



Characterization of central, systemic and peripheral thermoregulation in the dromedary camel

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Such a Beauty !



Introduction

➤ Taxonomy:

Kingdom → Animalia

Phylum → Chordata

Sub-Phylum → Vertebrate

Class → Mammalia

Order → Artiodactyla (even-toed ungulates)

Suborder → Tylopoda (pad-footed)

Family → Camelidae

Genus → *Camelus*

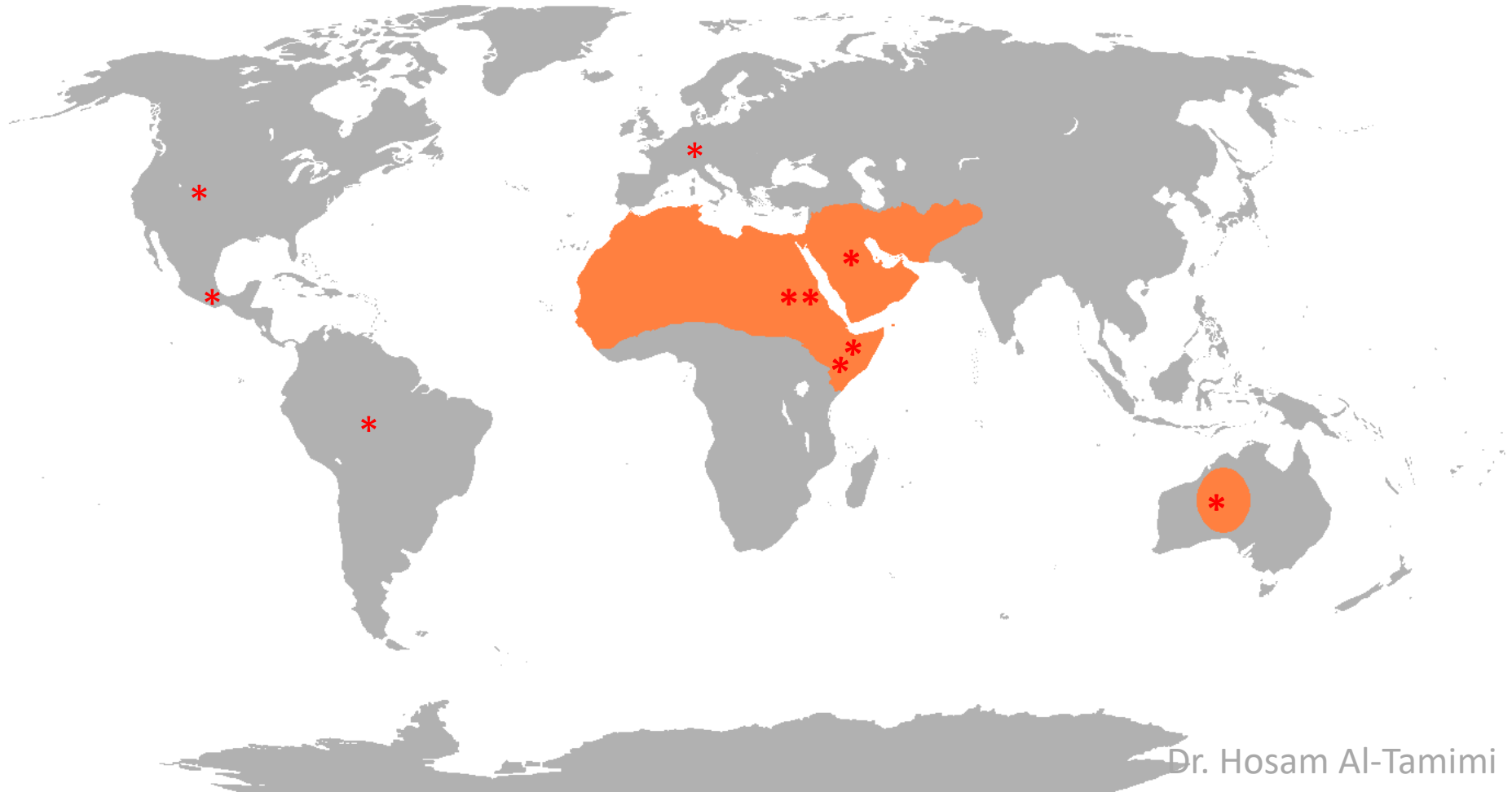
Species *dromedarius* ←

bactrianus

Introduction

➤ Population:

- Today's estimate ~15 million (*dromedary*) worldwide.



Introduction

Dromedary Camel:

- **Single-humped.**
- **Habitat: (Warm-Hot; Arid-Semi Arid)**
 - **Middle East.**
 - **Northern Africa: (Sudan, Somalia, Ethiopia, N. Kenya)**
 - **Near east-West central Asia.**
 - **First domesticated: ~3000 yrs B.C.**
 - **Domesticated for:**
Milk, meat, work (riding, packing), hides, hair, blood.

➤ **Morphology:**

- **Higher (long spindle legs).**
- **Thinner (lighter).**
- **Sparse, light hair cover.**



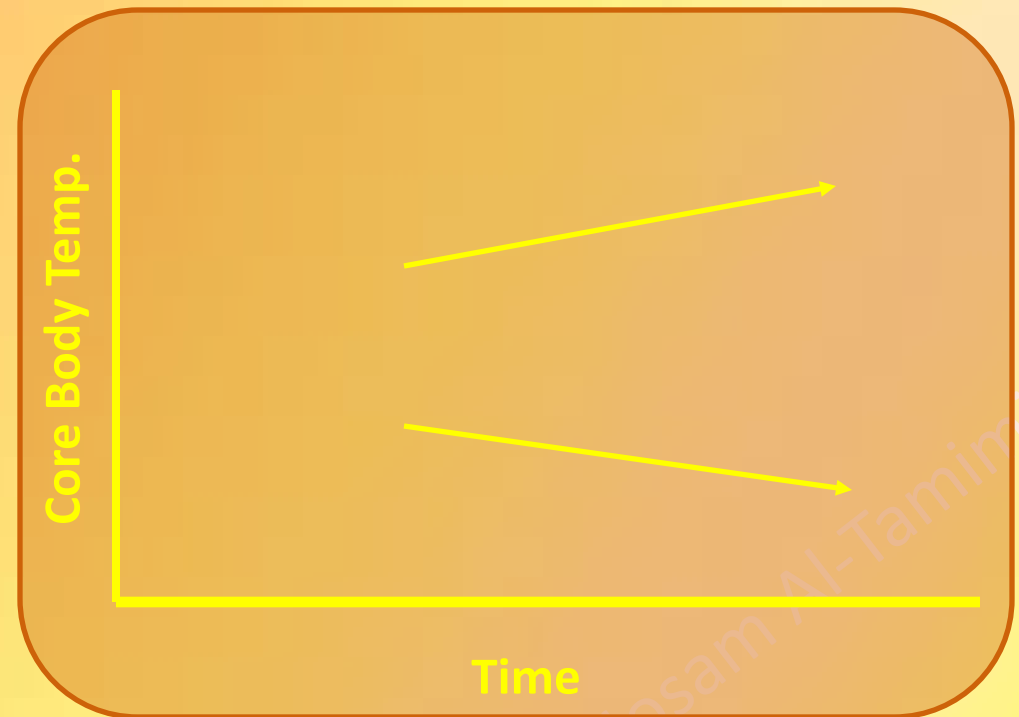
Introduction

- ✓ **Dromedary camel → well adapted to harsh climatic conditions of the desert:**
 - ✓ **Heat-tolerance.**
 - ✓ **Can keep up with low quality forages.**
 - ✓ **Withstand nomadic grazing system.**

Introduction

- ✓ Early reports (Schmidt-Nielsen et al., 1956; Schmidt-Nielsen et al., 1957; Schmidt-Nielsen, 1959; Schmidt-Nielsen et al., 1981):
 - ✓ **Adaptive heterothermic** (dehydration + HS):

- ✓ Higher T_{core} Maxima → lower thermal gradient (lower heat gain)
- ✓ Lower T_{core} Minima (expedited thermolytic inertia)



Introduction

- ✓ In contrary, more recent work (Al-Haidary, 2001; Abdoun et al., 2012; Samara et al., 2013) utilizing more advanced temperature measurement technologies (high sensitivity radiotelemetry) reported much lower extents of heterothermy.
- ✓ The 2 approaches had limitations:
 - ✓ 1. Older studies: only discrete measurements, animal restraint.
 - ✓ 2. More recent (radiotelemetry): limited roaming.

Objectives:

Study dromedary's thermoregulation, simultaneously:

- **Central**
- **Systemic**
- **Peripheral**

Intensively + chronically in unrestrained freely-roaming setting.

Materials & Methods



Materials & Methods

✓ **Animals:**

- ✓ **4 male dromedary camels (Majaheem breed), 3.7-4.5 years of age.**
- ✓ **Vaccinated against enterotoxaemia prior to the experimental procedures.**
- ✓ **Allowed a 7-day acclimatization period, within which body weights and blood profiles obtained, received prophylactic anti-parasite.**
- ✓ **Fasted for 12 hours prior to the day of surgery.**
- ✓ **Deeply sedated using xylazine (0.5 mg/kg BW; I.M.), followed 5 minutes later by intravenous injection of ketamine (2.2 mg/kg BW) to induce general anesthesia for ~40 minutes.**
- ✓ **Surgical implantation of 8 miniature thermologgers:**

Materials & Methods

- ✓ 8 miniature dataloggers (iButton, DS-1922L, Maxim, USA):



