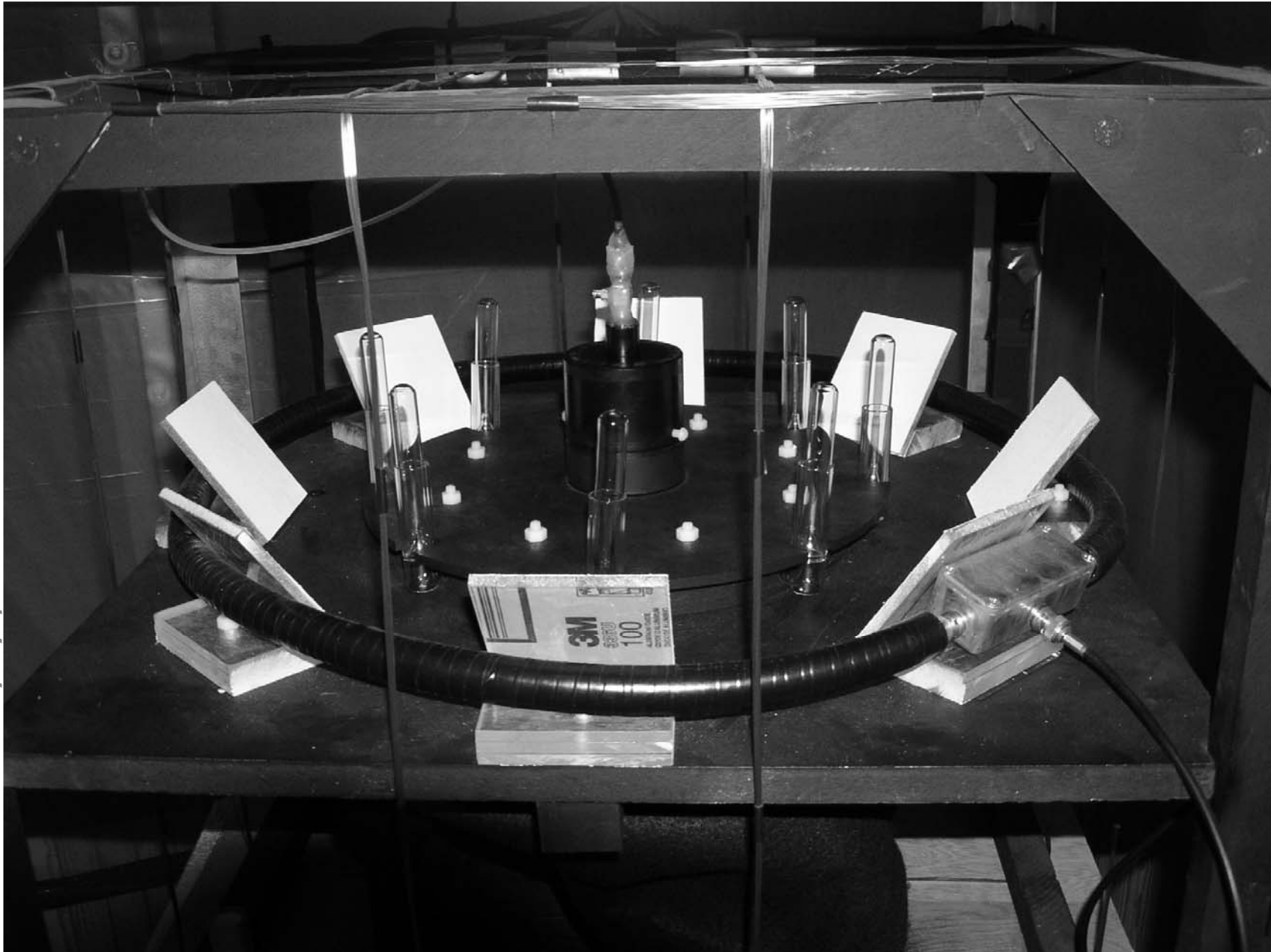




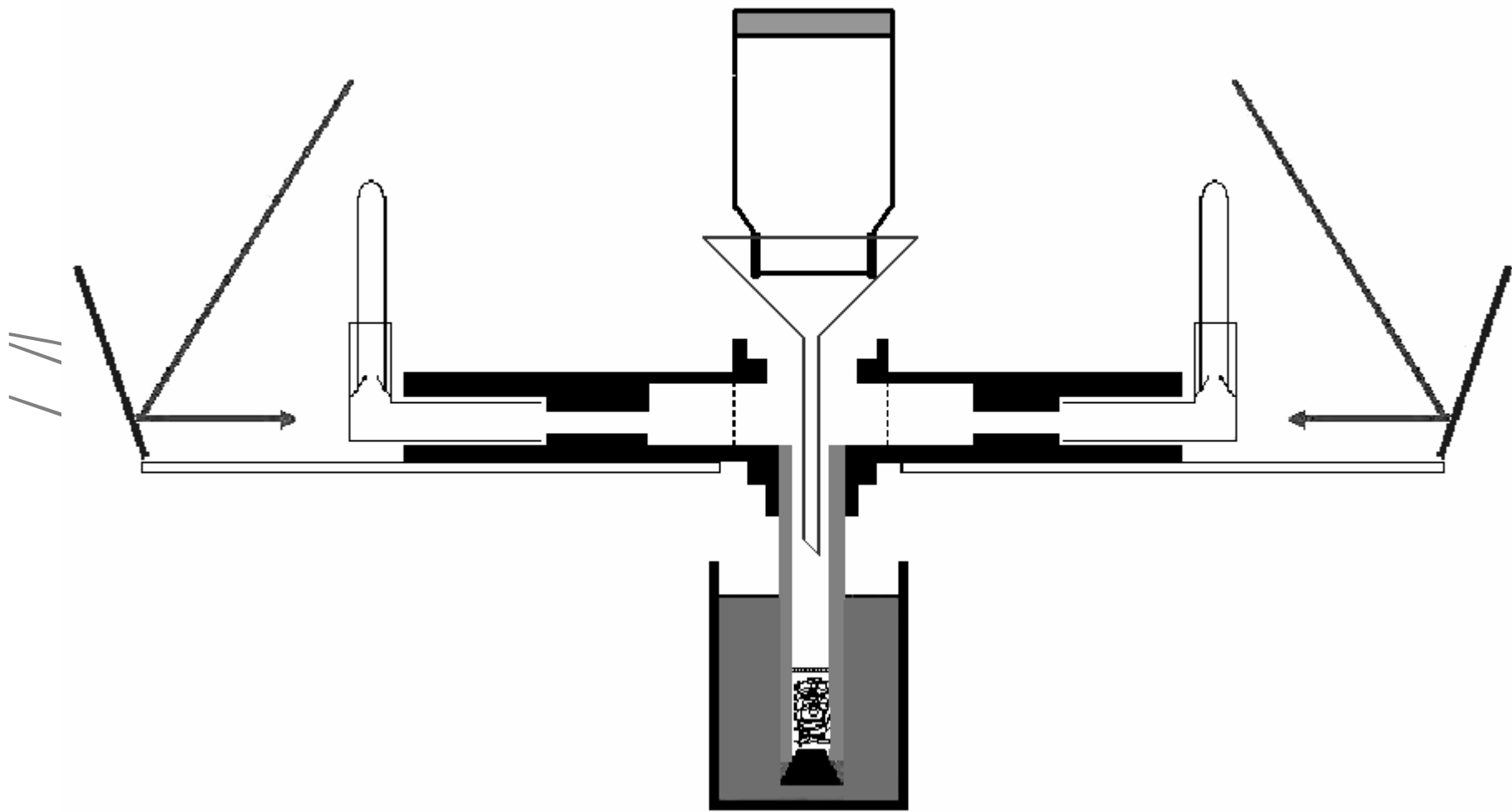




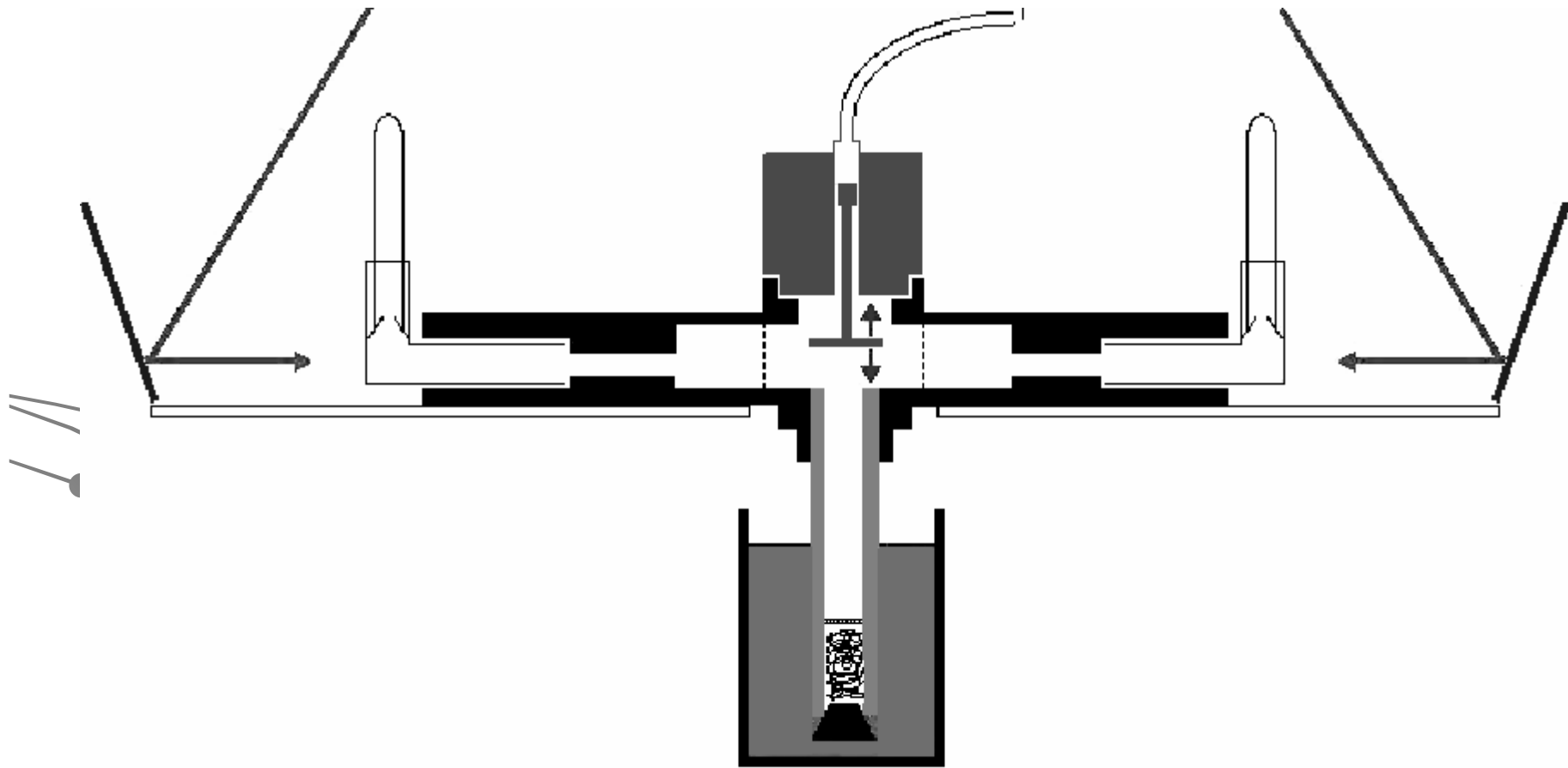
Test



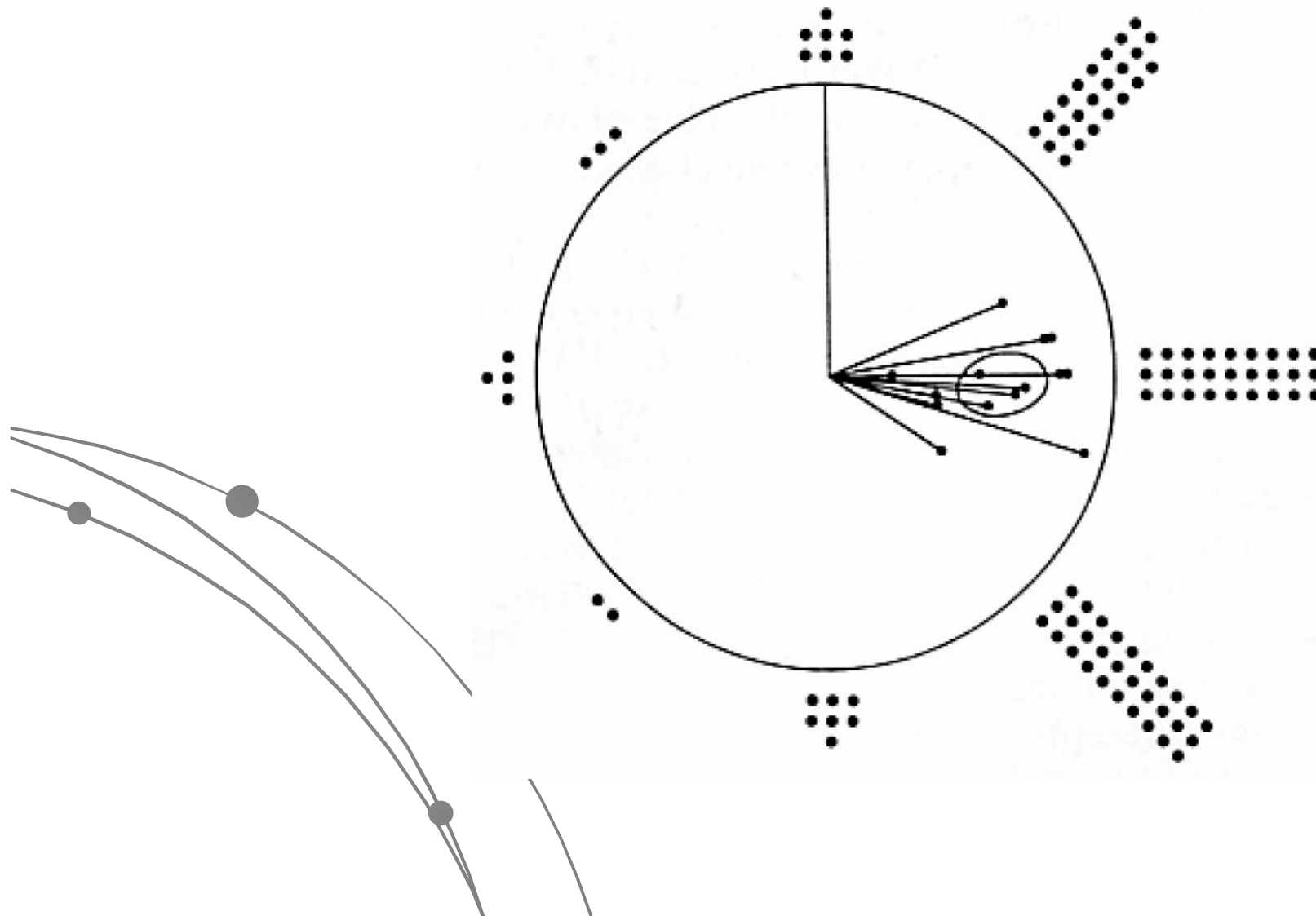
# Test Drosophila



# Test Drosophila



# Cirkulární diagramy orientace

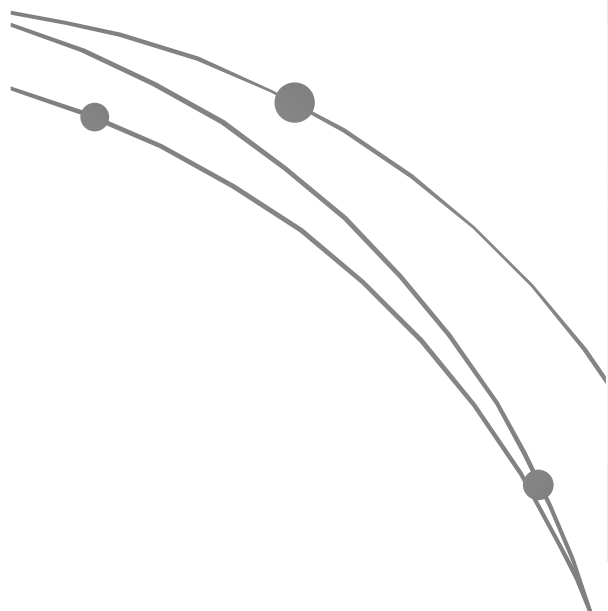
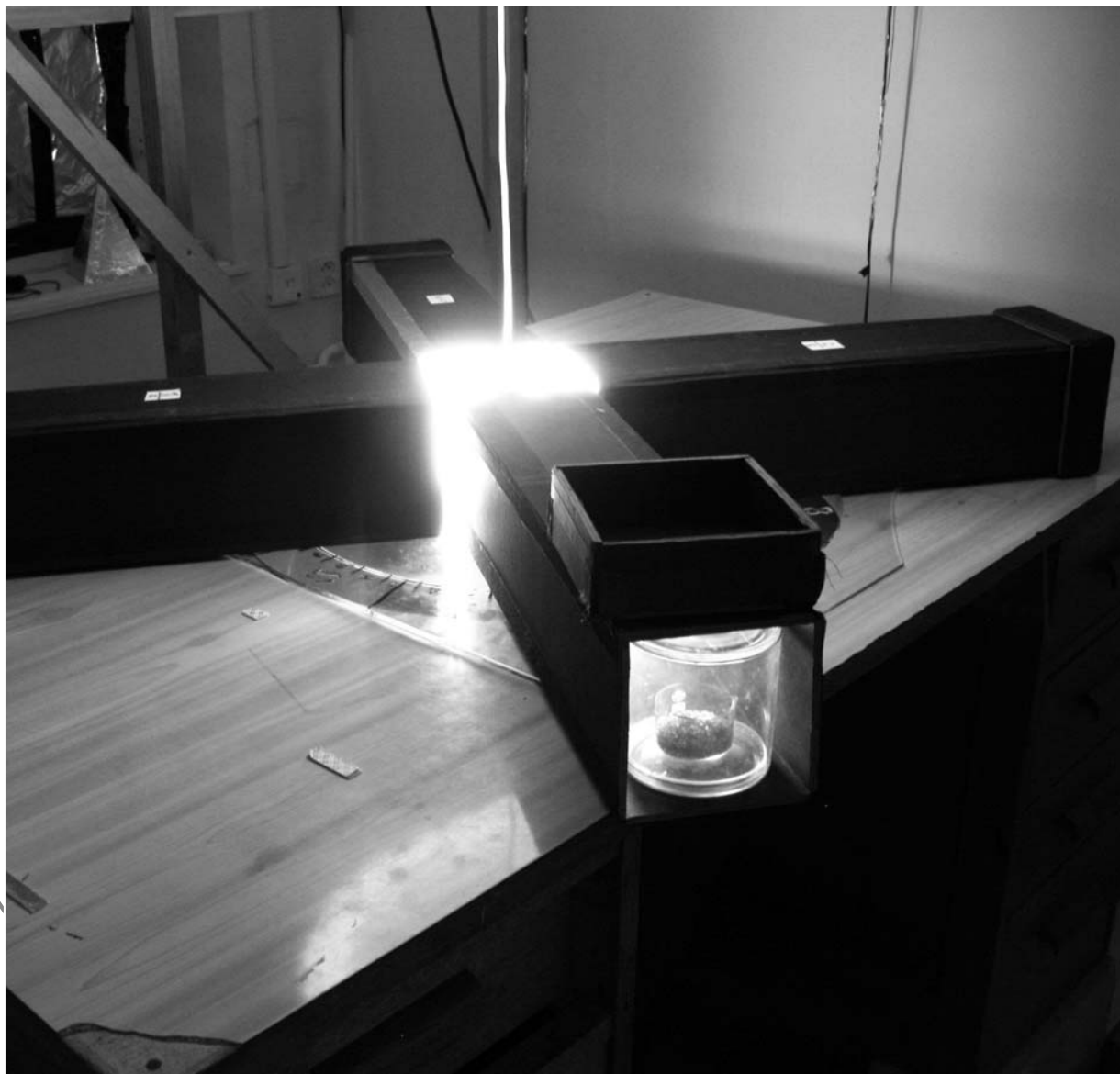


Tenebrio molitor



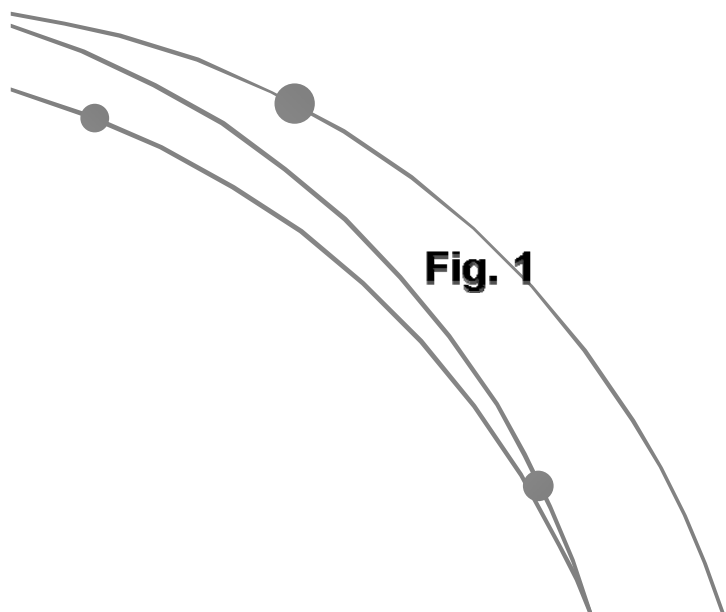
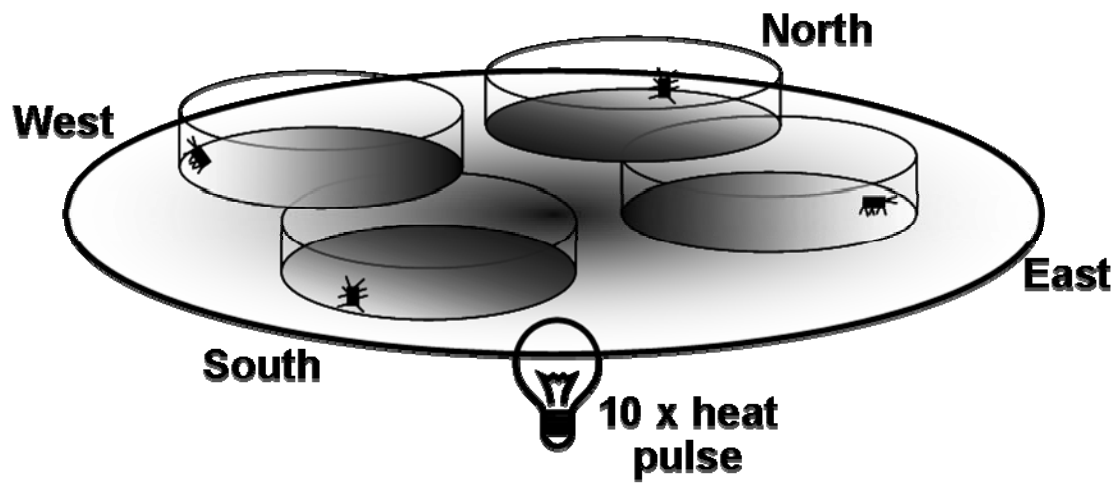
Tribolium castaneum

