Water-saving strategies in desert animals

Marcus Clauss

Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Switzerland

Biologie und Erkranungen der Wildtiere 2009

University of Zurich
Vetsuisse Faculty

Clinic
of Zoo Animals, Exotic Pets and Wildlife

Definition Desert

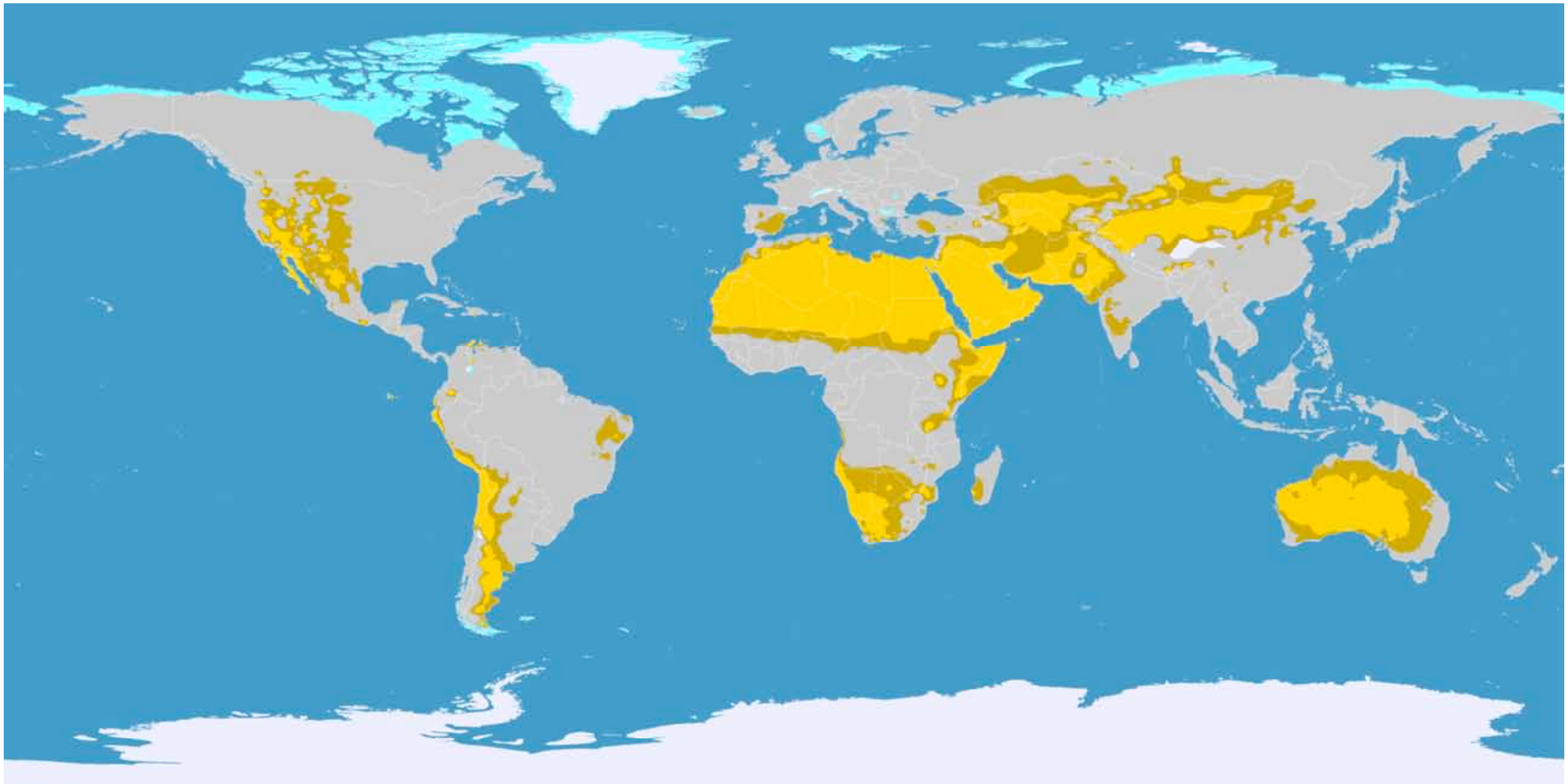
Definitions Desert

- Vegetation < 5% of surface
- Ice desert (cold), draught desert (aridity/heat)
- “Anökumene”
- Rainfall < 250 mm/year

  (cf.

  Zurich, CH: app. 1000 mm/year;

  Rain forest up to 2000 mm/year)
- More water loss from evaporation than added by rainfall



Charakteristics of deserts

- Temperature fluctuations (dry soil stores not heat and only heats up superficially; lack of cloud cover results in extreme solar radiation during the day and heat radiation during night)

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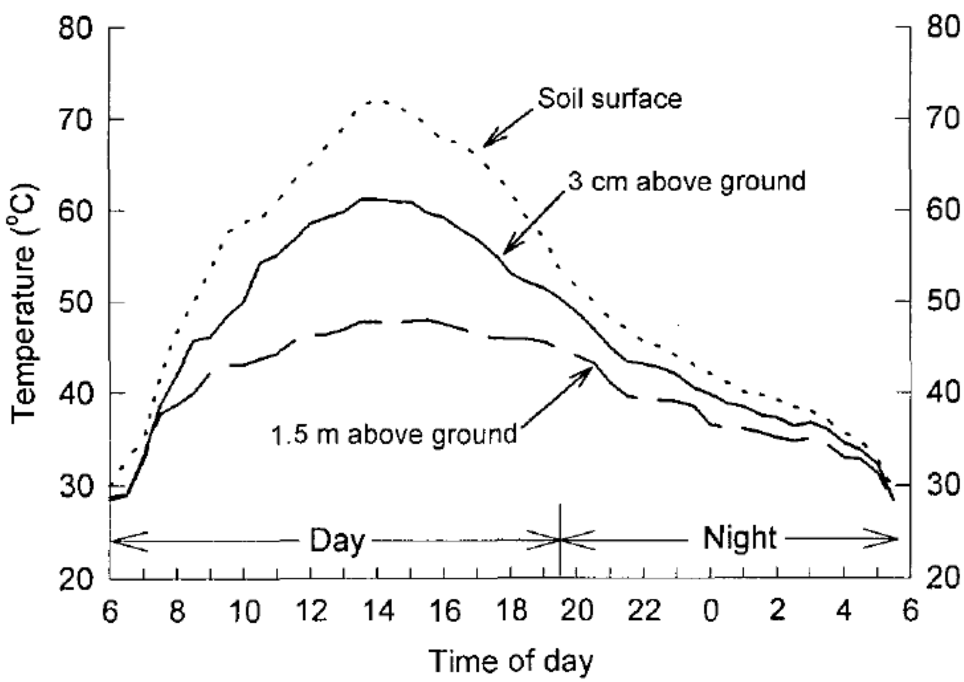

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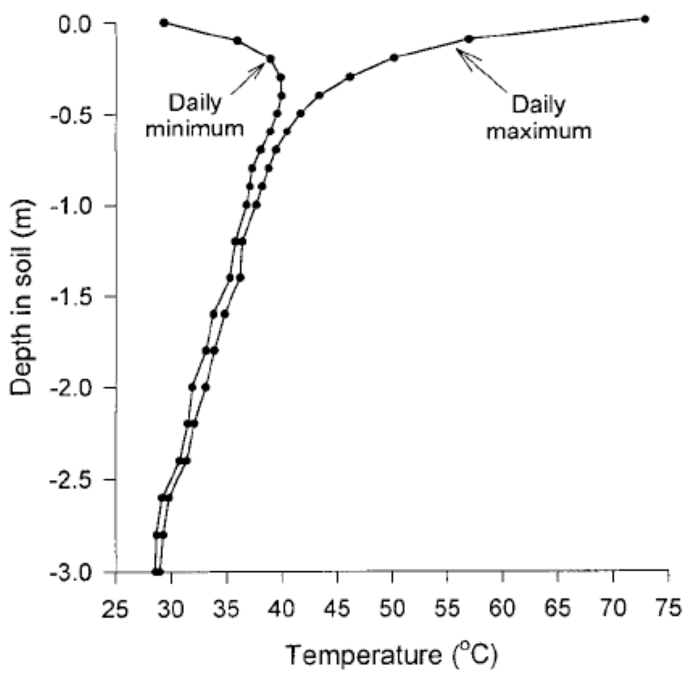
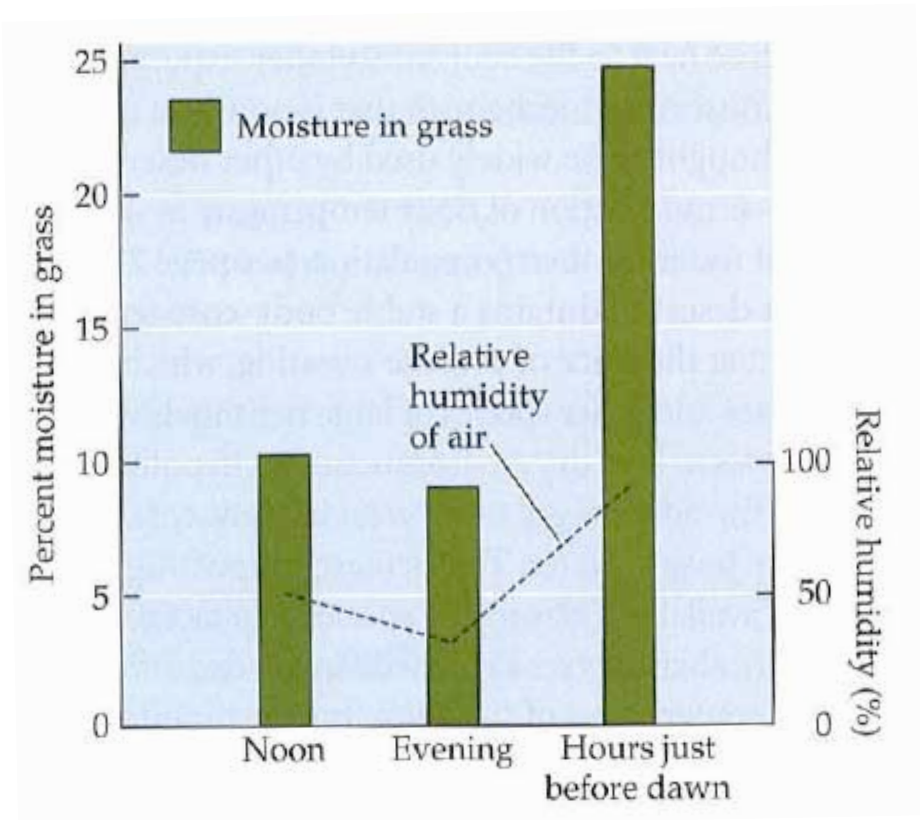


Charakteristics of deserts

- Extreme cooling can lead to condensation even at low humidities - dew



from Hill et al. (2004)

Necessary adaptations

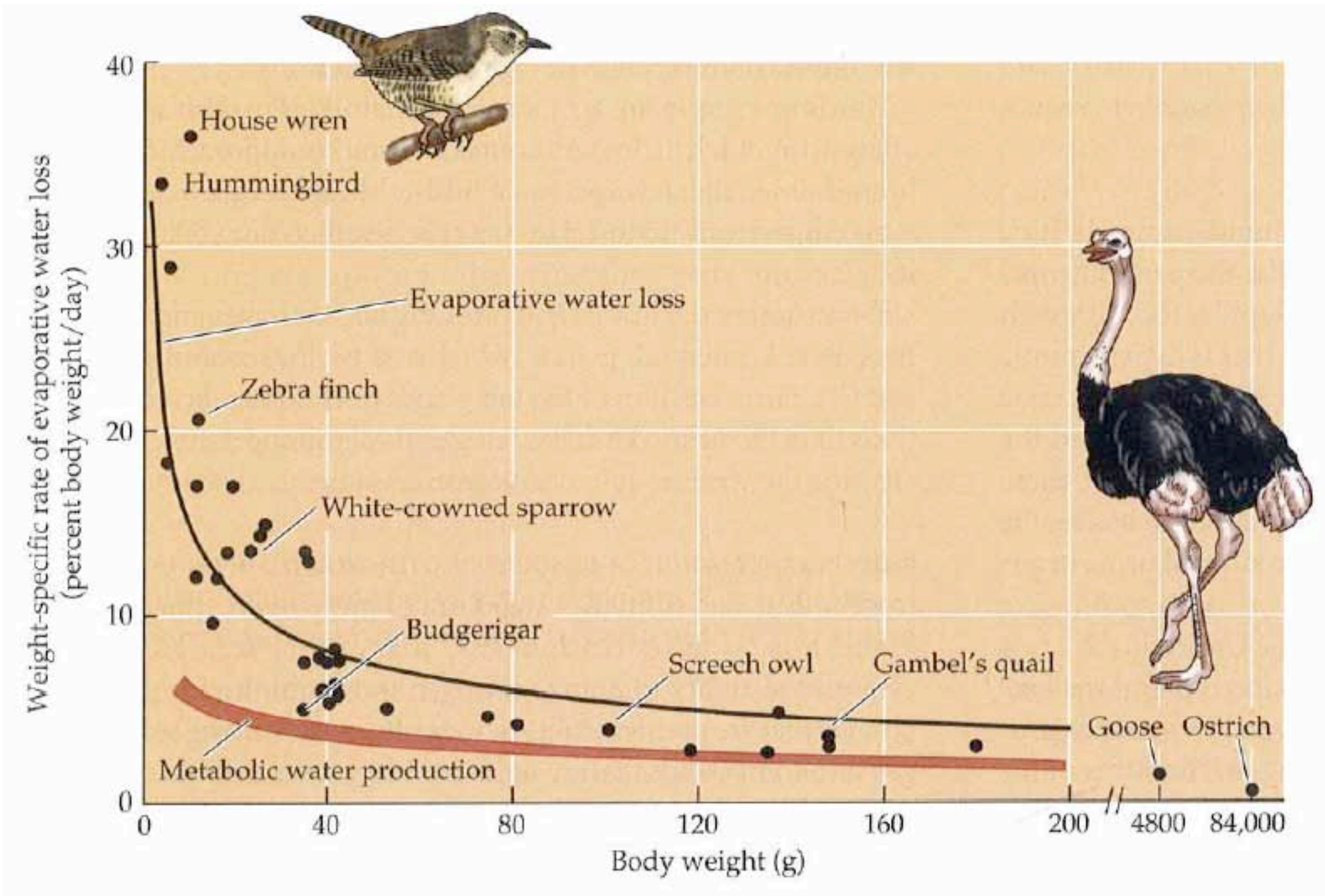
- Direct consequence of heat: burning

- Indirect consequence of heat: water loss

Three strategies - Triple E

- Evaders
- Evaporators
- Endurers

Evader - Endurer - Continuum



from Hill et al. (2004)

General statements

- Desert animals have a lower water flux than other animals
- This is also due to a lower metabolic rate in desert animals

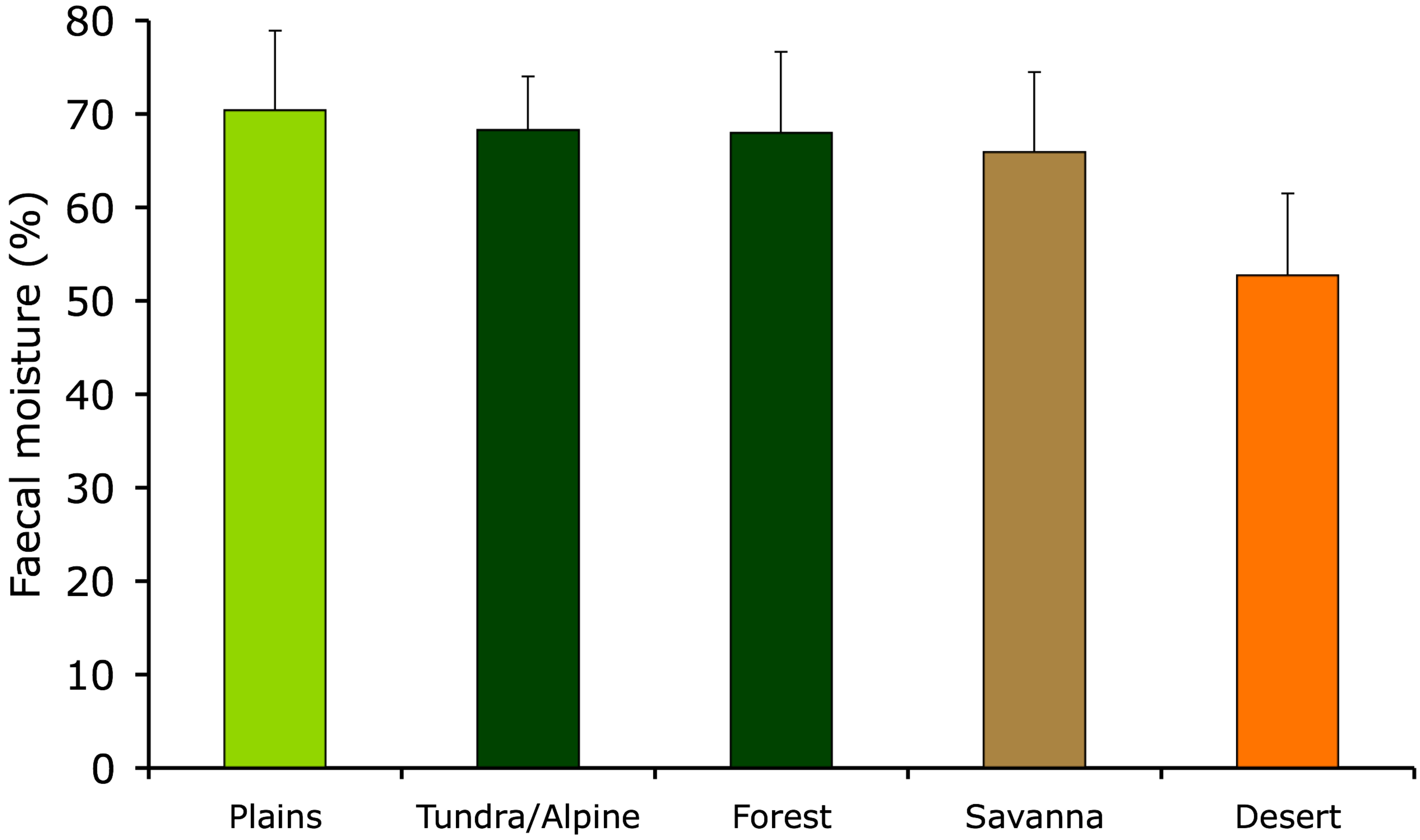
Ways to lose water

- Faeces
- Urine
- Exhalate
- Sweat

Water loss in faeces

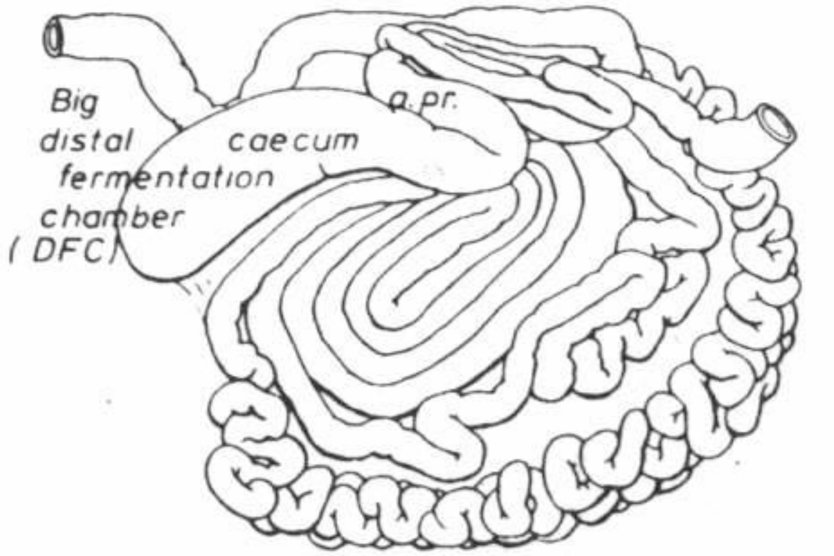
Moisture in faeces of 81 ruminant species with *ad libitum* water access

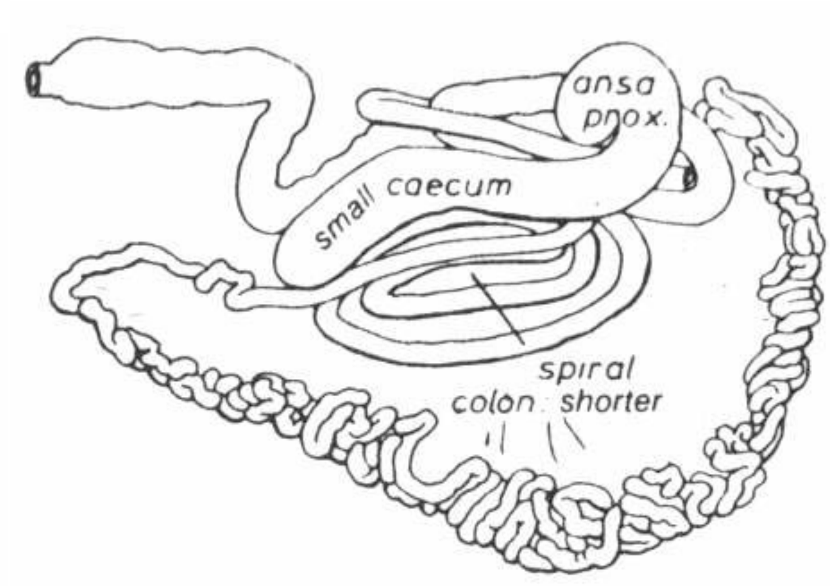
Moisture in faeces of 81 ruminant species with *ad libitum* water access



from Clauss et al. (2004)