Hump SQ

Peri-Rectal

Intra-Scrotal

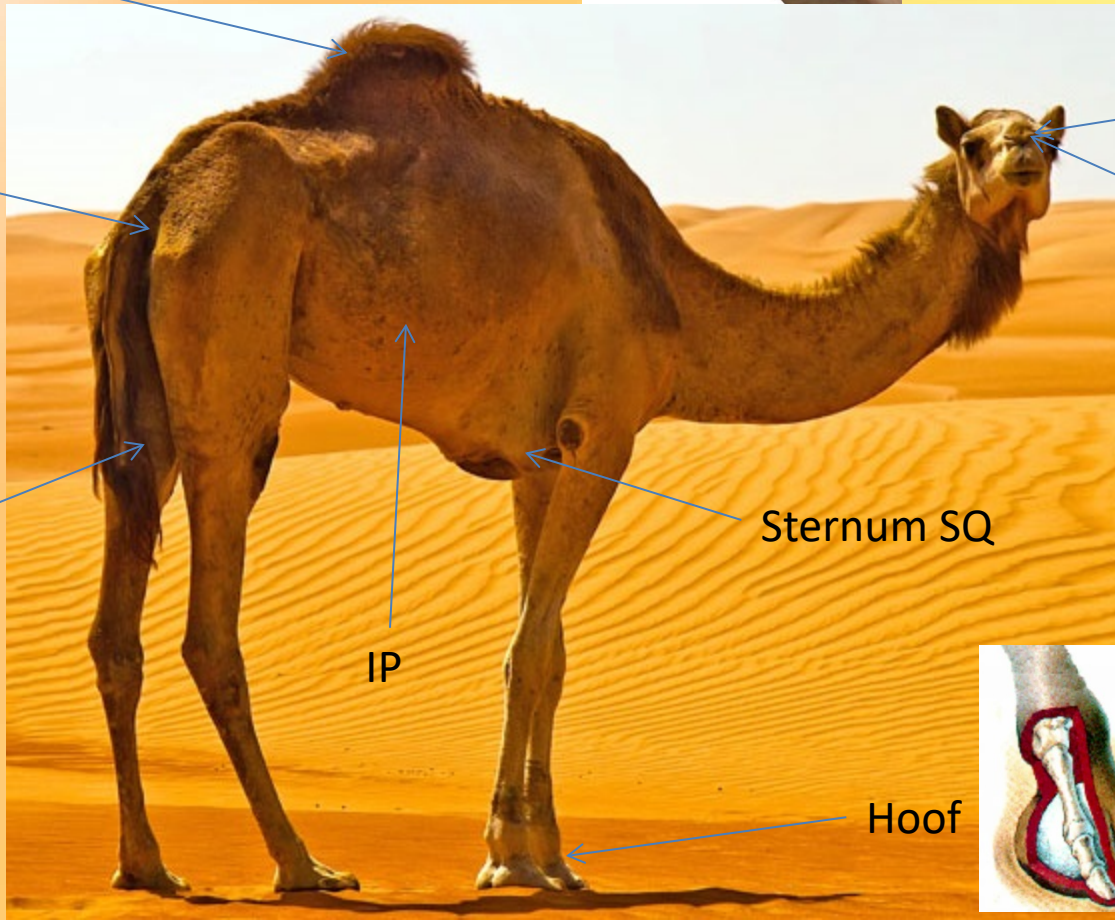
IP

Sternum SQ

Hoof

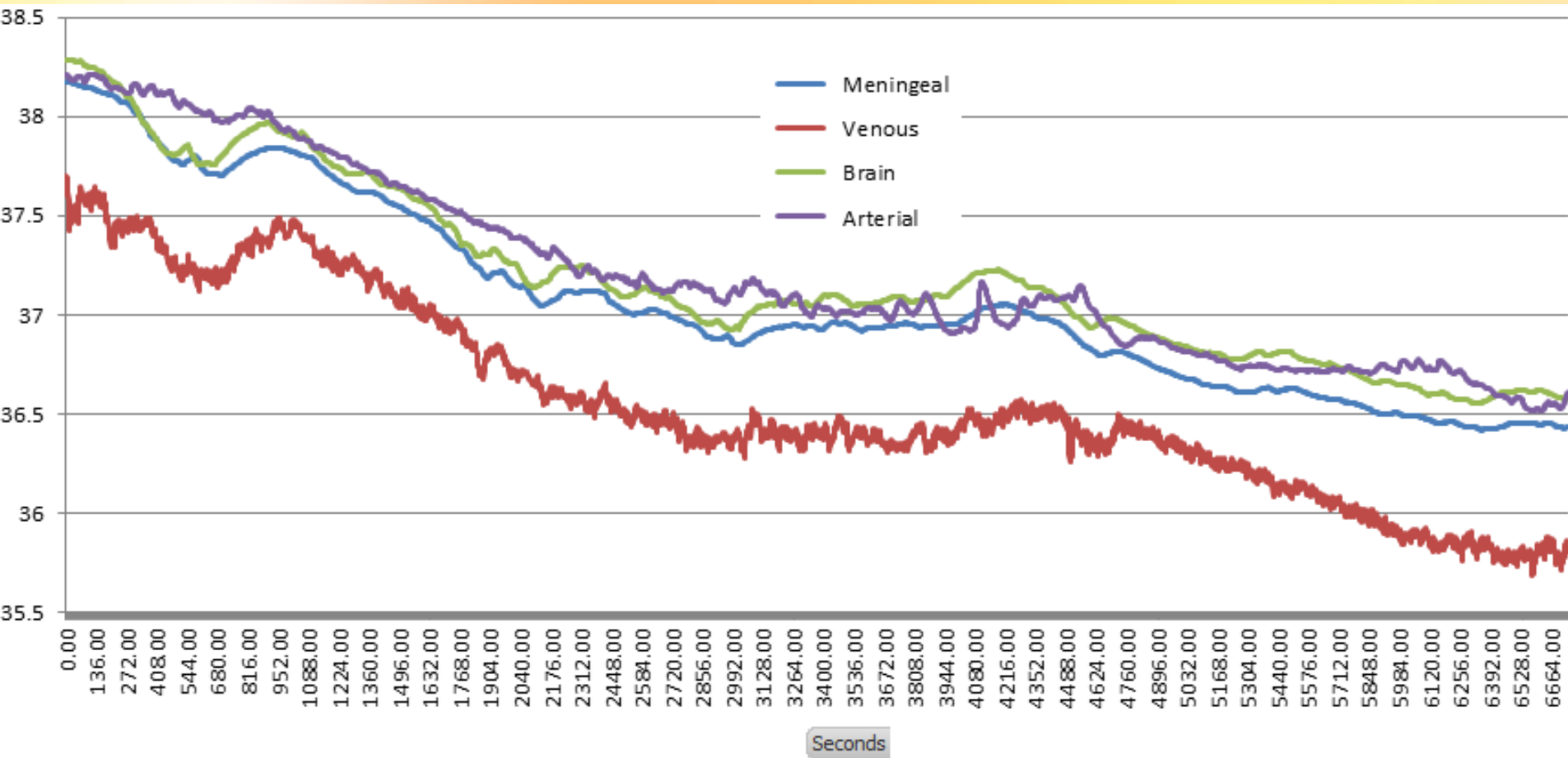
Head SQ

Meningeal



Materials & Methods

Preliminary comparison: **Brain temp. VS. Meningeal temp.**



Materials & Methods

- ✓ All procedures conformed with ACUC.
- ✓ Trial took place at Animal Research Center, Jordan University of Science and Technology, Irbid Jordan.
- ✓ Duration: (May-August, 2015)
 - ✓ 14 days: post operative recovery period. No health complications.
 - ✓ 87 days: baseline + characterization.
 - ✓ 8 days: water deprivation + direct solar heat.

Materials & Methods

✓ Meteorological data

✓ (HOBO-U30 NRC Weather Station, Onset Comp, USA):

- ✓ Ambient/air temperature (T_a ; °C).
- ✓ % RH.
- ✓ Solar radiation (W/m^2).
- ✓ Light Intensity (Lux).



✓ Deduced thermal index:

$$ESI = 0.62T_a - 0.007RH + 0.002SR + 0.0043(T_a * RH) - 0.078(0.1 + SR)^{-1}$$

(Moran et al., 2003)

Materials & Methods

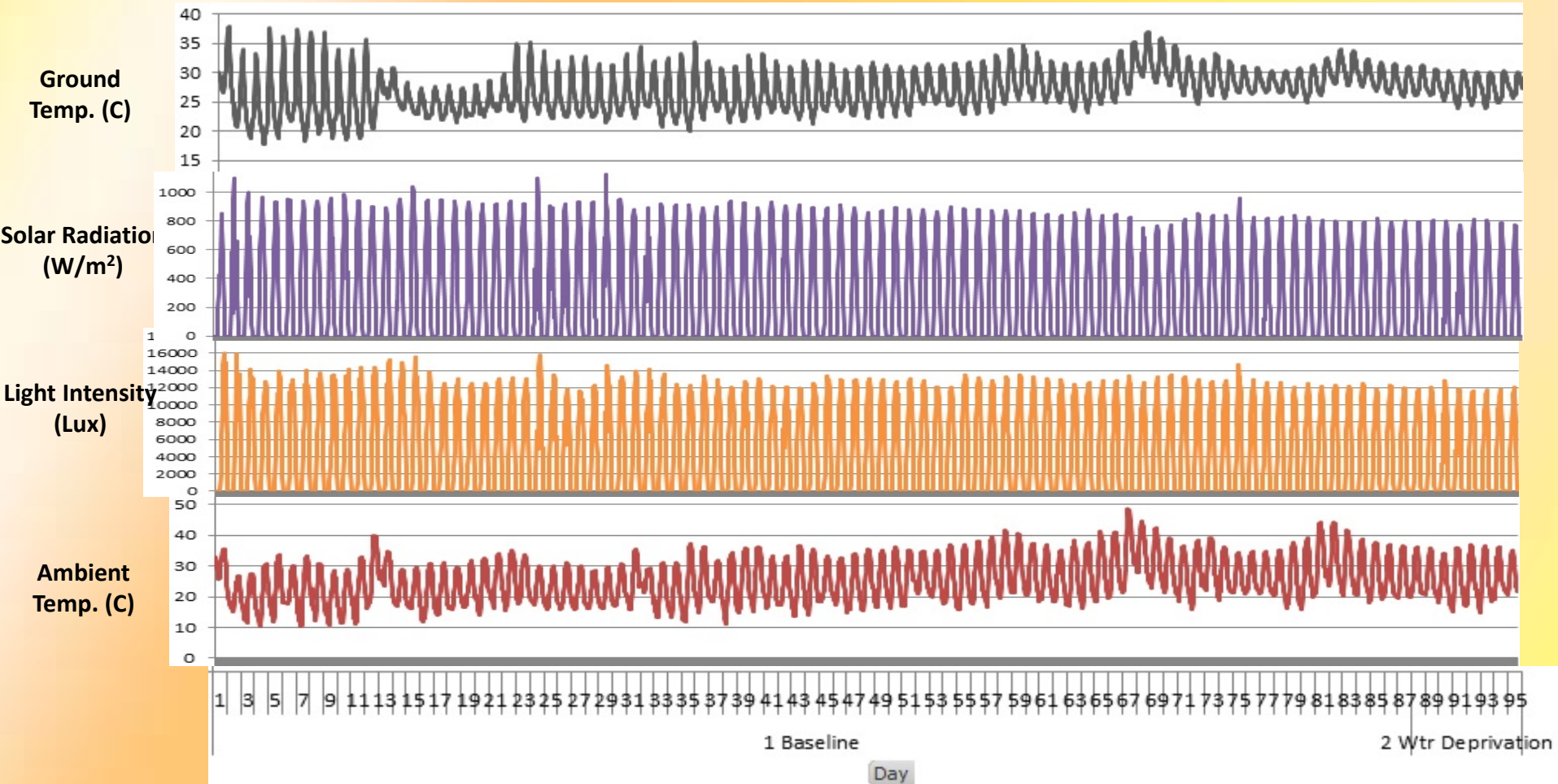
- ✓ **Bodily-embedded thermologgers and climatic sensors synchronized and programmed to record at 60-minute intervals, throughout the trial period.**
- ✓ **Statistics:**
 - ✓ **Freely roaming: animals acted as their own controls, then compared to performance during water deprivation period.**
 - ✓ **Bivariate Regression Analyses (JMP).**