# Trénink

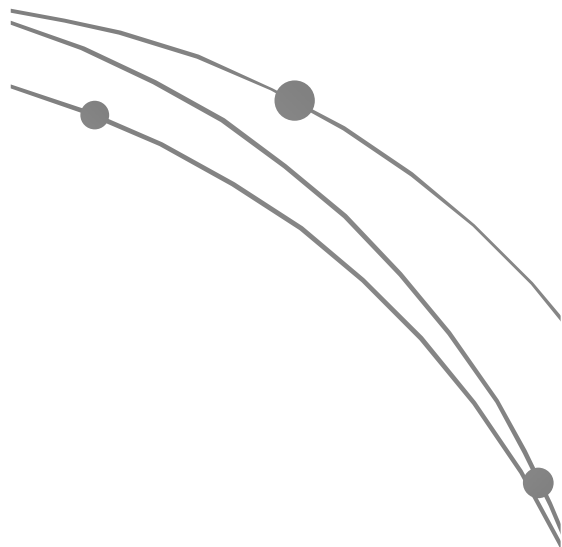




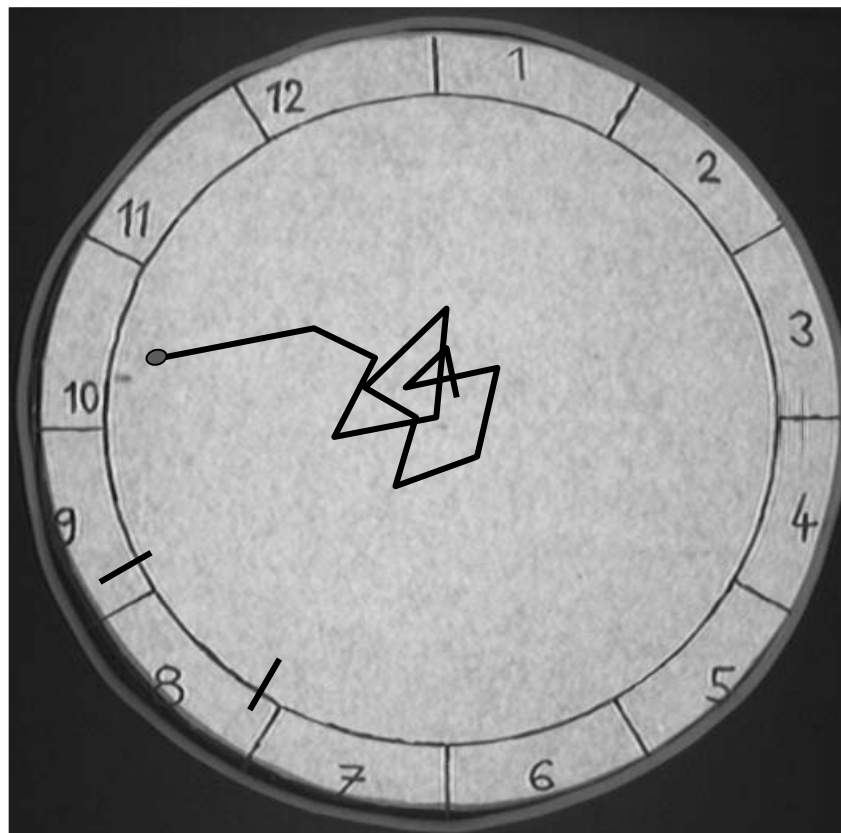
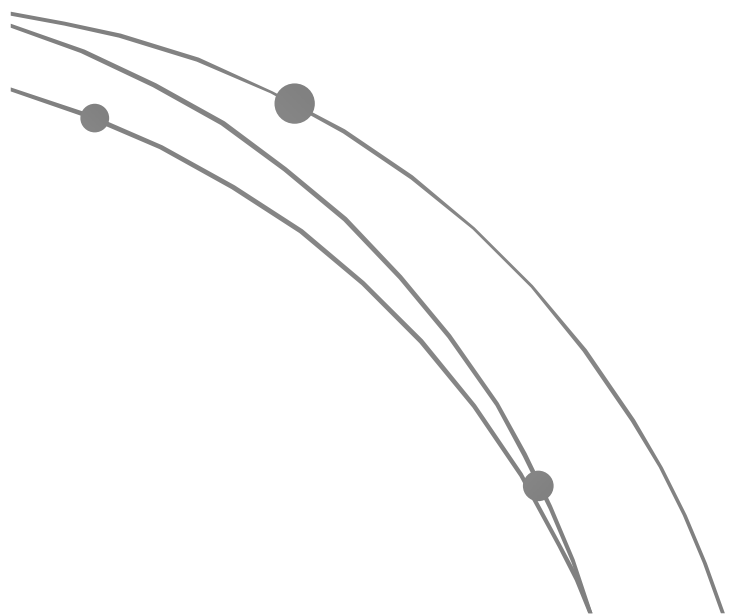
# Trénink



Test

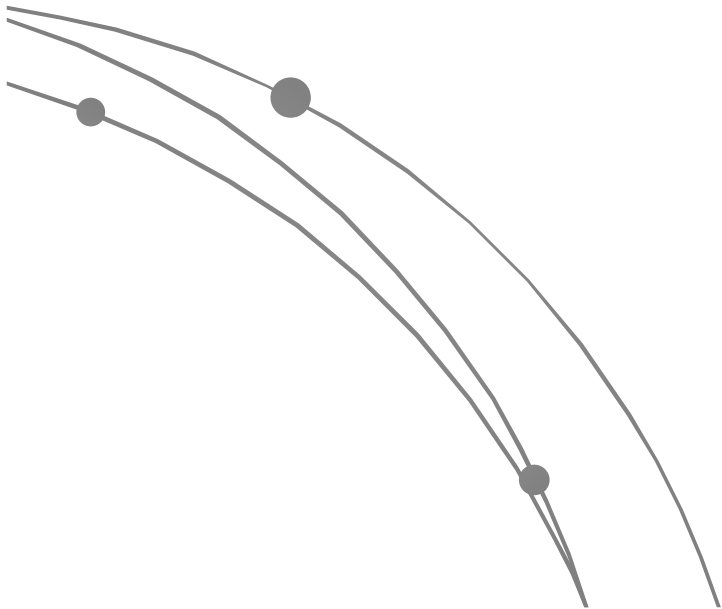


# Pohled kamery



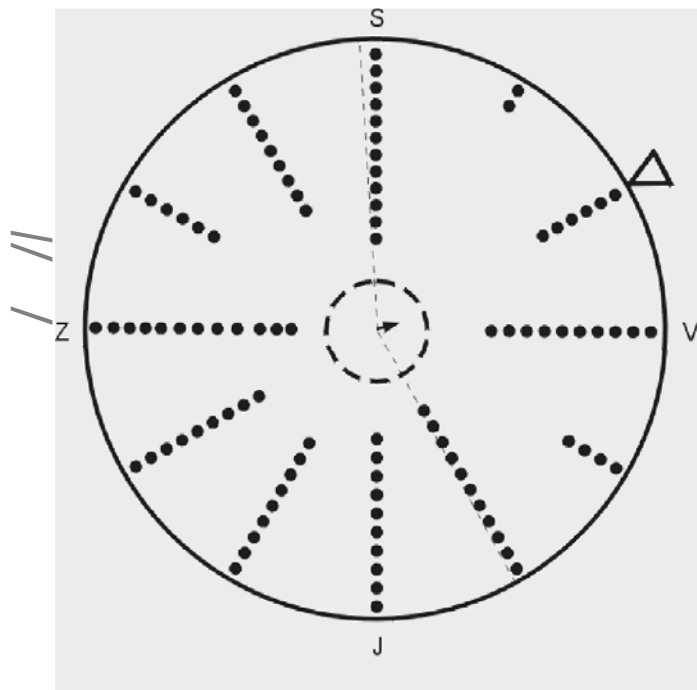
## Problémy:

- Je magnetorecepce závislá na světle?
- Dokáže kompas rozlišit polaritu pole?



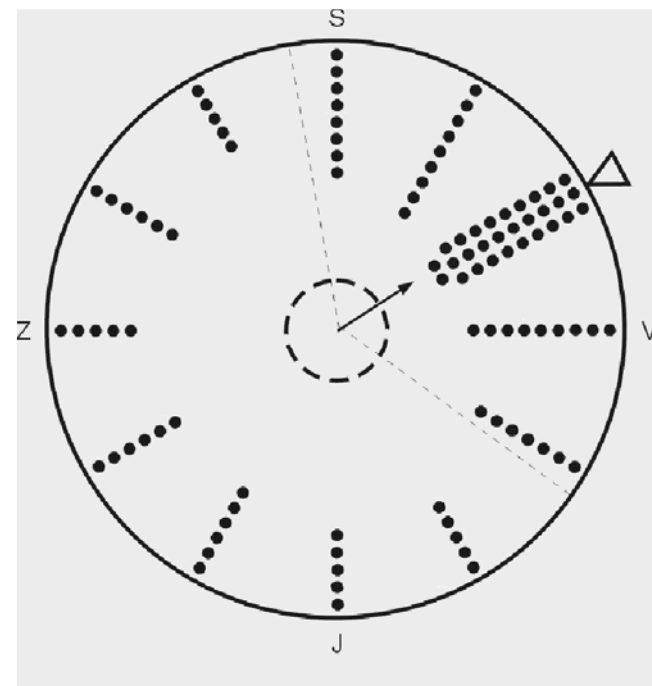
# Ve tmě kompas potemníka nefunguje

Tma  
0% RH



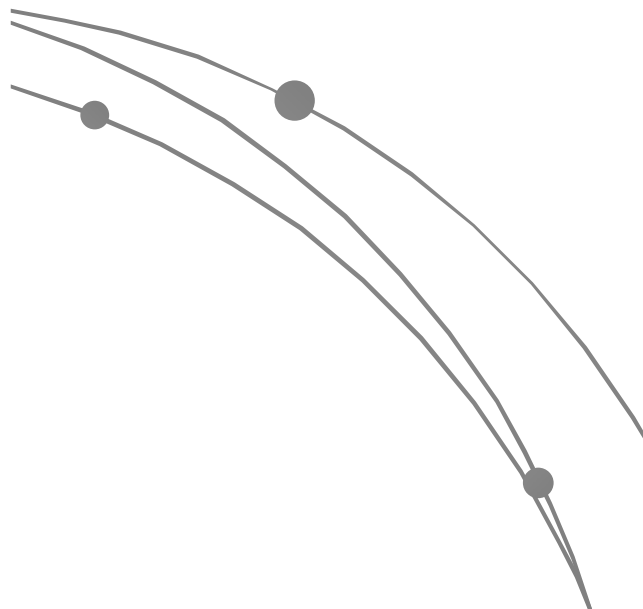
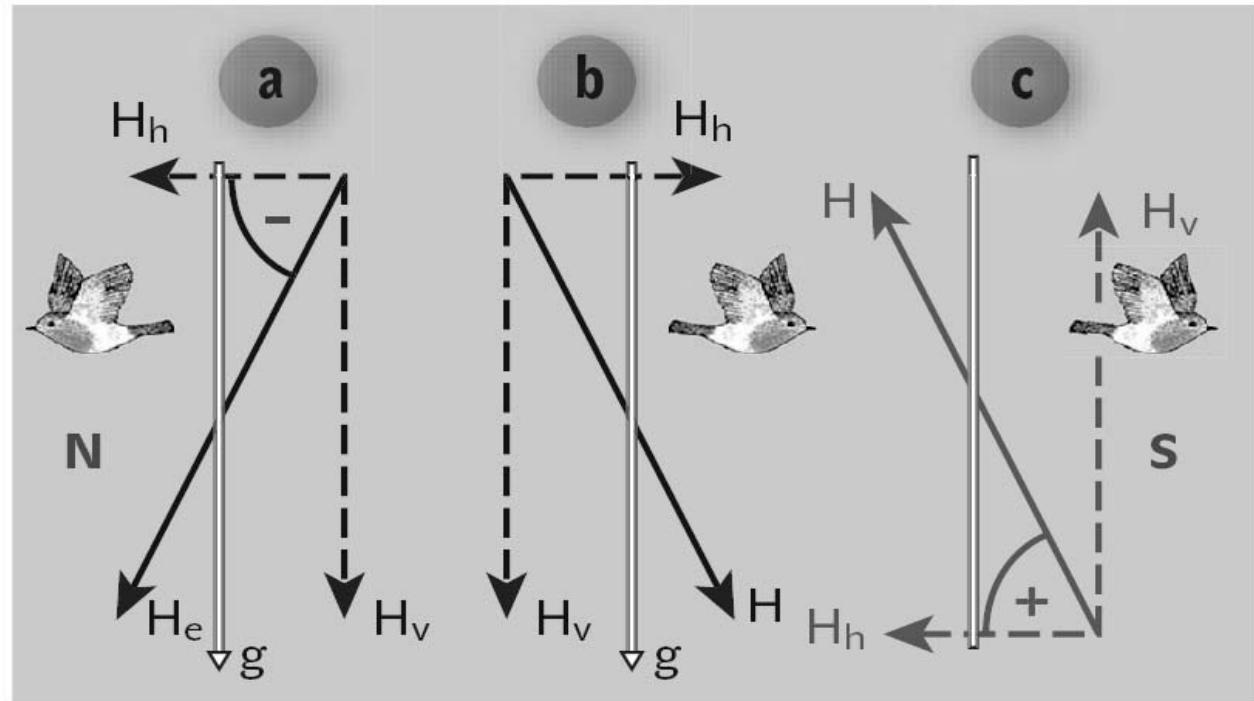
$N = 100$   
 $\theta = 60^\circ$   
 $\Phi = 74,6^\circ$   
 $r = 0,08$   
 $s = 78,0^\circ$

Světlo  
0% RH



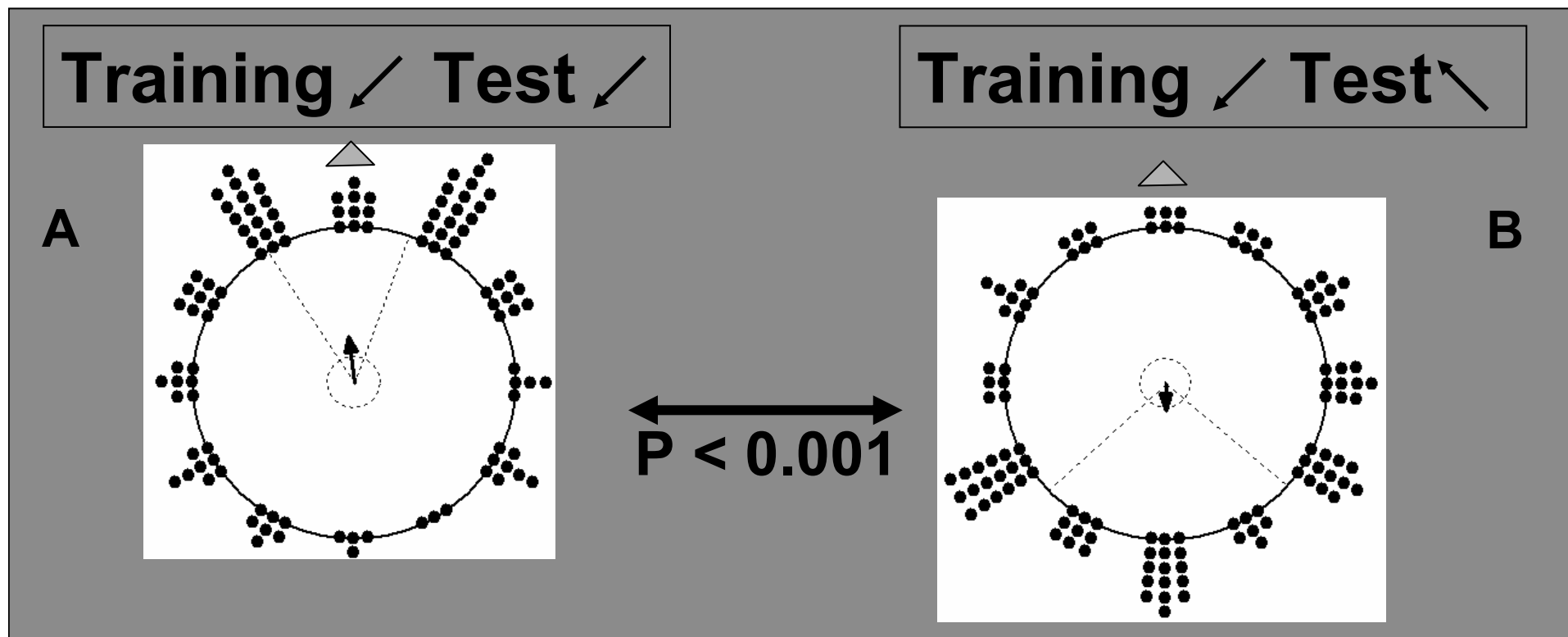
$N = 100$   
 $\theta = 60^\circ$   
 $\Phi = 57,1^\circ$   
 $r = 0,31$   
 $s = 67,3^\circ$

# Rozlišení inklinanční a polaritní reakce ukazuje na typ recepce



9. Inklinanční kompas ptáků. Normální orientace (a). Otočíme-li experimentálně vertikální složku geomagnetického pole (b), má to stejný účinek jako otočení složky horizontální (c). Ptáci (ale také čolci a želvy) odvozují tedy polaritu pole ze znaménka sklonu pole (inklinace). (Podle: Wiltschko W., Wiltschko R.: J. Comp. Physiol. A 191, 675–693, 2005)

# Obrácení inklinace otočí orientaci potemníka – kompas není polaritní

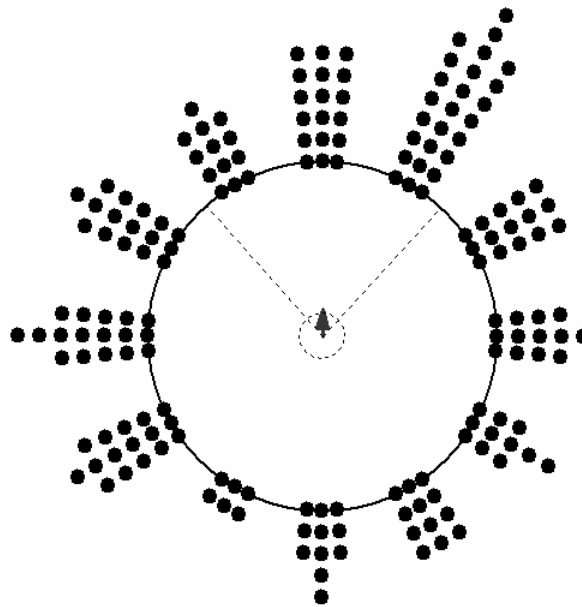


**N = 109**  
**MVB = 354°**  
**P < 0.001**

**N = 115**  
**MVB = 179°**  
**P = 0.03**

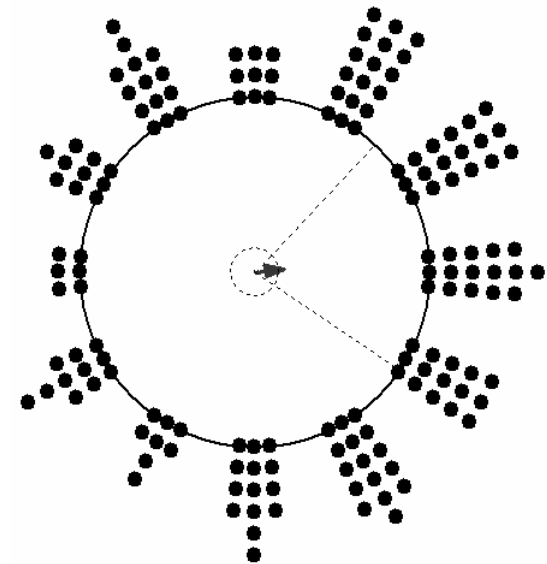
# Změna barvy světla způsobí posun orientace

UV/UV

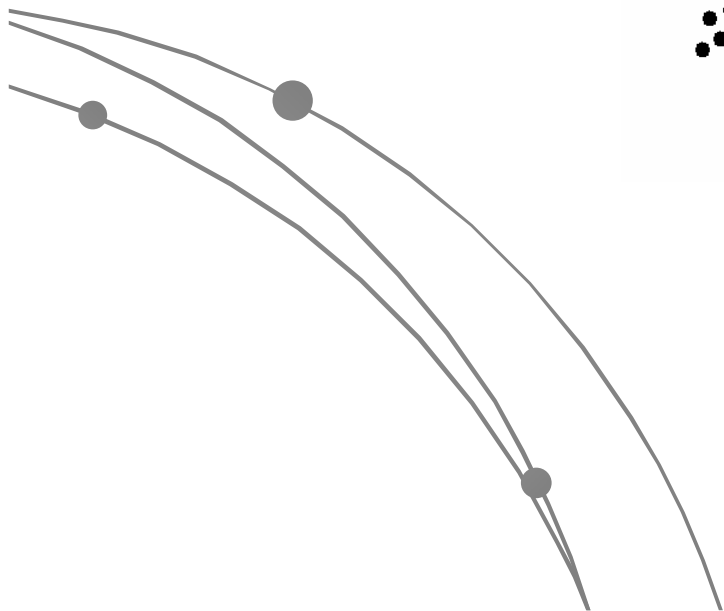


n=174  
MVB=1°  
r=0.16  
P=0.0143

UV/Green

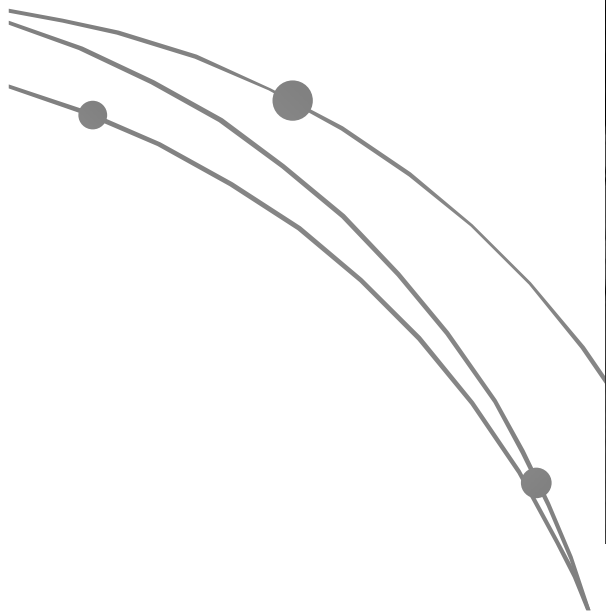


n=155  
MVB=84°  
r=0.17  
P=0.0106

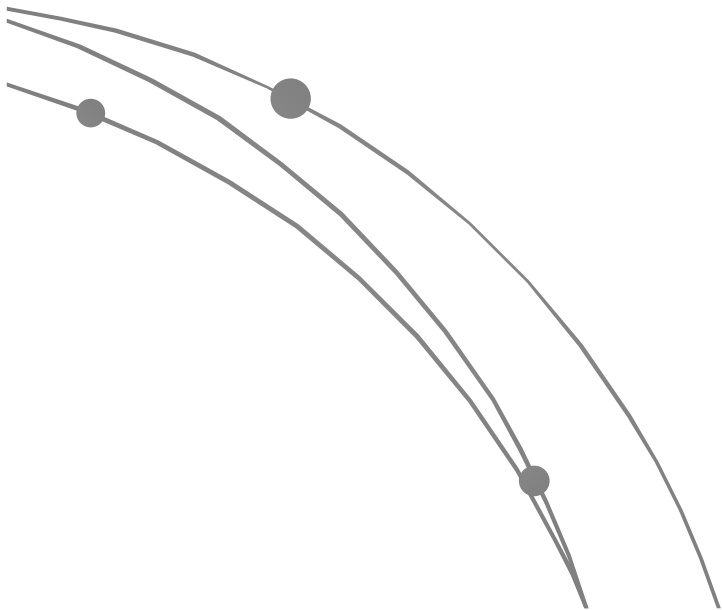




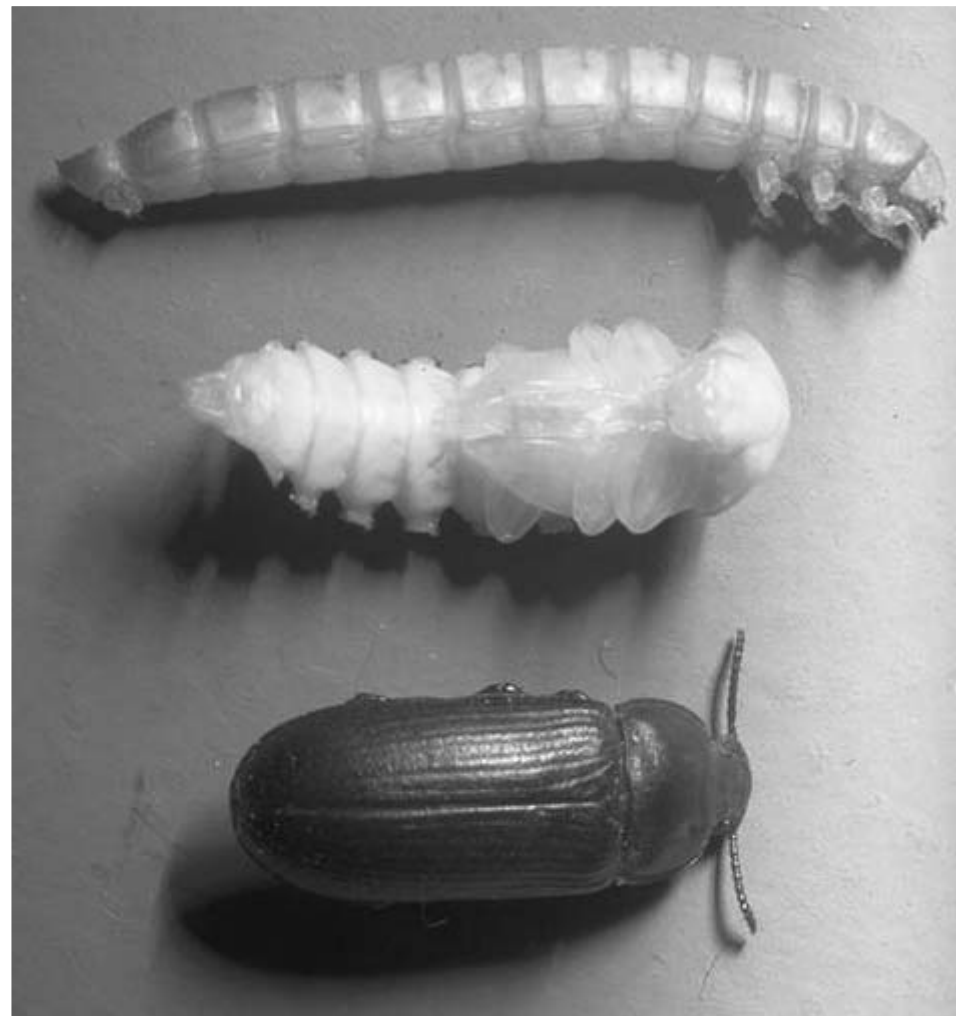
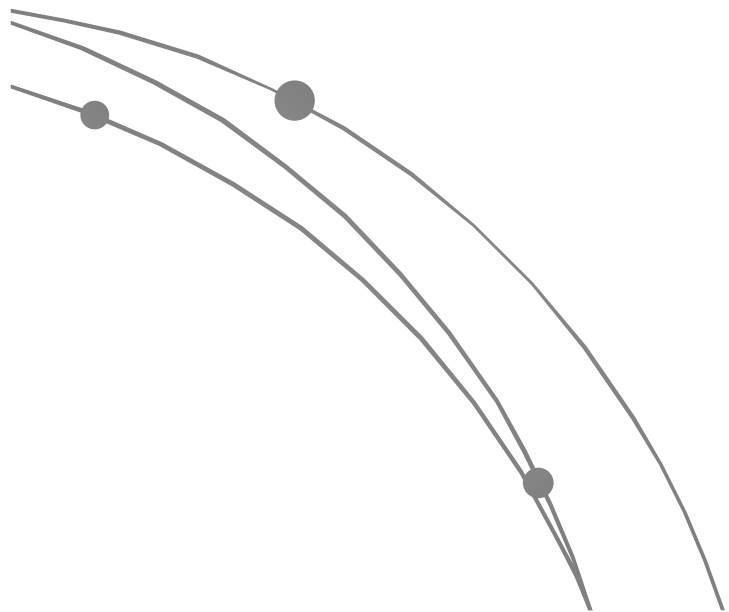
Změna barvy světla způsobí posun orientace



Kompas potemníka Tenebrio má znaky na světle závislého mechanismu.