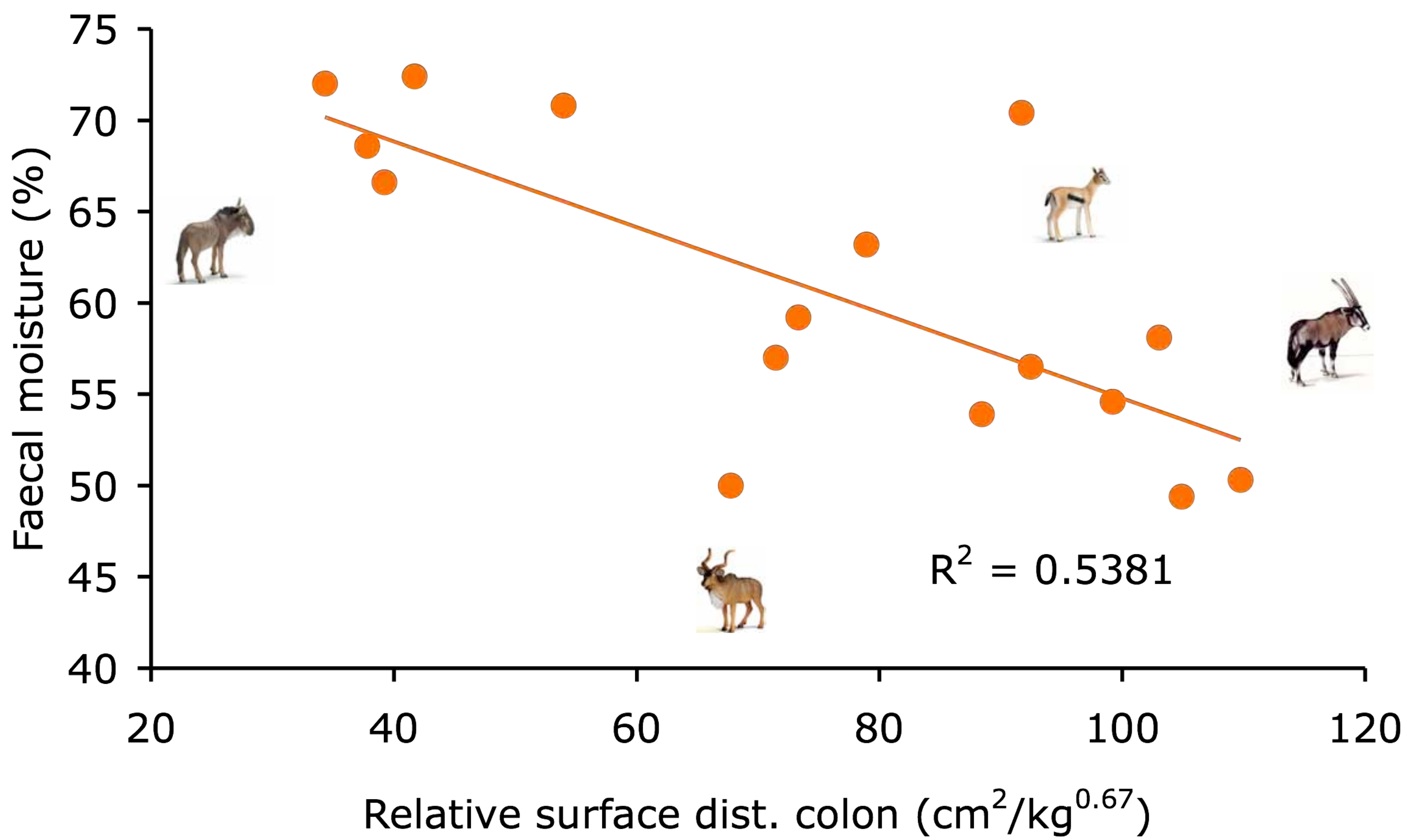
Water absorption in the large intestine





modified from Hofmann (1989)

Faecal Moisture and colonic surface in ruminants



from Woodall & Skinner (1993)

Water loss in faeces

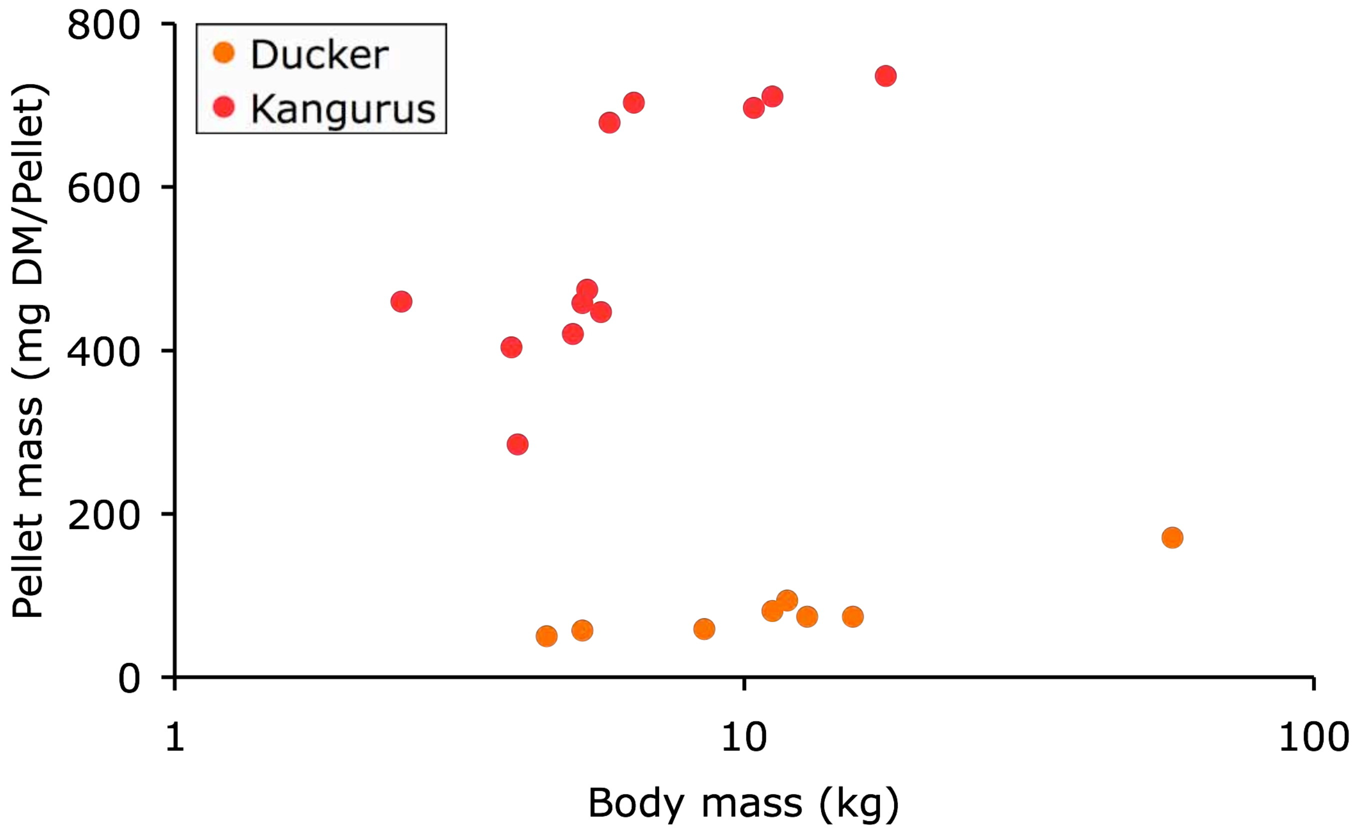
- The smallr the fecal pellet, the larger its relative surface, i.e. the easier to absorb water from it ...

Size and moisture content of faecal pellets of small African antelope and Australian macropods

Peter F. Woodall[1], Viv J. Wilson[2] and Peter M. Johnson[3]

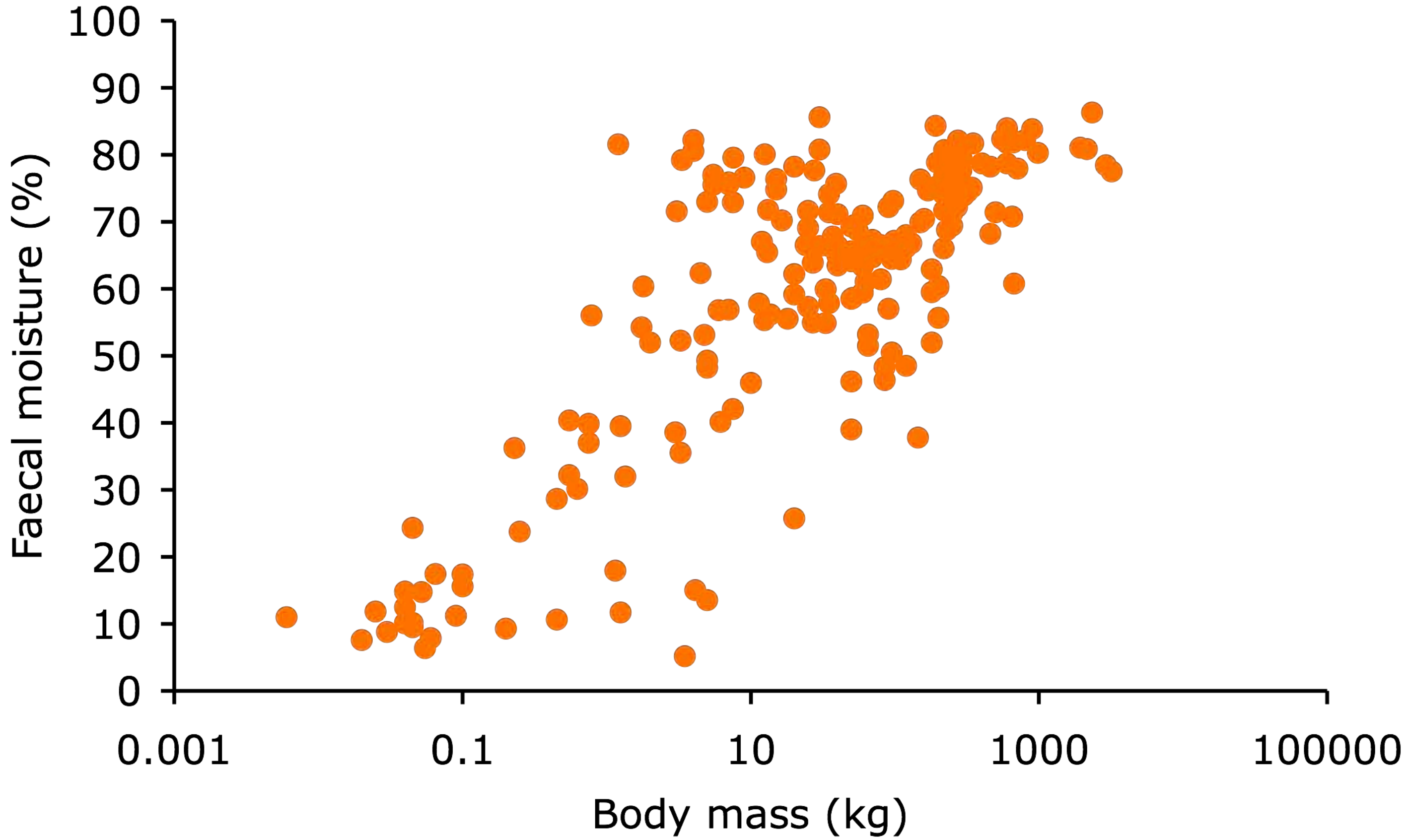
Afr. J. Ecol. 1999, Volume 37, pages 471–474

- Larger animals have larger faecal pellets



Water losses in faeces

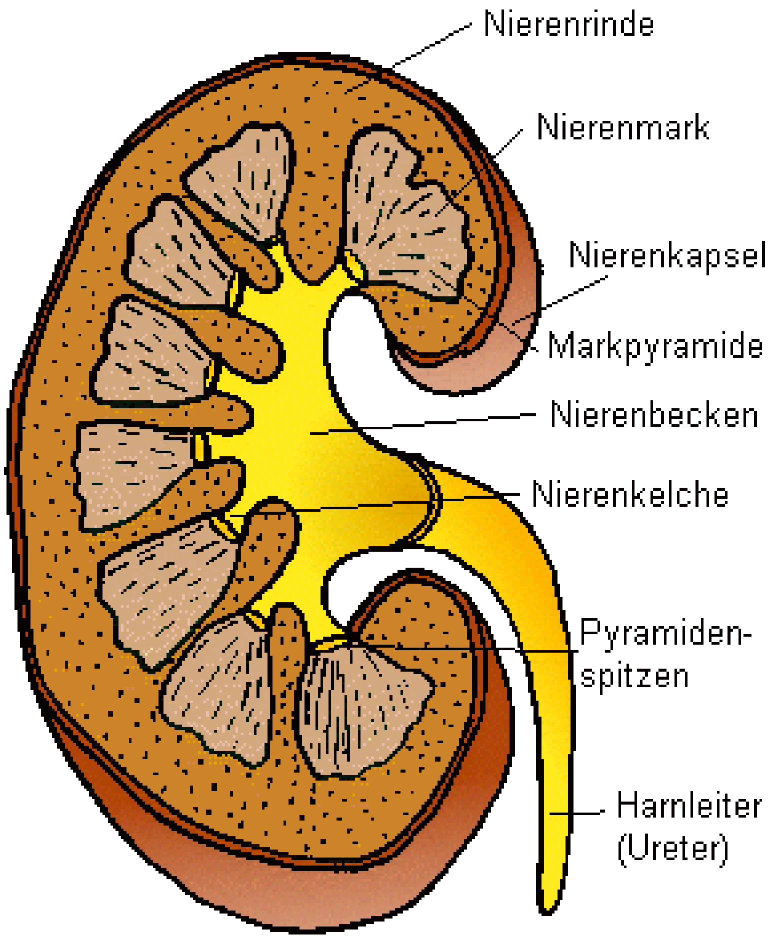
- the larger the mammal, the wetter its faeces...



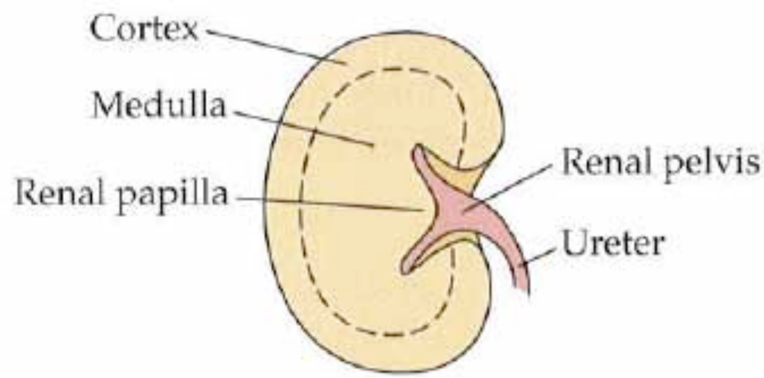
from Fritz (2007)

Water losses in urine

Kidney



Nierenrinde
Nierenmark
Nierenkapsel
Markpyramide
Nierenbecken
Nierenkelche
Pyramiden-
spitzen
Harnleiter
(Ureter)

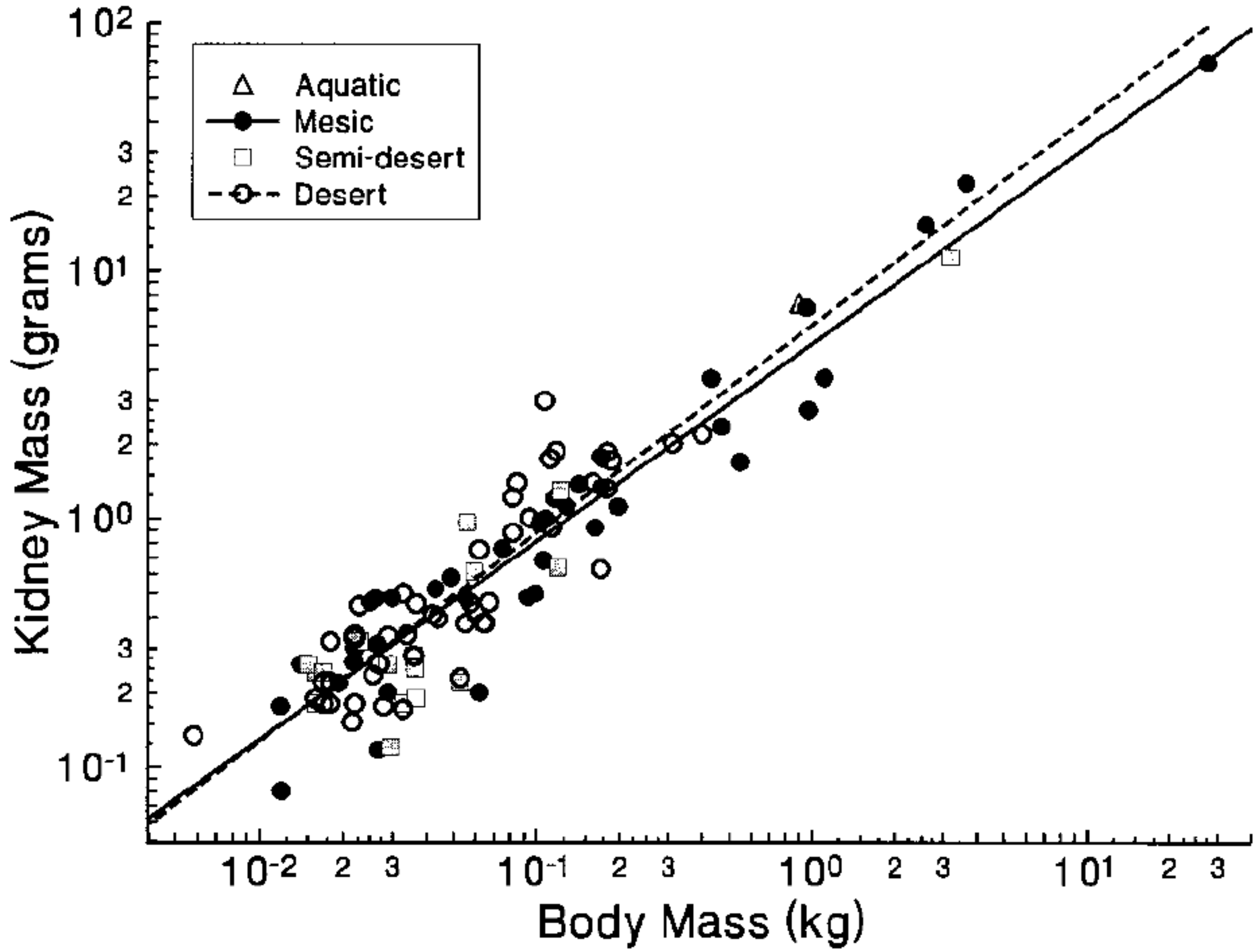


Cortex
Medulla
Renal papilla
Renal pelvis
Ureter

Kidney Mass and Relative Medullary Thickness of Rodents in Relation to Habitat, Body Size, and Phylogeny

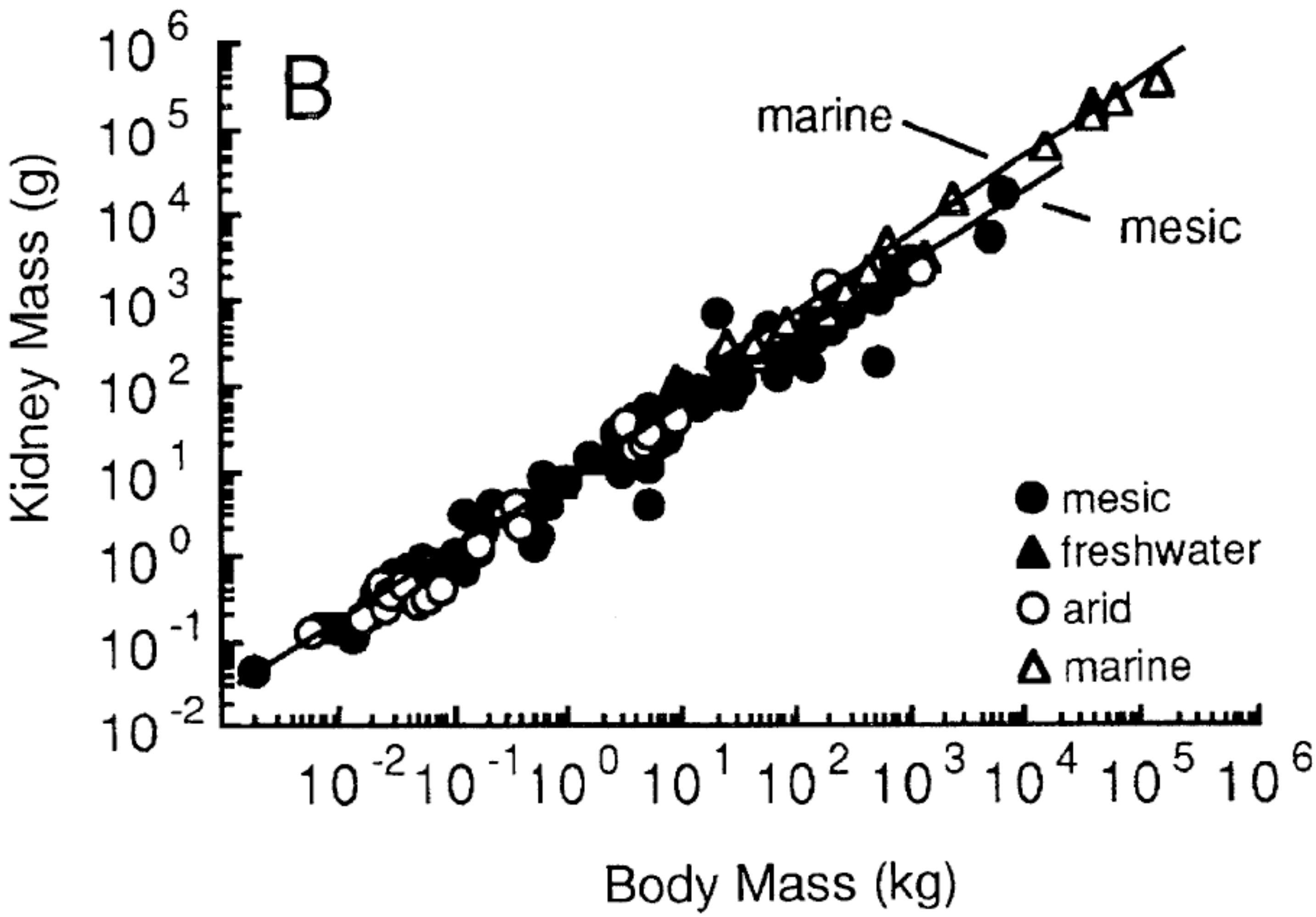
Mohammed A. Al-kahtani[1,*]
Carlos Zuleta[2]
Enrique Caviedes-Vidal[3]
Theodore Garland, Jr.[4,†]

Physiological and Biochemical Zoology 77(3):346–365. 2004.