Results & Discussion

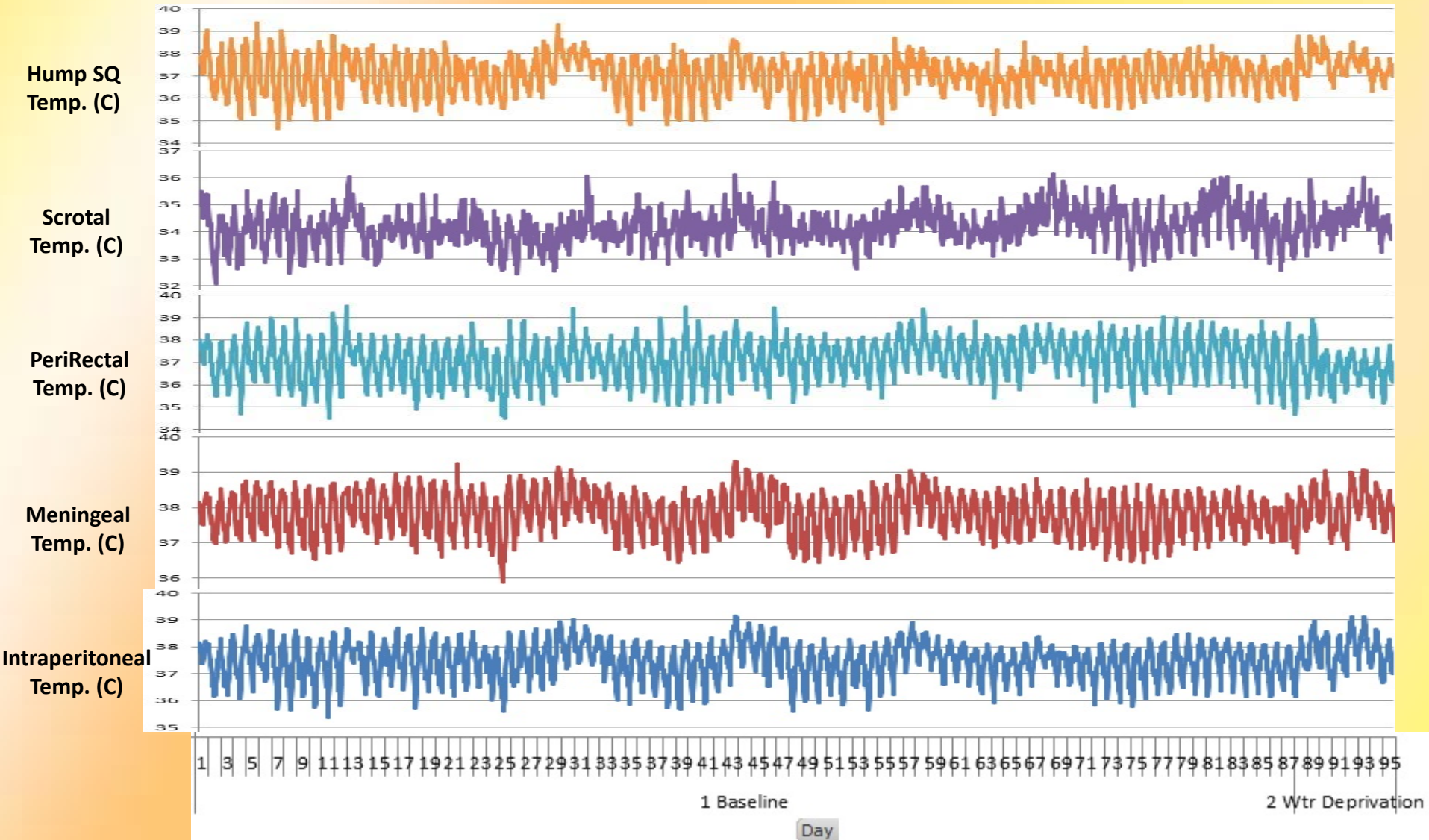
Results & Discussion

✓ 200,640 raw data points collected (body and climatic).