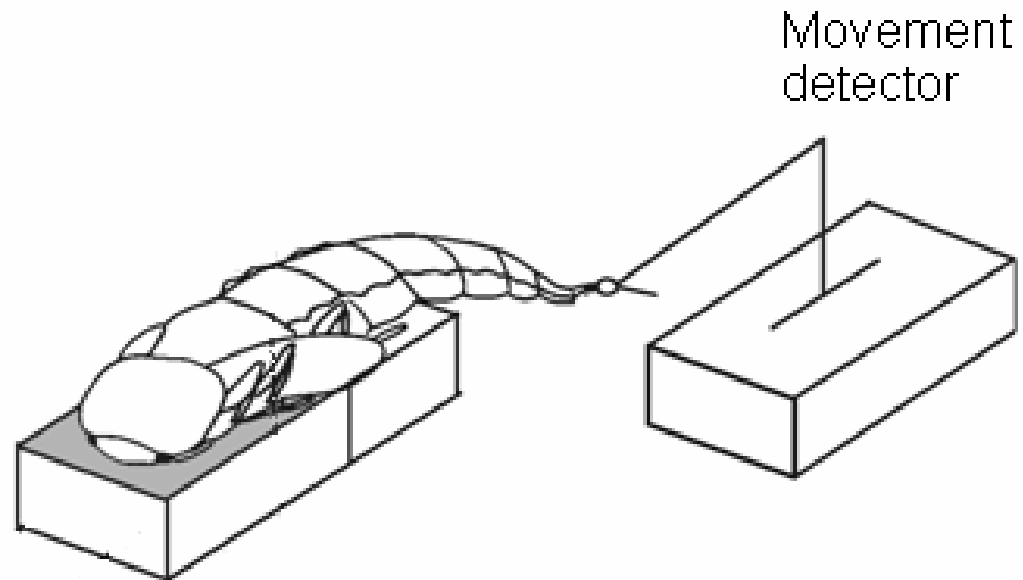
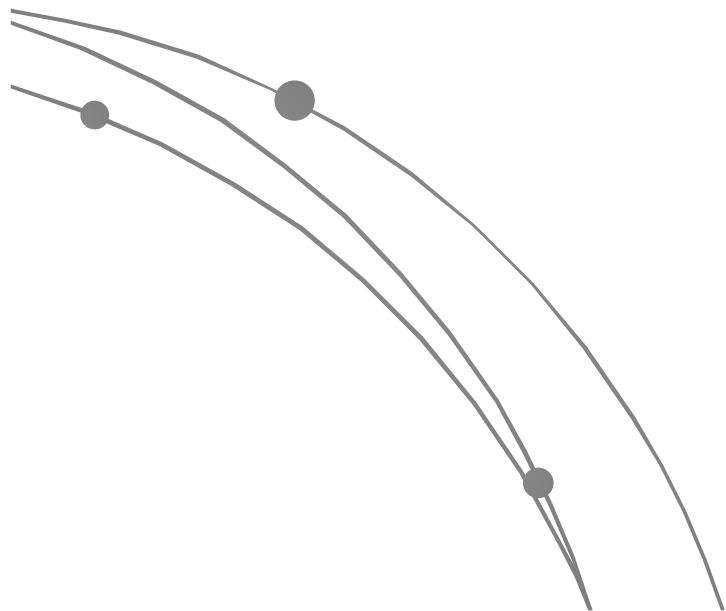
Kukla?

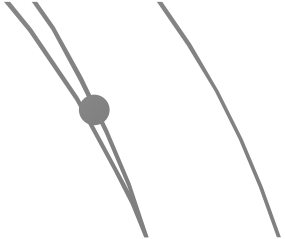
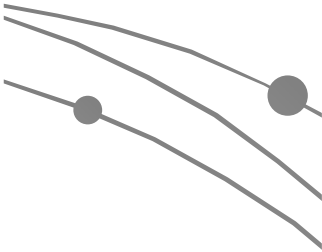
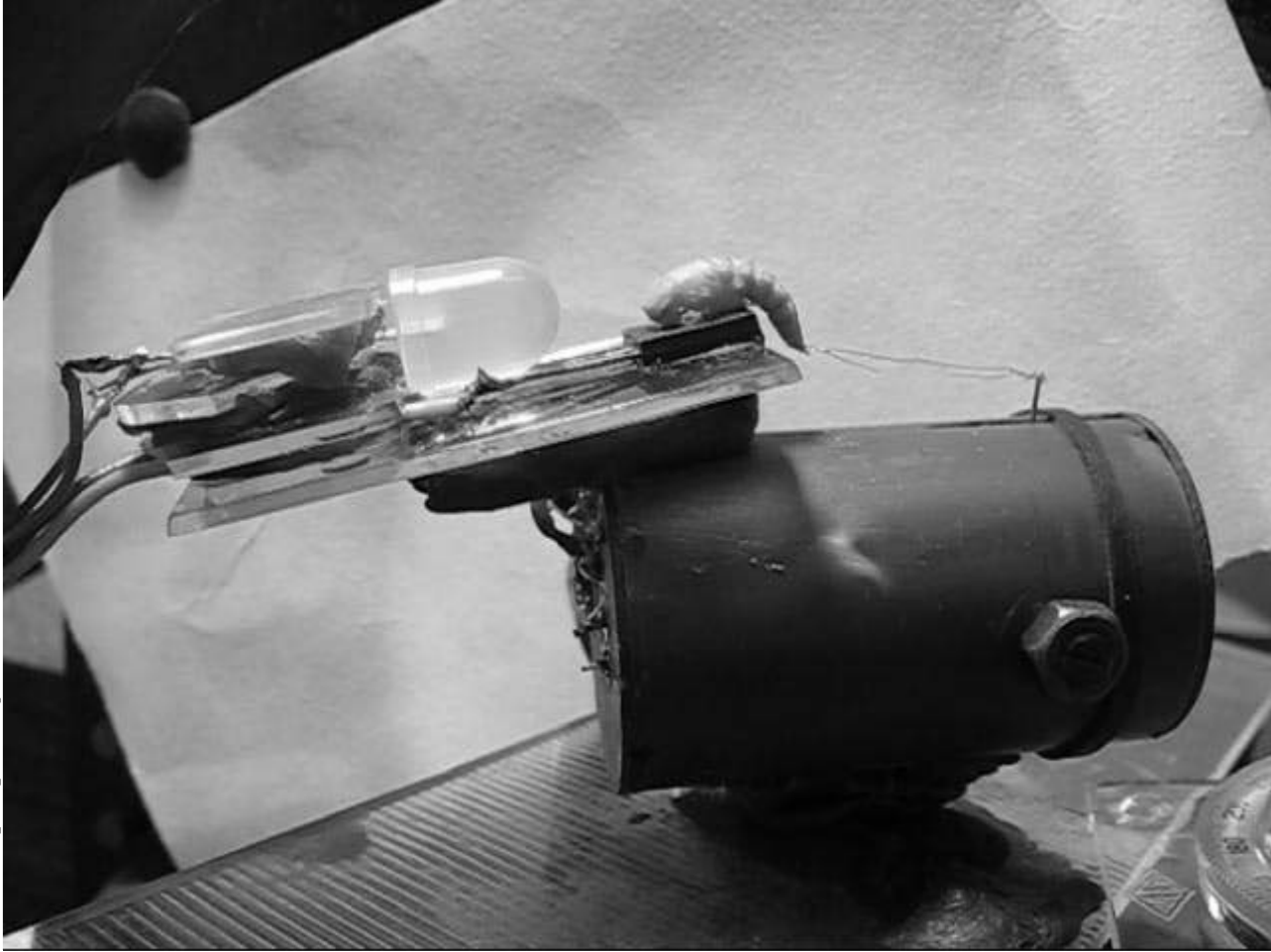


# Kukla jako neuroetologický model

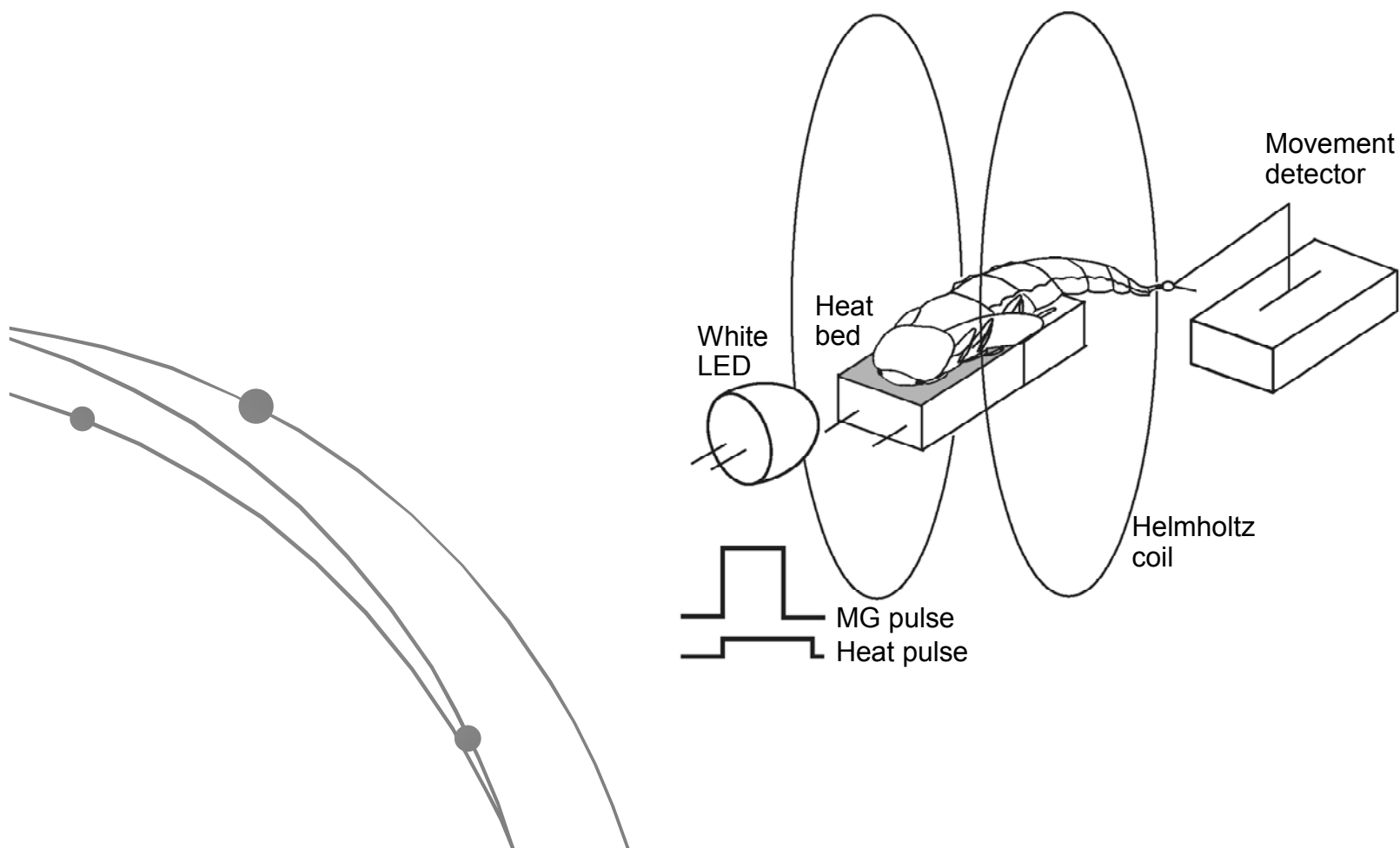


Etologie v jediném parametru  
Nestresována fixací  
Citlivá na vnější podněty

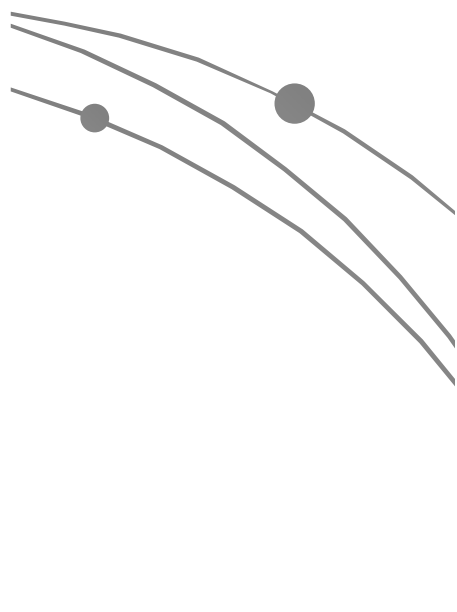




# Podmiňování: magnetický stimul předchází tepelný „trest“

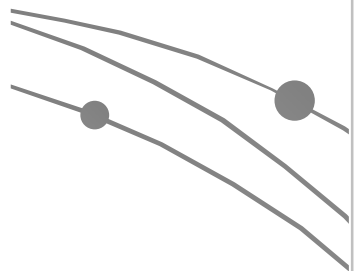
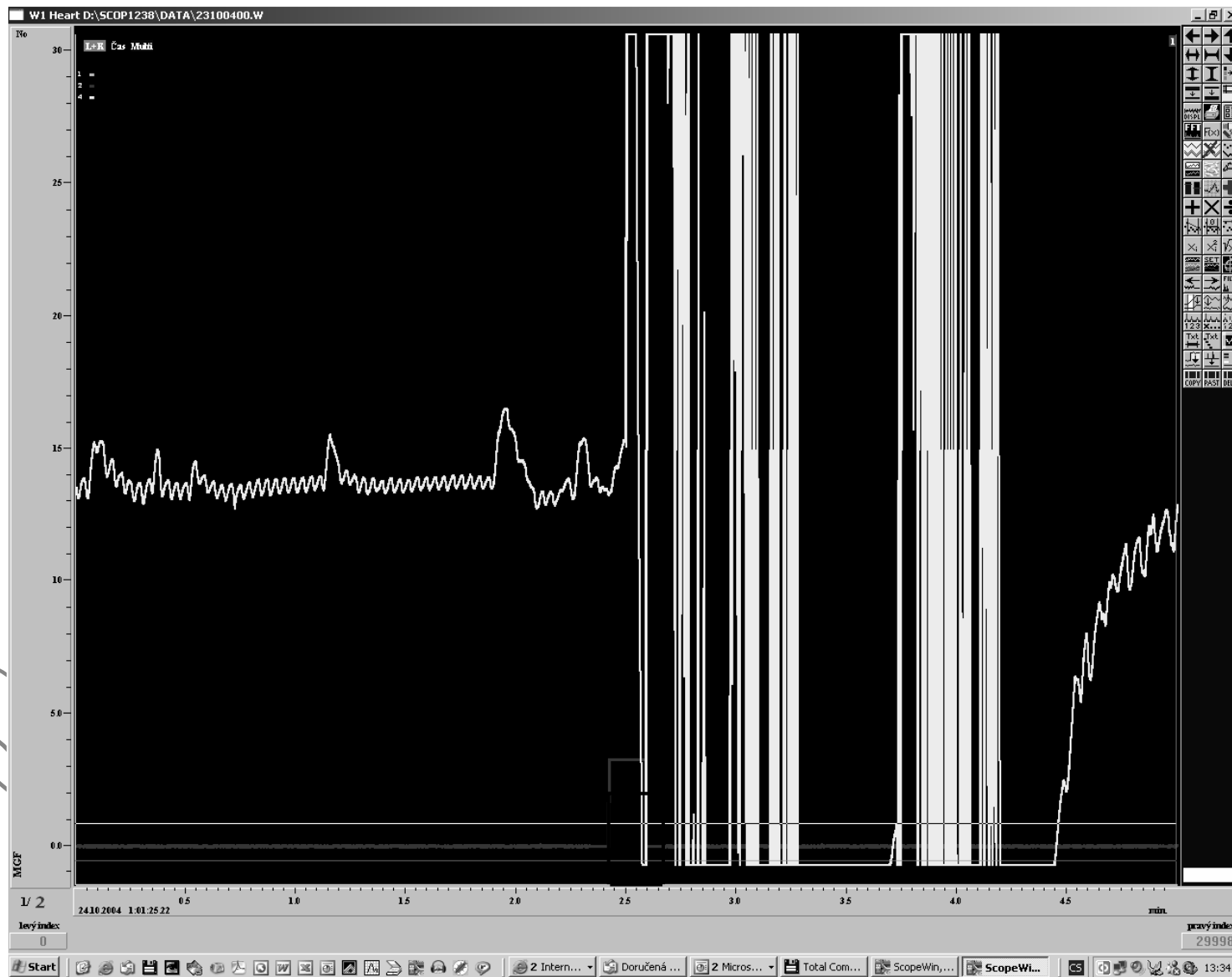


Podmiňování: magnetický stimul předchází tepelný „trest“

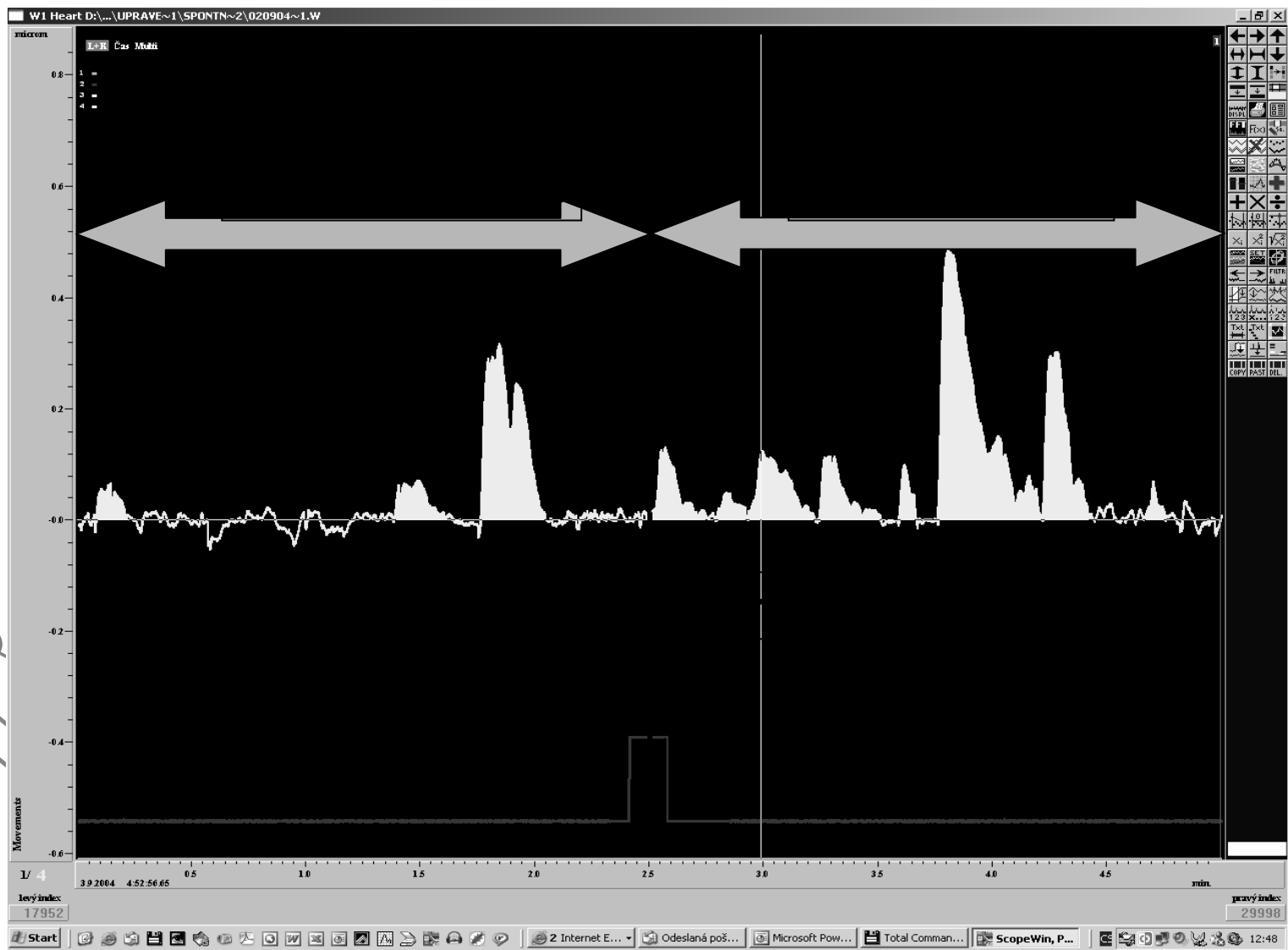




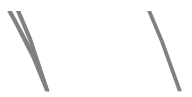
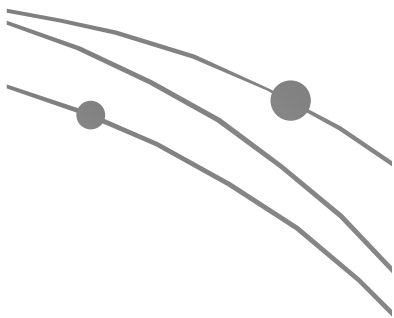
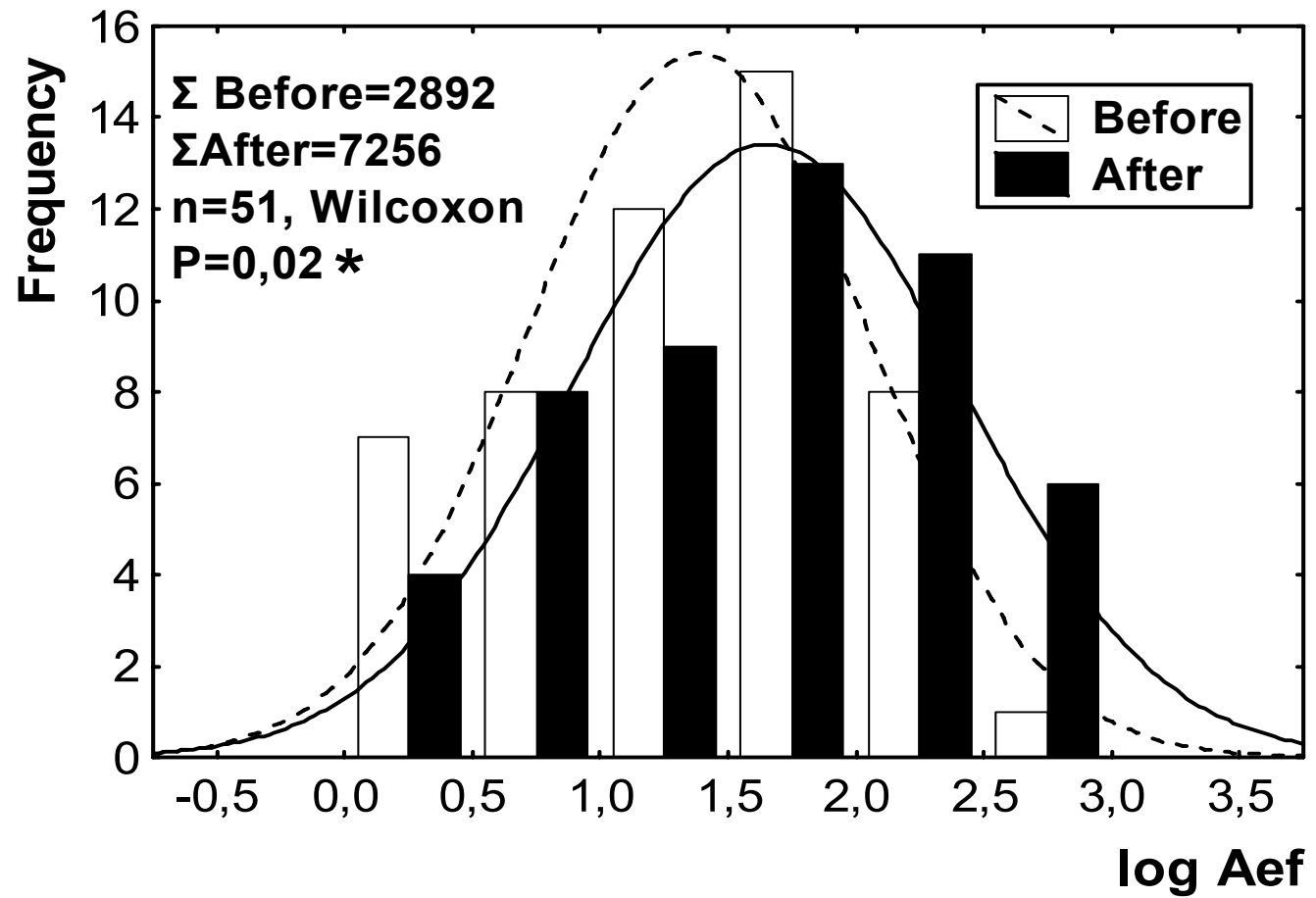
# Trénink:



# Test:



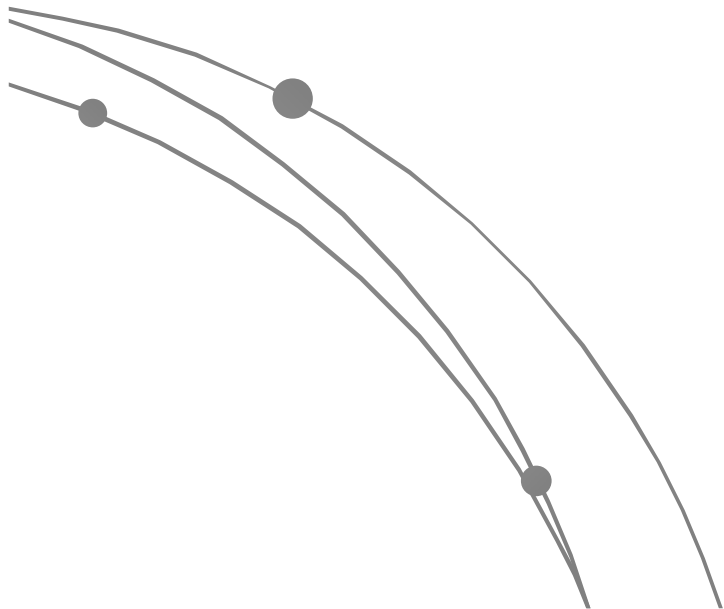
### Conditioned light



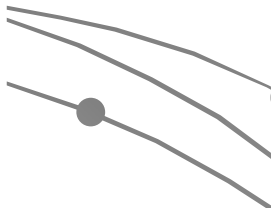
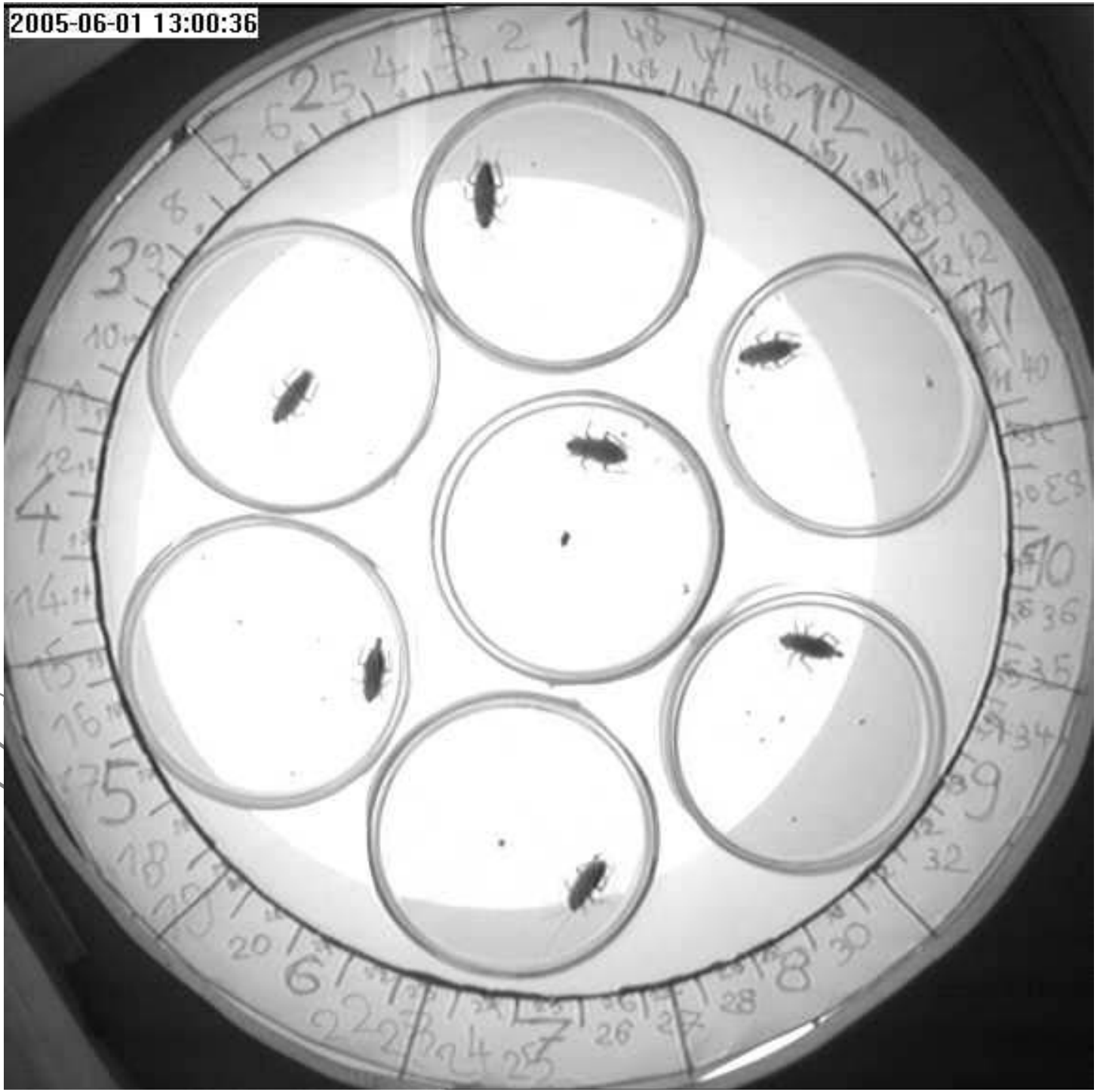
# Nepodmíněná reakce?

- Poziční chování

*Periplaneta americana*

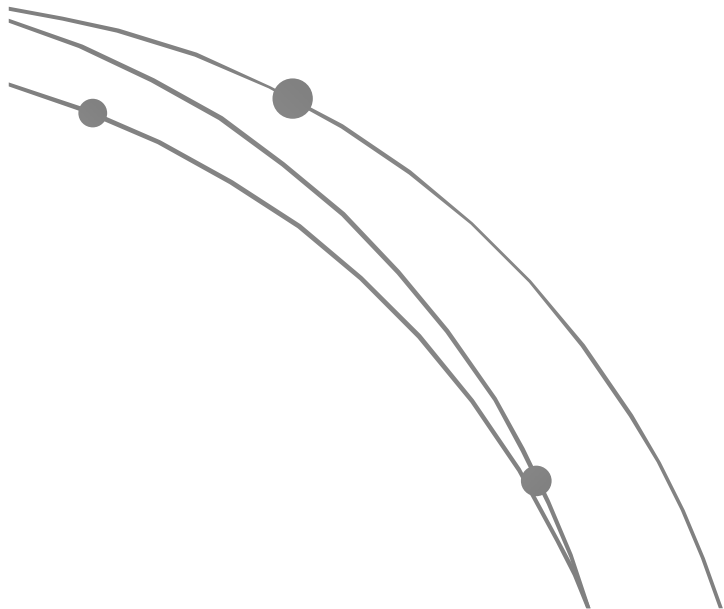


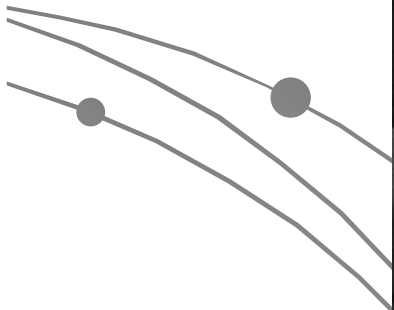
2005-06-01 13:00:36



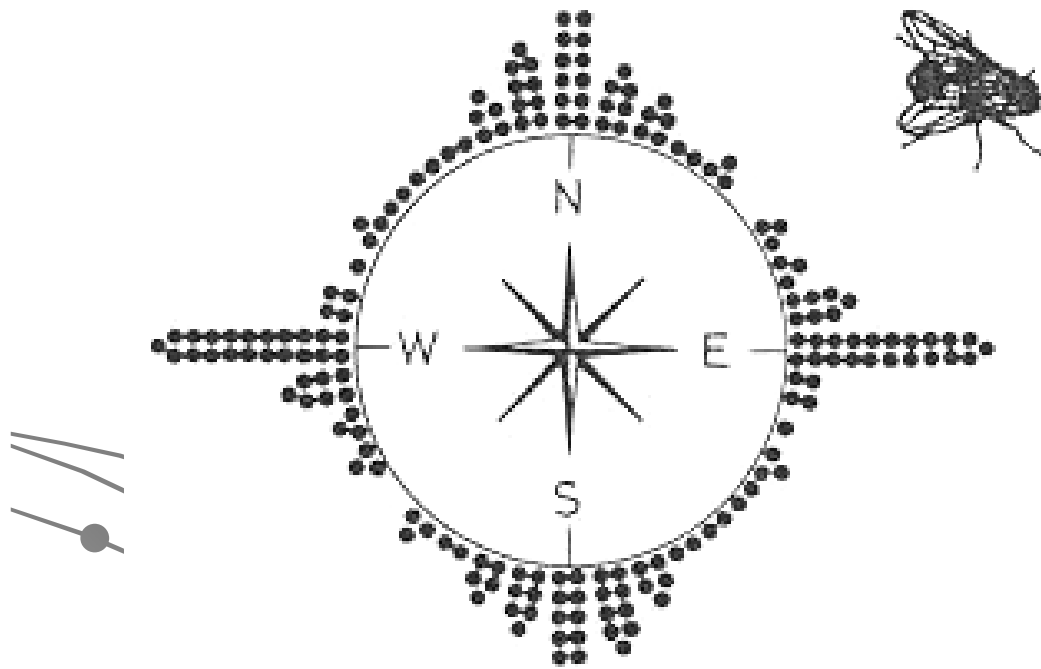
# Methods:

2x4 Helmholtz coil system  
rotating GMF 60°CW

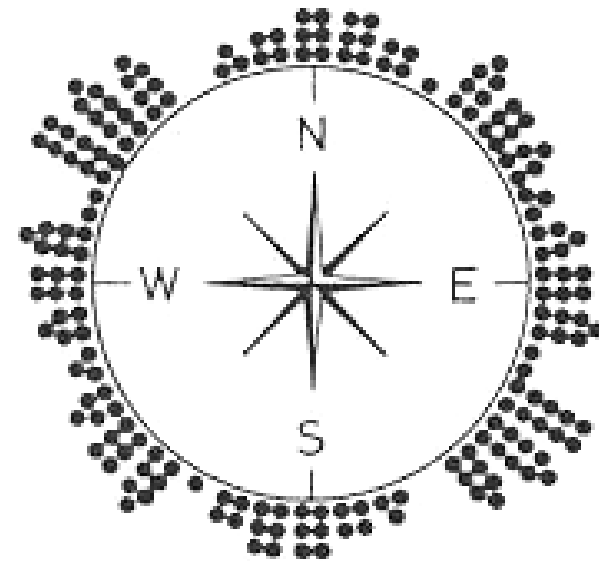




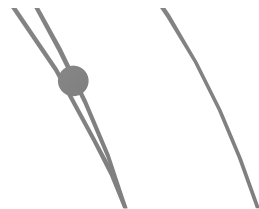
# Alignment behavior



geomagnetic  
field



compensated  
magnetic field



Becker, (1965)



# Alignment behavior

## Natural field

## Field rotated 60° CW

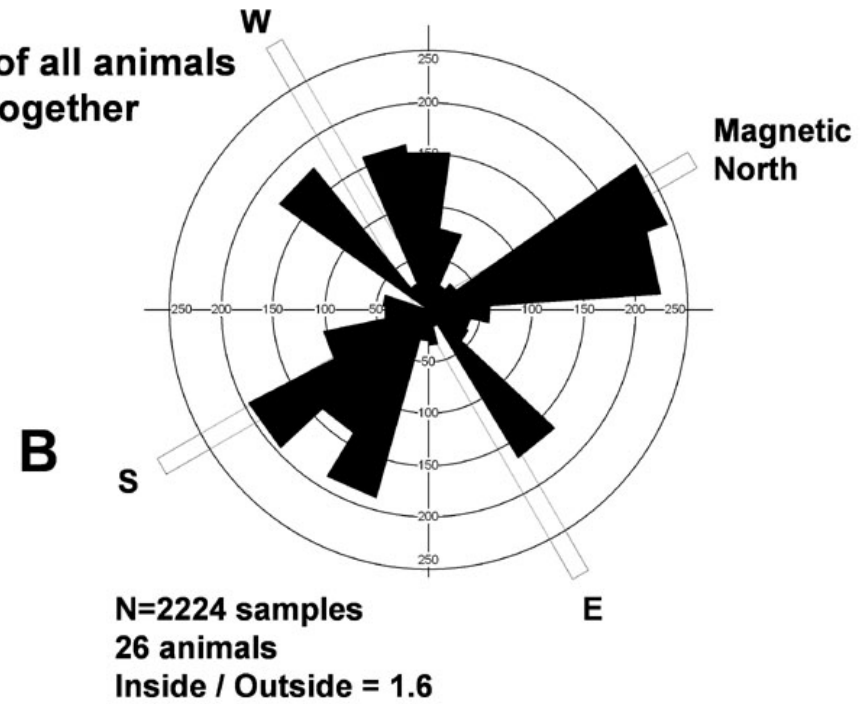
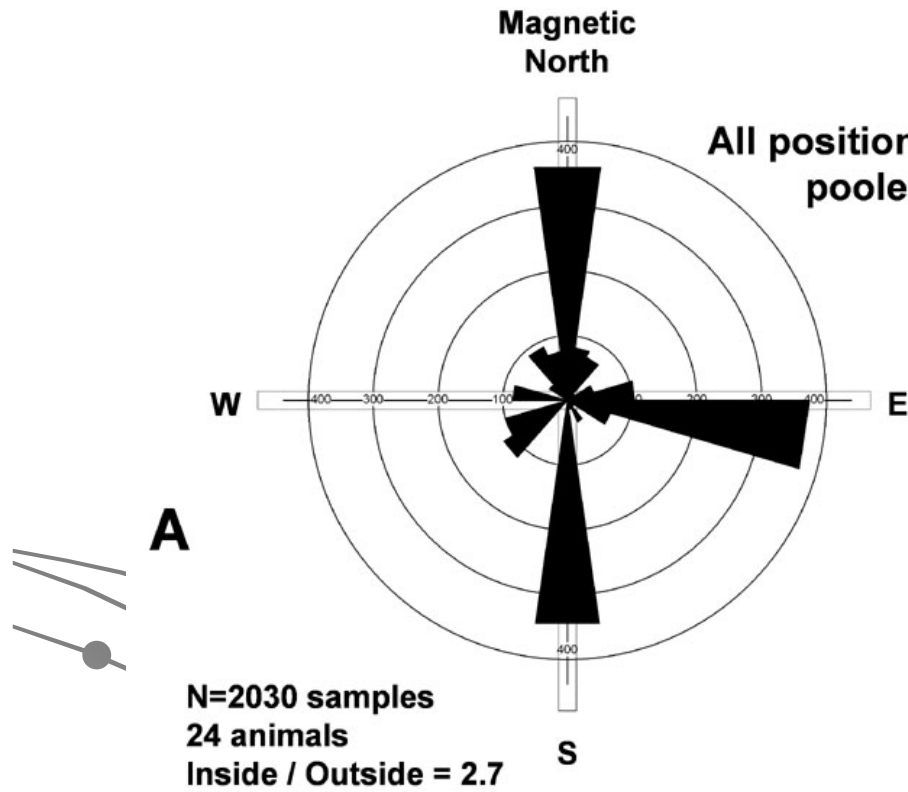
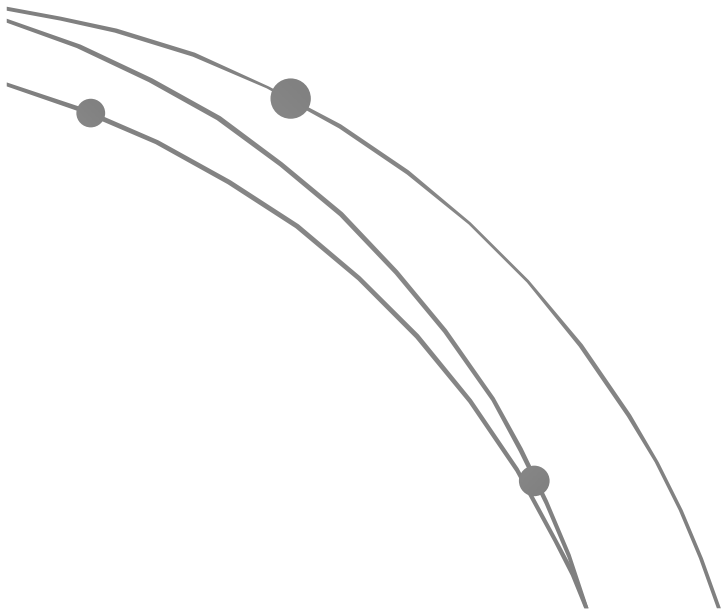
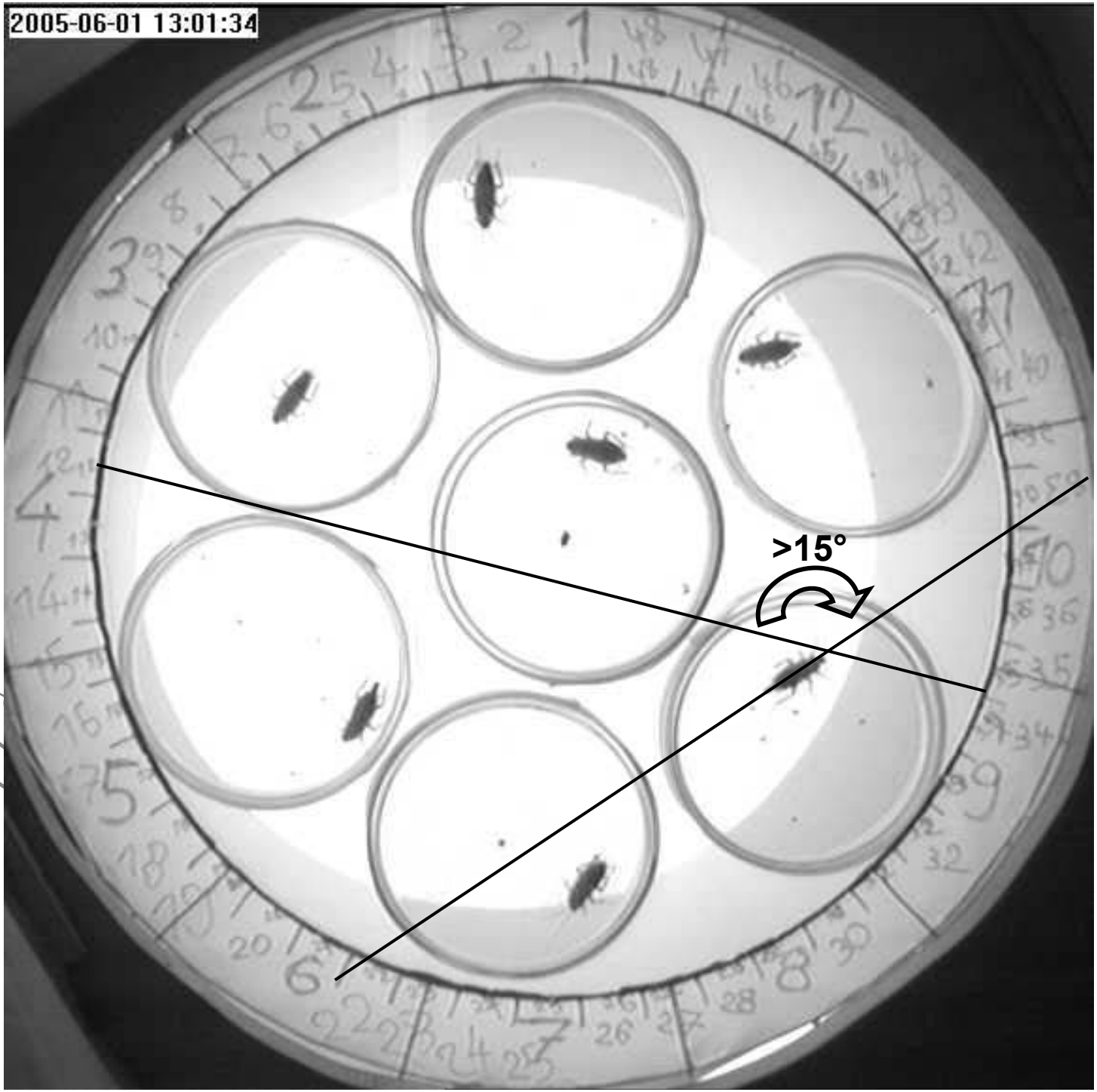


Fig. 1

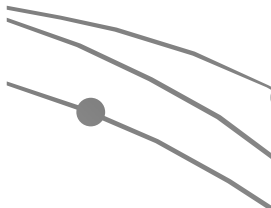
## B) Body turns in rotating field



2005-06-01 13:01:34

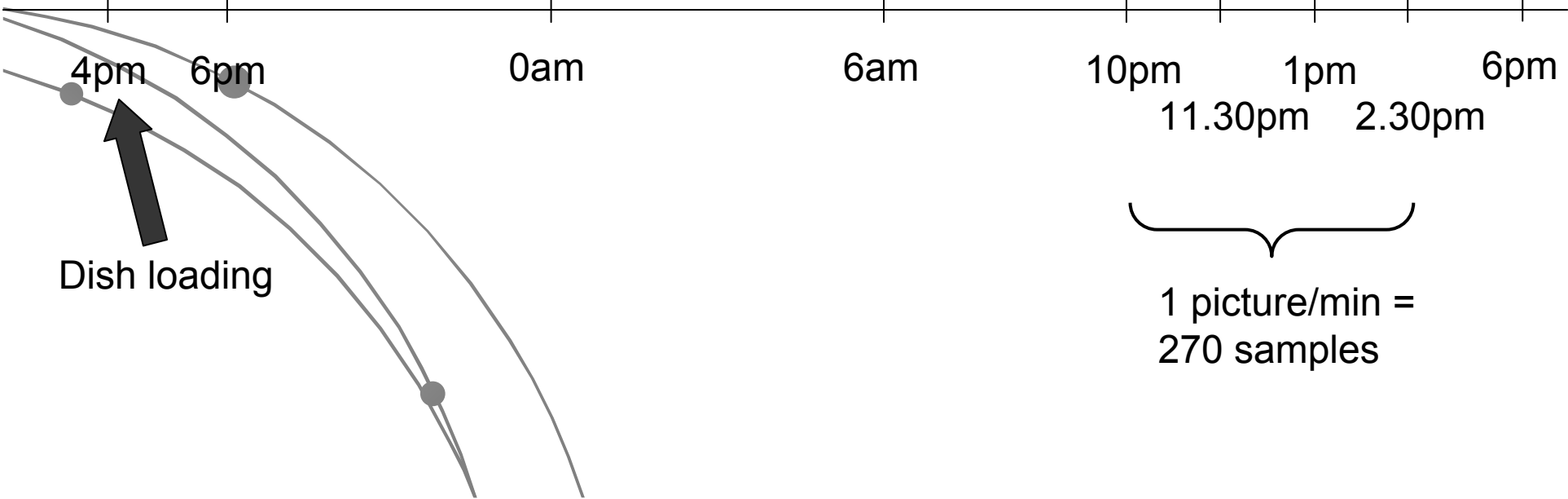


>15°



Time schedule:

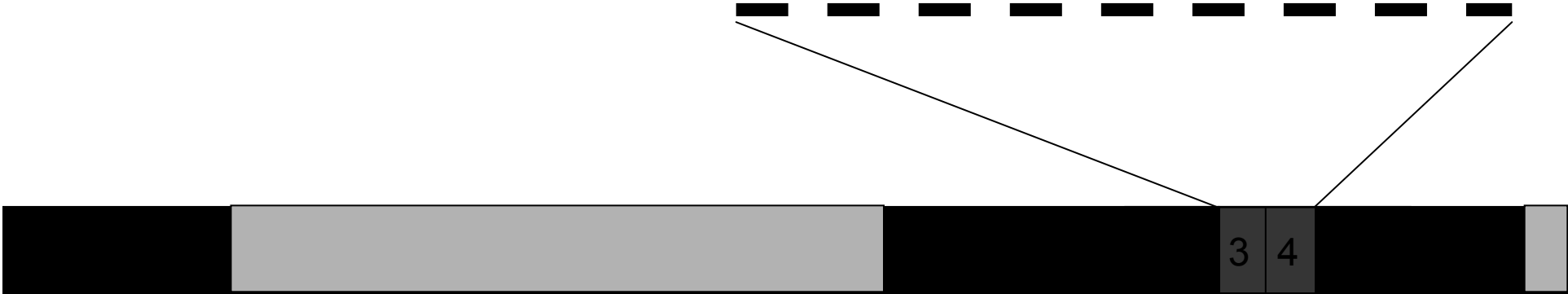
Control



Time schedule:

Test

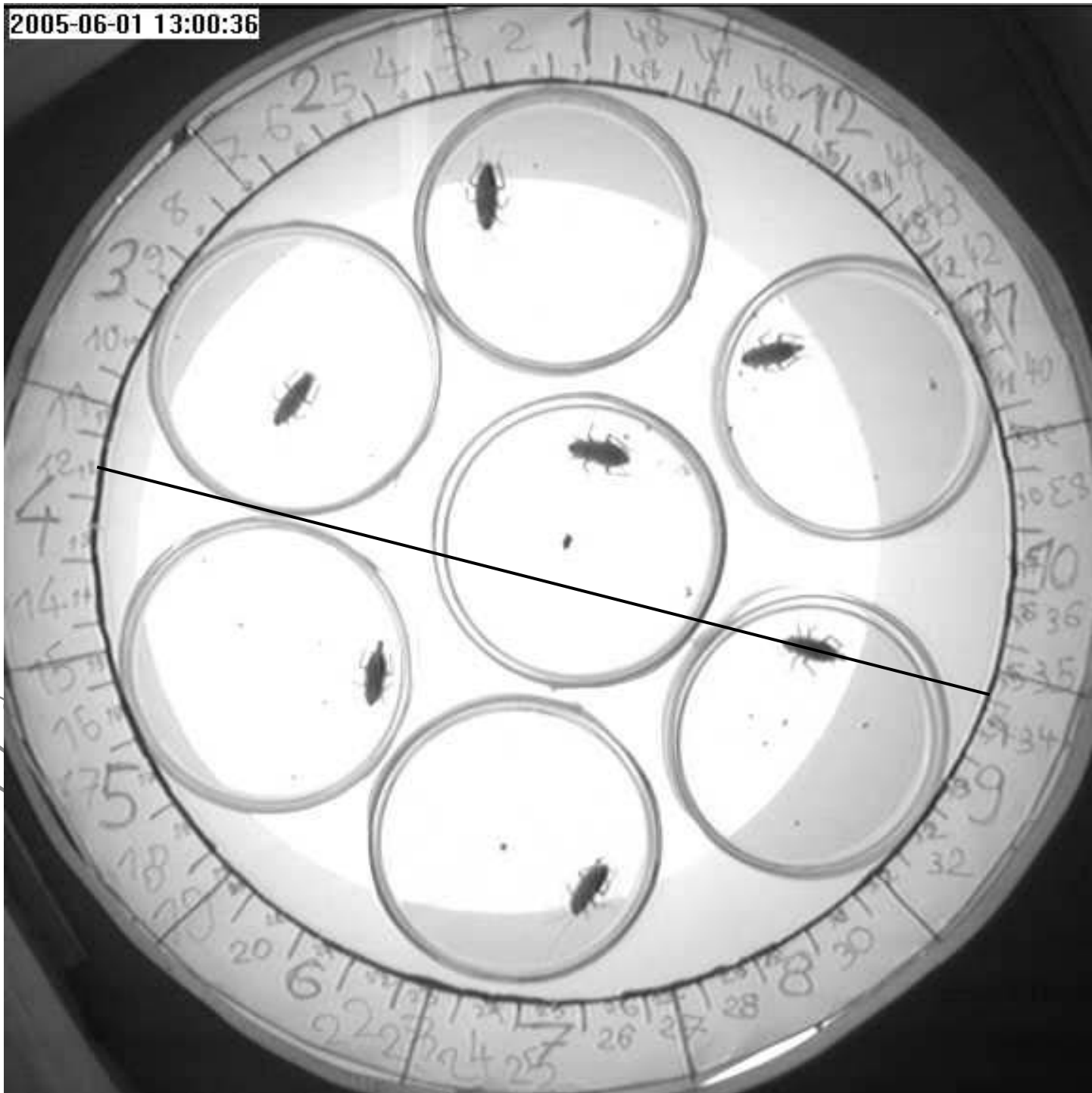
GMF 60° CW rotation  
Pulses 5min/5min



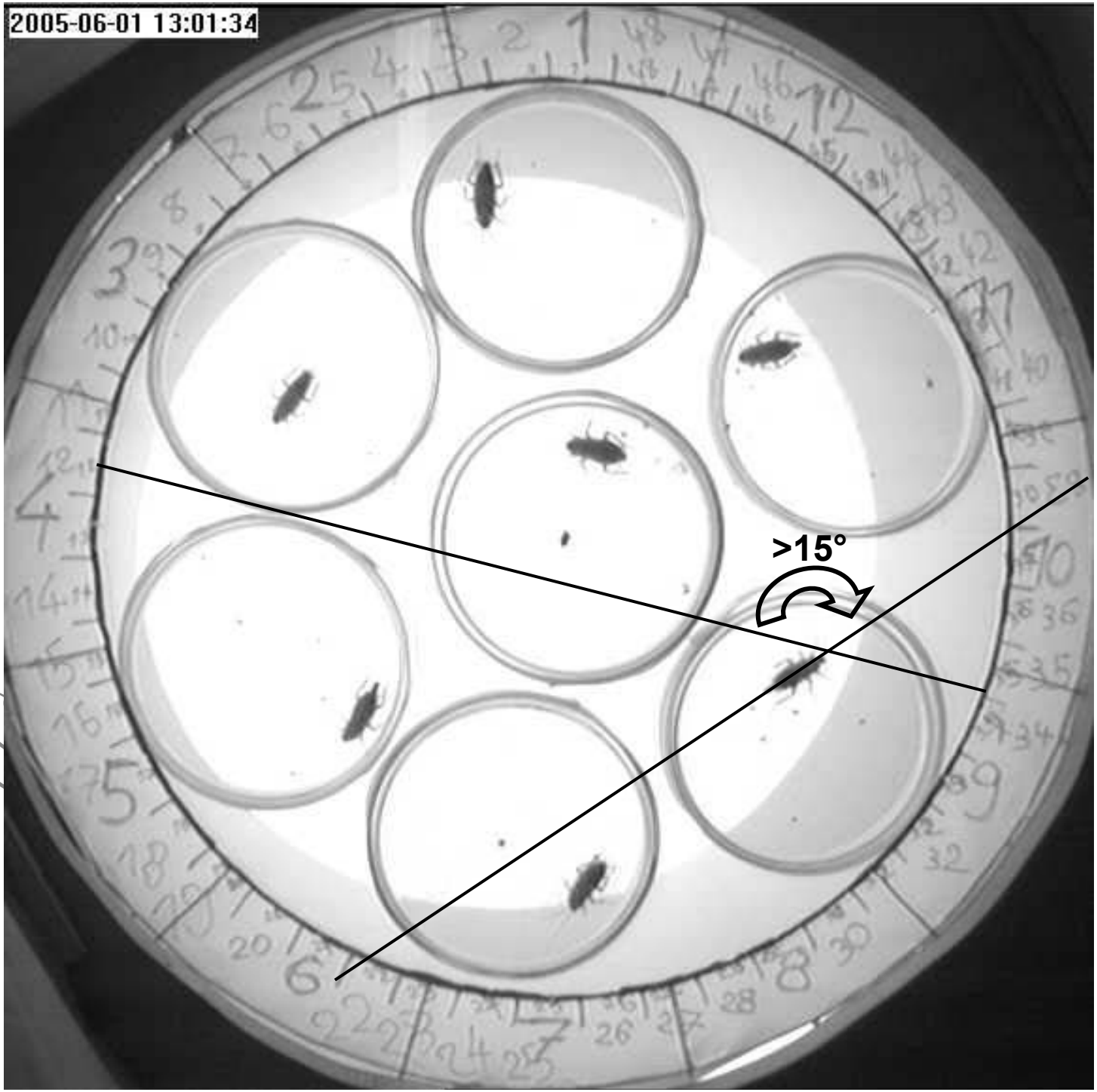
Dish loading

1 picture/min =  
270 samples

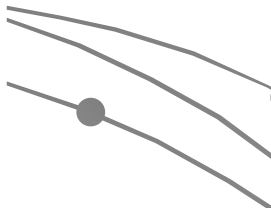
2005-06-01 13:00:36



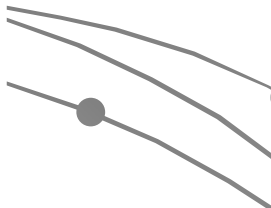
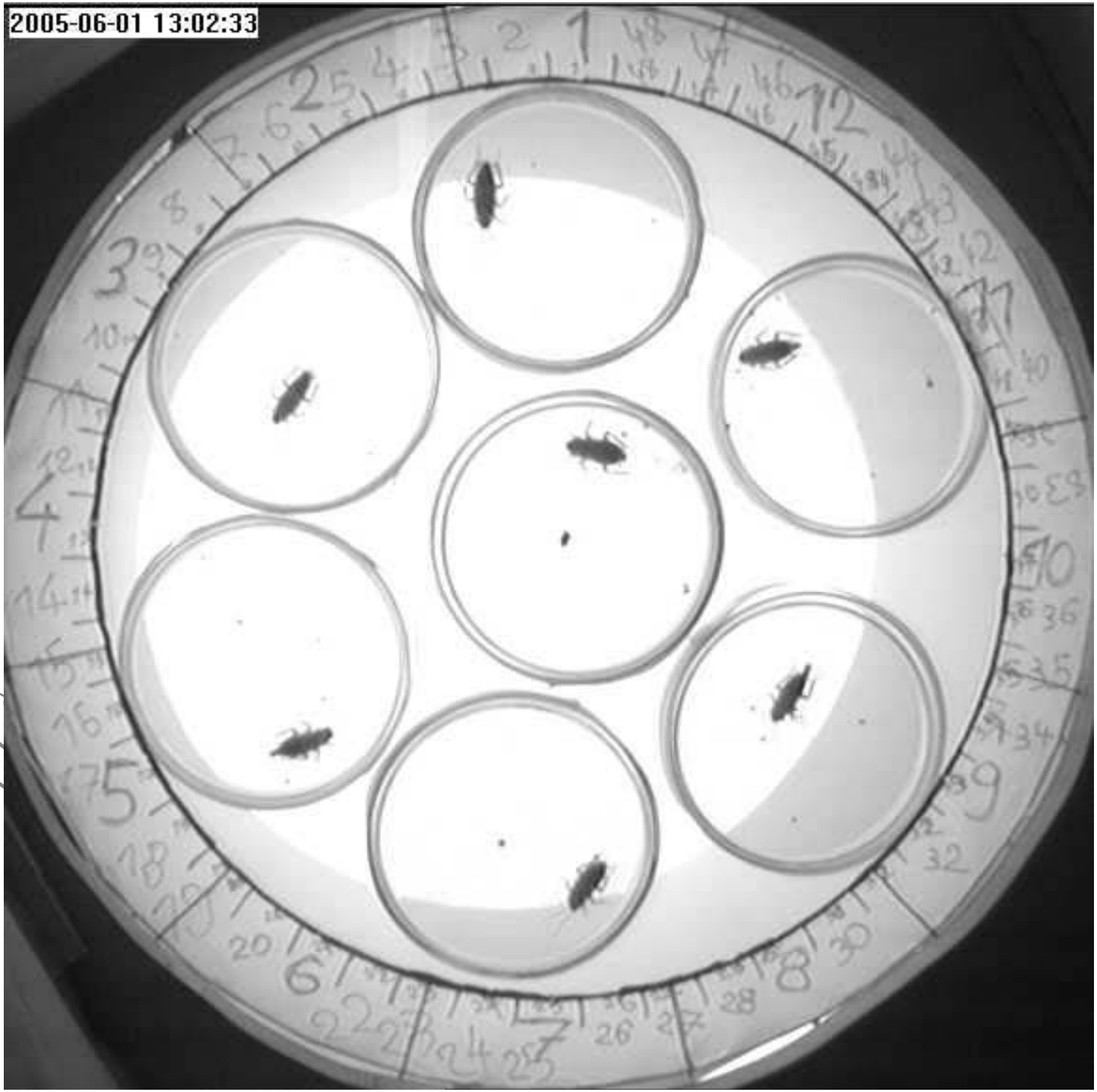
2005-06-01 13:01:34



>15°

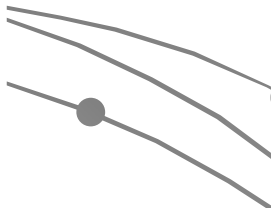
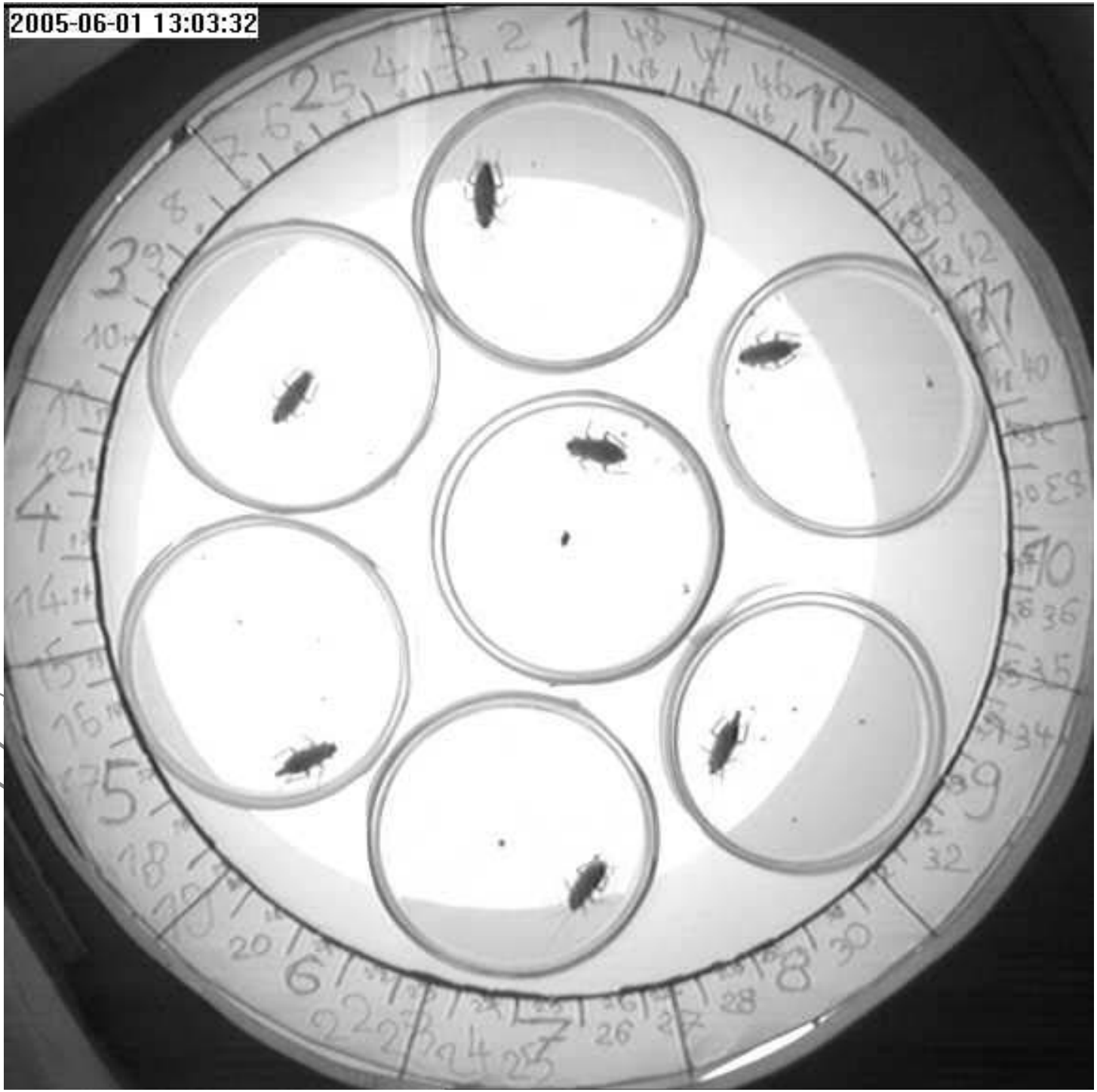


2005-06-01 13:02:33

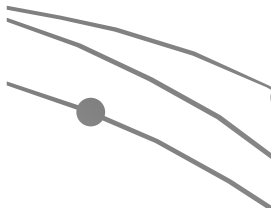
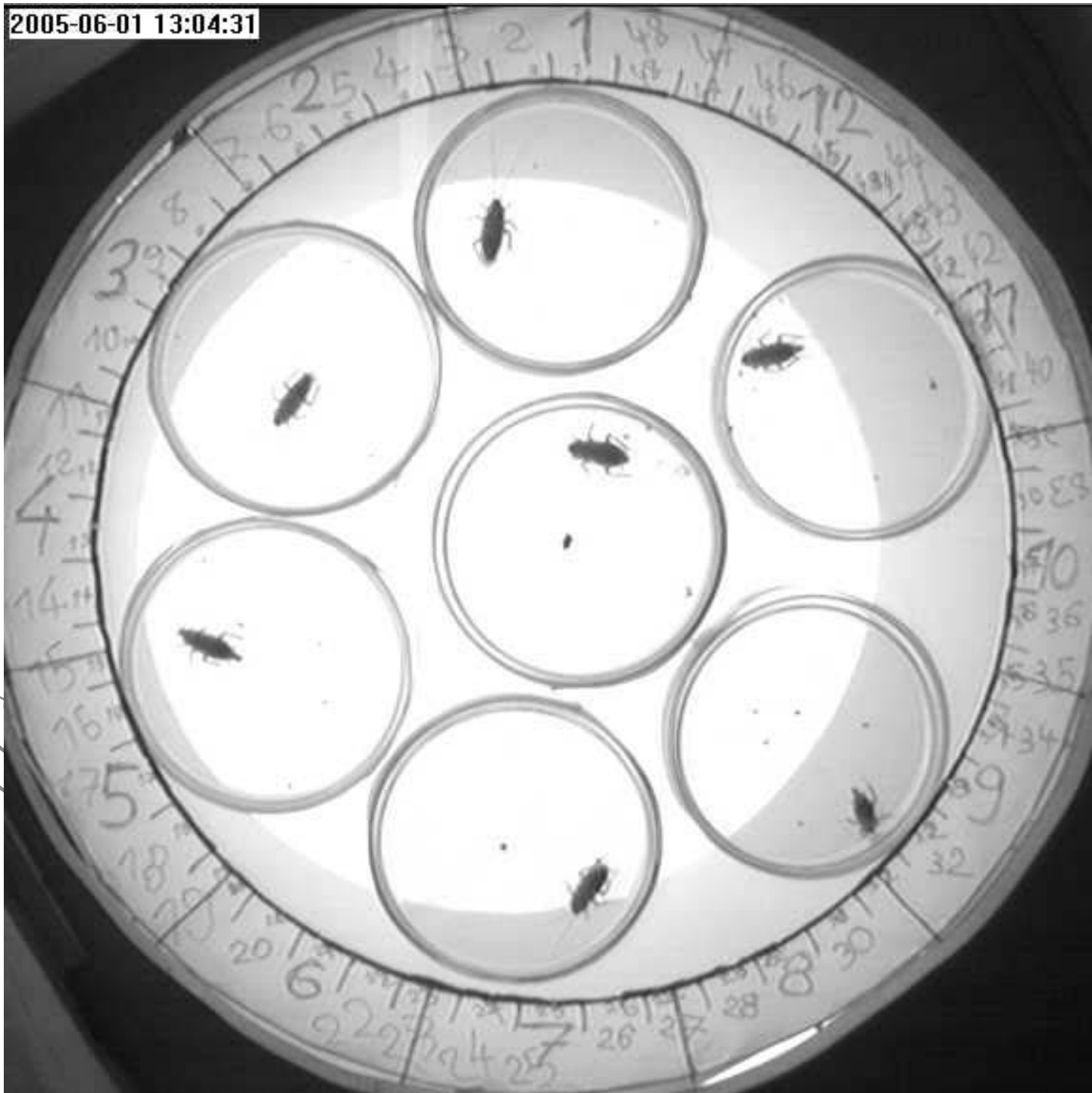




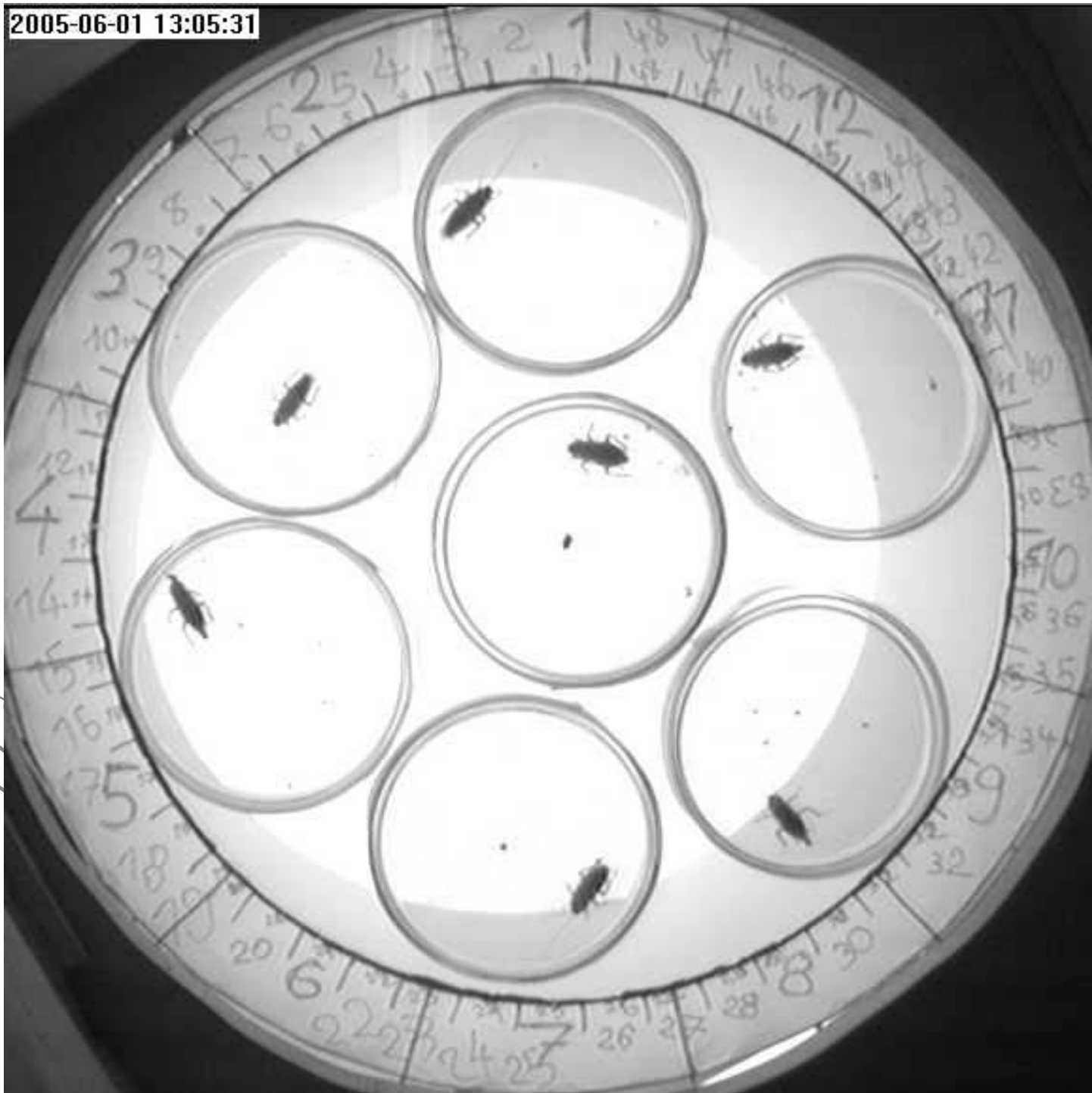
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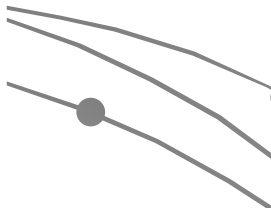
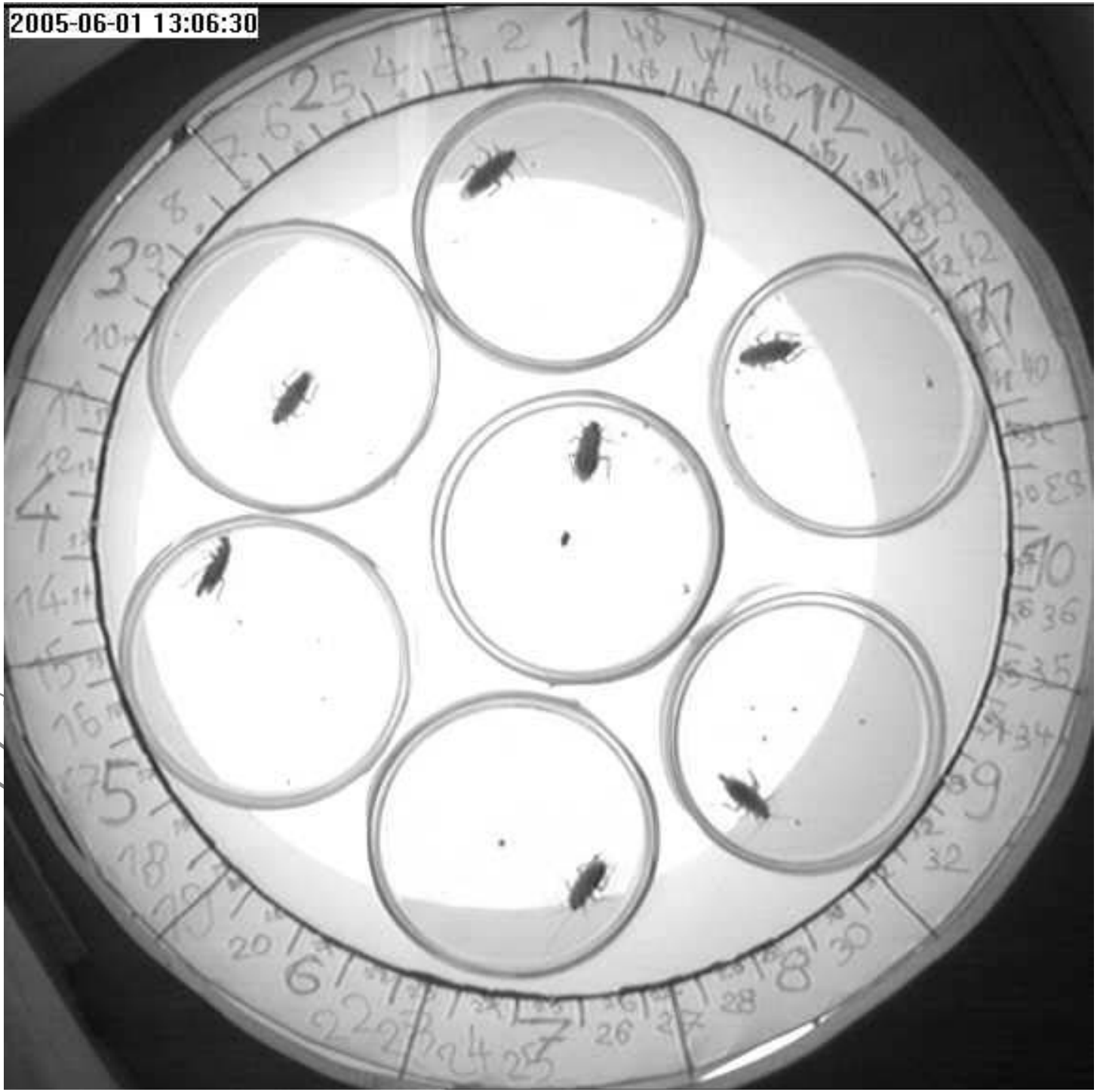
2005-06-01 13:04:31