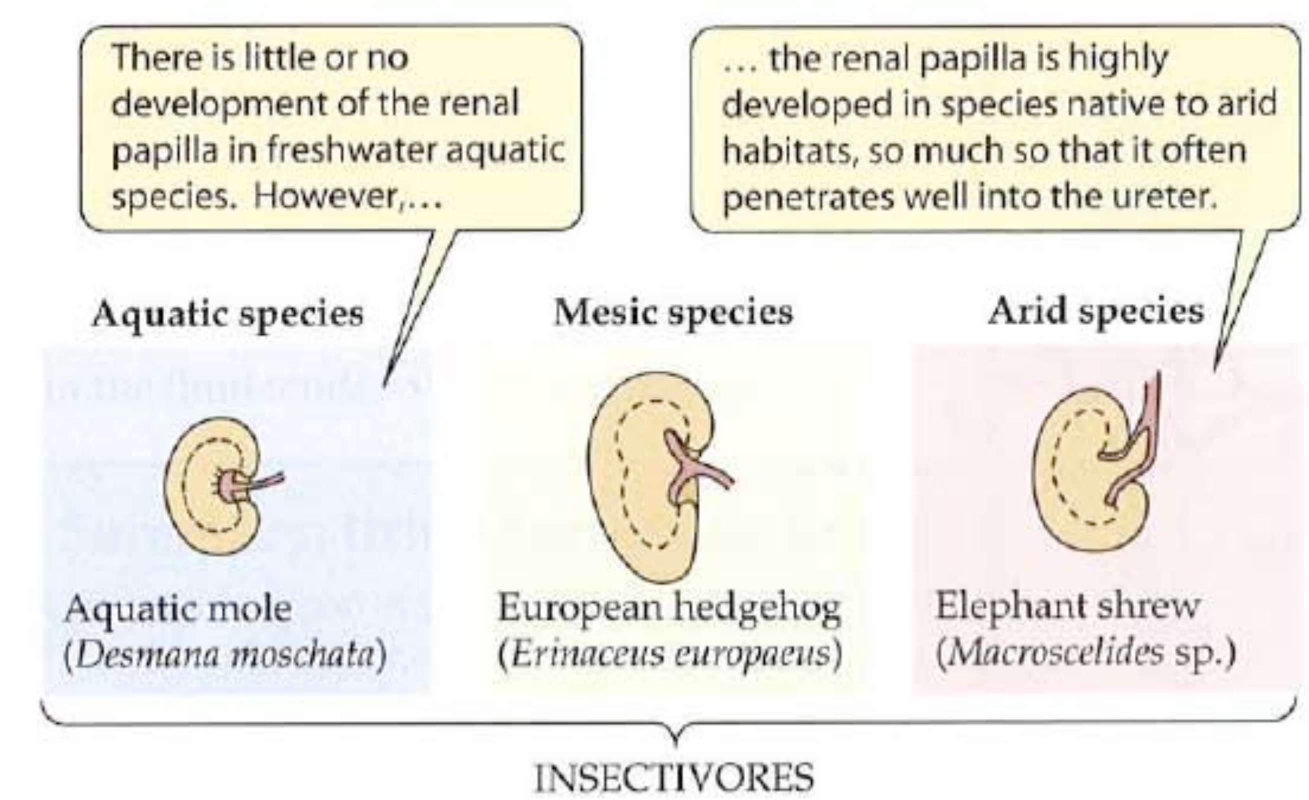


Structure and concentrating ability of the mammalian kidney: correlations with habitat

CAROL A. BEUCHAT Am. J. Physiol. (1996)



Renal papilla



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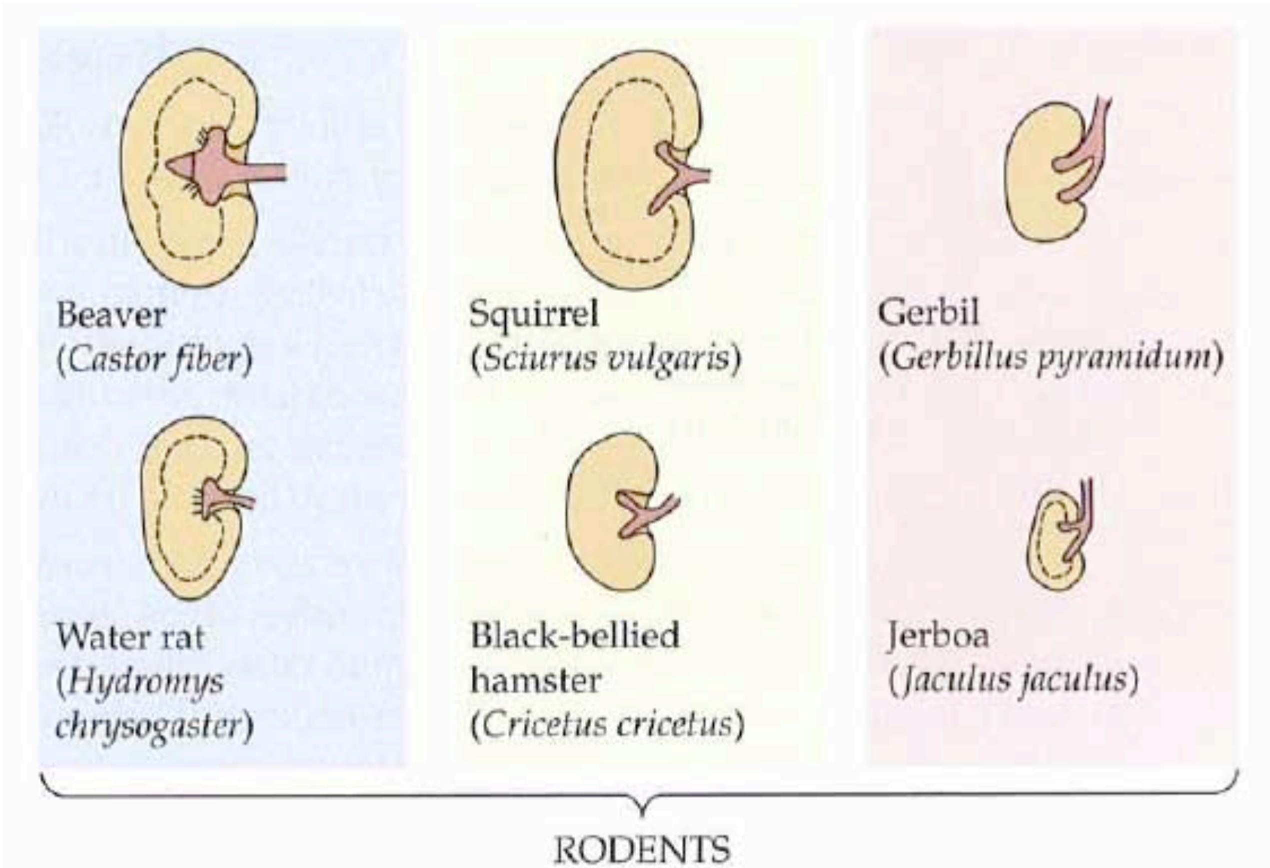
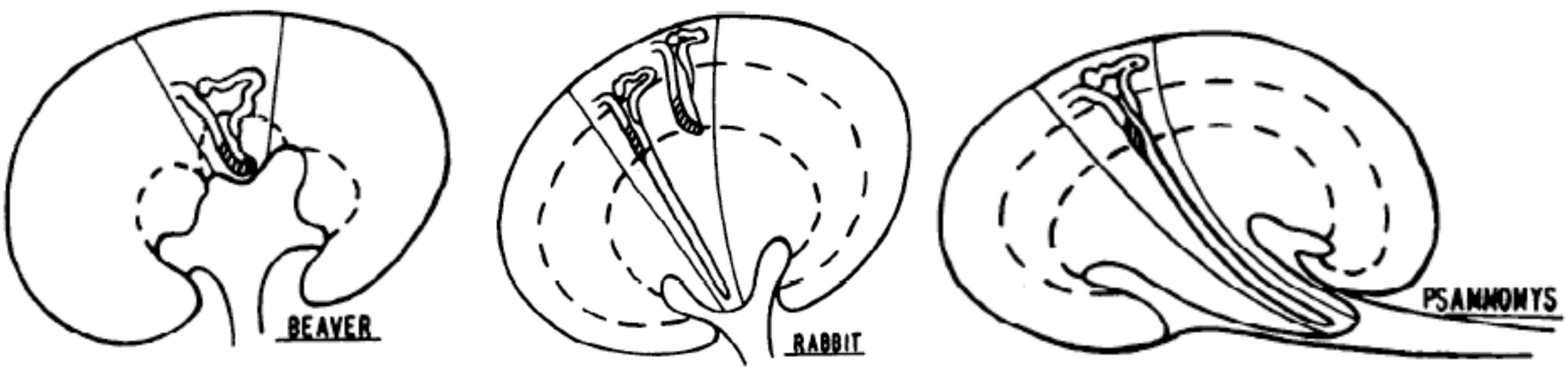


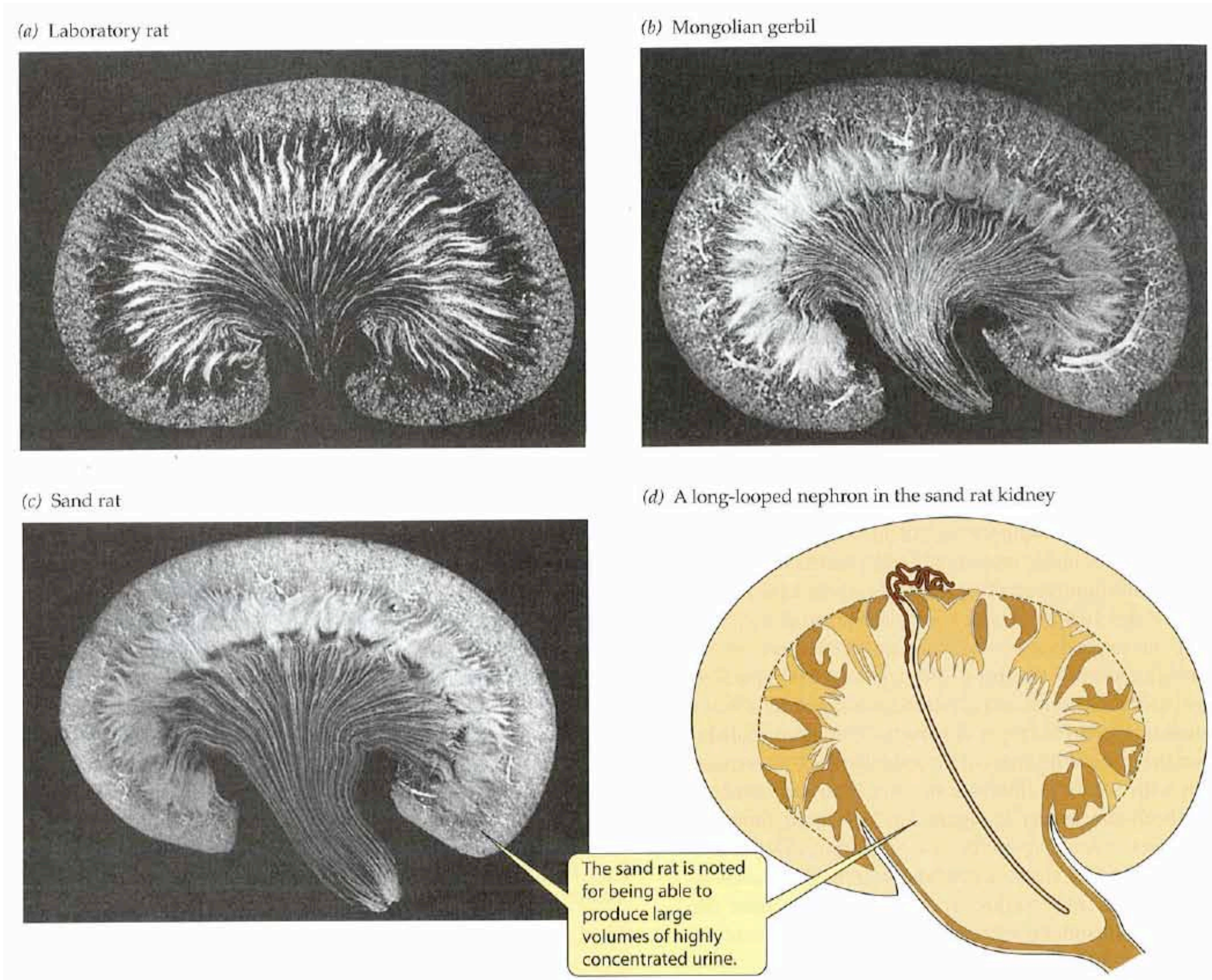
from Hill et al. (2004)

Structure and concentrating mechanism in the mammalian kidney[1]

BODIL SCHMIDT-NIELSEN[2] AND ROBERTA O'DELL[3]

Am. J. Physiol. (1961)





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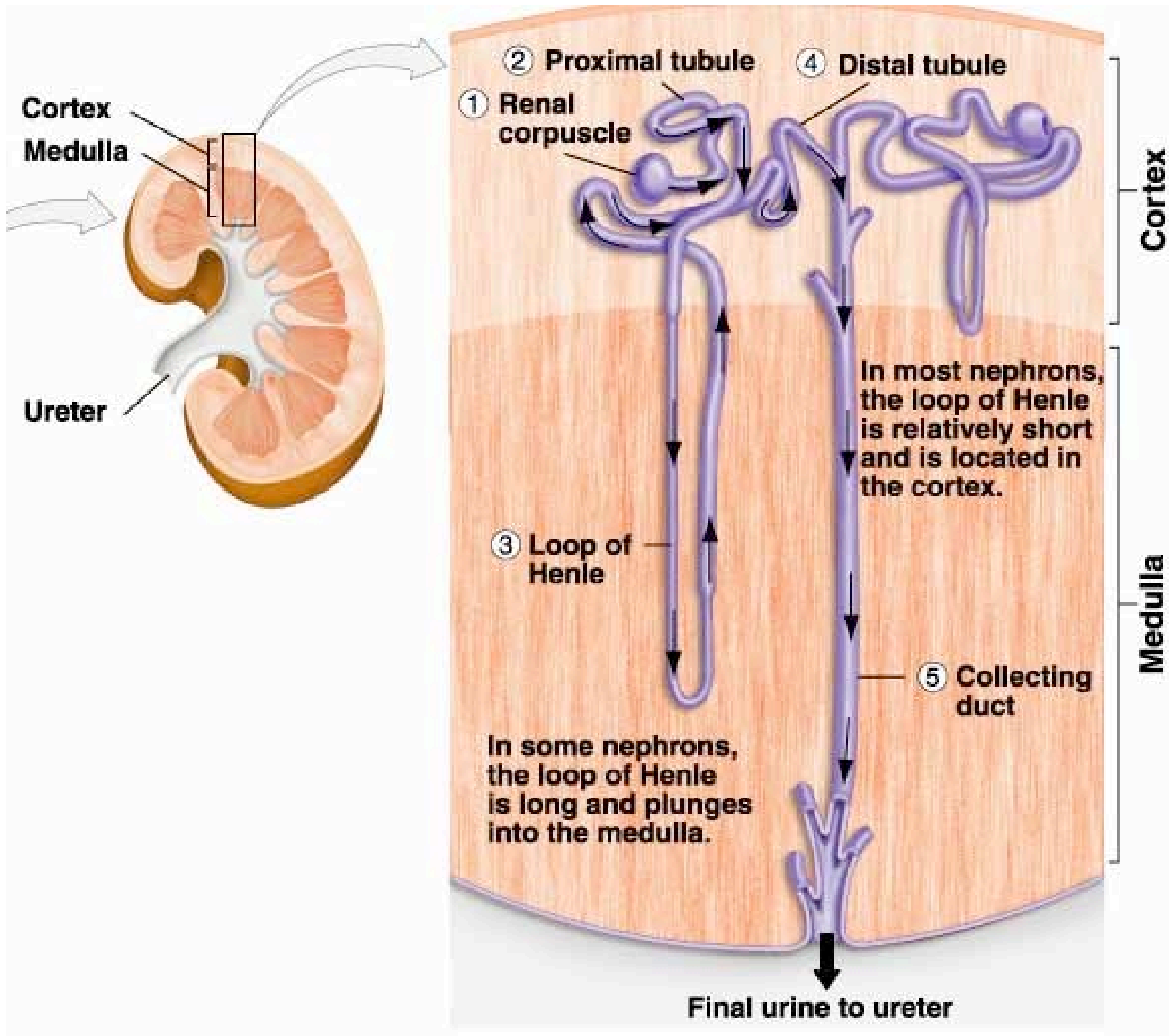
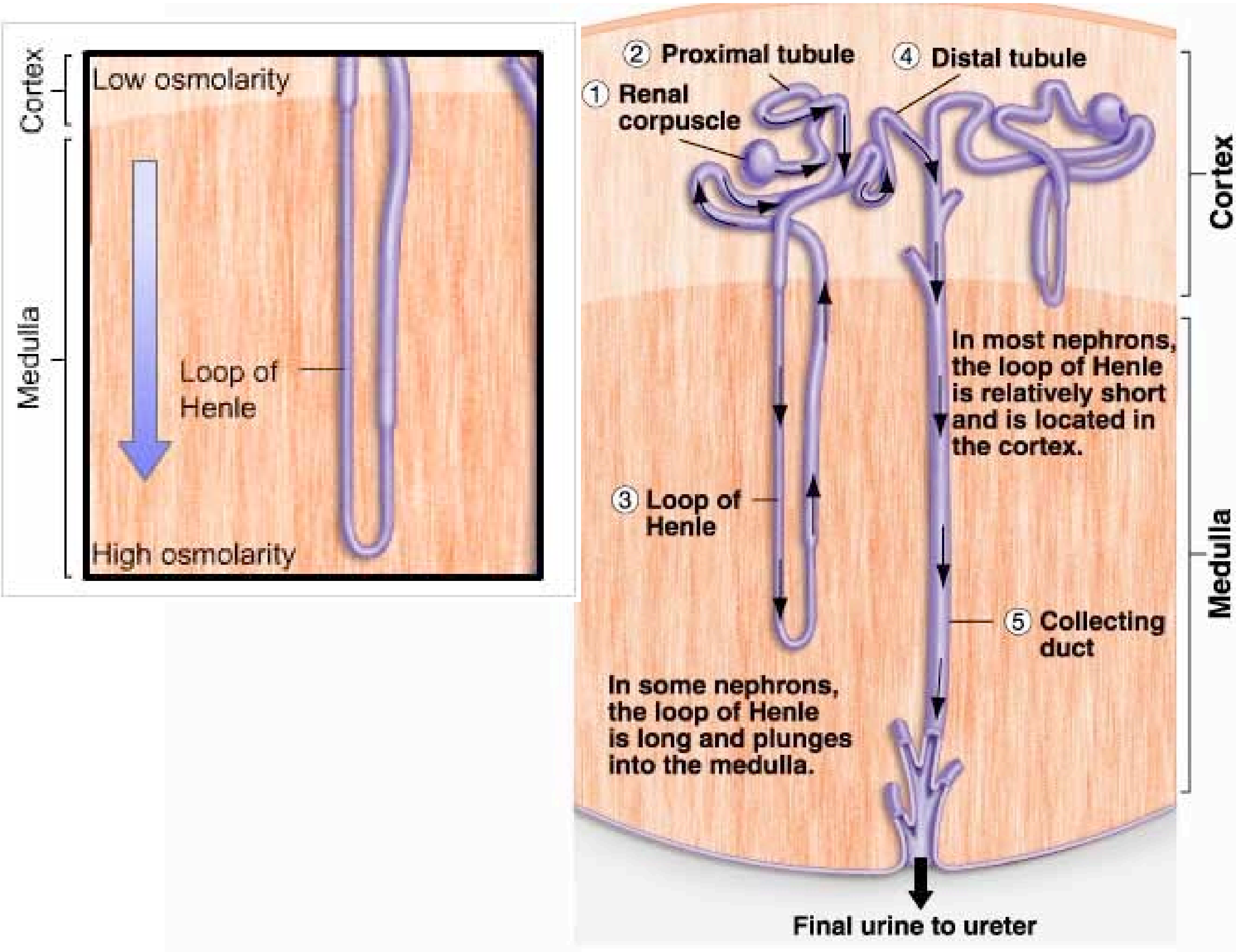
Kidney