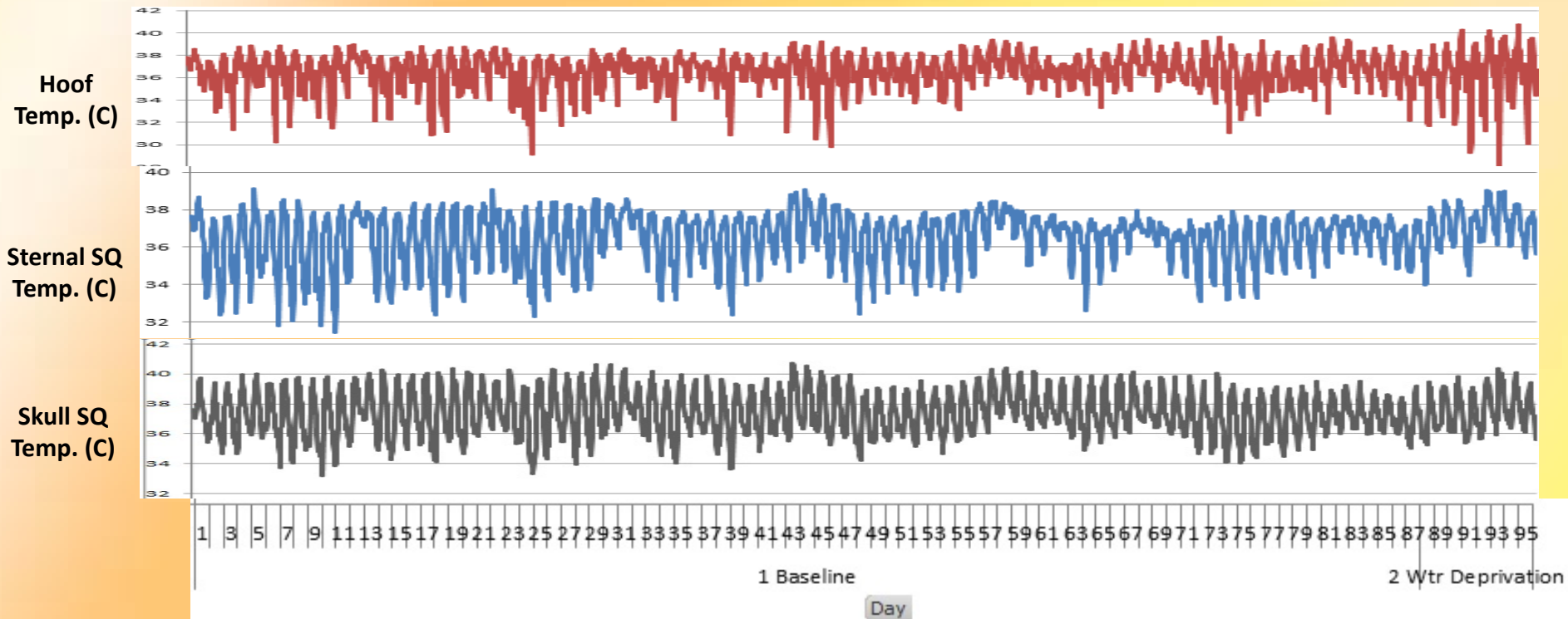
Results & Discussion

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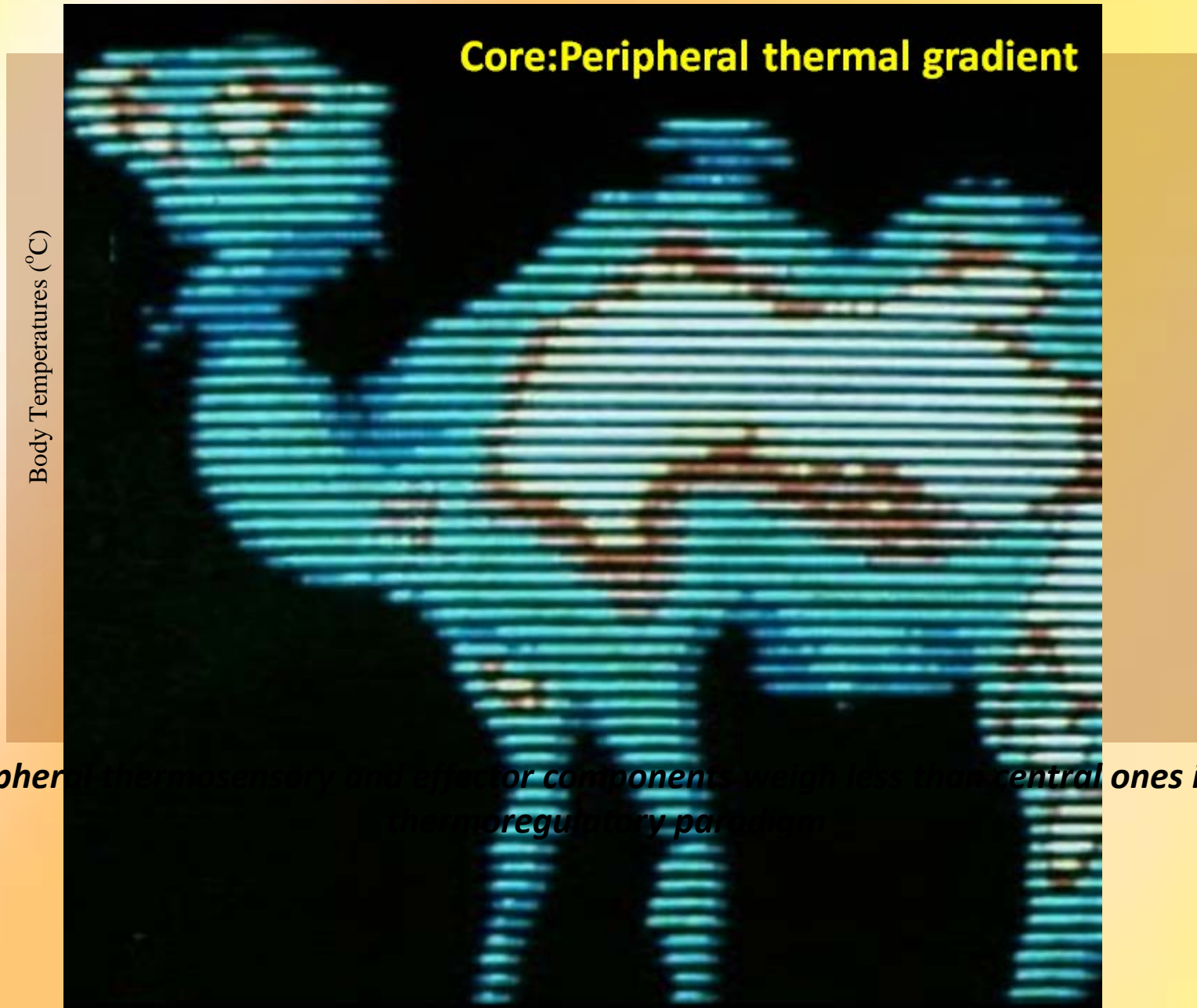


Results & Discussion

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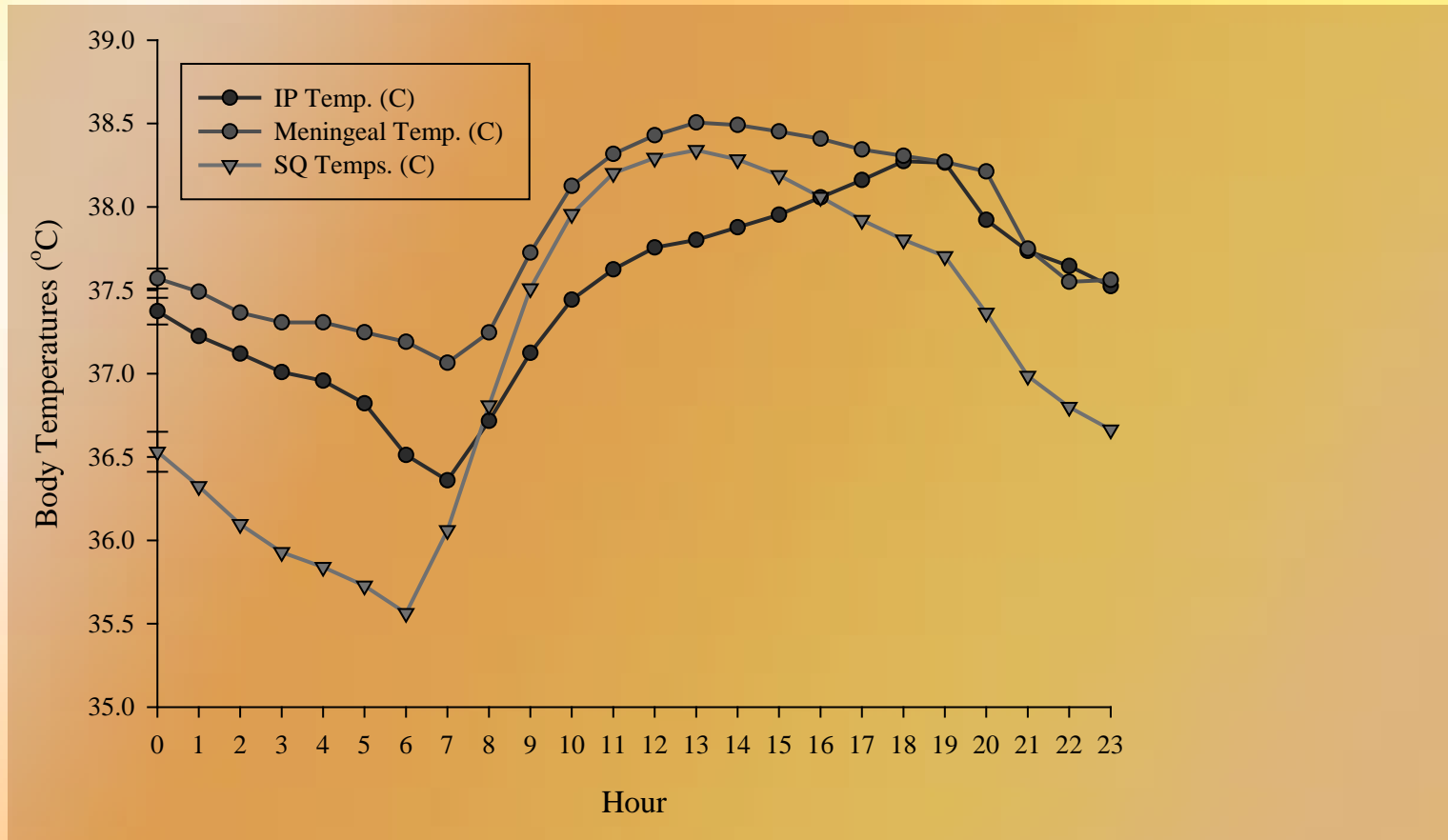
Results & Discussion



- *Peripheral thermosensory and effector components weigh less than central ones in the thermoregulatory partitioning of energy.*

Results & Discussion

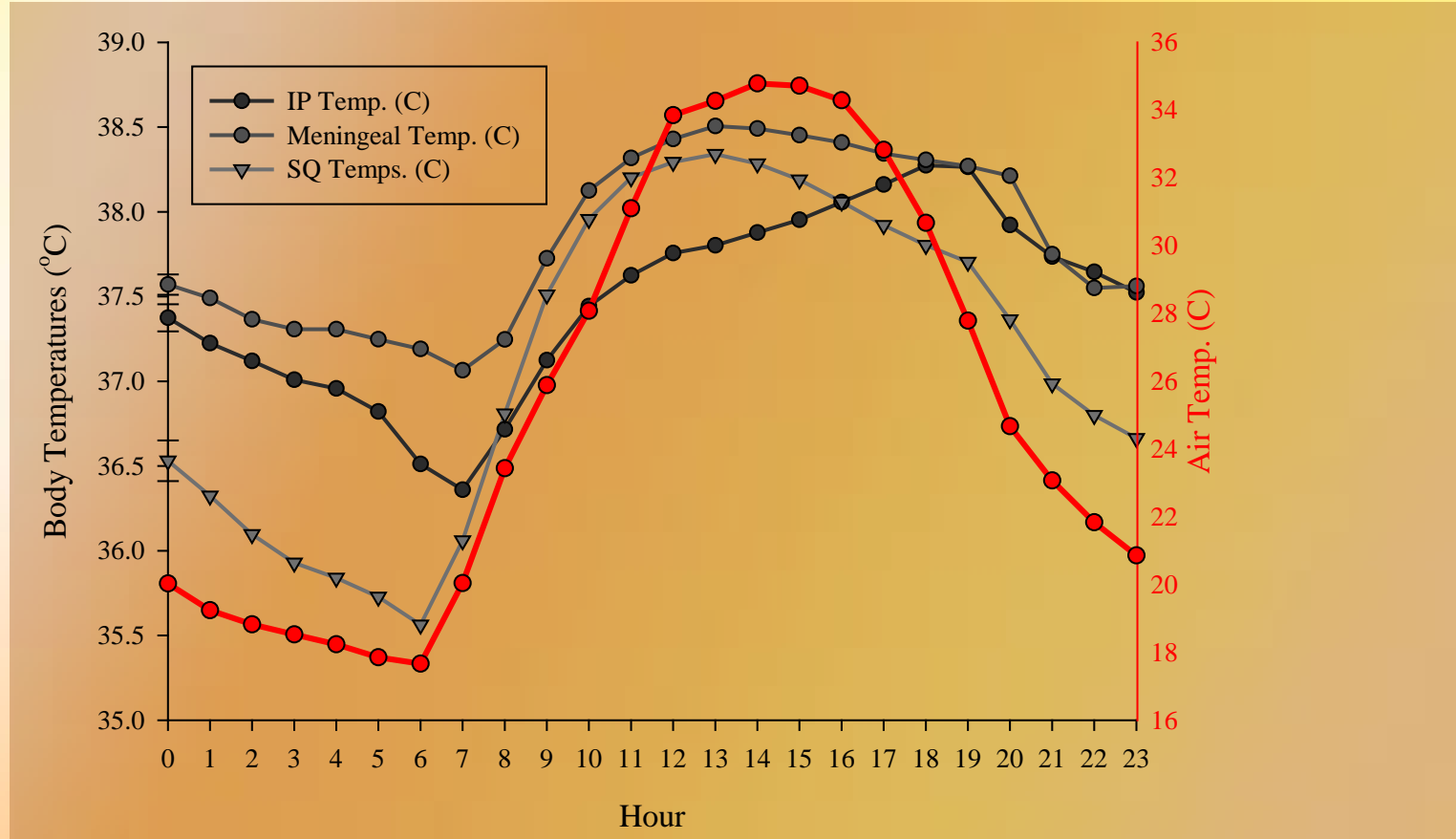
Mean Daily Body Temperatures Vs. Climatic Conditions



- ***Peripheral thermosensory and effector components weigh less than central ones in the thermoregulatory paradigm.***
- ***However, there are exceptions (e.g., gonads, udder; sheep, goats, cattle, wild animals).***