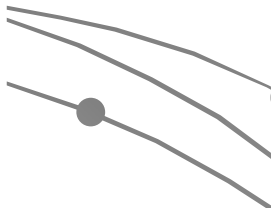
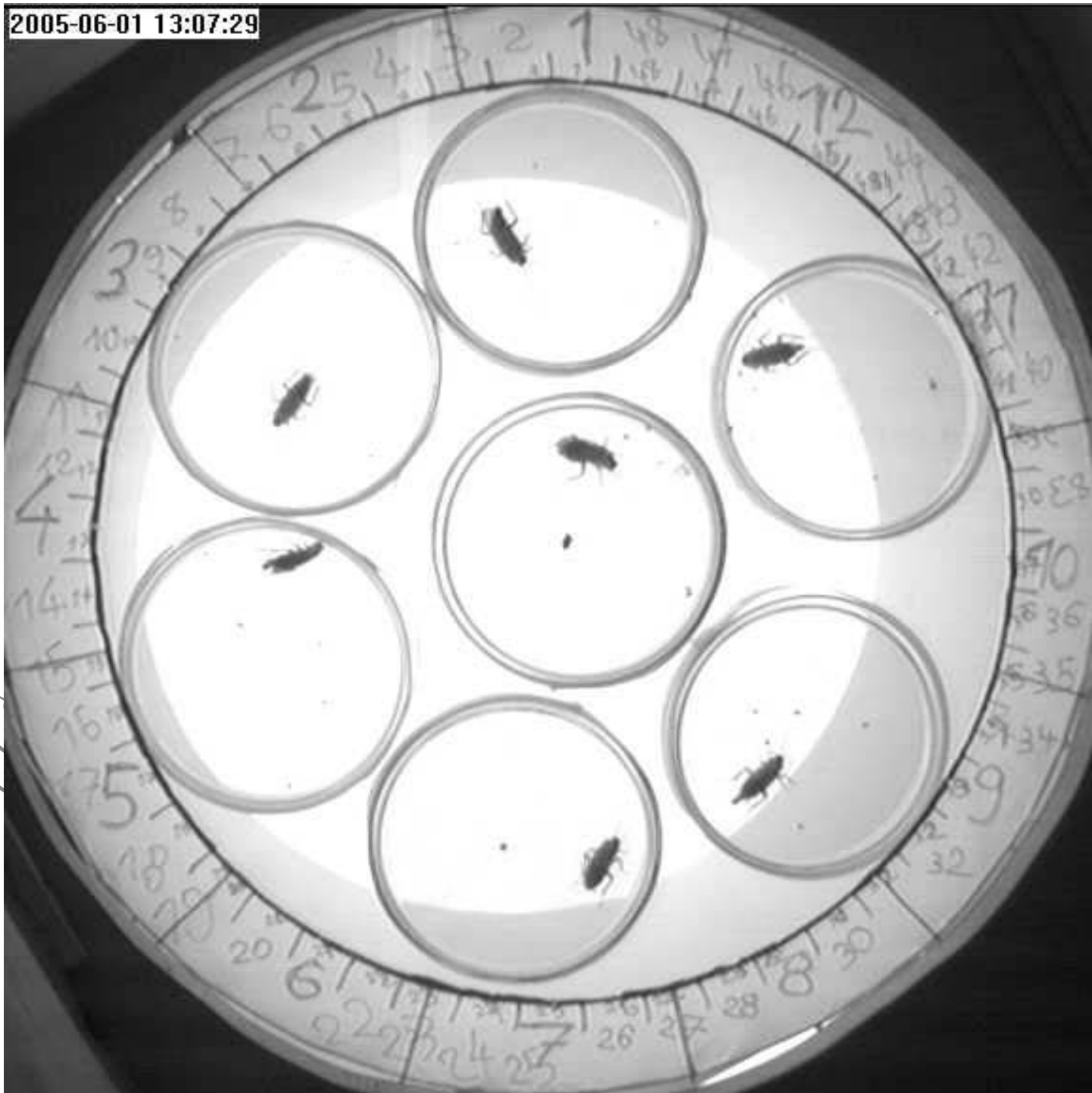
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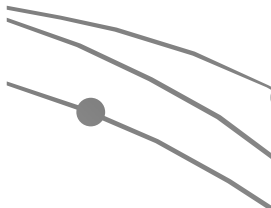
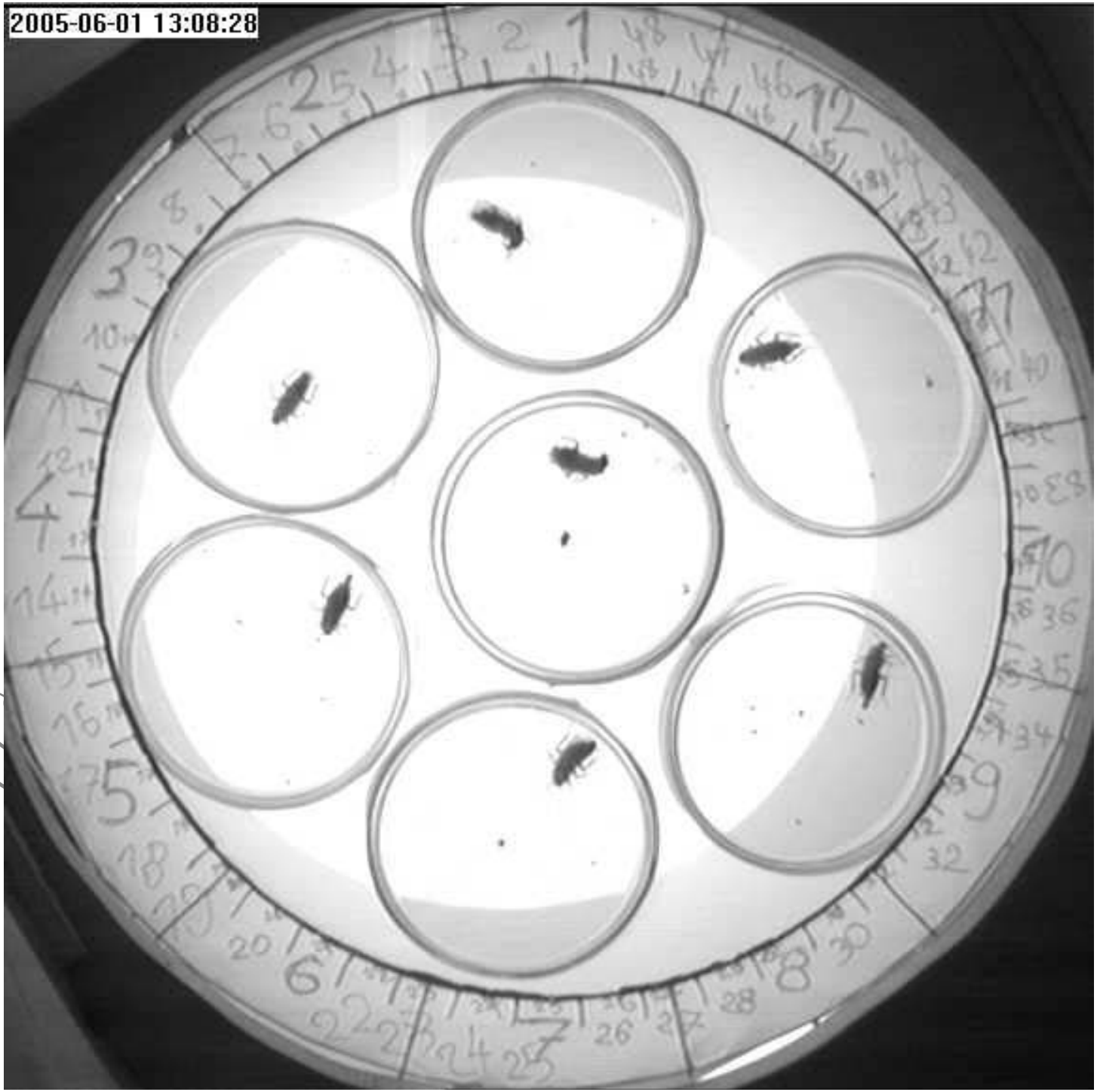
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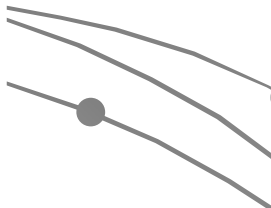
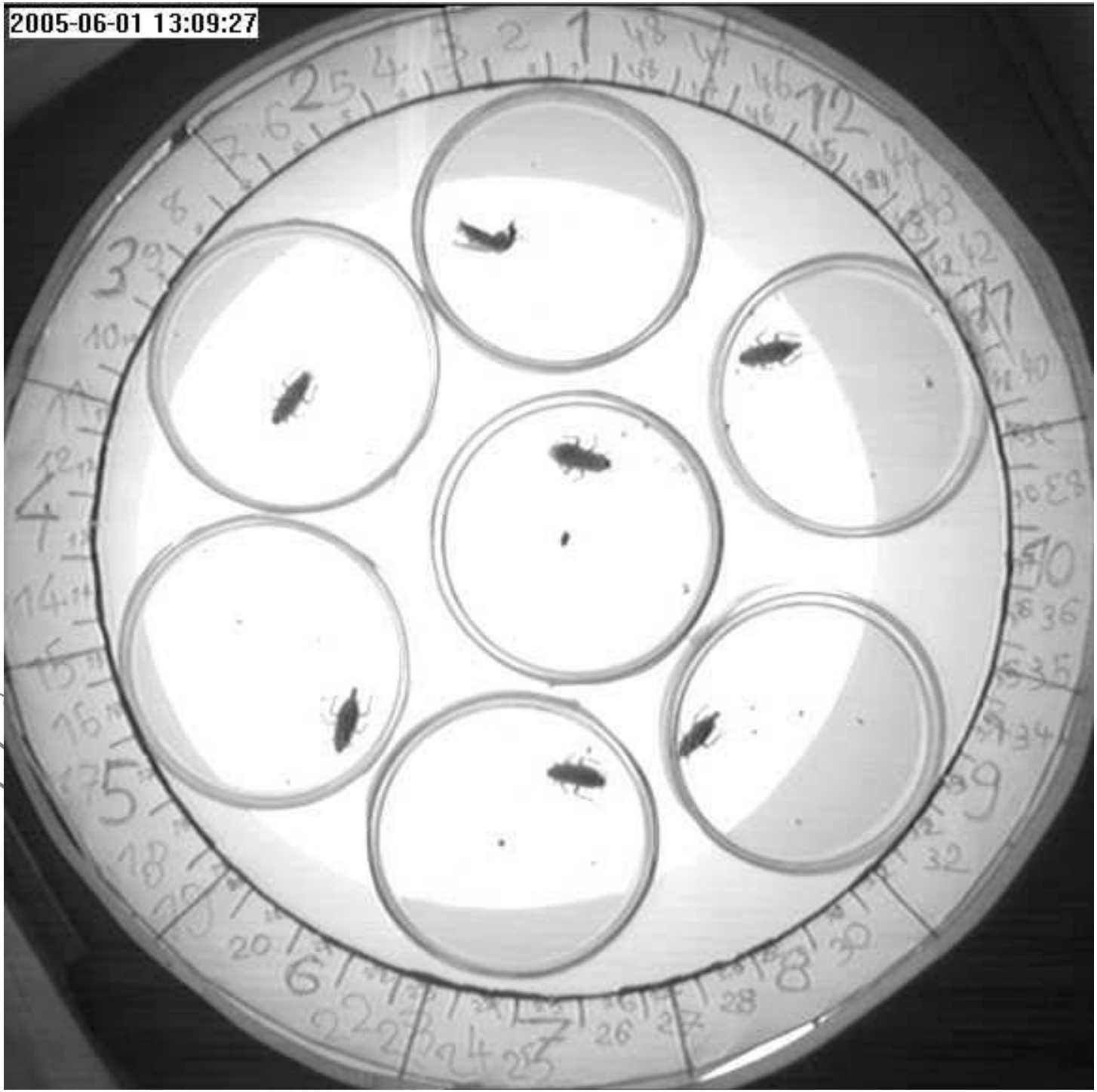
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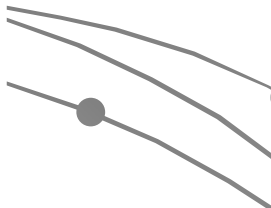
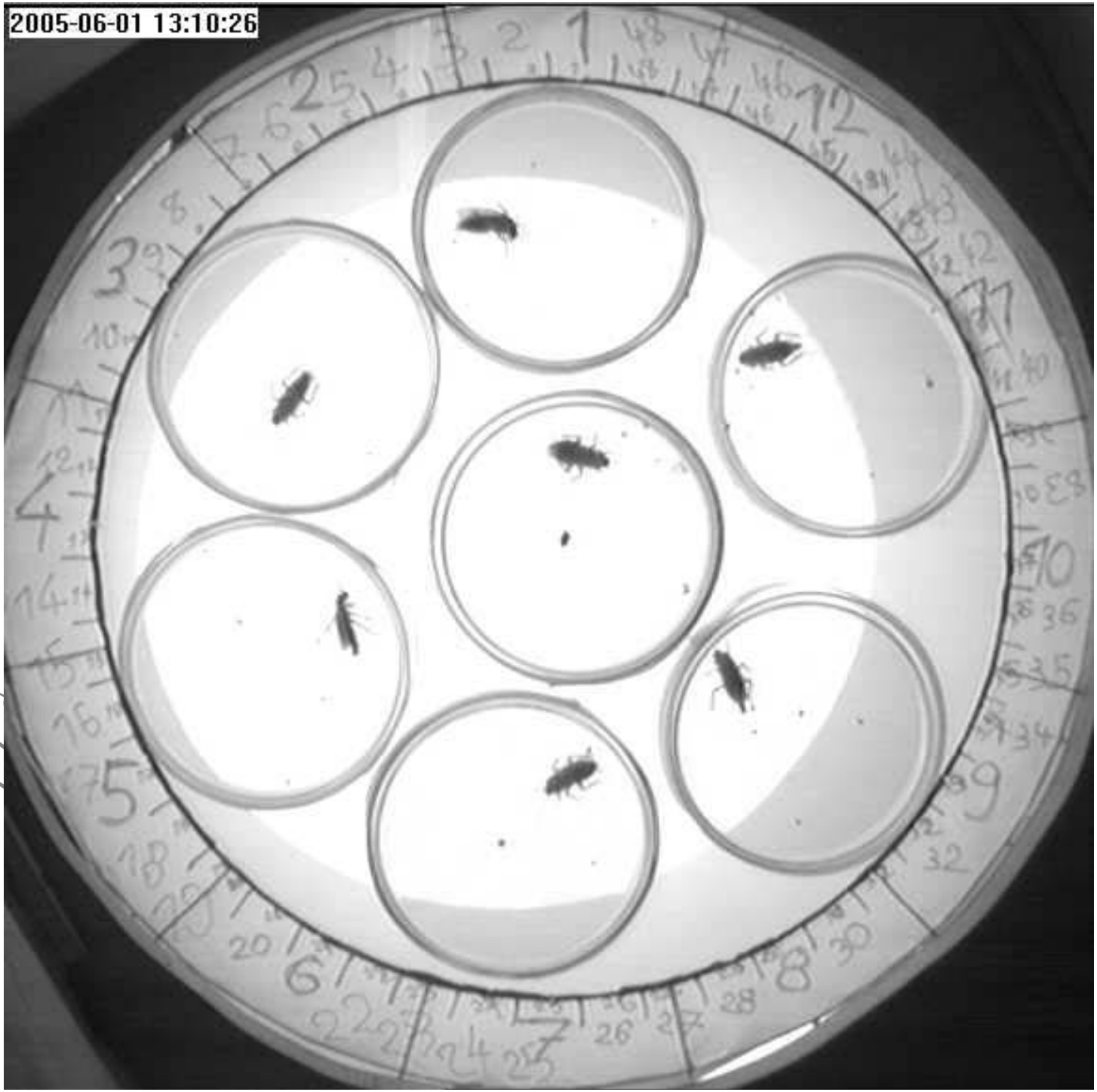
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2005-06-01 13:09:27

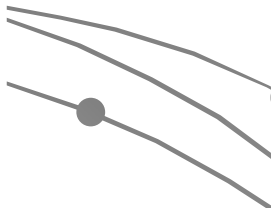
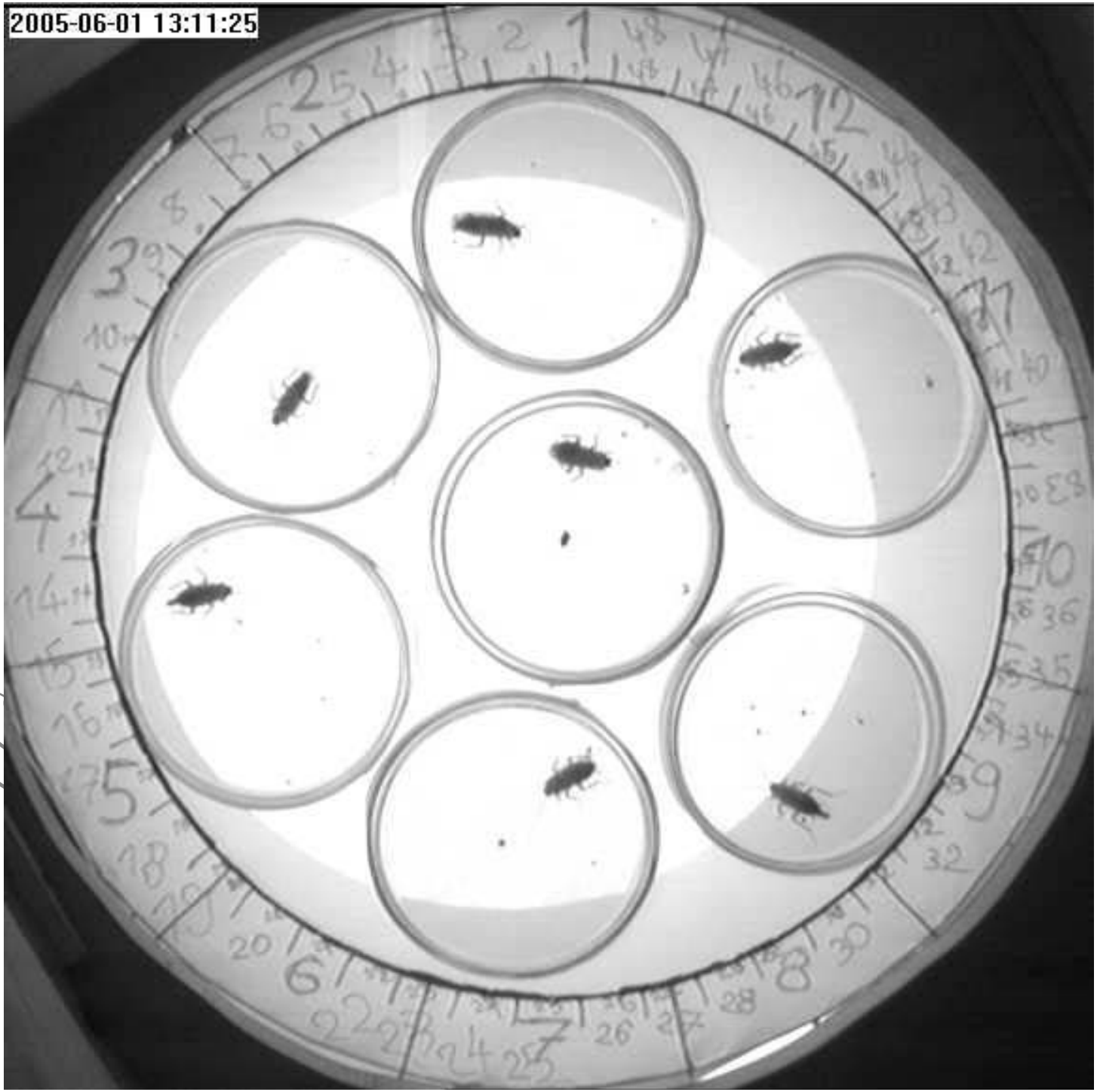