Cortex
Medulla
Ureter
② Proximal tubule
④ Distal tubule
① Renal corpuscle
In most nephrons, the loop of Henle is relatively short and is located in the cortex.
③ Loop of Henle
⑤ Collecting duct
In some nephrons, the loop of Henle is long and plunges into the medulla.
Final urine to ureter
Cortex
Medulla

Kidney



Cortex
Medulla
Low osmolarity
Loop of Henle
High osmolarity
① Renal corpuscle
② Proximal tubule
③ Loop of Henle
④ Distal tubule
⑤ Collecting duct
Cortex
Medulla
In most nephrons, the loop of Henle is relatively short and is located in the cortex.
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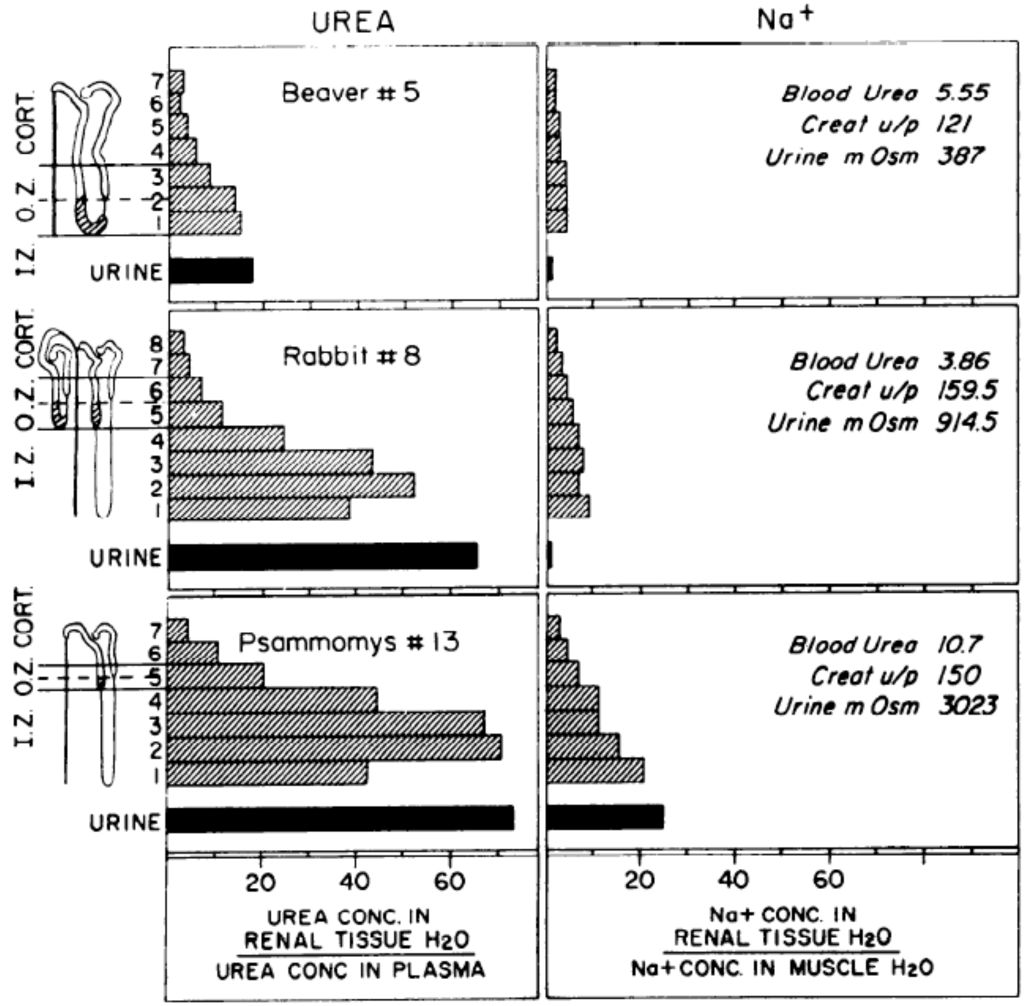

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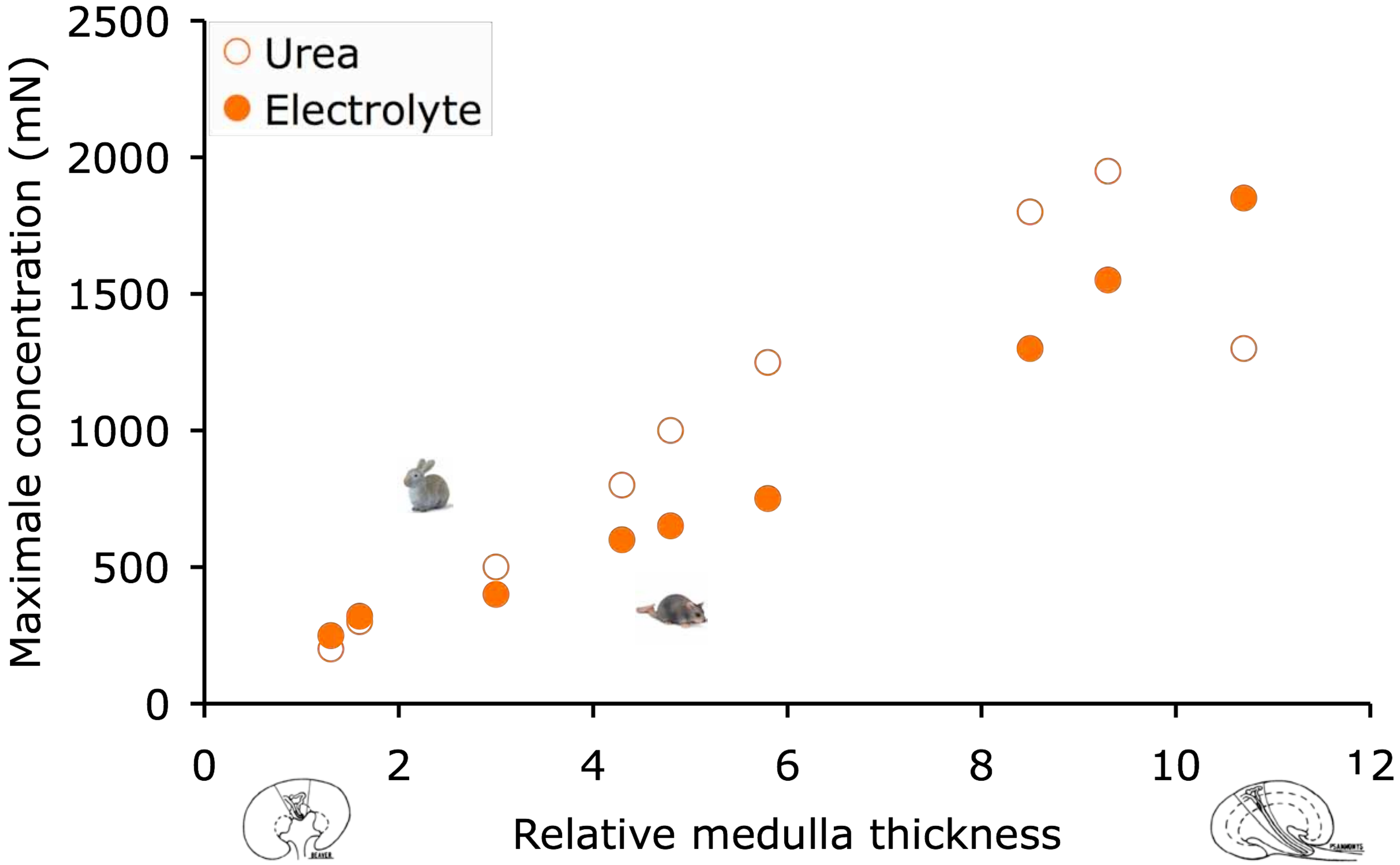
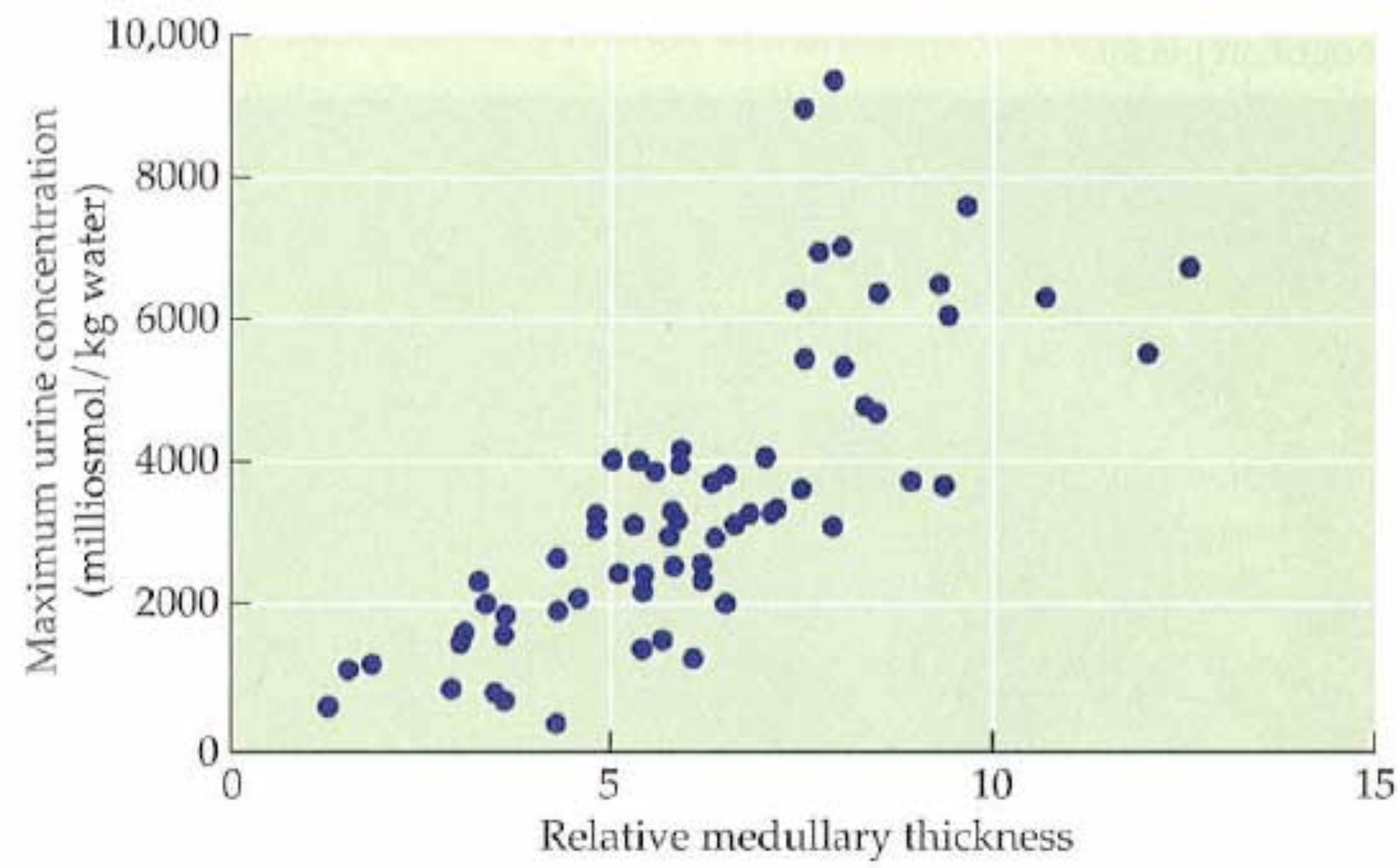


Body size, medullary thickness, and urine concentrating ability in mammals

CAROL A. BEUCHAT

Am. J. Physiol. (1990)



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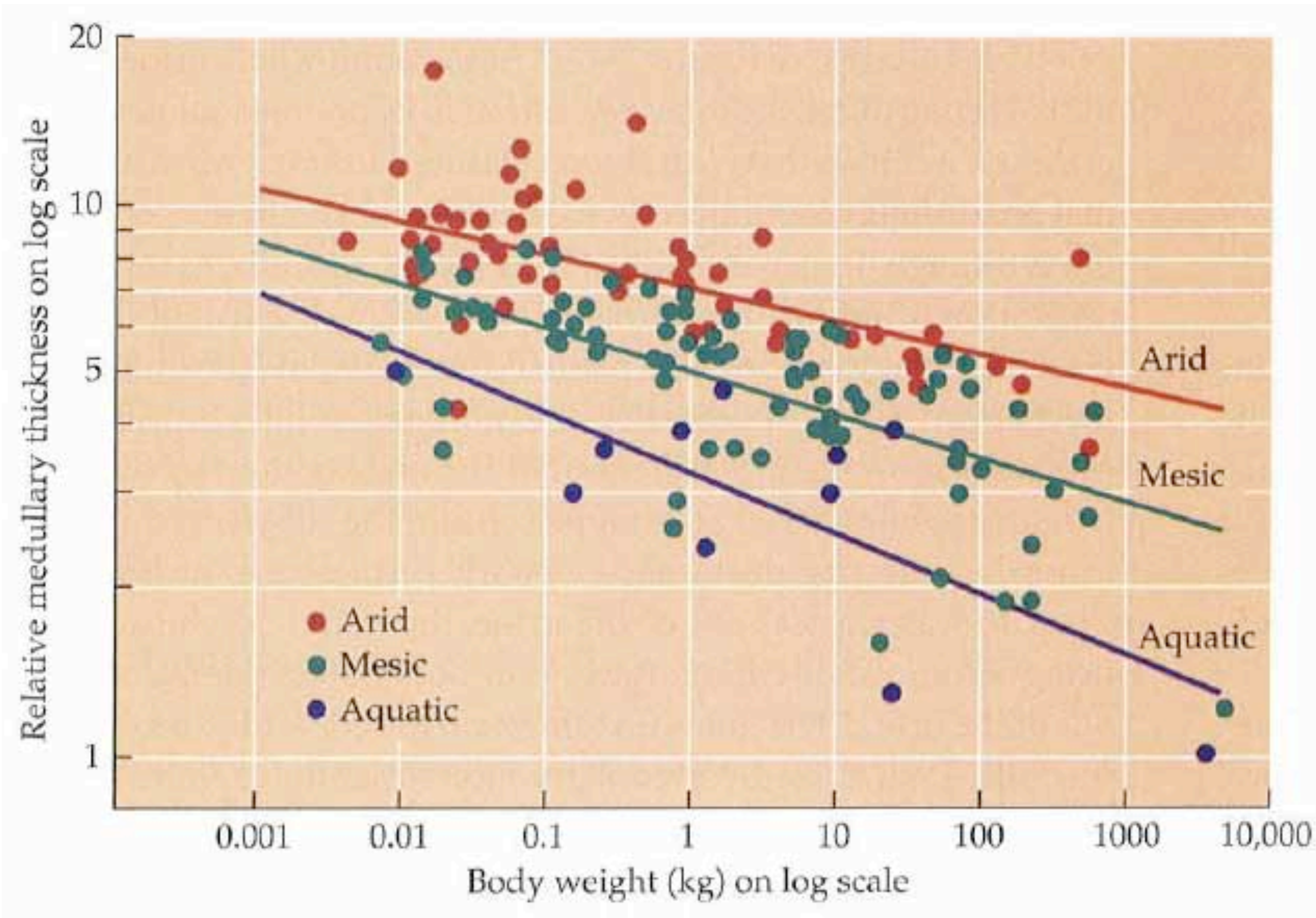
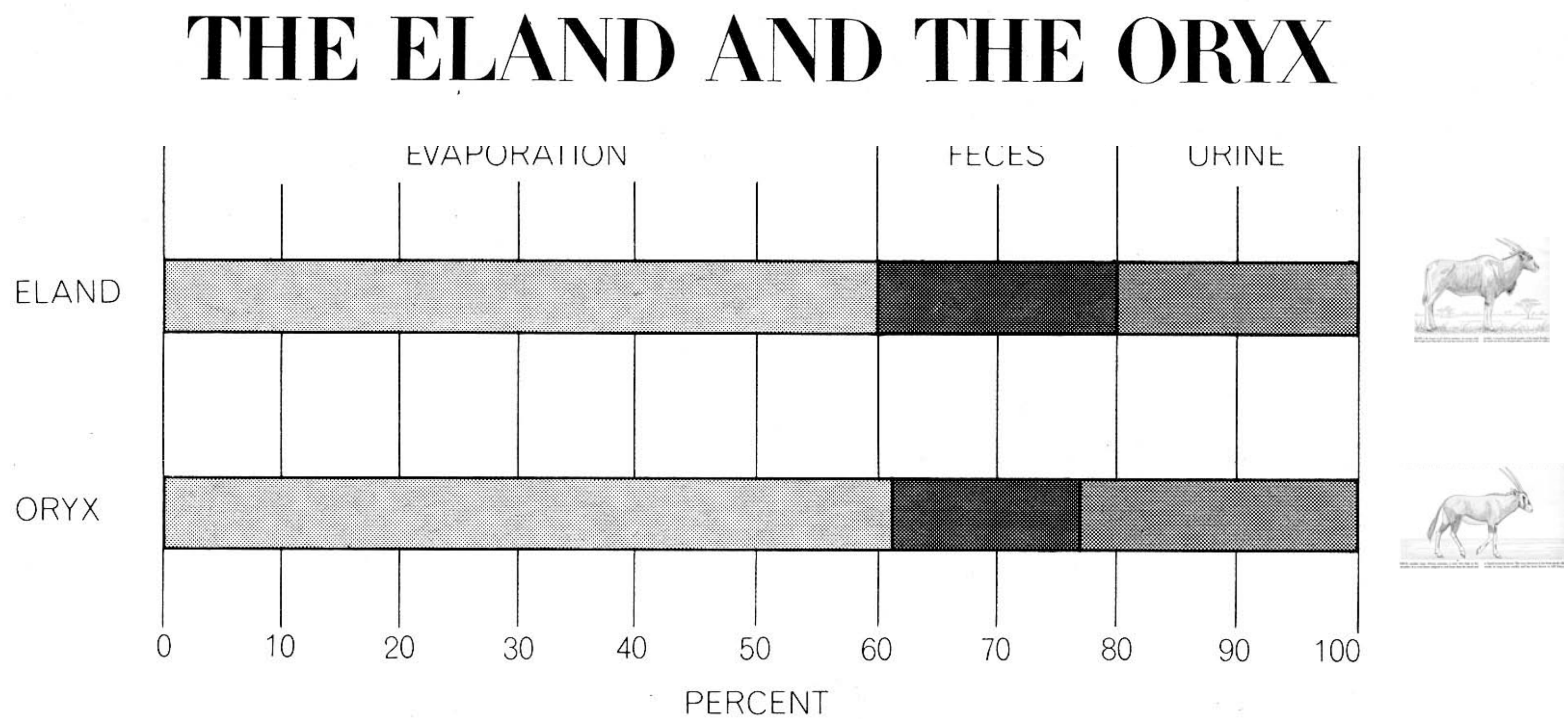


Water loss by evaporation (sweat, exhalate)



Water loss by evaporation (sweat, exhalate)

- Depends on
  - Heating of body
  - Difference between set control temperature and actual body temperature

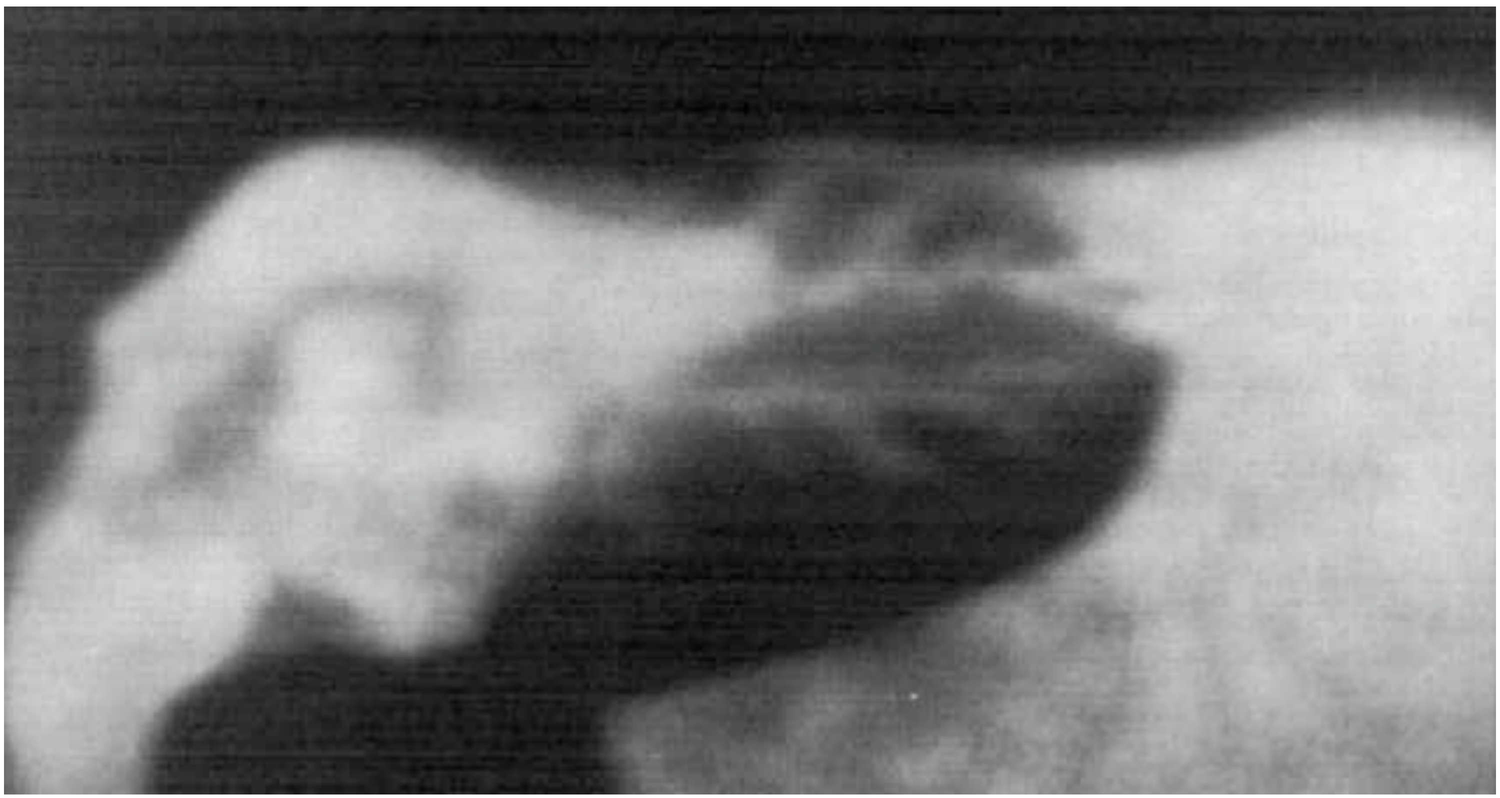
Reduction of solar radiation/ increase of heat loss