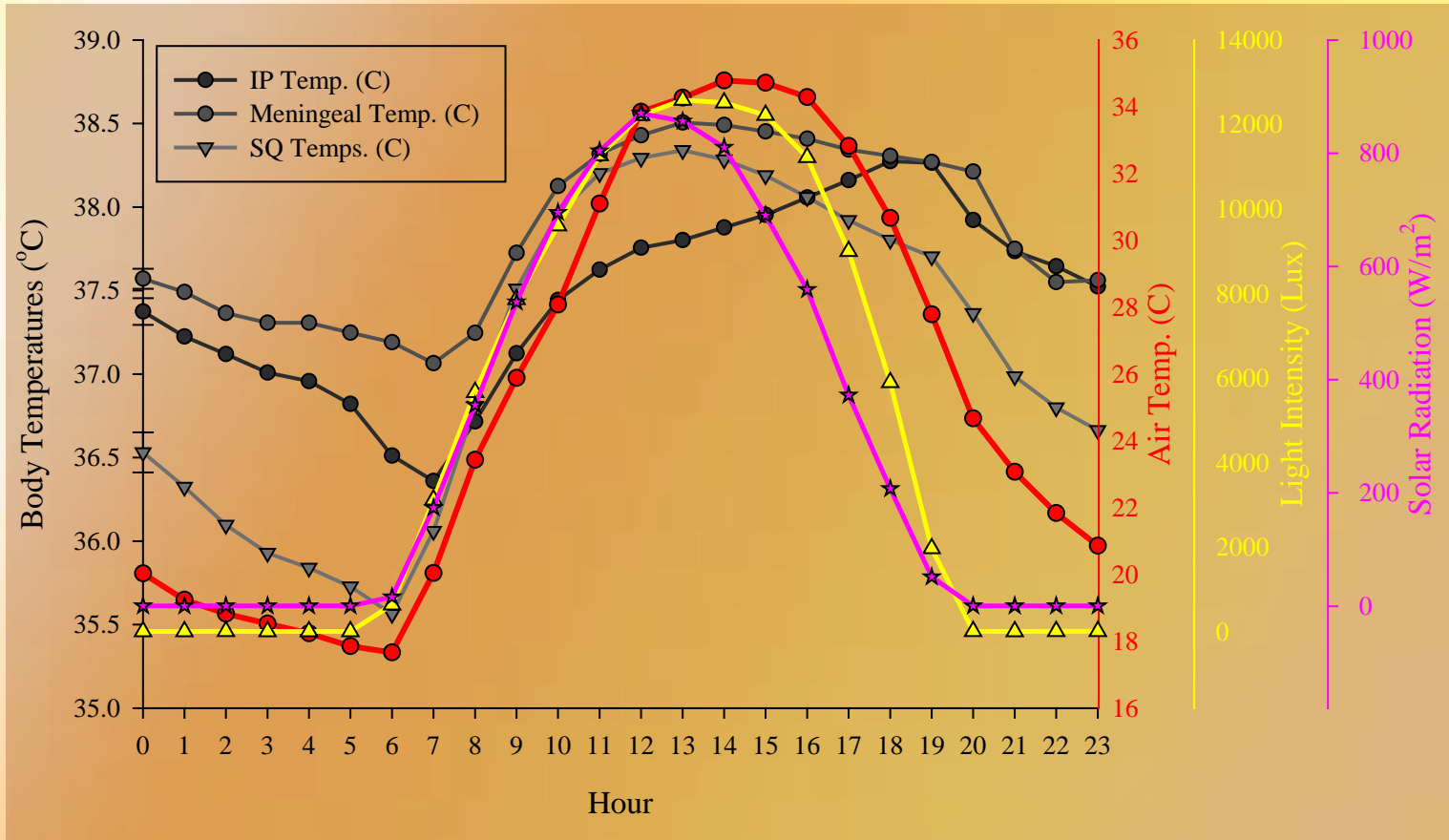
Results & Discussion

Mean Daily Body Temperatures Vs. Climatic Conditions



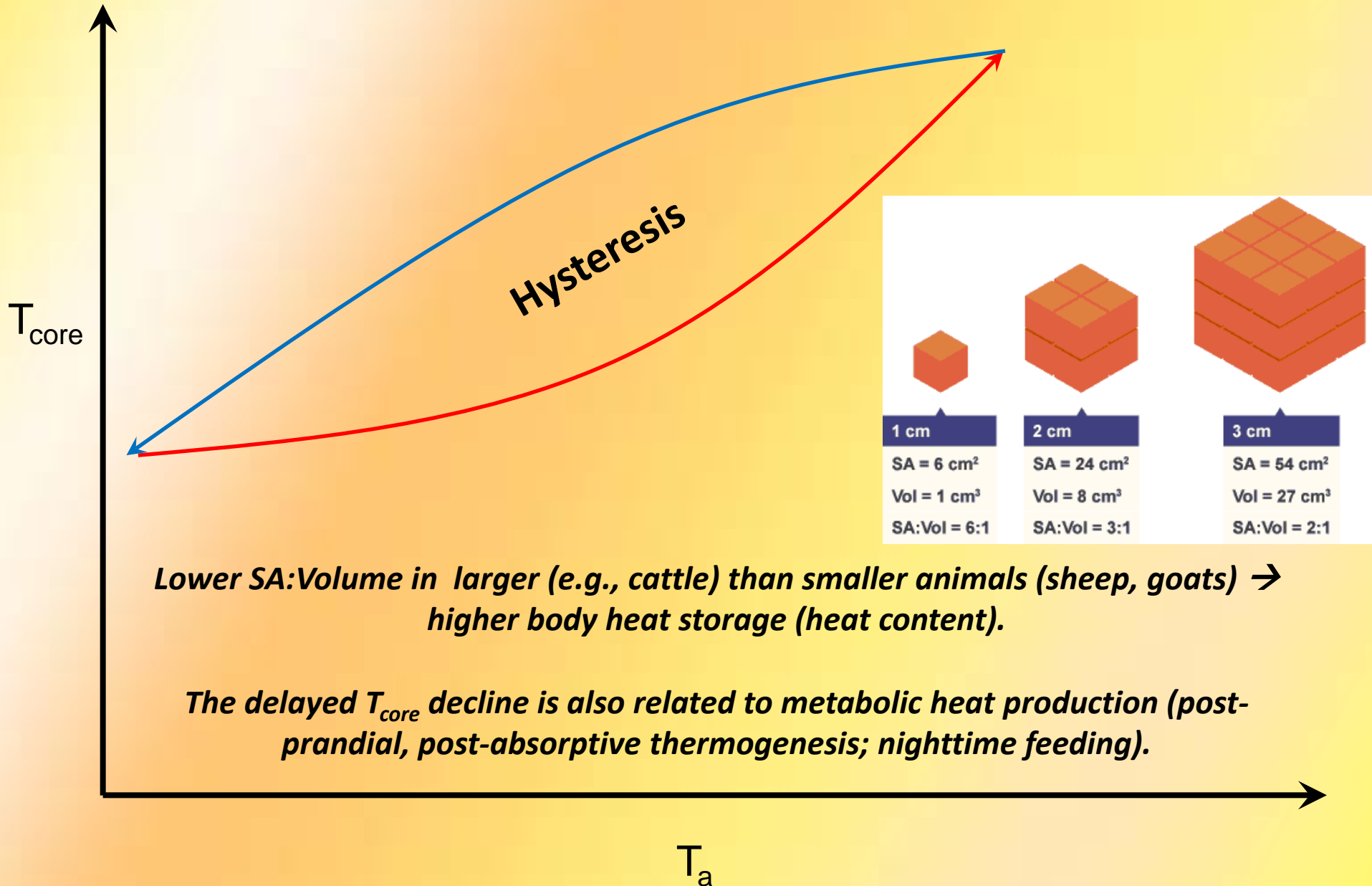
Results & Discussion

Mean Daily Body Temperatures Vs. Climatic Conditions



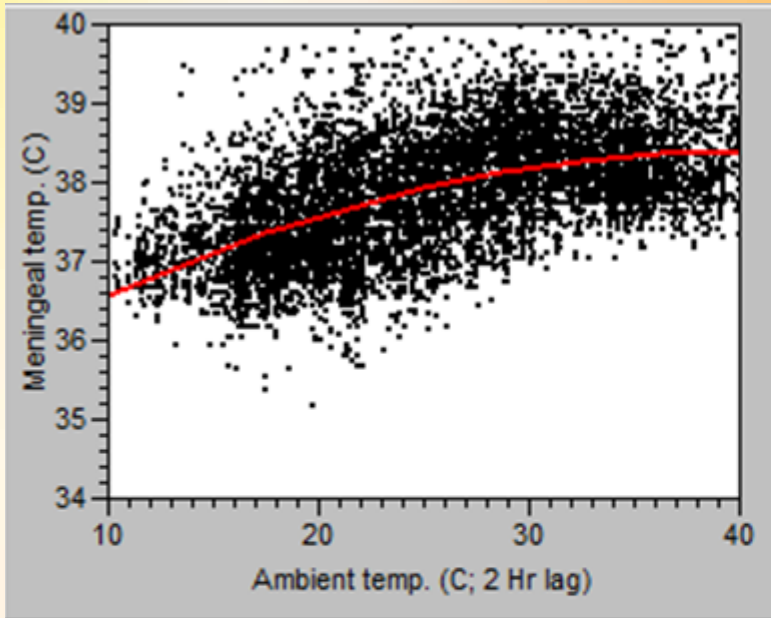
1-2 Hour Lag

Results & Discussion



Results & Discussion

Central (*meningeal temp.*) most driven by *light intensity (2Hr lag)*:
Circadian rhythm: biological clock, arousal for feeding and ranging