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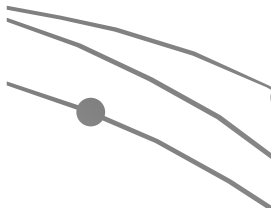
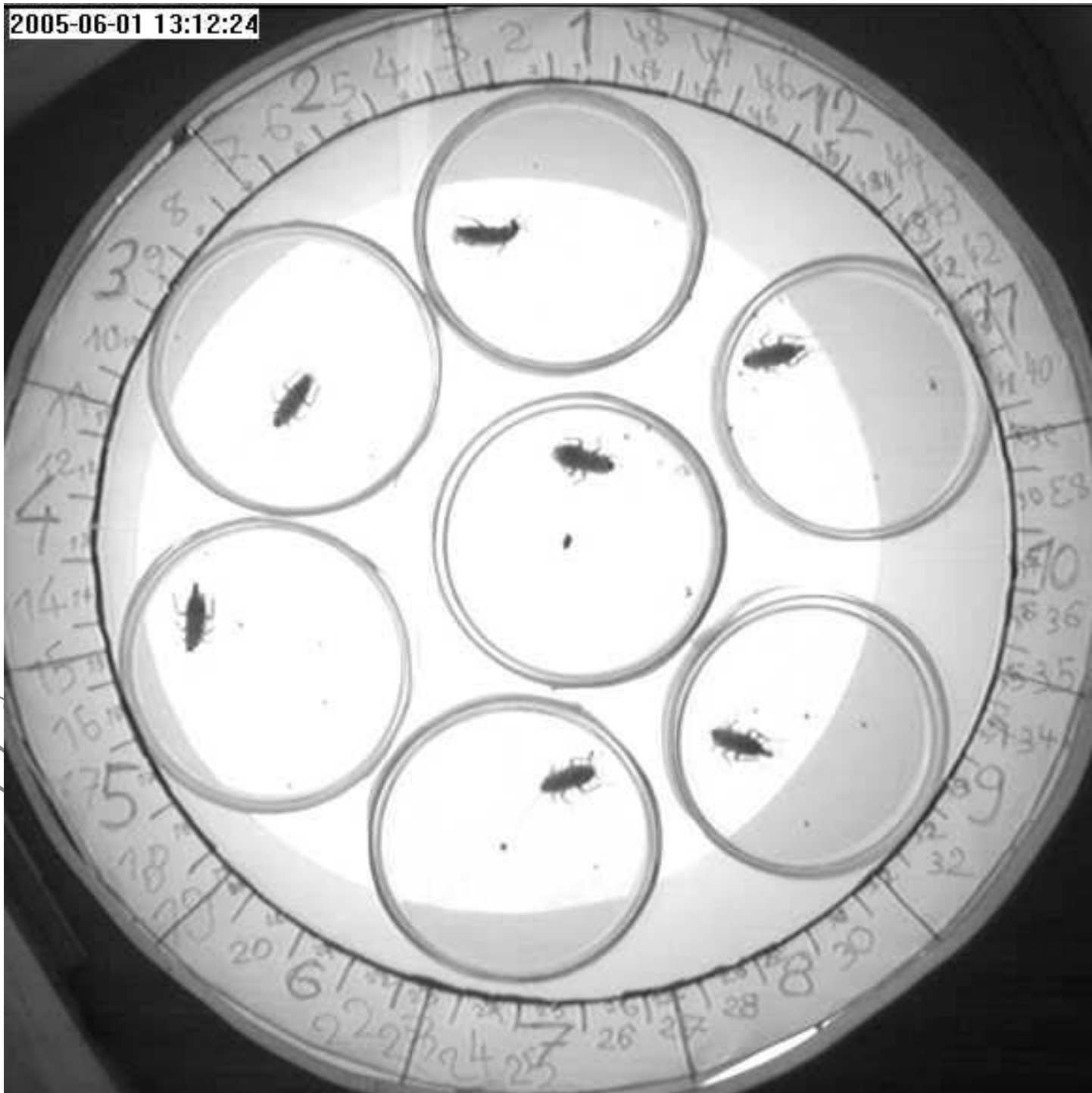




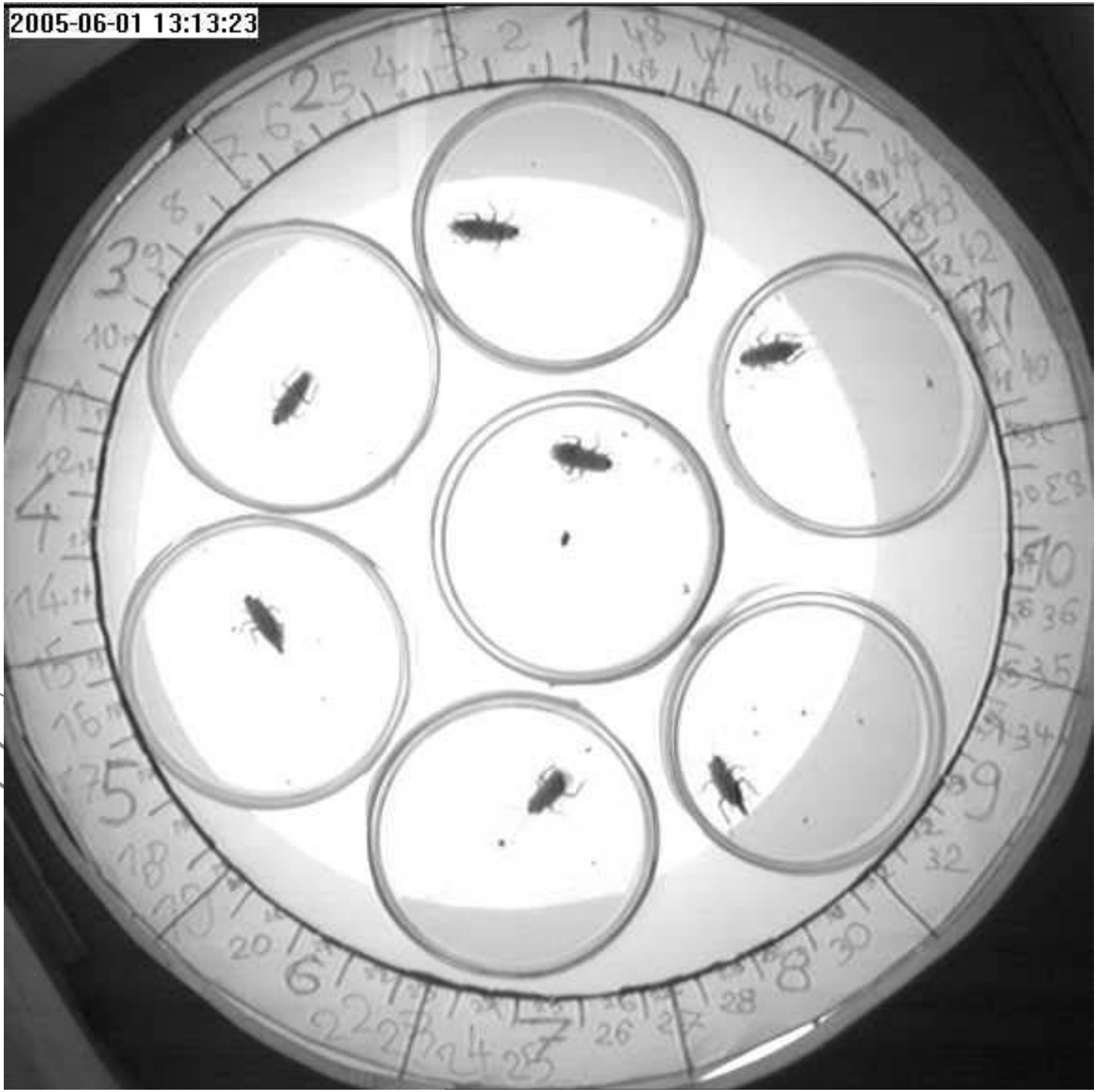
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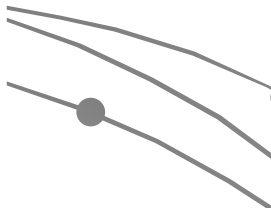
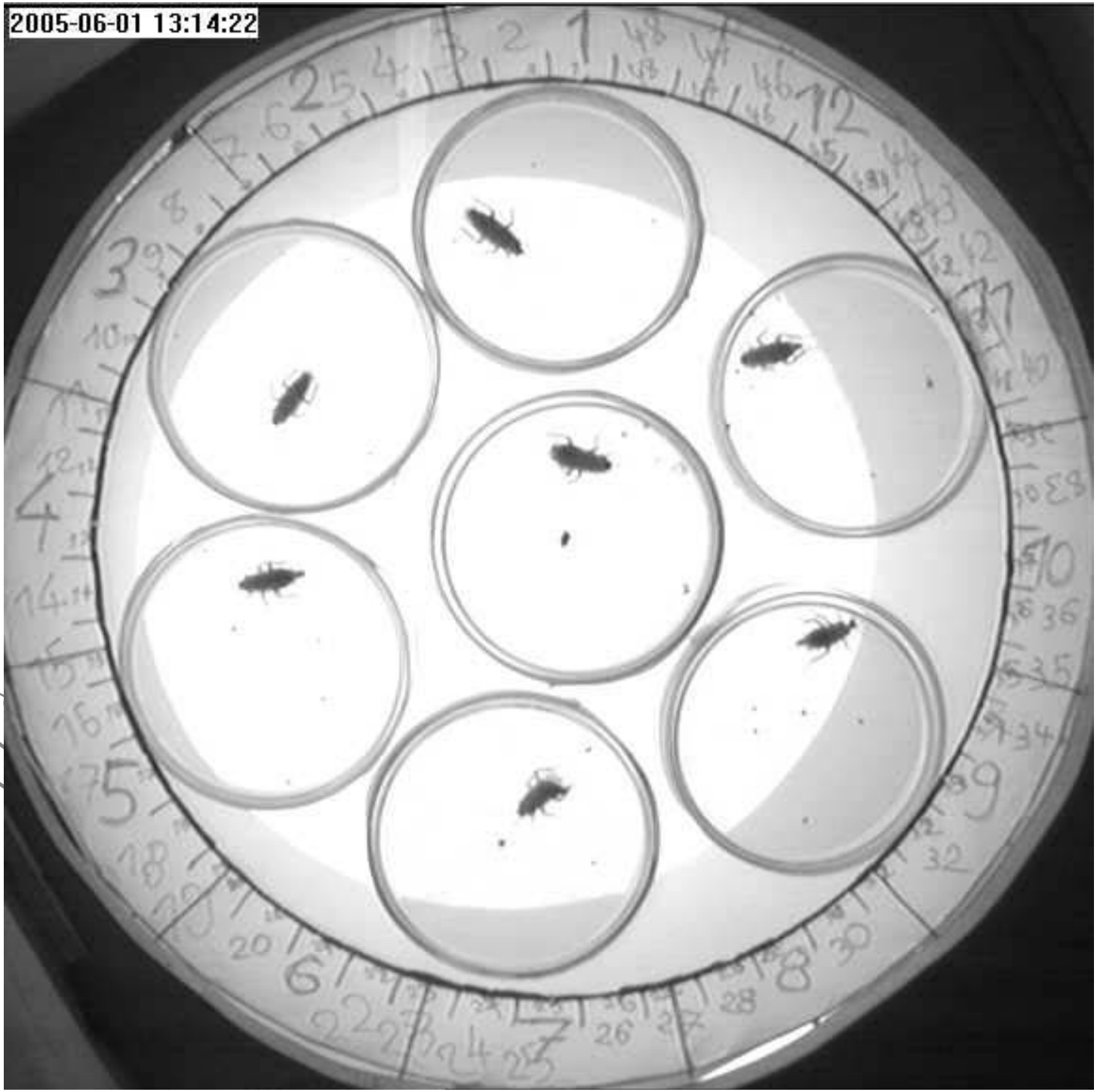
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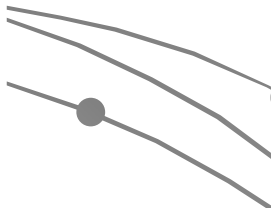
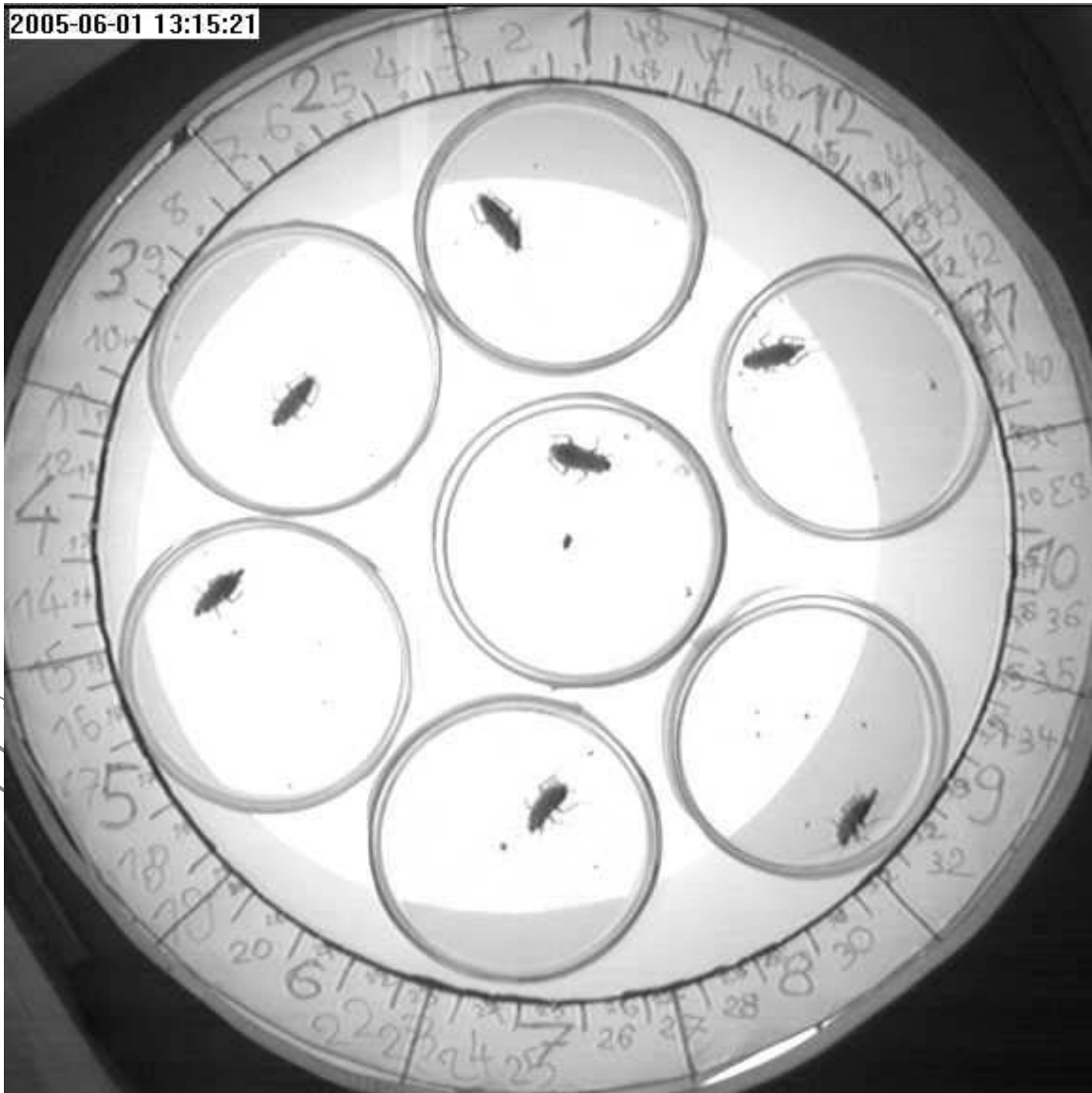
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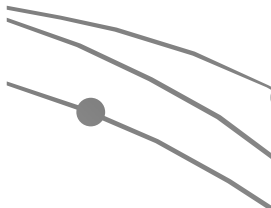
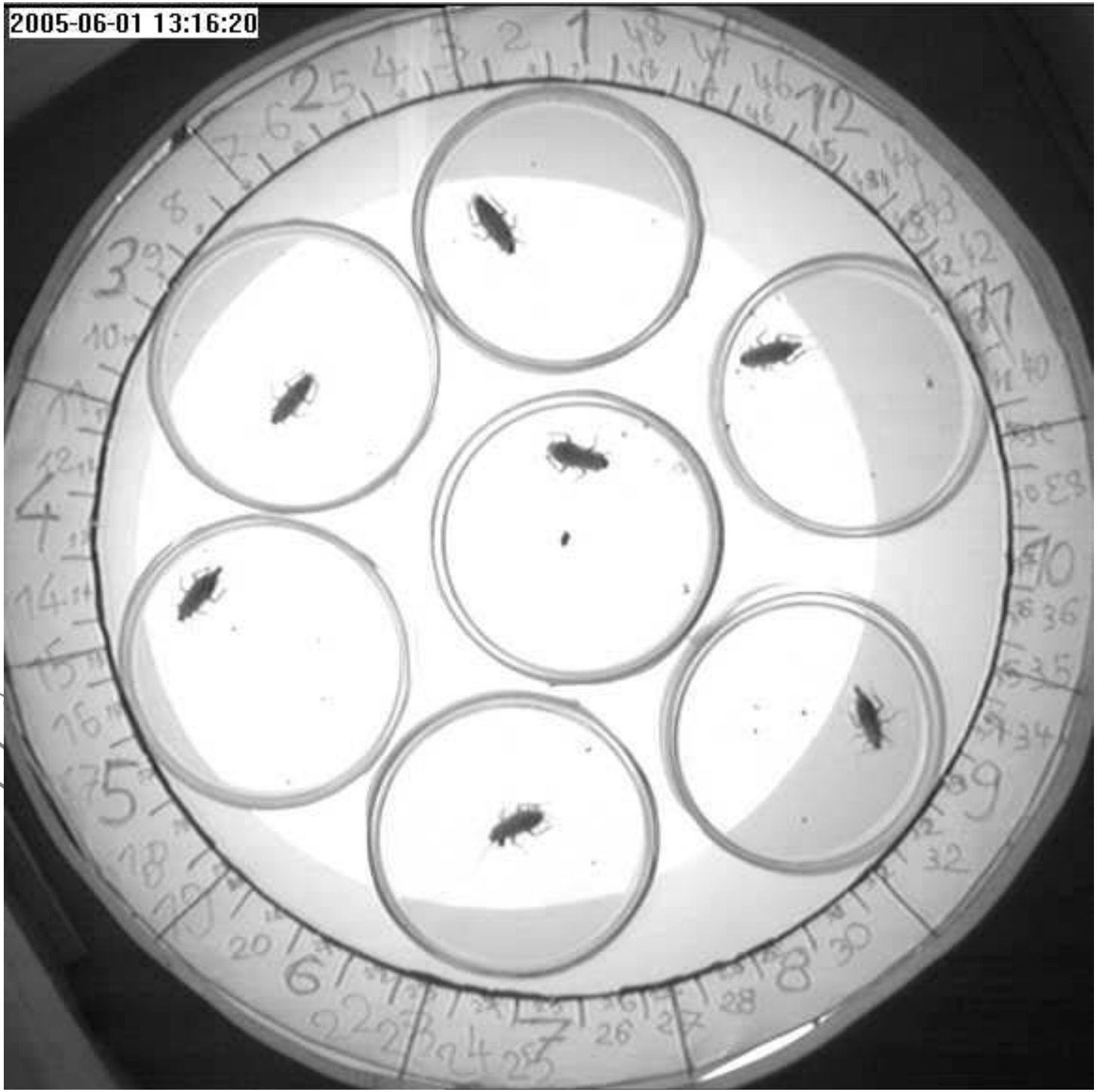
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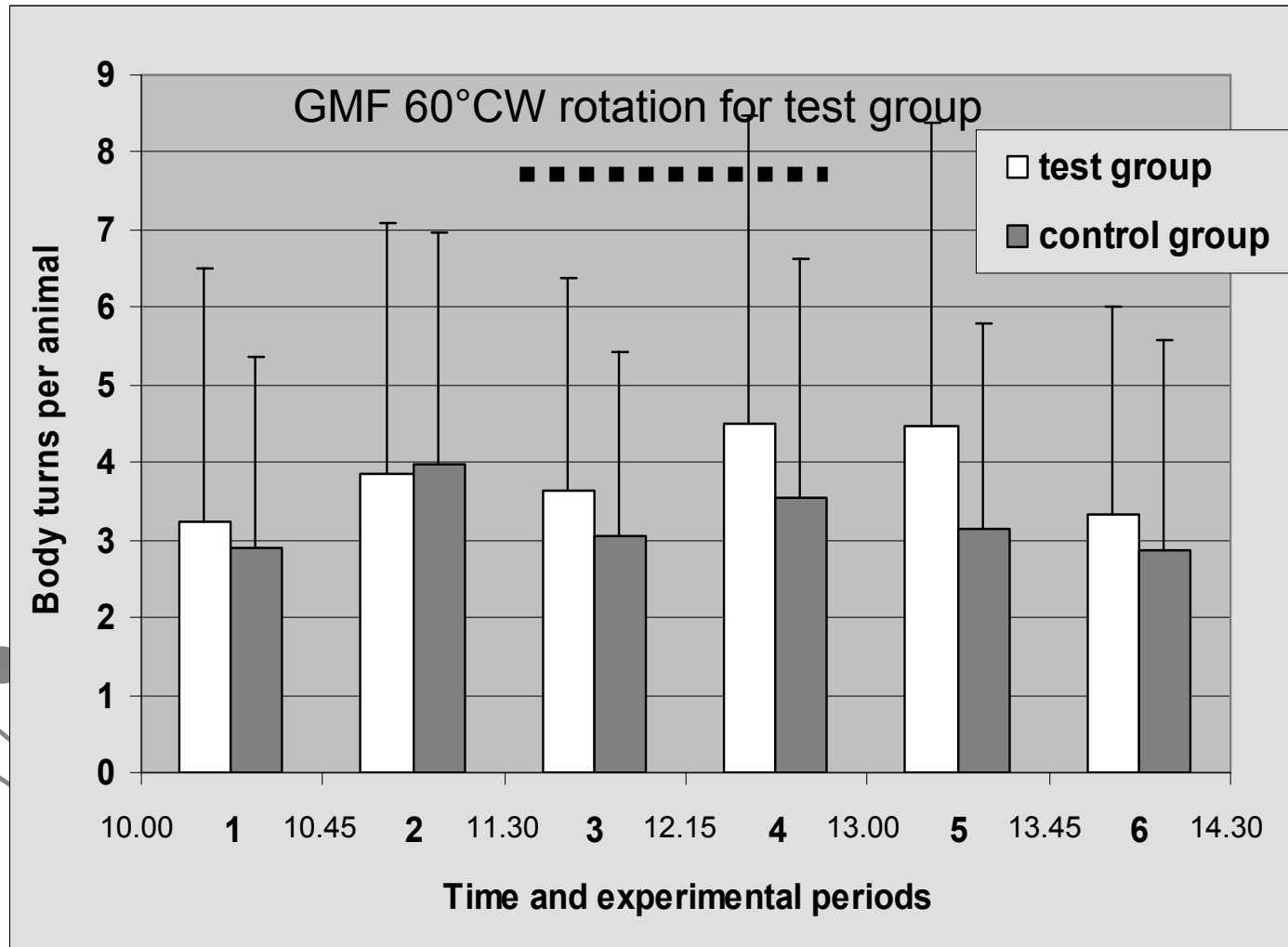
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2005-06-01 13:16:20