- Behaviour
  - Seeking of shade
  - Orient body according to sun
  - Seeking of windy spots
- Anatomy
  - Body shape

HEAT EXCHANGE BY THE PINNA OF THE AFRICAN ELEPHANT (*LOXODONTA AFRICANA*)

POLLY K. PHILLIPS* and JAMES EDWARD HEATH

Comp. Biochem. Physiol. Vol. 101A, No. 4, pp. 693–699, 1992



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Heat loss in Dumbo: a theoretical approach

P.K. Phillips*, J.E. Heath[1]

Journal of Thermal Biology 26 (2001) 117–120

THE PARASOL TAIL AND THERMOREGULATORY BEHAVIOR OF THE CAPE GROUND SQUIRREL XERUS INAURIS[1]

ALBERT F. BENNETT, RAYMOND B. HUEY, HENRY JOHN-ALDER, AND KENNETH A. NAGY

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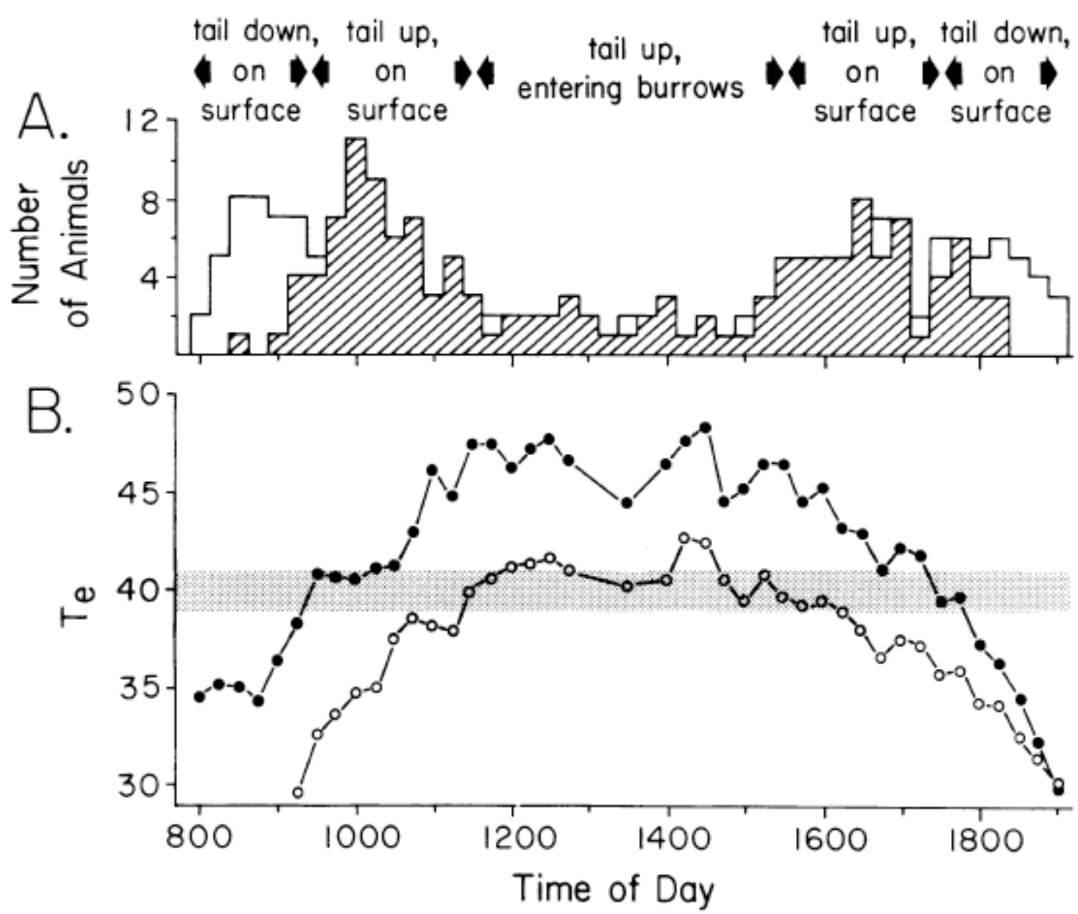
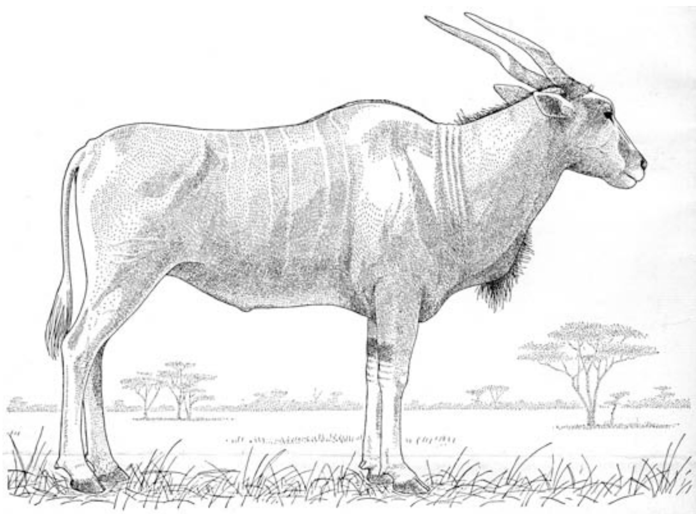


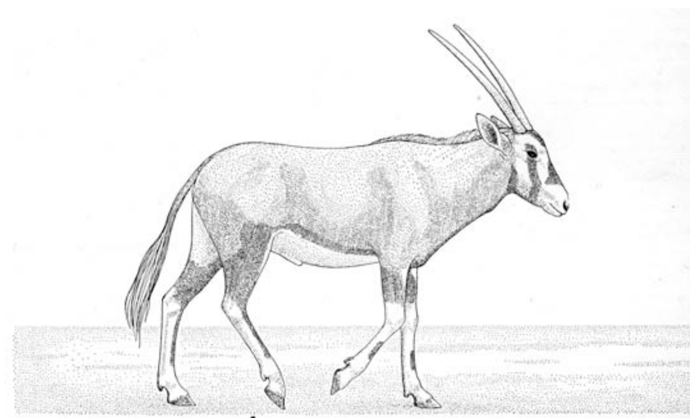
THE ELAND AND THE ORYX

These large African antelopes can survive indefinitely without drinking. Their feat is made possible by stratagems of physiology that minimize the amount of water they lose through evaporation

by C. R. Taylor

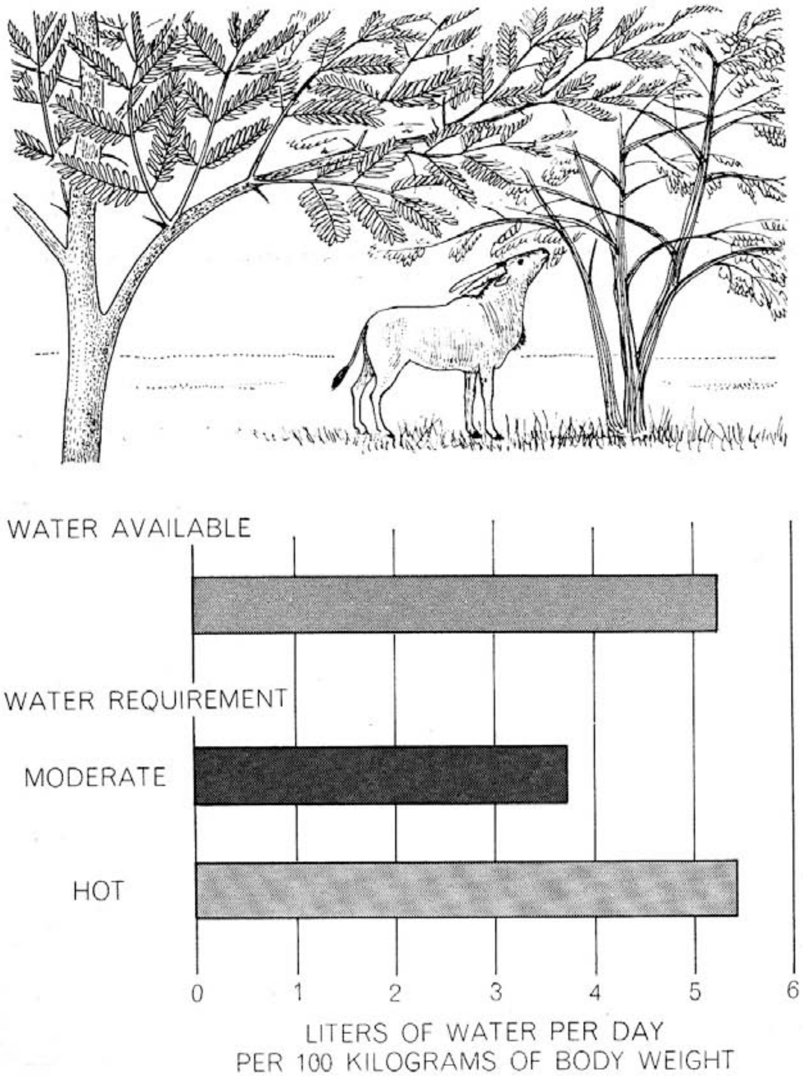


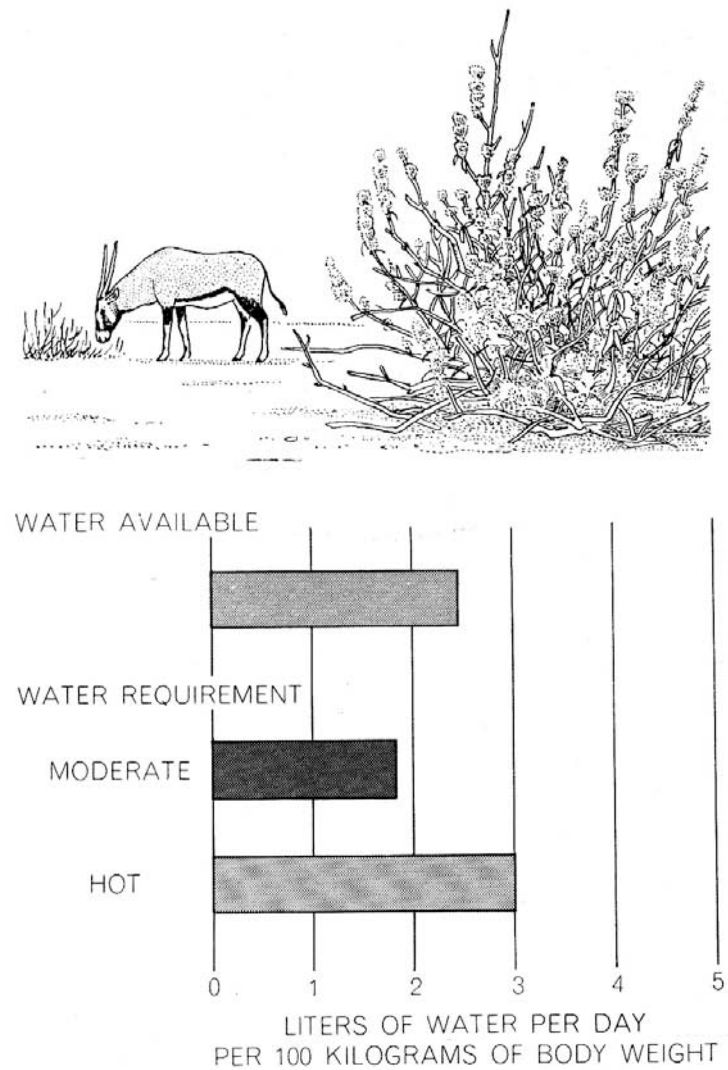
ELAND is the largest of all African antelopes. An average adult bull weighs more than half a ton and may measure six feet at the shoulder. A gregarious and docile member of the family Bovidae, the eland can thrive in drought-ridden rangeland unfit for cattle.



ORYX, another large African antelope, is four feet high at the shoulder. It is even better adapted to arid lands than the eland and is found in barren desert. The oryx, however, is far from docile. It wields its long horns readily and has been known to kill lions.

THE ELAND AND THE ORYX

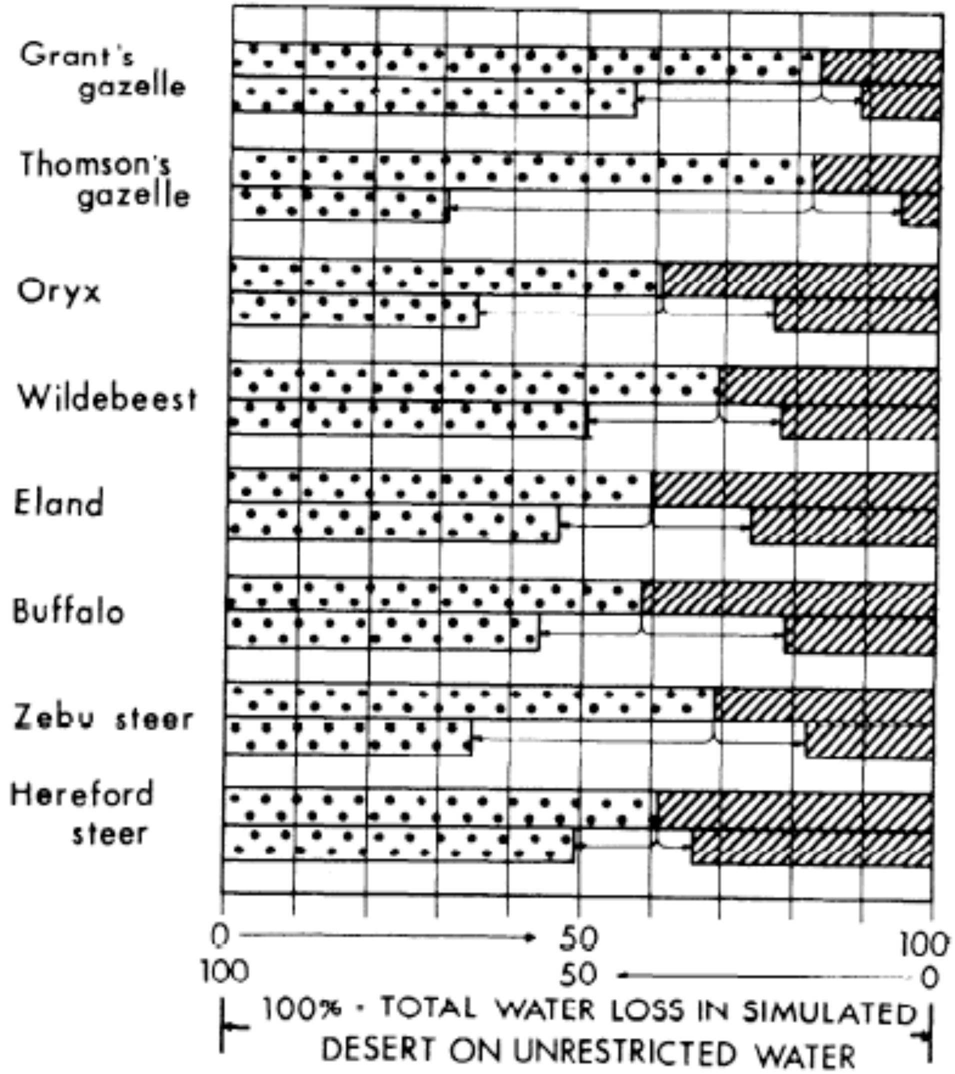




Strategies of temperature regulation: effect on evaporation in East African ungulates

C. RICHARD TAYLOR

Vol. 219, No. 4, October 1970. *Printed in U.S.A.*
AMERICAN JOURNAL OF PHYSIOLOGY



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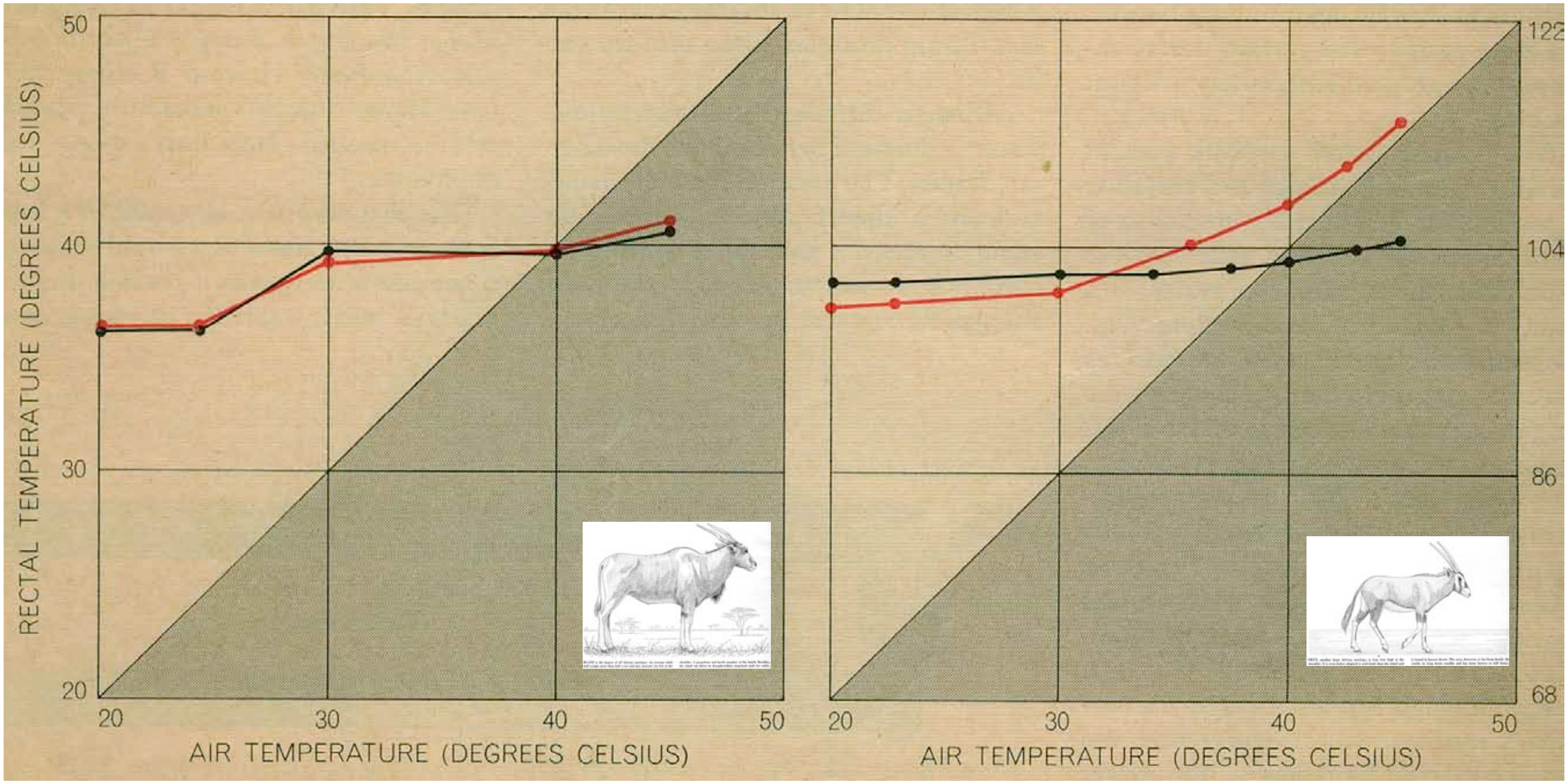

Normale Wasserversorgung

Wasserentzug

Dehydration and heat: effects on temperature regulation of East African ungulates