Polynomial Fit Degree=2

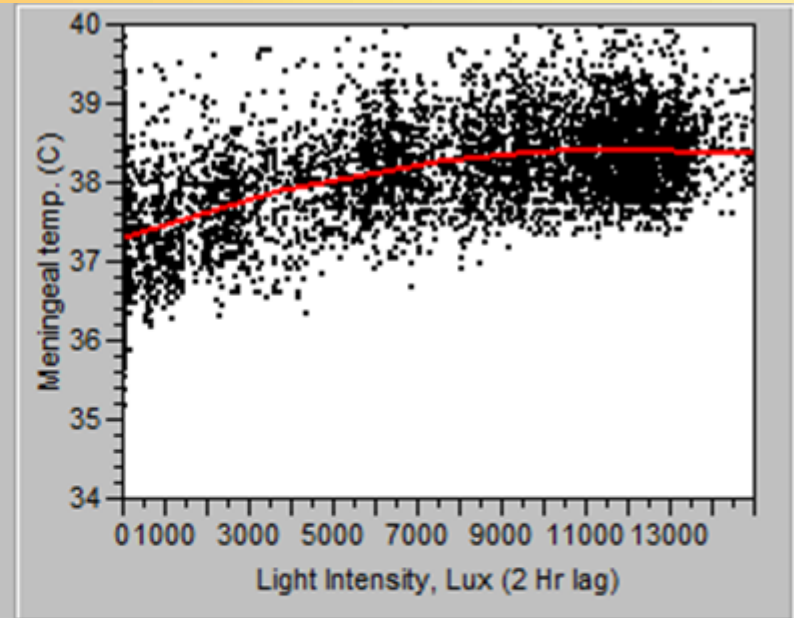
Polynomial Fit Degree=2

$$\text{Meningeal} = 36.569603 + 0.0551165 \text{ Ta } 2\text{H} - 0.0021105 (\text{Ta } 2\text{H} - 26.1816)^2$$

Summary of Fit

RSquare

0.295086



Polynomial Fit Degree=2

Polynomial Fit Degree=2

$$\text{Meningeal} = 37.545787 + 0.0001009 \text{ Lux } 2\text{H} - 7.8151\text{e-}9 (\text{Lux } 2\text{H} - 5521.21)^2$$

Summary of Fit

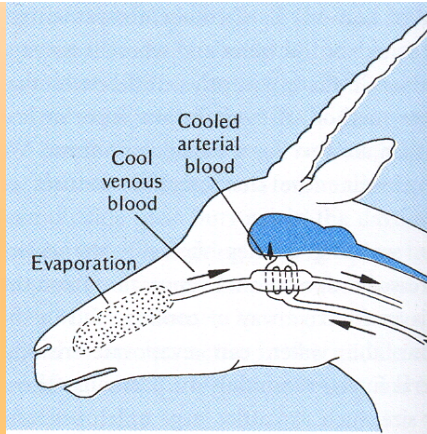
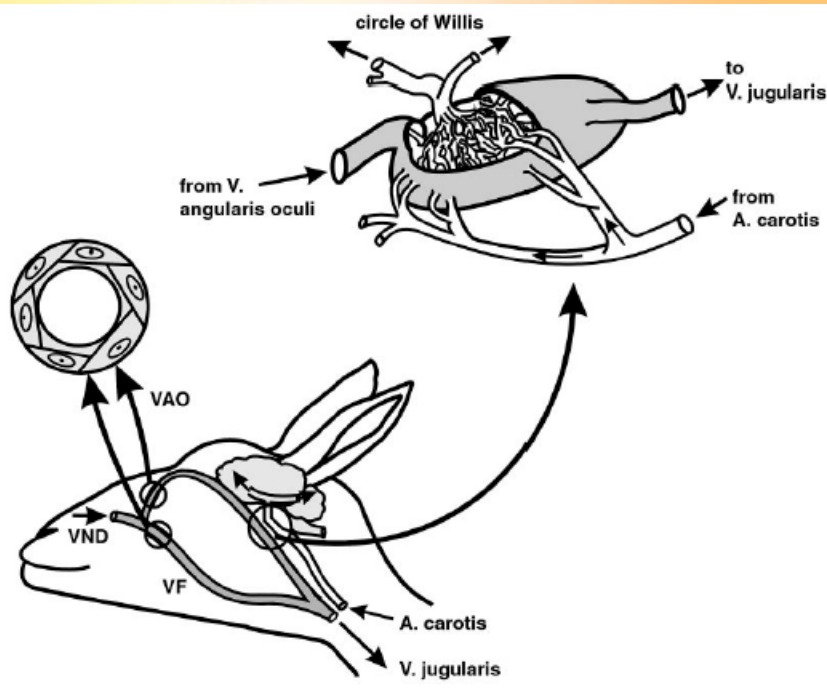
RSquare

0.427458

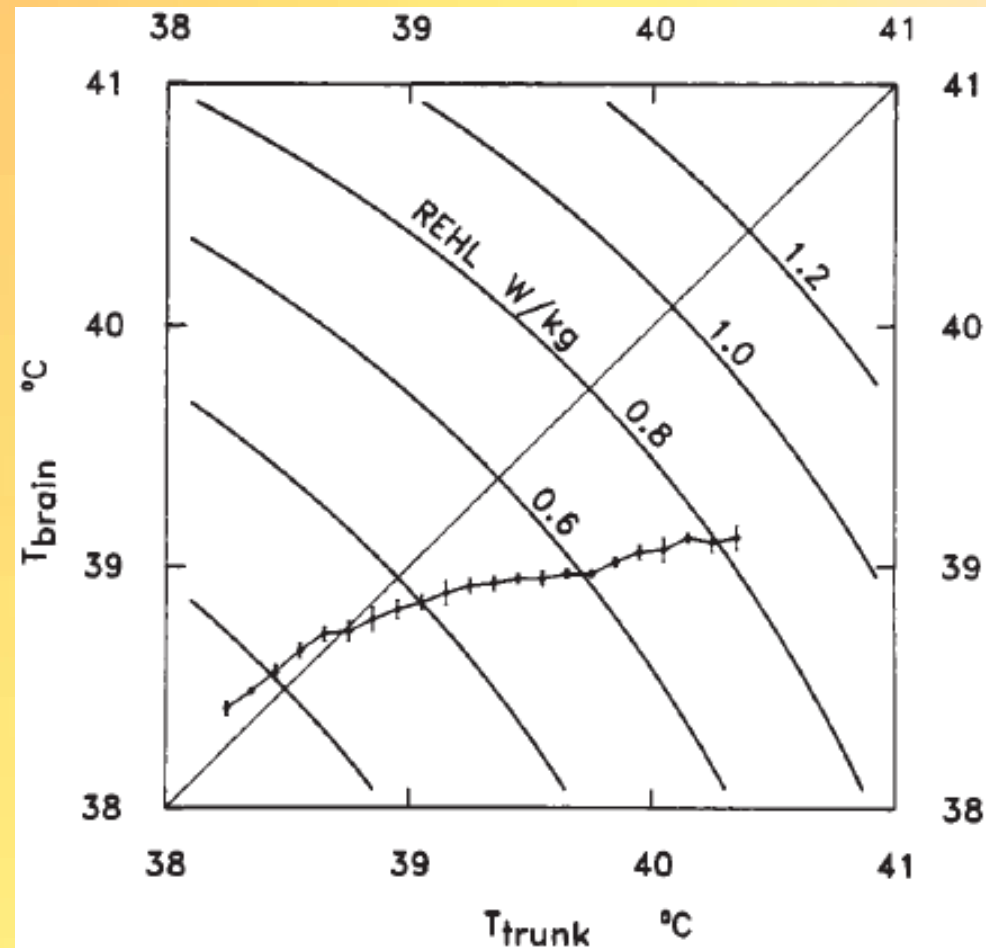
($P < 0.001$)

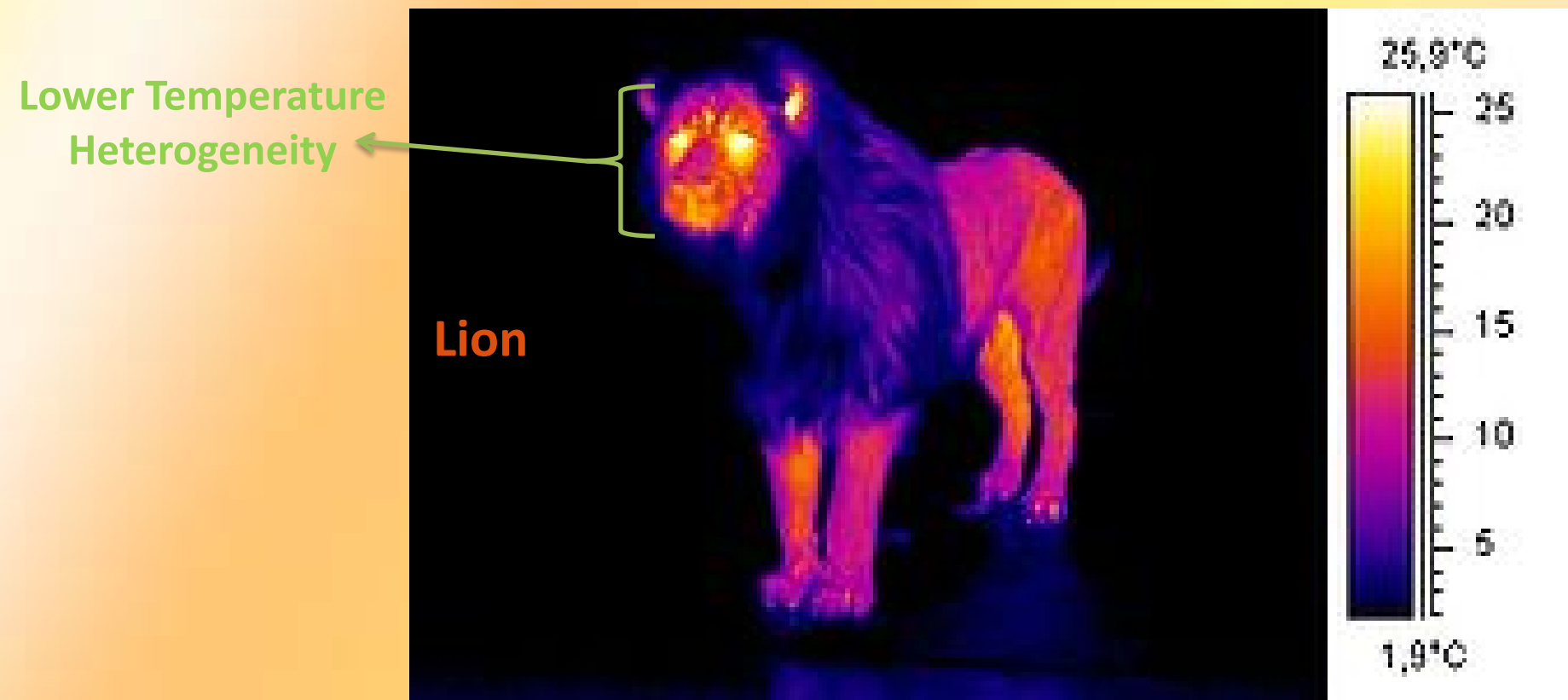
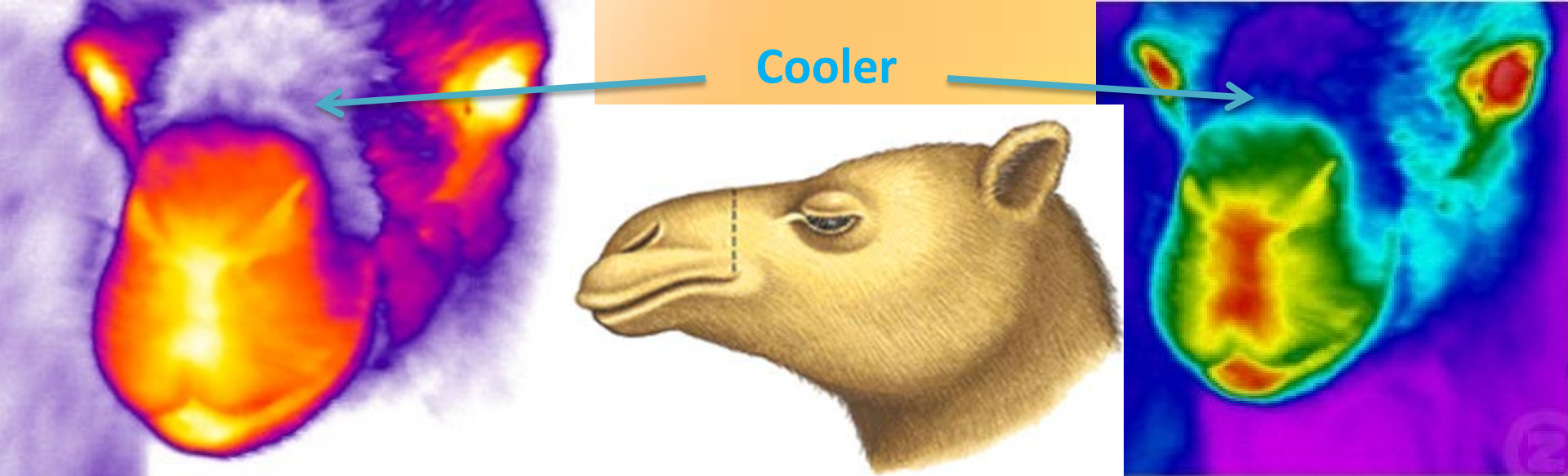
Introduction