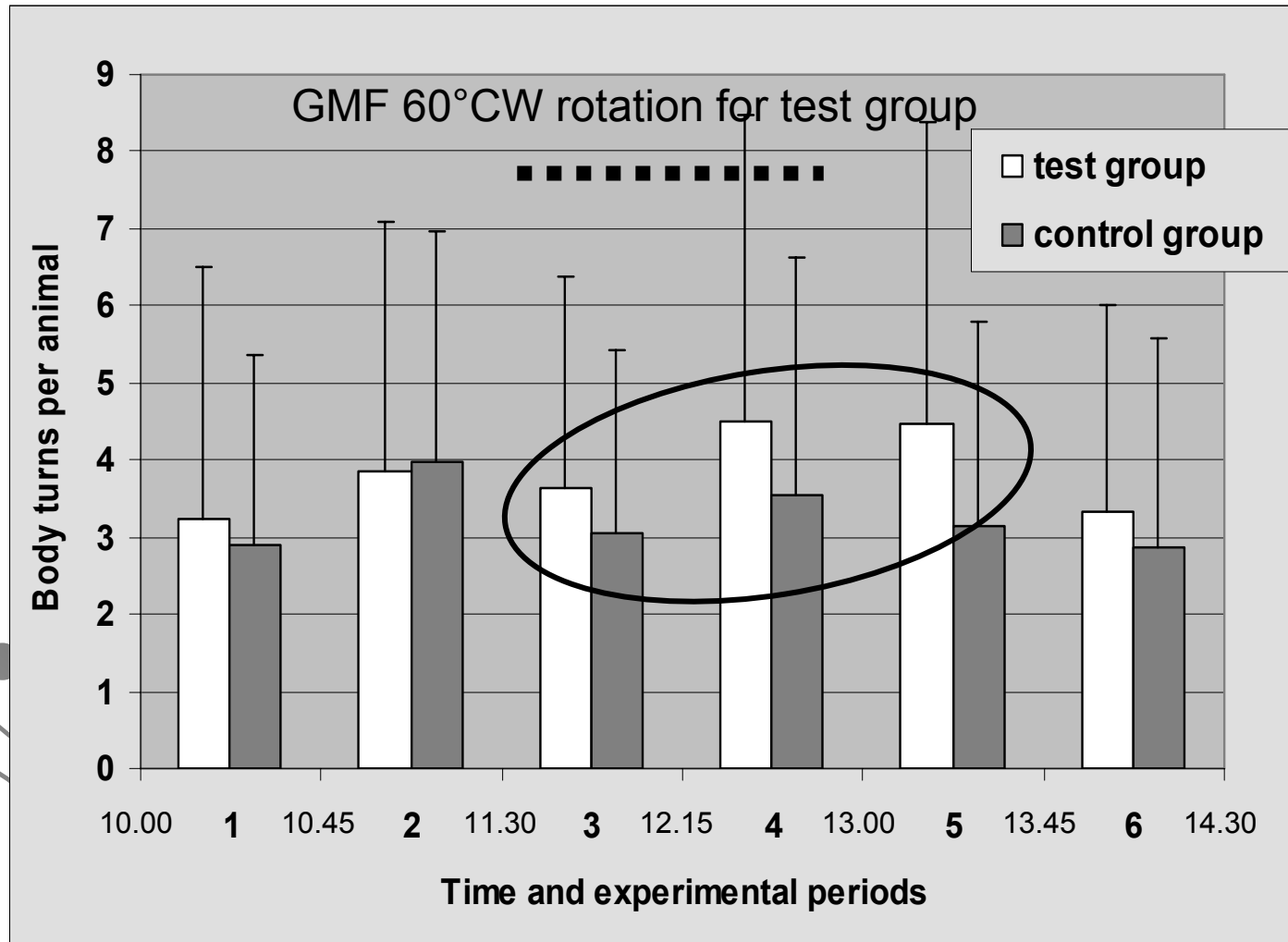


# Results:



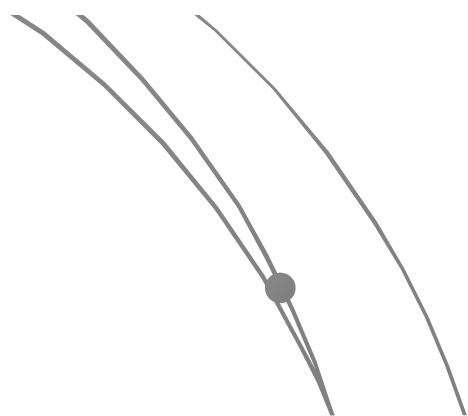
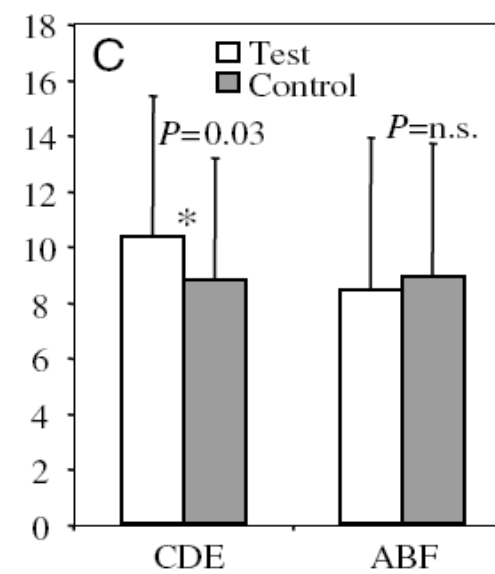
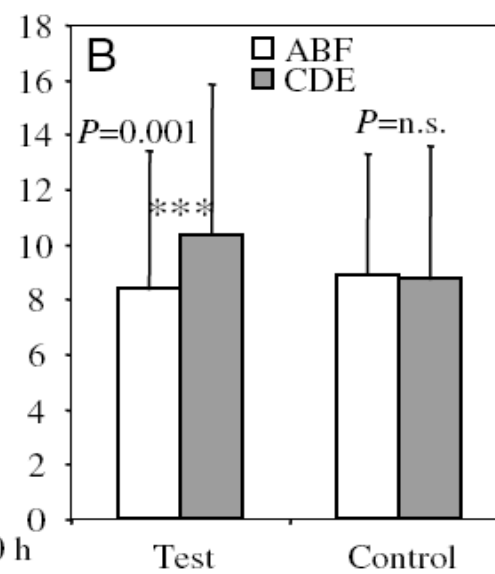
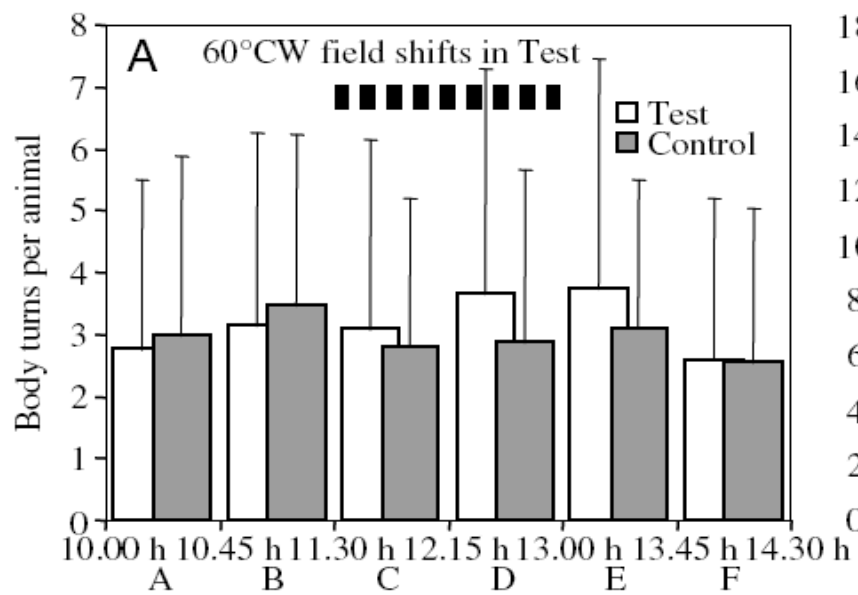
(n=62/66)

# Results:



(n=62/66)



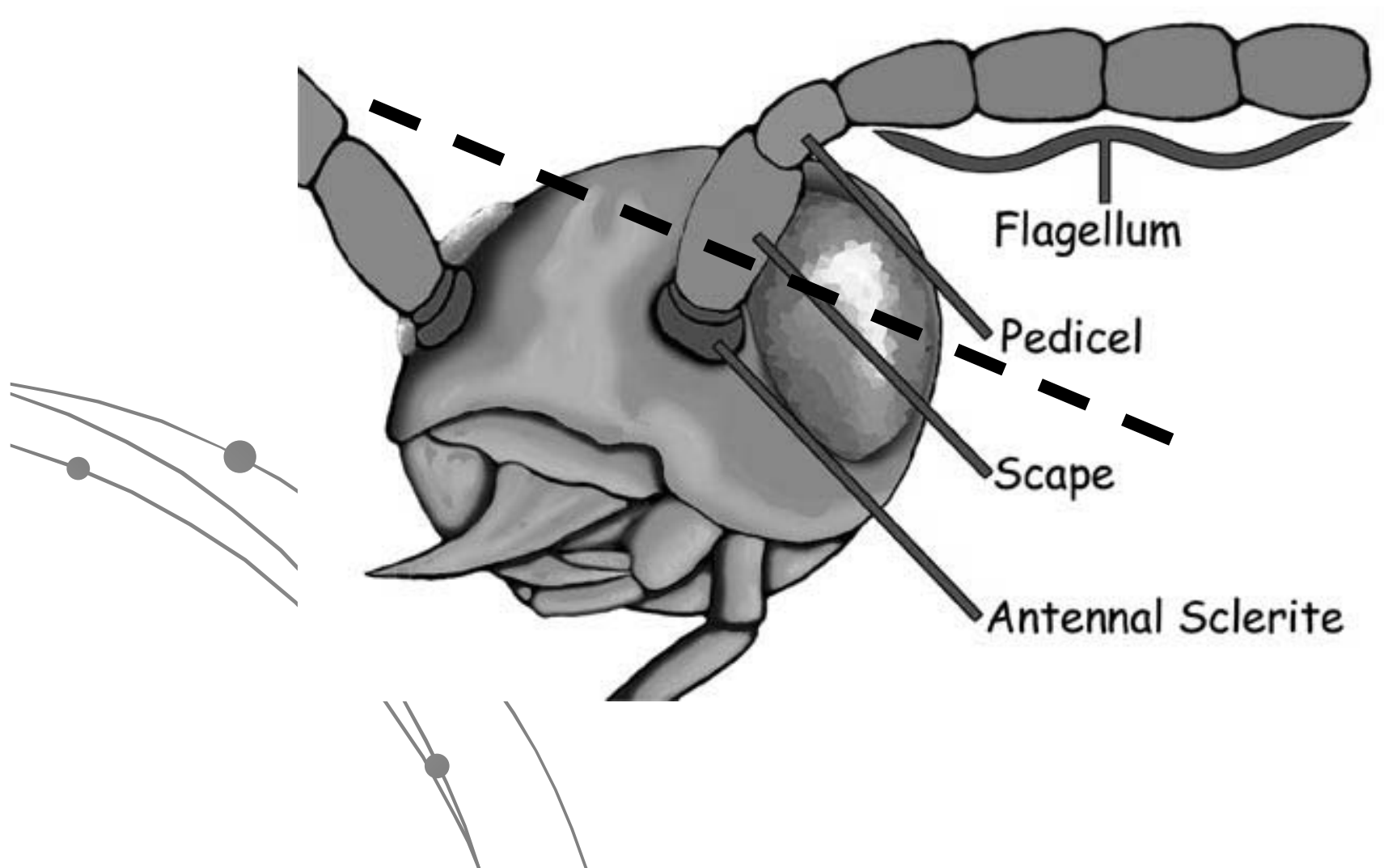


Kandidát na receptor ?

*Periplaneta americana*



# Amputace tykadel



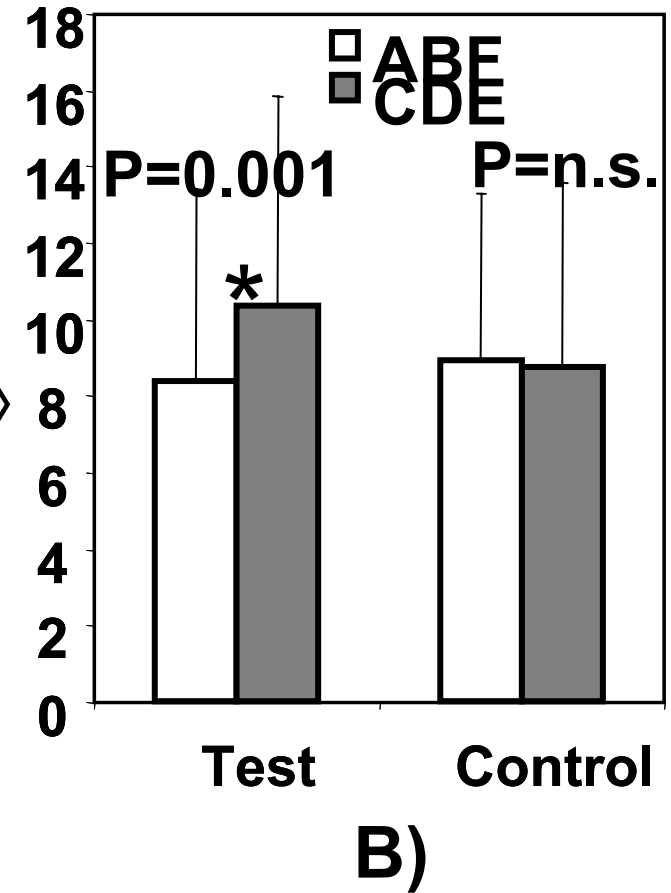
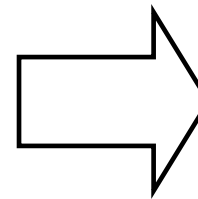
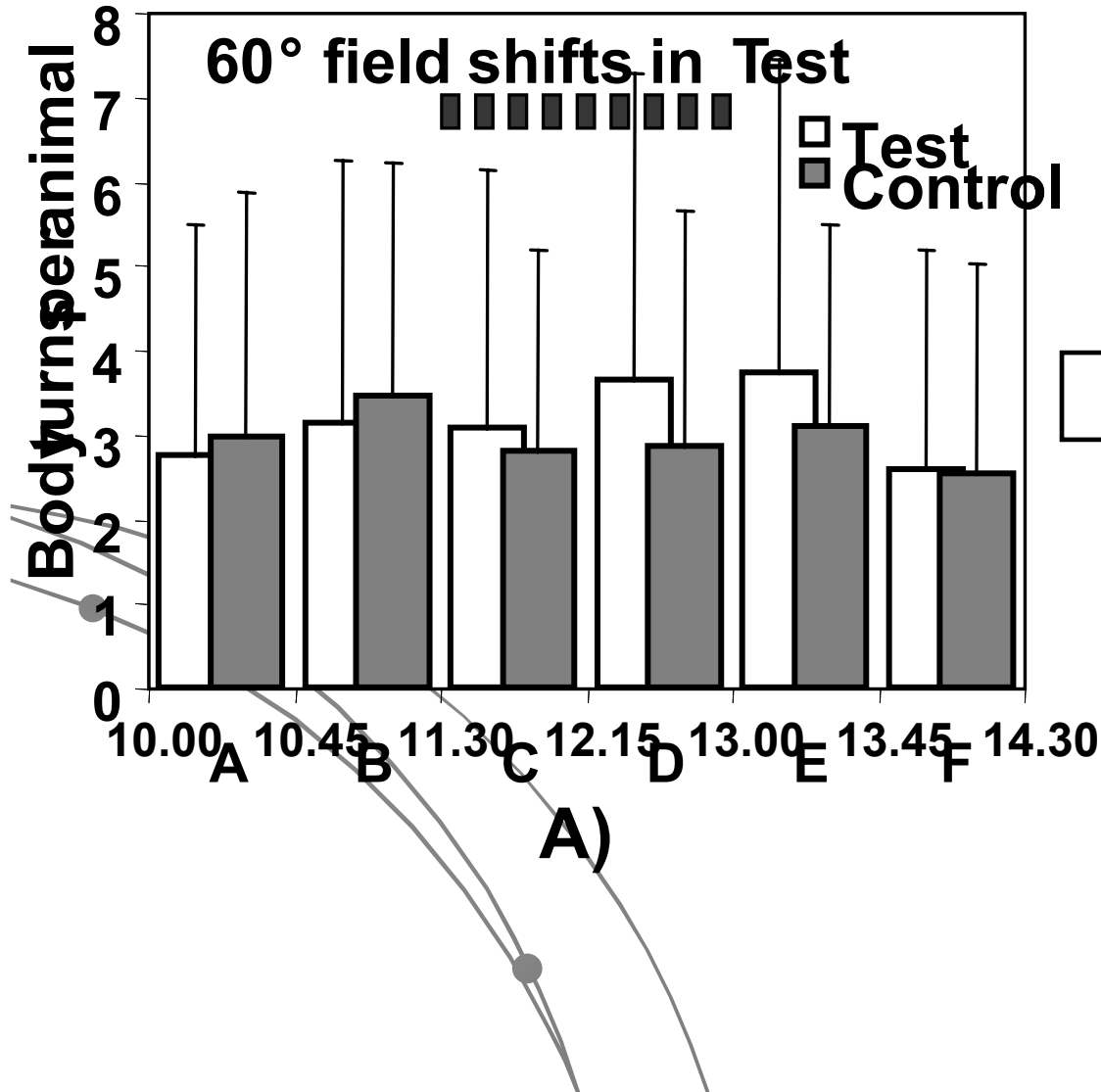
# Amputace tykadel



Po týdnu

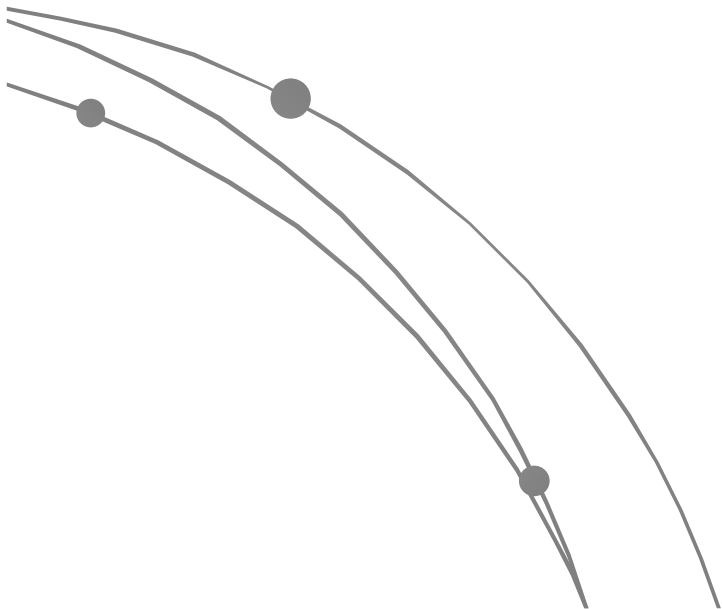


# Rotace pole zvýší neklid periplaneta americana

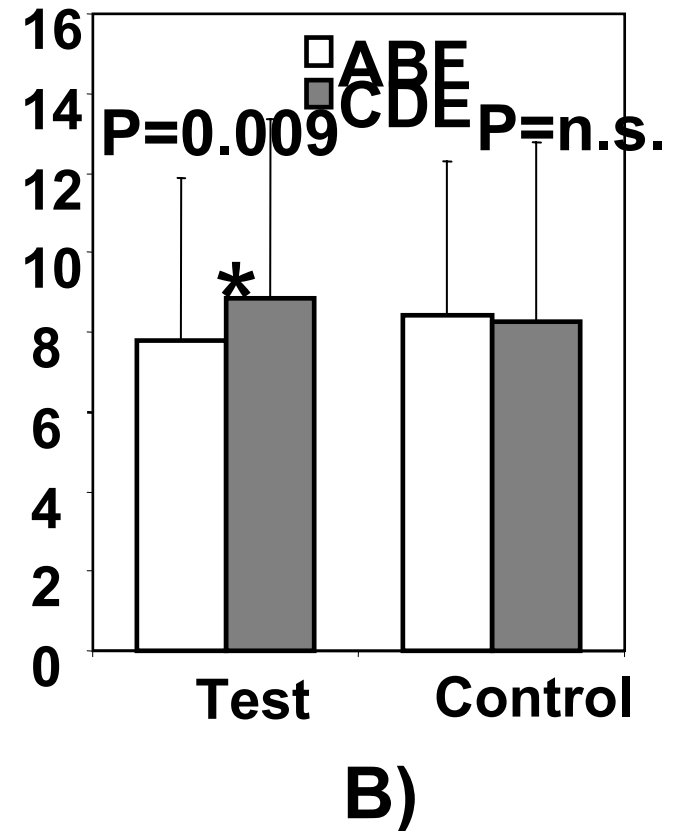
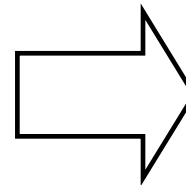
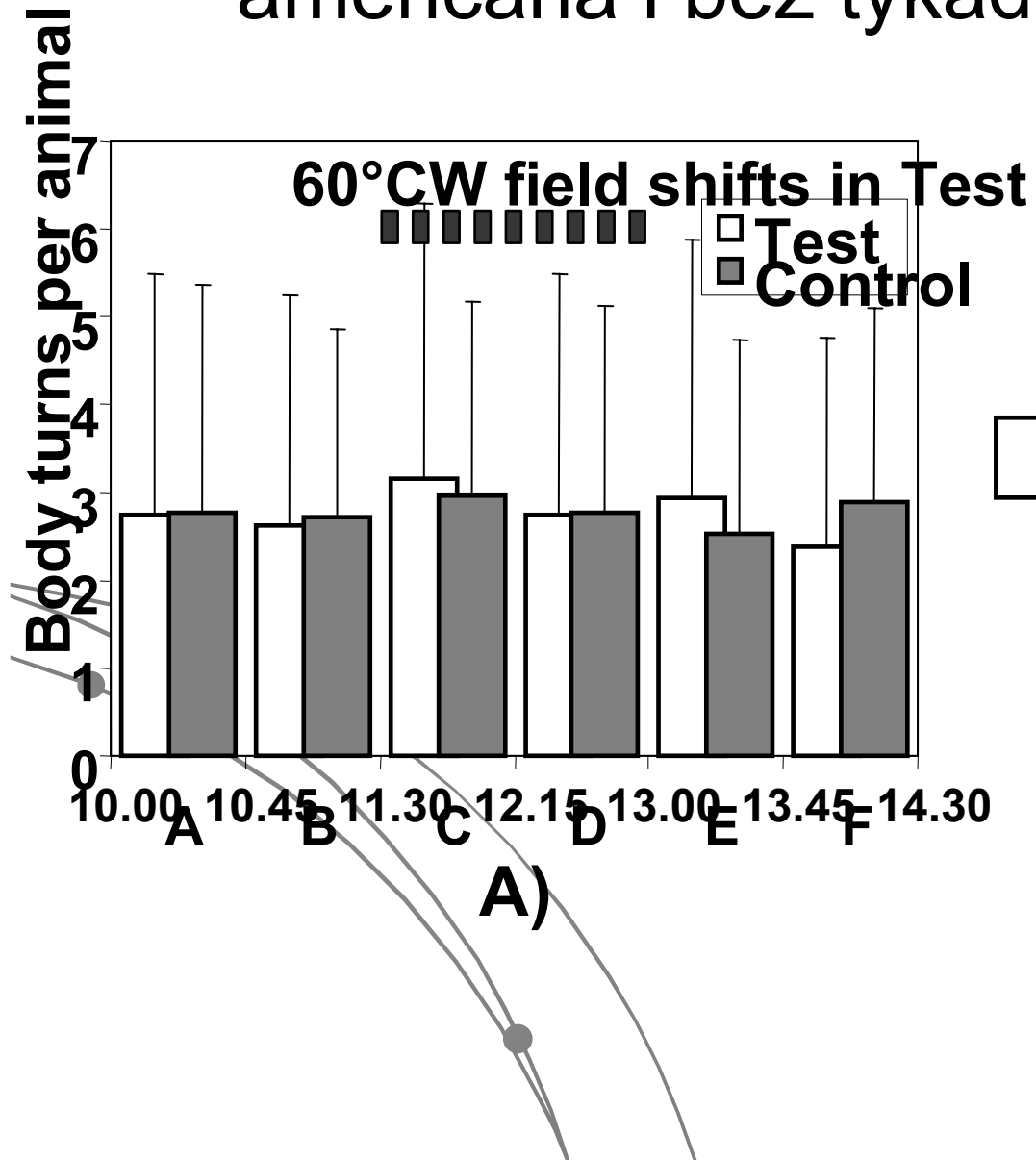


# Amputace tykadel:

- Ztráta sensitive reakce – receptor je v tykadlech nebo nespecifický vliv stresu
- Zachování reakce – receptor není v tykadlech



# Rotace pole zvýší neklid *Periplaneta americana* i bez tykadel





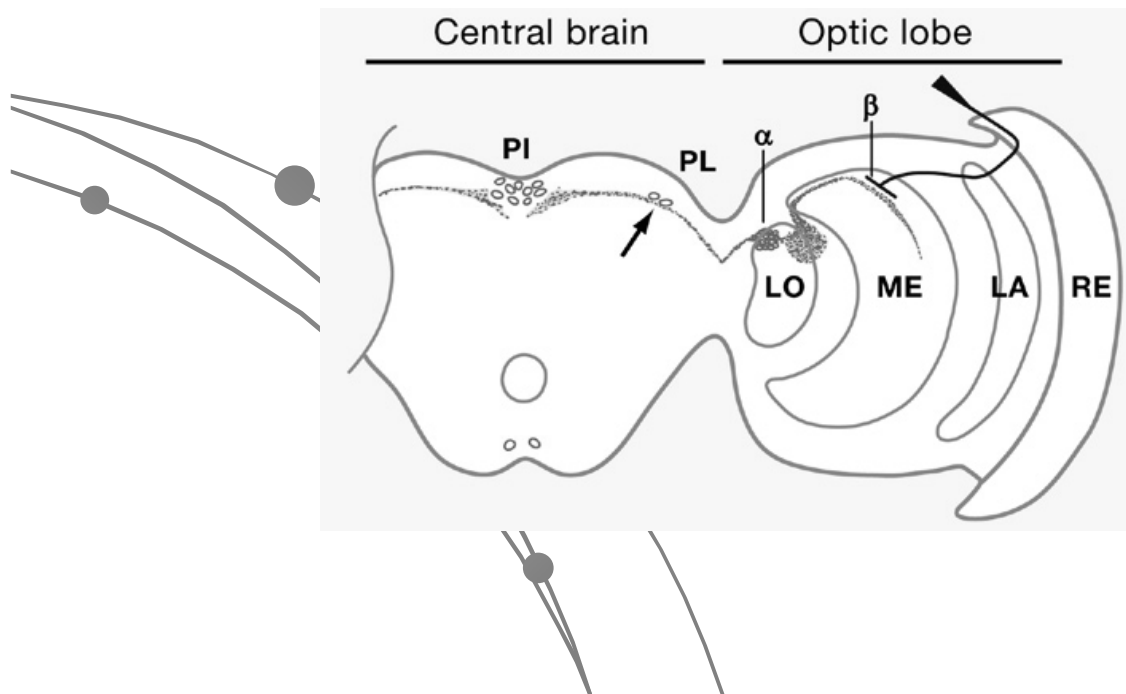
## ZÁVĚR:

- Bezobratlí jsou vděčným neuroetologickým modelem.
- Podmiňování je užitečným nástrojem smyslové fyziologie a neurofyziologie.

- 
- Bezobratlí pomáhají odhalit tajemství magnetorecepce

# Projekt kryptochromy

- Metody reverzní genetiky – iRNA
- Chirurgie – léze, ablace
- Imunohistochemie



Děkuji za pozornost.