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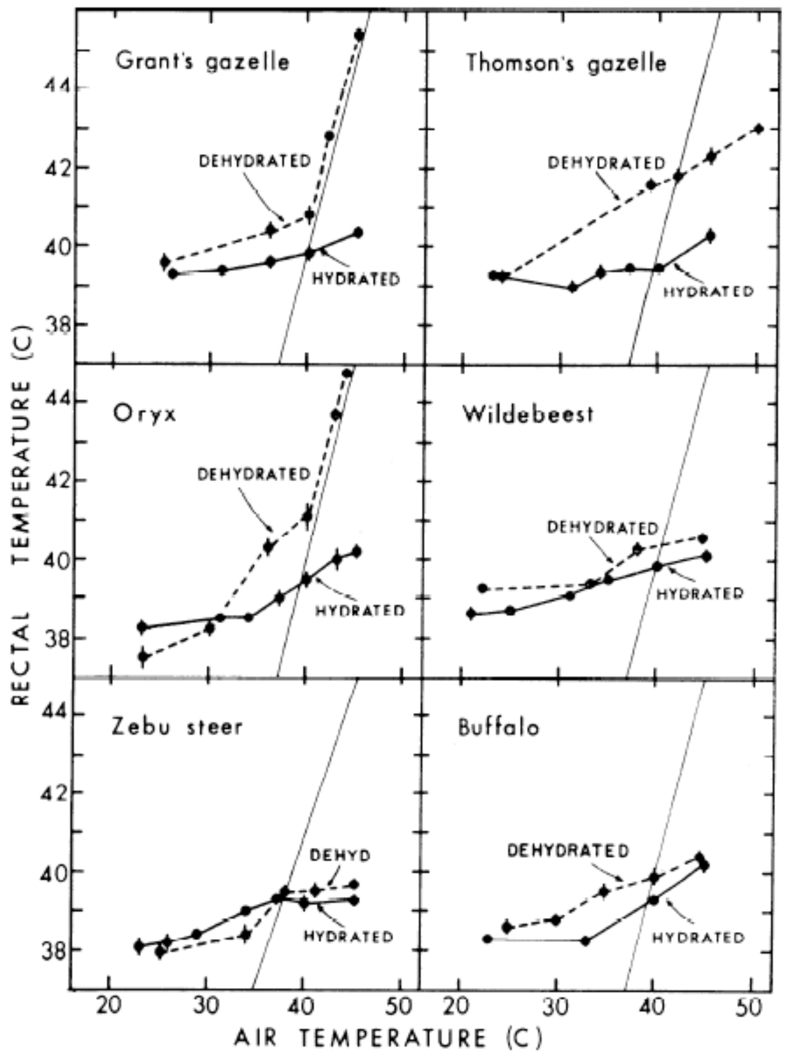
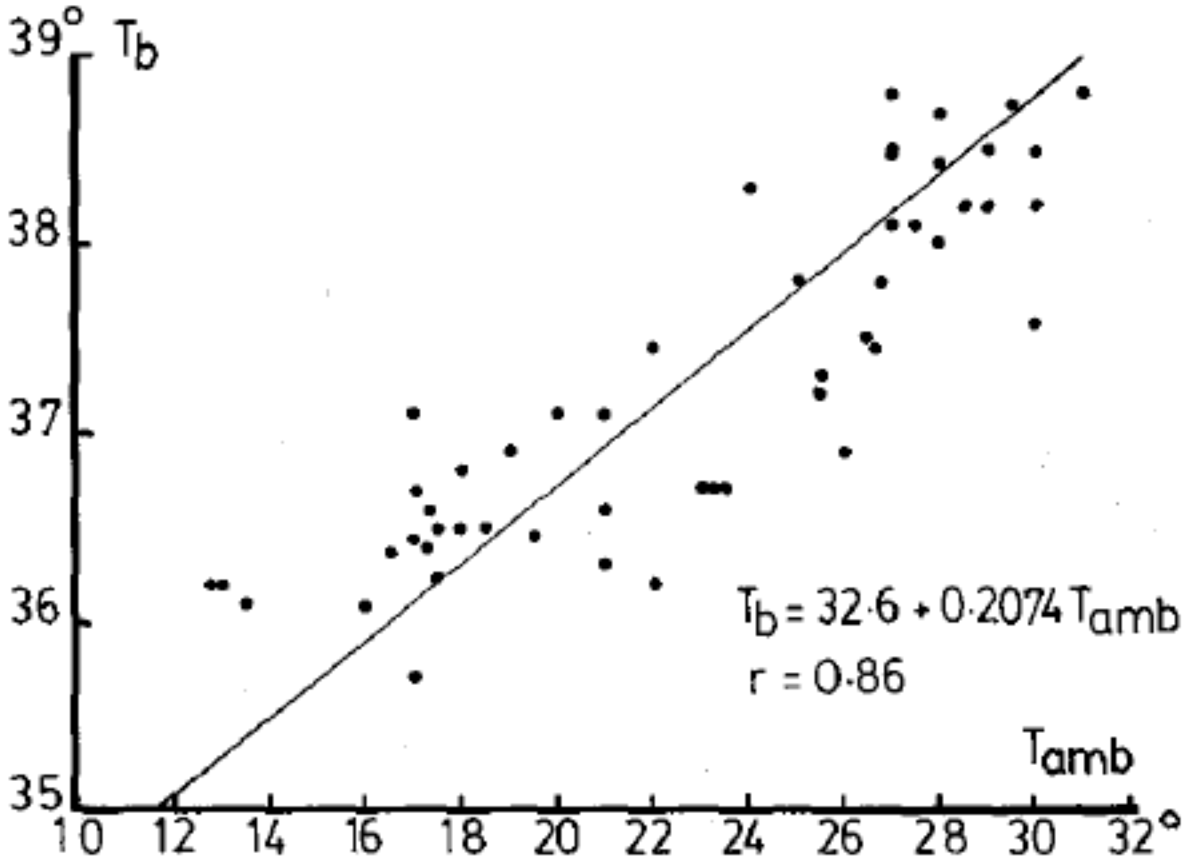
AMERICAN JOURNAL OF PHYSIOLOGY



RESPIRATION AND METABOLISM IN THE GIRAFFE

V. A. LANGMAN[1], O. S. BAMFORD[2] and G. M. O. MALOIY[1]

Respiration Physiology (1982) **50,** 141–152



Water loss by evaporation (sweat, exhalate)

- Depends on
  - Heating of body
  - Difference between set control temperature and actual body temperature
- *If you tolerate higher body temperatures you do not sweat !*

The eland and the oryx revisited: body and brain temperatures of free-living animals

A. Fuller[a,*], S.K. Maloney[a,b], G. Mitchell[a,c], D. Mitchell[a]

International Congress Series 1275 (2004) 275–282

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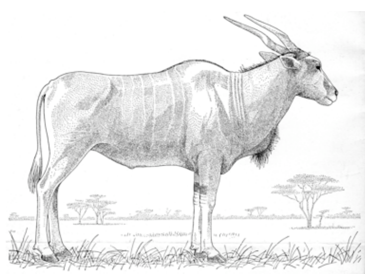

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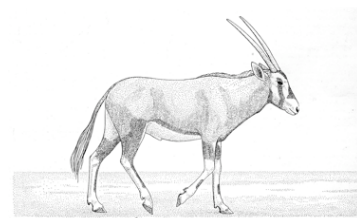

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The eland and the oryx revisited: body and brain temperatures of free-living animals

A. Fuller[a,*], S.K. Maloney[a,b], G. Mitchell[a,c], D. Mitchell[a]

International Congress Series 1275 (2004) 275–282

Data from captive animals denied the opportunity for behavioural adjustments !

Is there no adaptation by heterothermia?

Blood and brain temperatures of free-ranging black wildebeest in their natural environment

CLAUS JESSEN, HELEN P. LABURN, MICHAEL H. KNIGHT, GERNOT KUHNEN, KATHLEEN GOELST, AND DUNCAN MITCHELL

Am. J. Physiol. 267 (*Regulatory Integrative Comp. Physiol.* 36): R1528–R1536, 1994

Activity, blood temperature and brain temperature of free-ranging springbok

Duncan Mitchell · Shane K. Maloney · Helen P. Laburn
Michael H. Knight · Gernot Kuhnen · Claus Jessen

J Comp Physiol B (1997) 167: 335–343

Brain, abdominal and arterial blood temperatures of free-ranging eland in their natural habitat

Andrea Fuller · Dominic G. Moss · John D. Skinner
Paul T. Jessen · Graham Mitchell · Duncan Mitchell

Pflügers Arch – Eur J Physiol (1999) 438:671–680

Brain and arterial blood temperatures of free-ranging oryx (*Oryx gazella*)

Shane K. Maloney · Andrea Fuller · Graham Mitchell
Duncan Mitchell

Pflügers Arch - Eur J Physiol (2002) 443:437–445

... or is there ?

Heterothermy and the water economy of free-living Arabian oryx (*Oryx leucoryx*)

Stéphane Ostrowski[1,*], Joseph B. Williams[2] and Khairi Ismael[1]

The Journal of Experimental Biology 206, 1471-1478

Heterothermy of free-living Arabian sand gazelles (*Gazella subgutturosa marica*) in a desert environment

Stéphane Ostrowski[1,*] and Joseph B. Williams[2]

The Journal of Experimental Biology 209, 1421-1429

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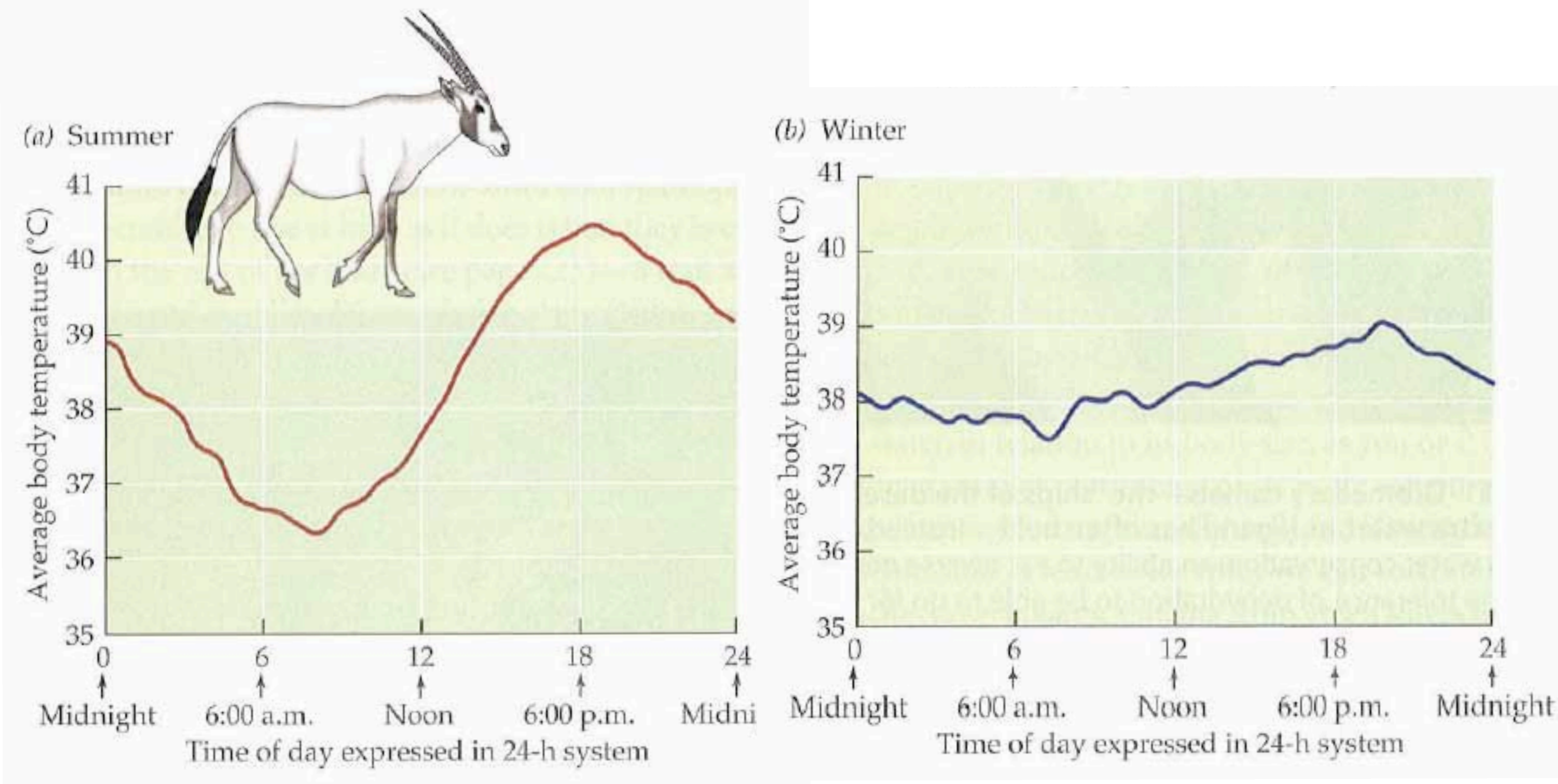

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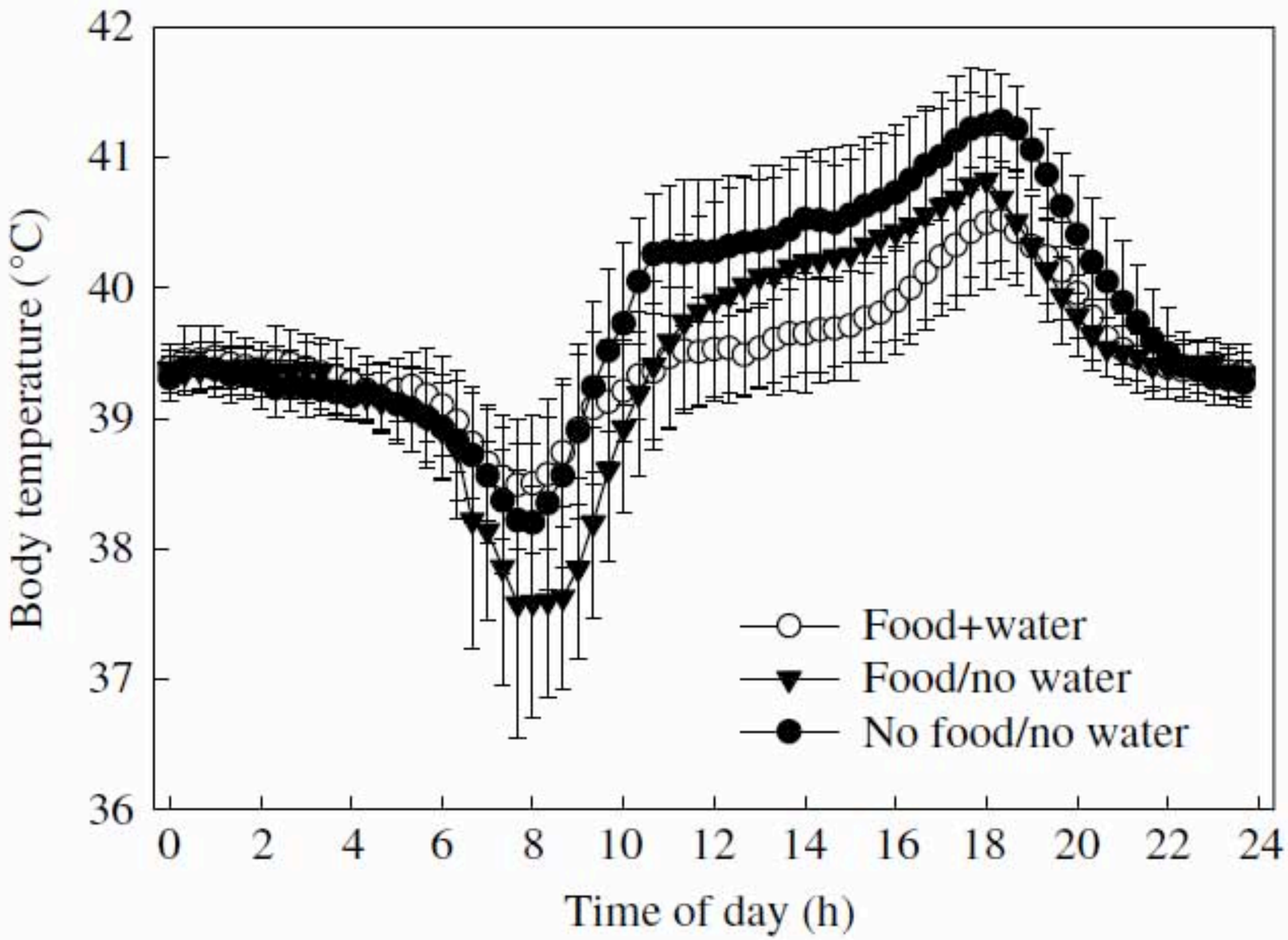
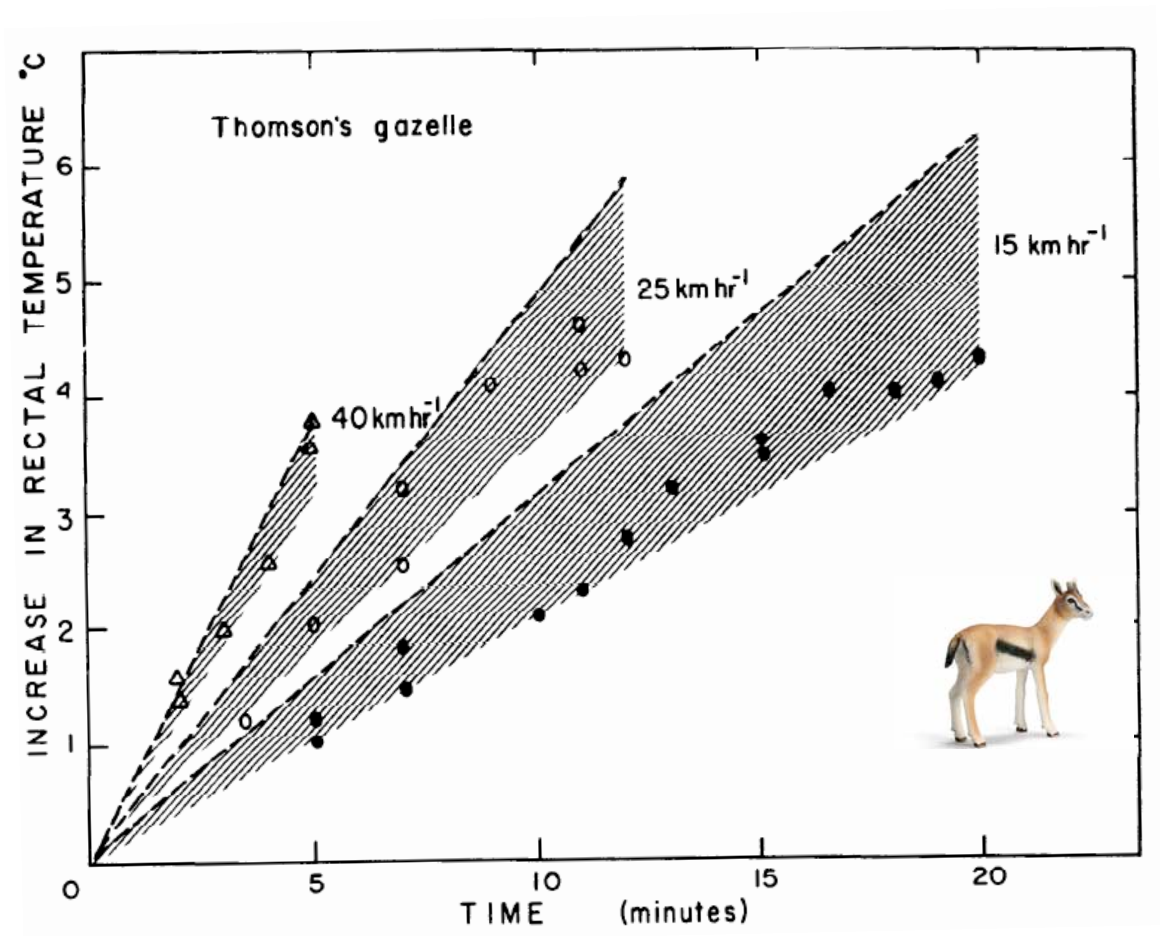


Heat storage in running antelopes: independence of brain and body temperatures

C. RICHARD TAYLOR AND C. P. LYMAN

AMERICAN JOURNAL OF PHYSIOLOGY
Vol. 222, No. 1, January 1972. *Printed in U.S.A.*