- ✓ Selective brain cooling is a helpful tool to economize on water during thermal/hydration stress (Ohta et al., 1992; Fuller et al., 2000; Jessen, 2001; Mitchell et al., 2002; Fuller et al., 2007; Wei et al., 2008; Maloney et al., 2009).



SBC in artiodactyls



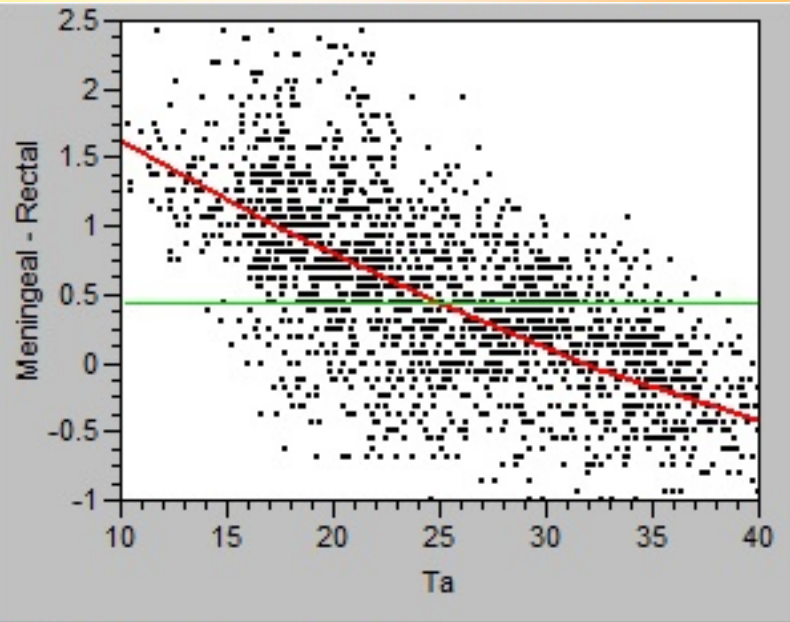


Results & Discussion

With *dehydration*: Meningeal temperature → more *sensitive* (faster response; 1Hr delay) to ambient temperature (*thermal takeover*)



Hydrated camels



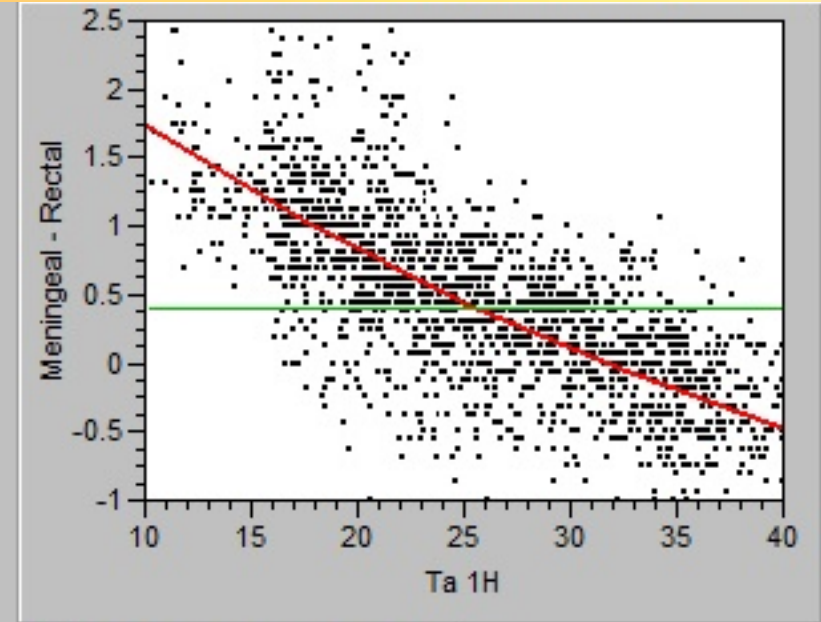
Polynomial Fit Degree=2
Fit Mean

Polynomial Fit Degree=2

$$\text{Meningeal - Rectal} = 2.1247364 - 0.0676993 \text{ Ta} + 0.0007577 (\text{Ta} - 25.5226)^2$$

Summary of Fit

RSquare 0.44444



Polynomial Fit Degree=2
Fit Mean

Polynomial Fit Degree=2

$$\text{Meningeal - Rectal} = 2.2341107 - 0.0714817 \text{ Ta 1H} + 0.0008547 (\text{Ta 1H} - 26.3052)^2$$

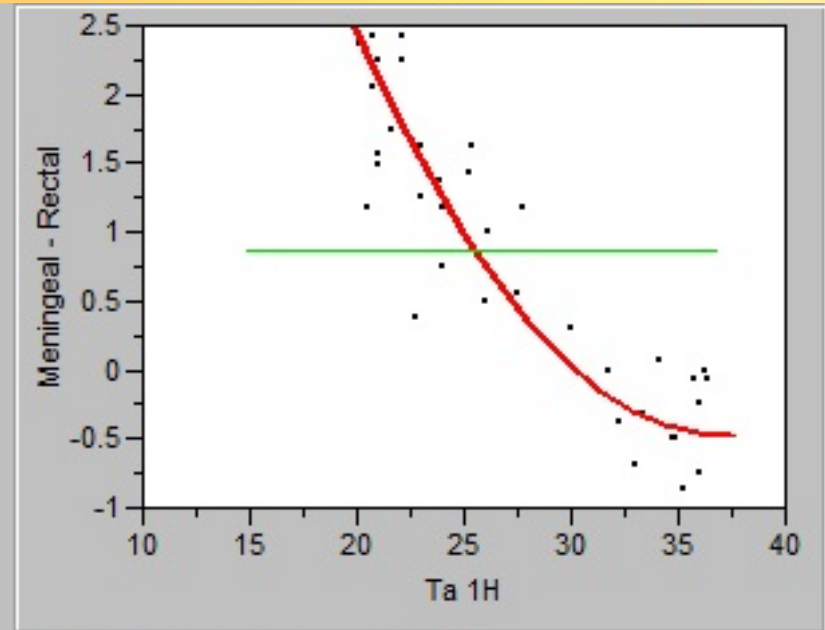
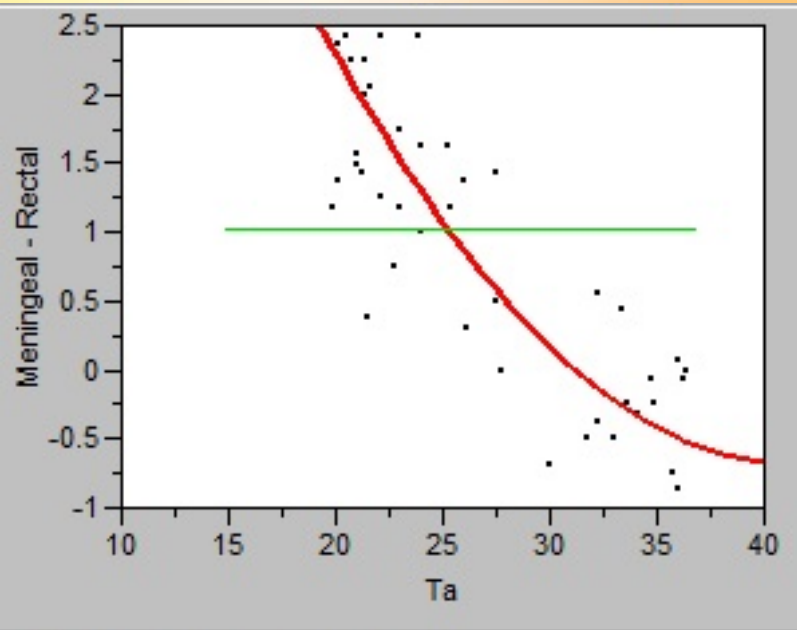
Summary of Fit

RSquare 0.516167

($P < 0.01$)