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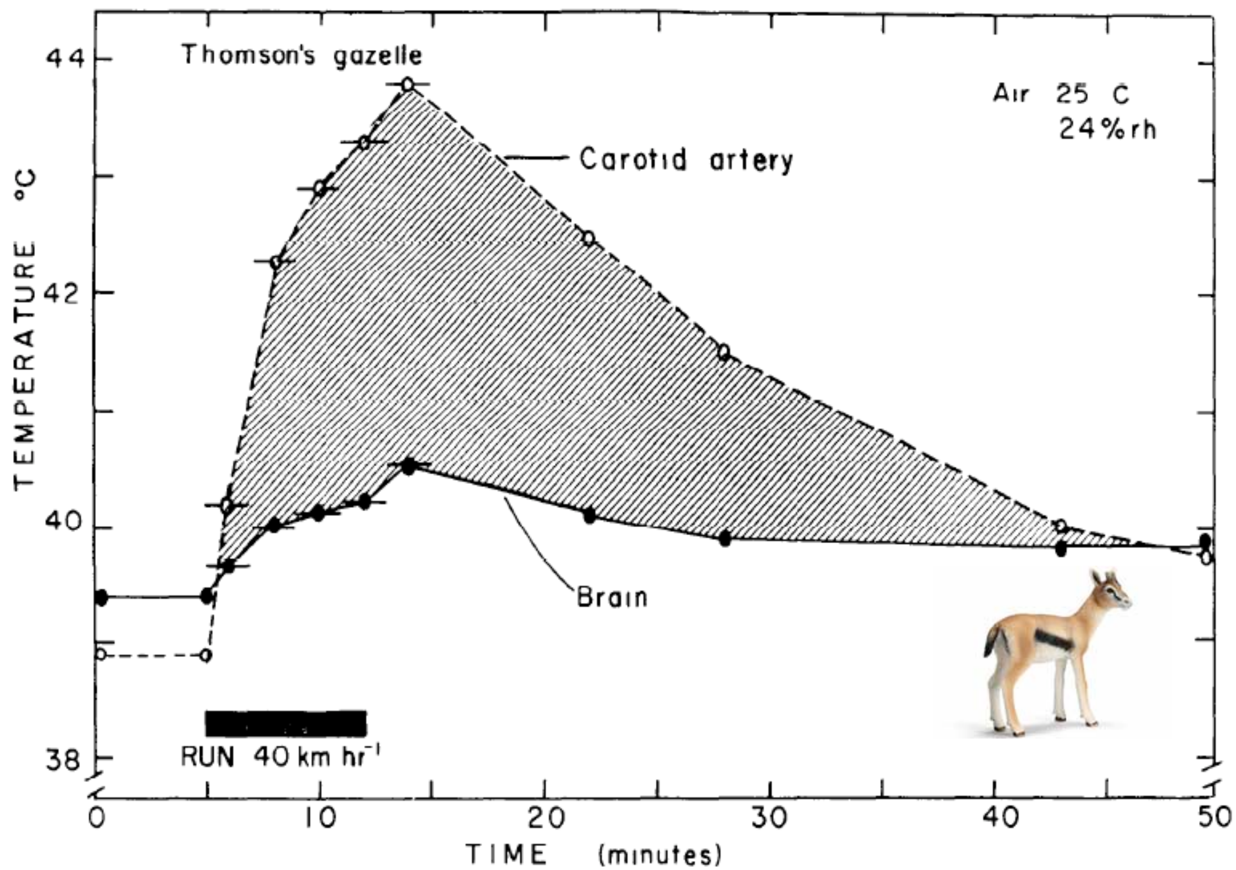
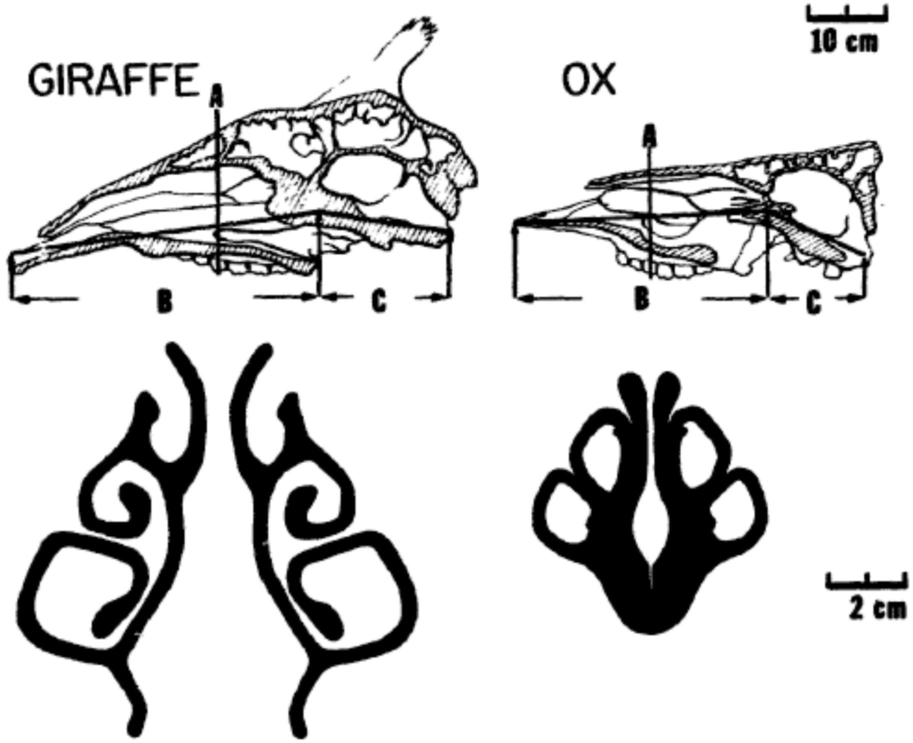


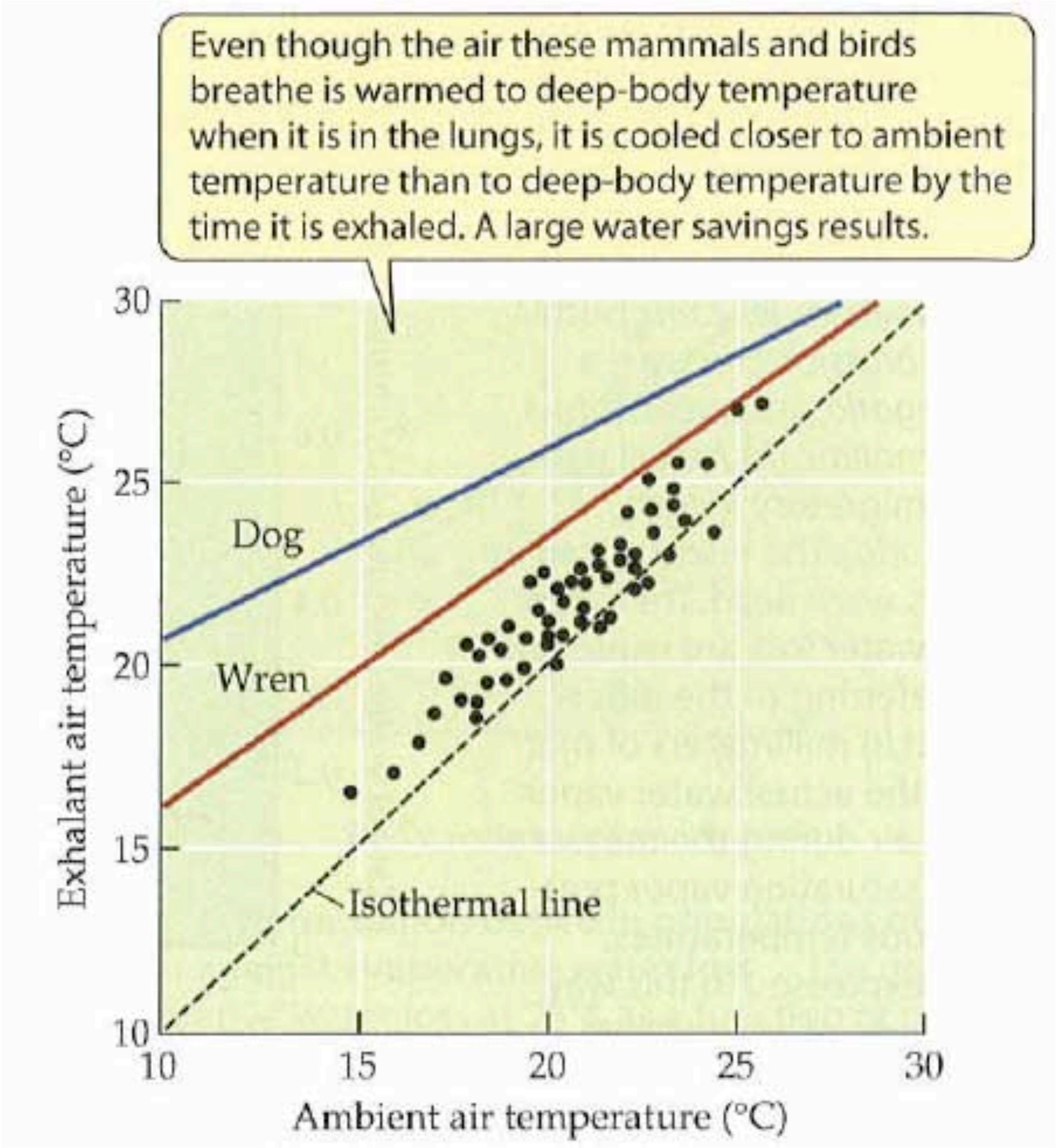
NASAL HEAT EXCHANGE IN THE GIRAFFE AND OTHER LARGE MAMMALS*

V. A. LANGMAN[1], G. M. O. MALOIY[2], K. SCHMIDT-NIELSEN[3] and R. C. SCHROTER[4]

Respiration Physiology (1979) **37**, 325–333

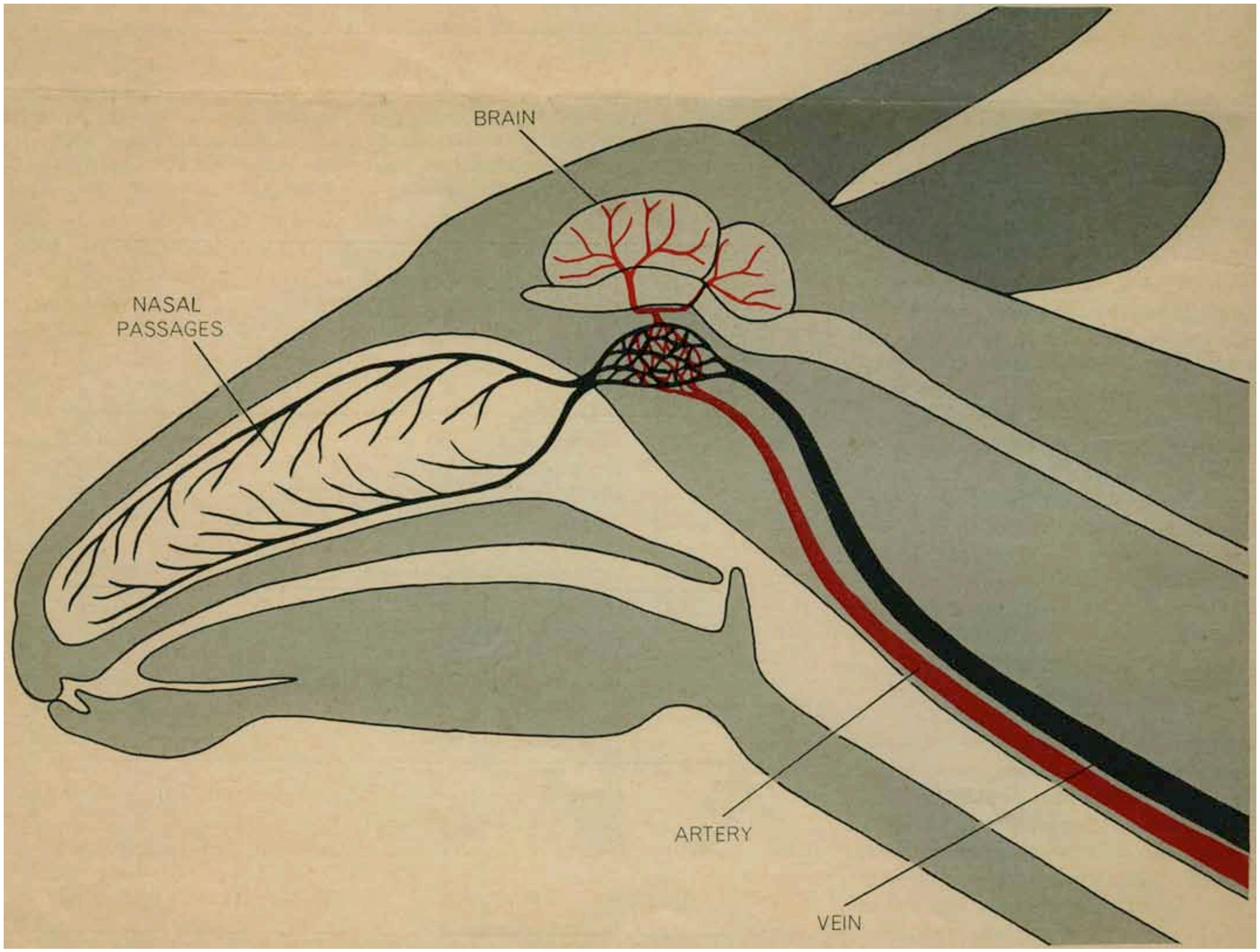
Abstract. The respiratory air of the giraffe is exhaled at temperatures substantially below body core temperature. As a consequence, the water content of the exhaled air is reduced to levels below that in pulmonary air, resulting in substantial reductions in respiratory water loss. Measurements under out-





from Hill et al. (2004)

THE ELAND AND THE ORYX



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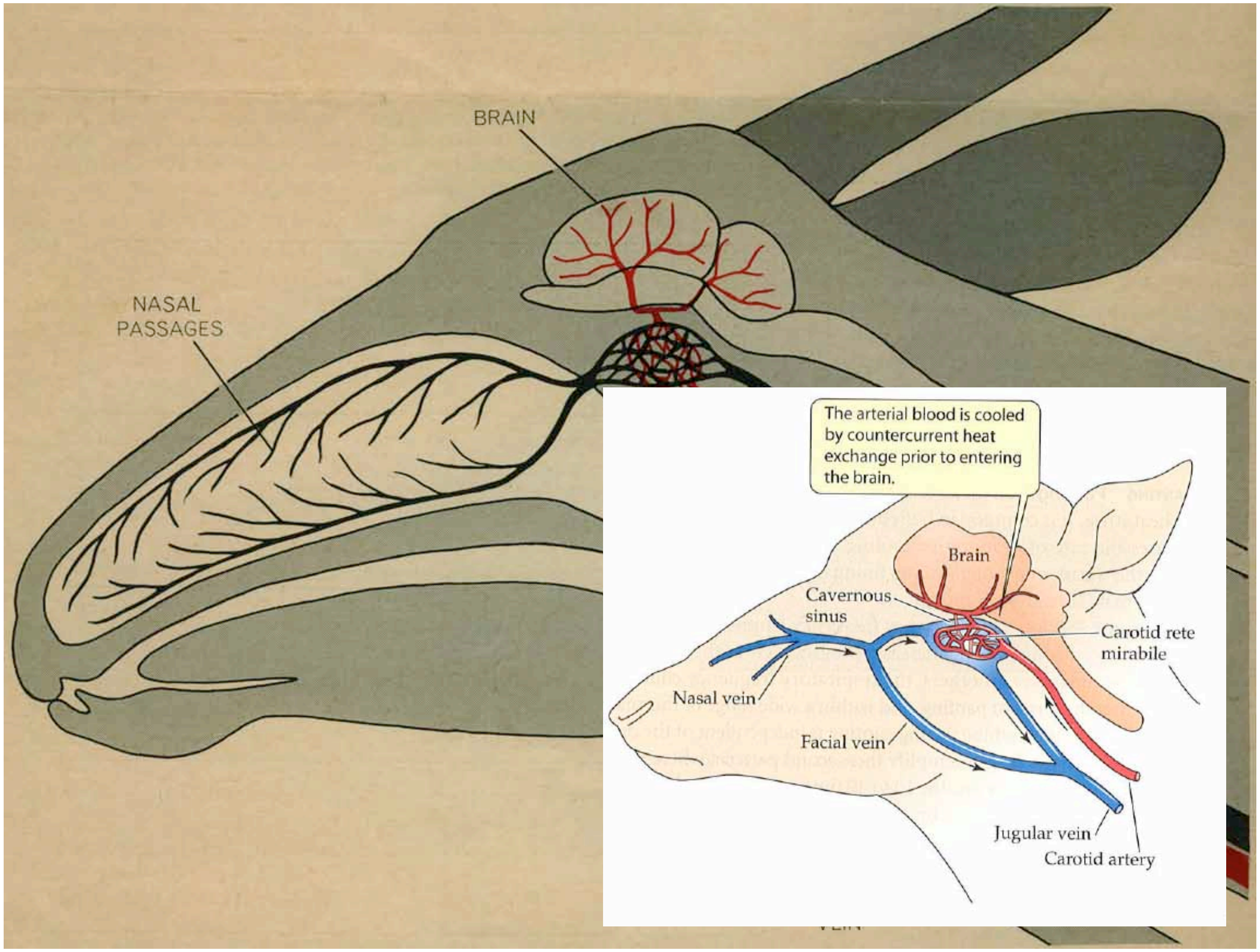
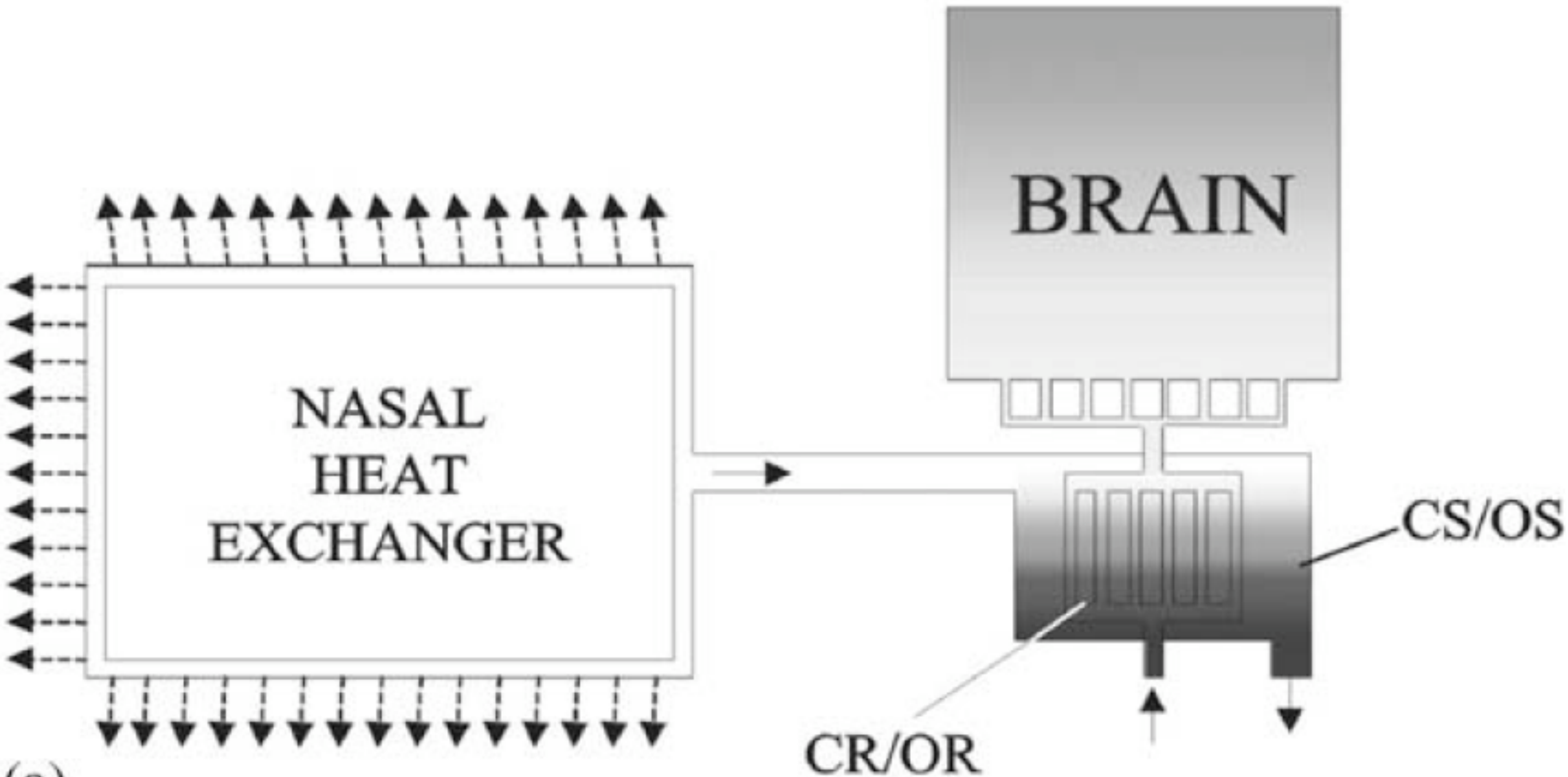


from Hill et al. (2004)

Selective brain cooling: a multiple regulatory mechanism

Michał Caputa*
Journal of Thermal Biology 29 (2004) 691–702



(a)