Results & Discussion

SBC is ON with dehydration



▼ Polynomial Fit Degree=2
▼ Fit Mean

▼ Polynomial Fit Degree=2

$$\text{Meningeal - Rectal} = 6.0594063 - 0.1998642 \text{ Ta} + 0.0063765 (\text{Ta} - 25.952)^2$$

▼ Summary of Fit

RSquare 0.726657

▼ Polynomial Fit Degree=2
▼ Fit Mean

▼ Polynomial Fit Degree=2

$$\text{Meningeal - Rectal} = 6.142043 - 0.2074665 \text{ Ta 1H} + 0.0099498 (\text{Ta 1H} - 26.6964)^2$$

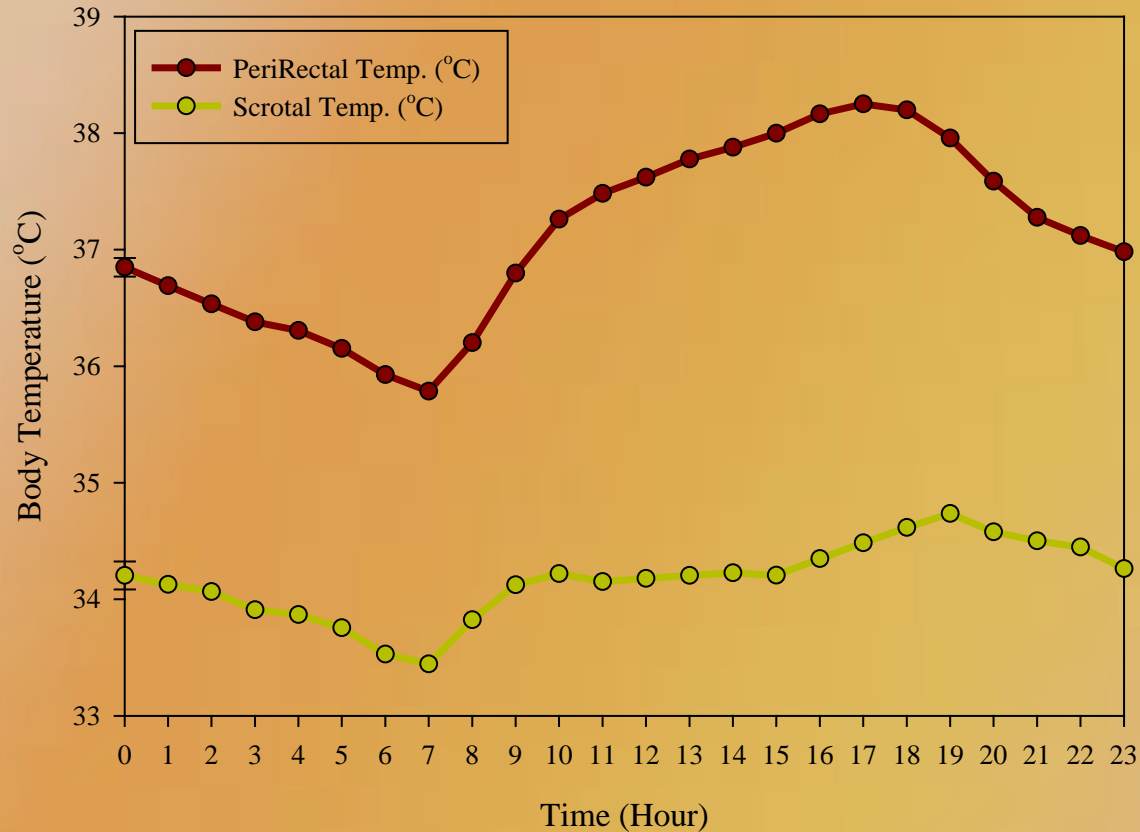
▼ Summary of Fit

RSquare 0.810927

(P < 0.05)

Results & Discussion

Core (PeriRectal) vs. Scrotal Temperatures ($^{\circ}\text{C}$)



Scrotal temp. < Core temp. (2-6 $^{\circ}\text{C}$) \rightarrow optimum spermatogenesis

Results & Discussion



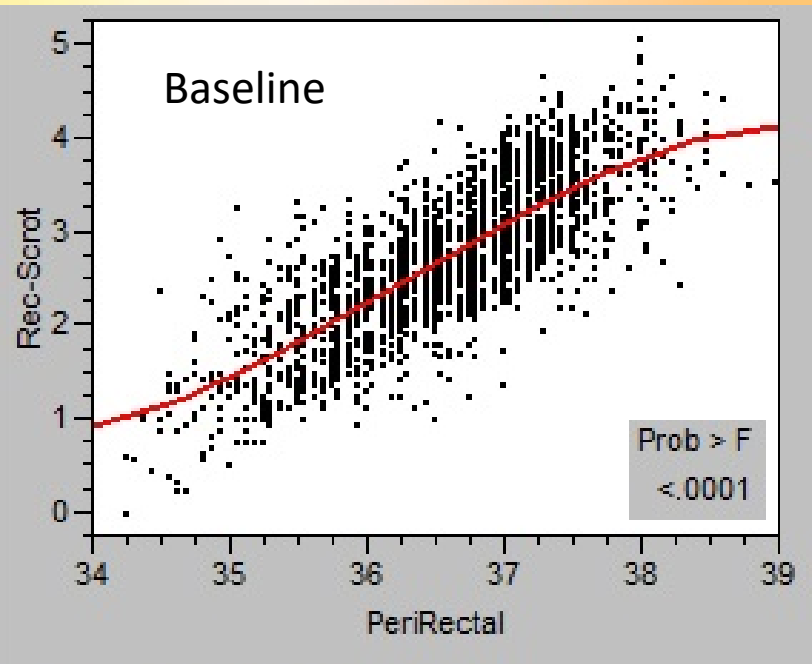
*Work in our lab → sheep, goats (frequently: Scrotal temp. ~ Tcore)
NOT in camels !*

Results & Discussion

Scrotal temperature is highly regulated → (spermatogenesis)

BUT

Dehydration → may compromise gonadal thermoregulation



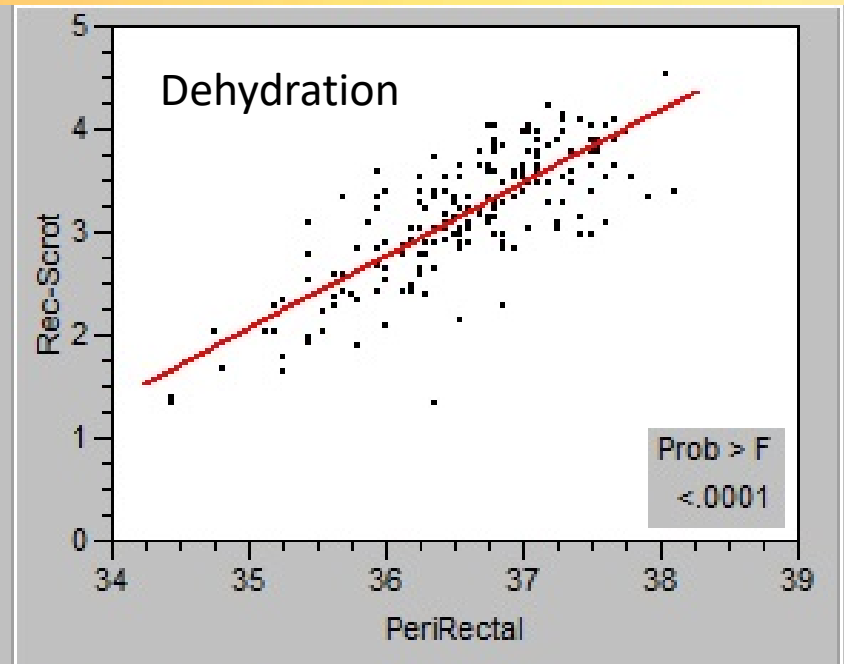
Polynomial Fit Degree=3

Polynomial Fit Degree=3

$$\text{Rec-Scrot} = -28.37436 + 0.8503694 \text{ PeriRectal} - 0.033784 (\text{PeriRectal}-36.5926)^2 - 0.0342146 (\text{PeriRectal}-36.5926)^3$$

Summary of Fit

RSquare 0.632169



Linear Fit

Linear Fit

$$\text{Rec-Scrot} = -22.63281 + 0.7058059 \text{ PeriRectal}$$

Summary of Fit

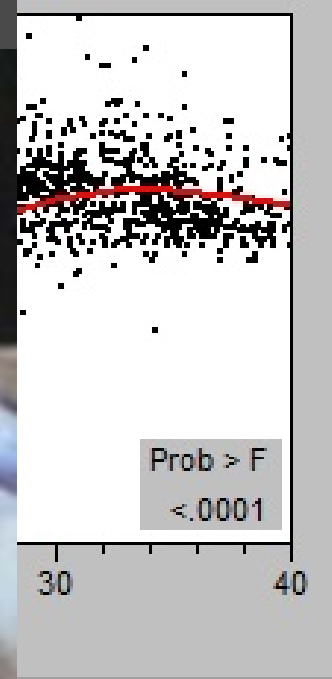
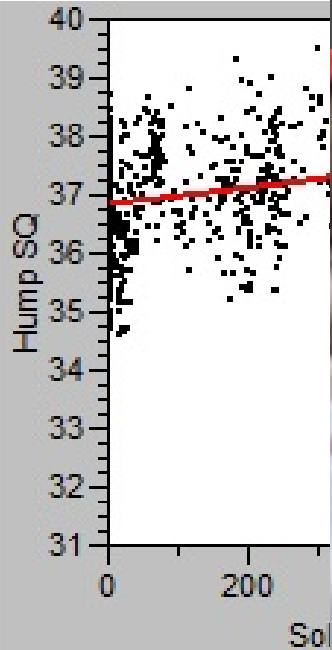
RSquare 0.61911

Results & Discussion

Hump is more responsive to air temp. than solar radiation:

Fat → low thermal conductivity

Unique curvature → diffraction of solar rays



Linear Fit

Linear Fit

Hump SQ = 36.847019

Summary of F

RSquare

- 0.008329 (Ta-25.5226)²

354967

Conclusions

- Hierarchical thermoregulatory stability in the camel: **Central then core then peripheral.**
- Appropriateness of thermoregulatory evaluation: **freely moving + intensive.**
- Extent of **heterothermy?**
- **Gonadal temperature:** variability from other farm animals.
- **Time-lag:** effect & response.

Thank You !