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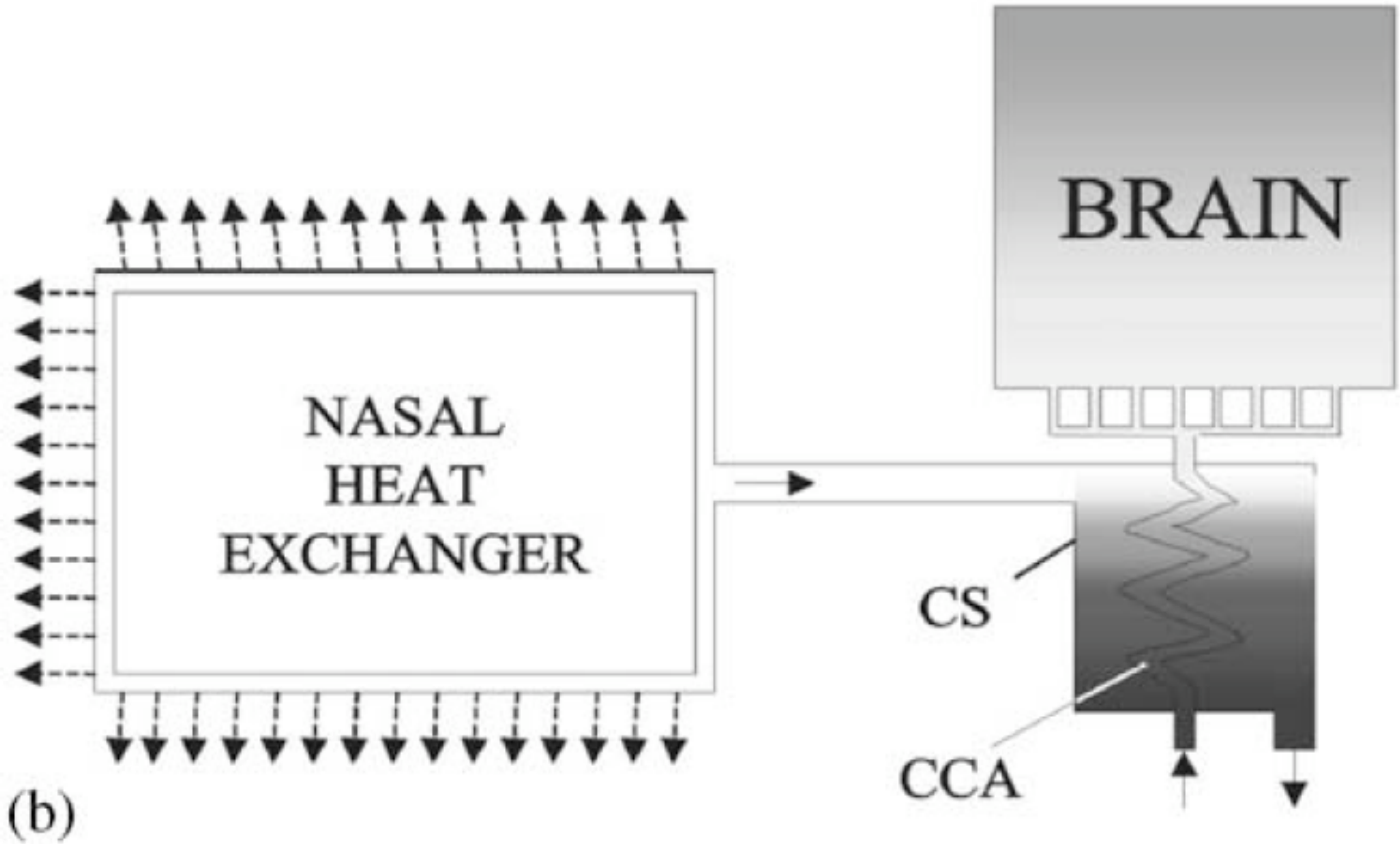

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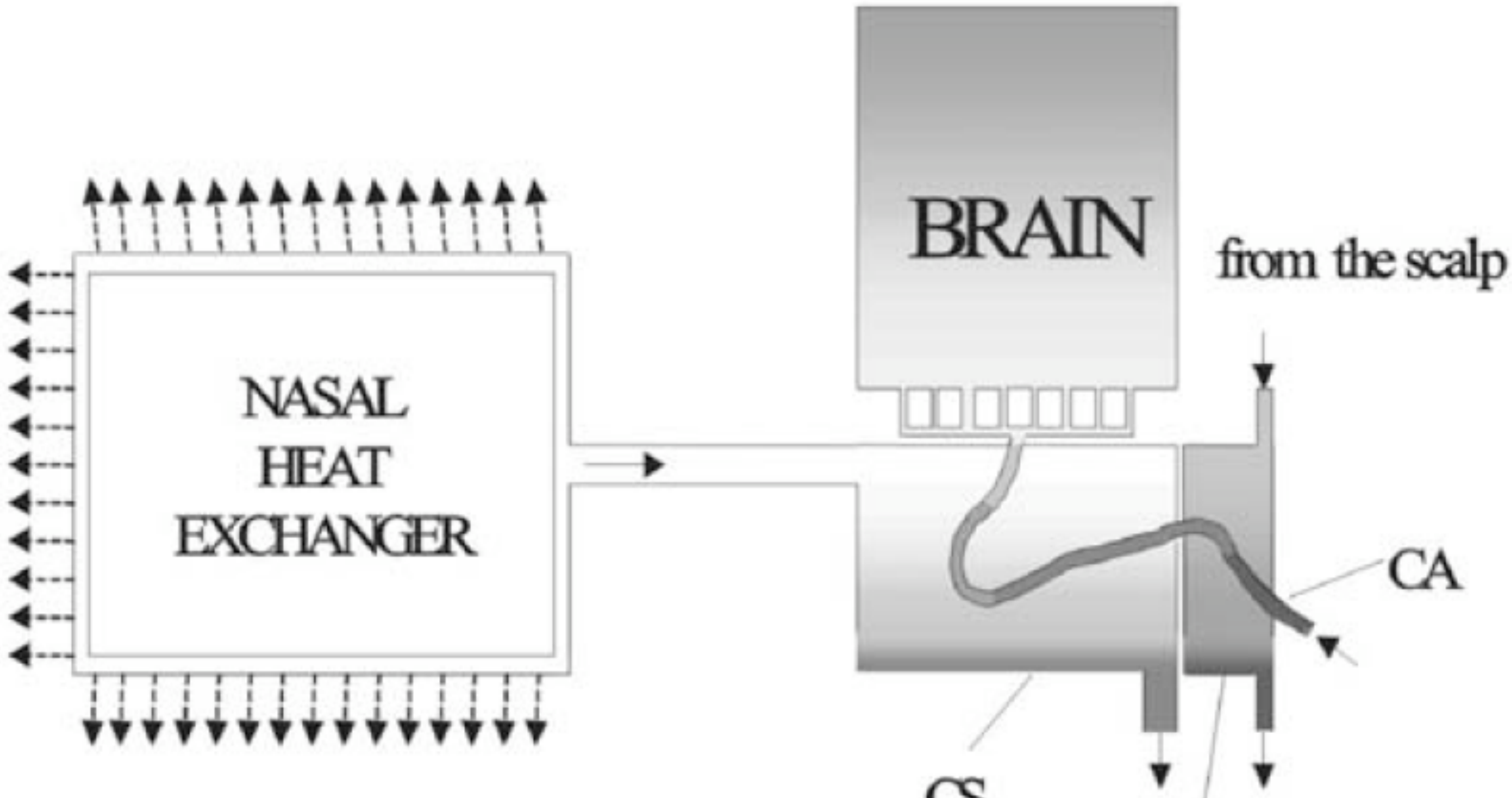
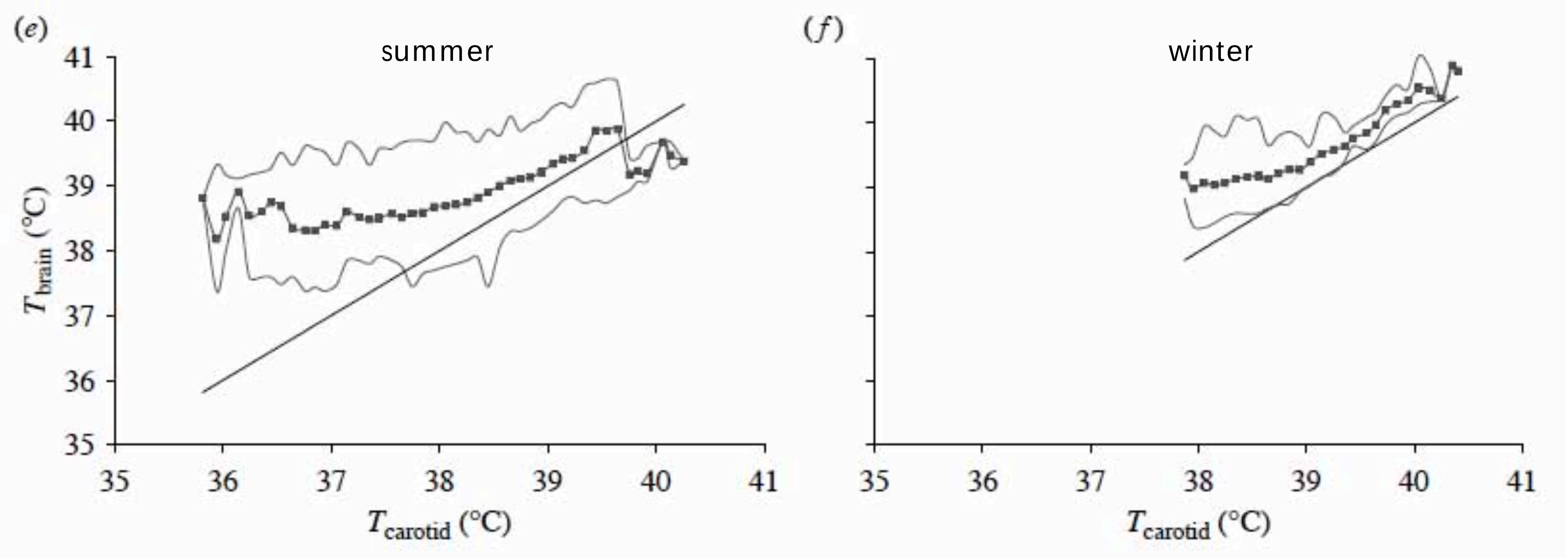


(c)

The carotid rete and artiodactyl success

G. Mitchell* and A. Lust

Biol. Lett. (2008) 4, 415–418



Pronghorn antelope

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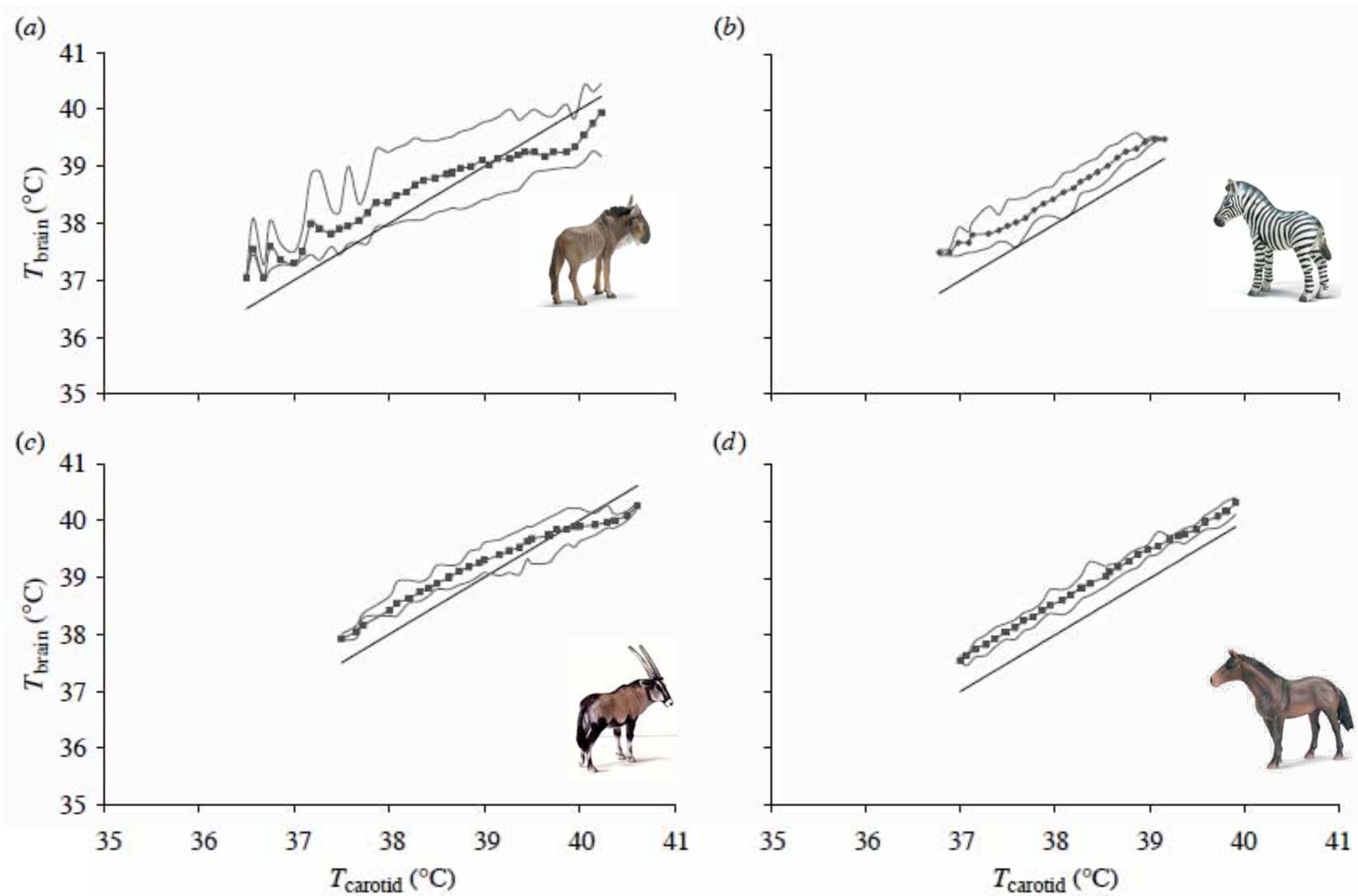
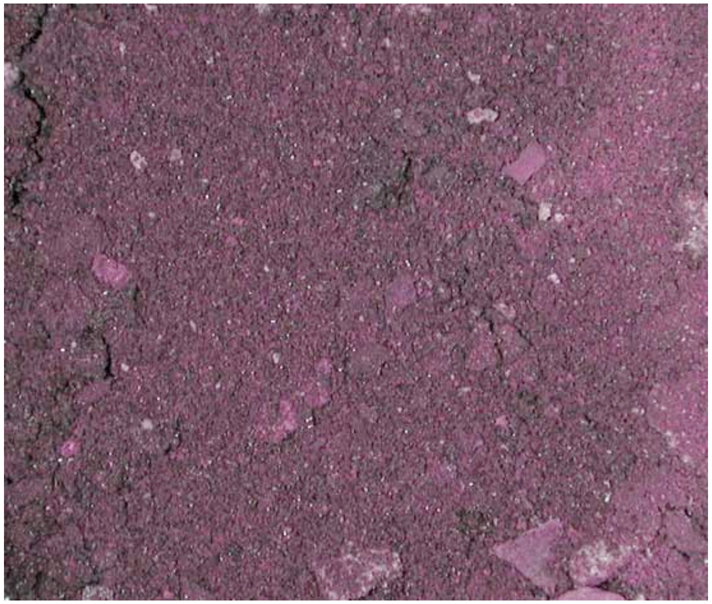


Can rumen contents serve as water reservoir?

Can rumen contents serve as water reservoir?

- Measure fluid passage in the forestomach
  - Feed a marker



Cobalt-EDTA

Can rumen contents serve as water reservoir?

- Measure fluid passage in the forestomach
  - Feed a marker
  - Collect faeces regularly

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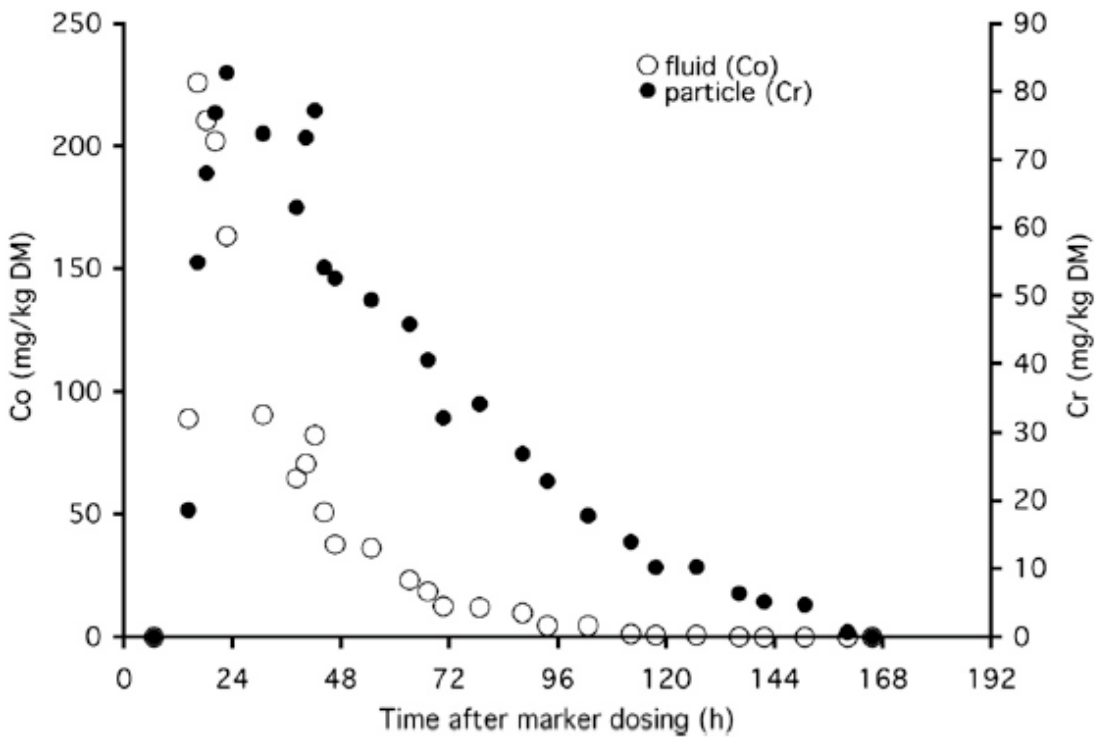
Can rumen contents serve as water reservoir?

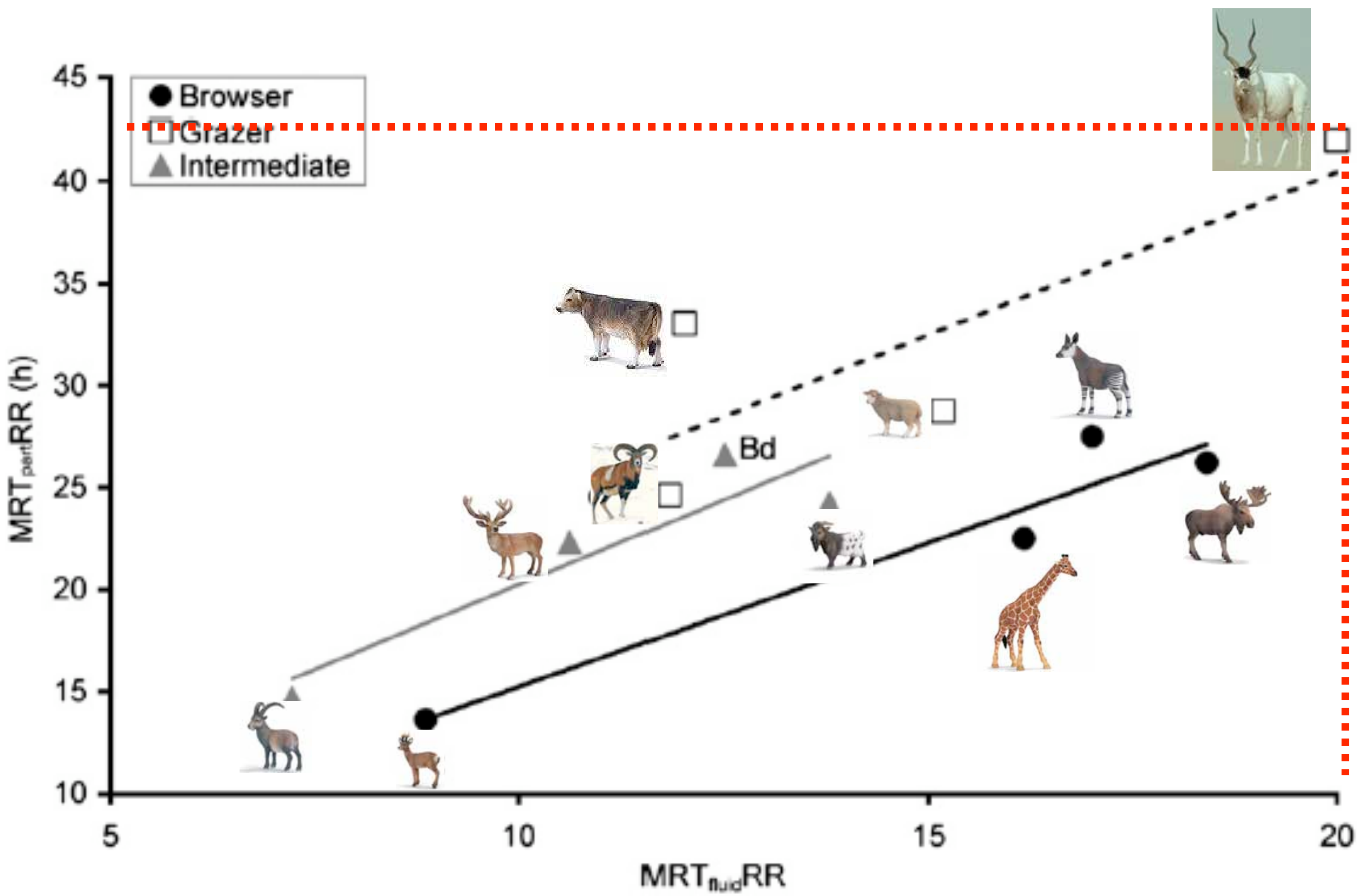
- Measure fluid passage in the forestomach
  - Feed a marker
  - Collect faeces regularly
  - Analyse faeces and plot excretion curve



Fluid and particle retention in the digestive tract of the addax antelope (*Addax nasomaculatus*)—Adaptations of a grazing desert ruminant

Jürgen Hummel [a,*], Patrick Steuer [a], Karl-Heinz Südekum [a], Sven Hammer [b], Catrin Hammer [b], W. Jürgen Streich [c], Marcus Clauss [d]

Comparative Biochemistry and Physiology, Part A 149 (2008) 142 – 149



Summary:
Desert animals save water by ...

- (behavioural adaptations)
- Long colon - dry faeces
- Thick renal medulla - concentrated urine
- Particular blood vessel anatomy
- Heterothermia
- Low metabolic rate

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Desert animals save water by ...

- (behavioural adaptations)
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- Thick renal medulla - concentrated urine
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- These adaptations are disadvantages in mesic habitats!
- Due to their ‘low spending strategy’, desert animals cannot compete out of the desert

What are human adaptations to desert environments?

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