



Introduction to animal physiology



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Wildlife Digestive Physiology Course Vienna 2013



University of Zurich
Vetsuisse Faculty



Clinic
of Zoo Animals, Exotic Pets and Wildlife



Physiology

Science of organismal function from the subcellular level to the whole organism.

Describes interactions of organism and environment.

Quantifies rules for functions, linking them to physical and (bio)chemical principles.



Cell physiology – molecular biology

Genome

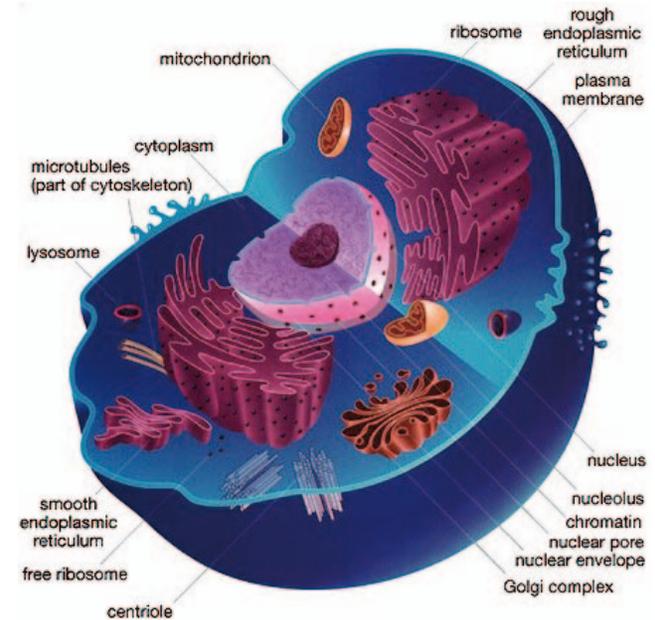
Proteins & Pathways

Cell



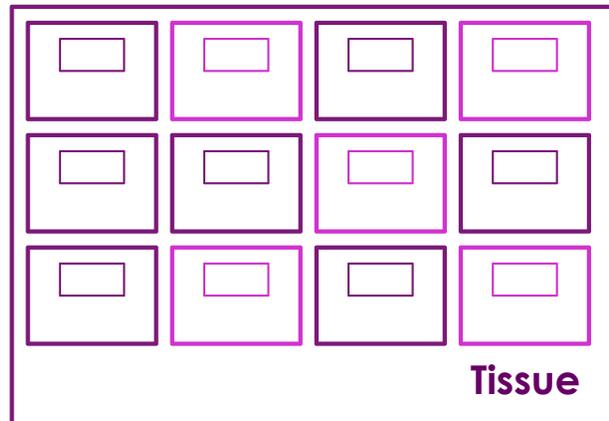
Cell physiology – molecular biology

Genome
Proteins & Pathways
Cell



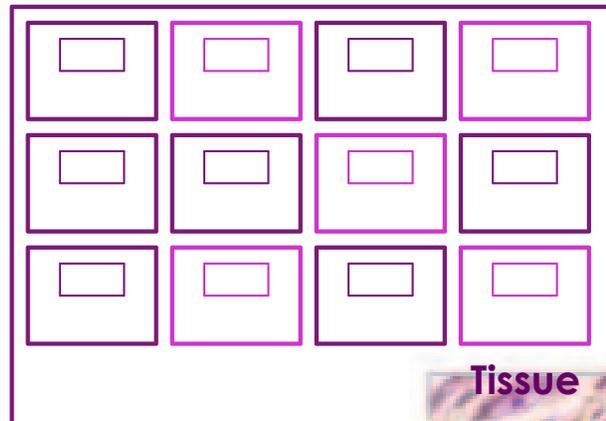


Tissue physiology

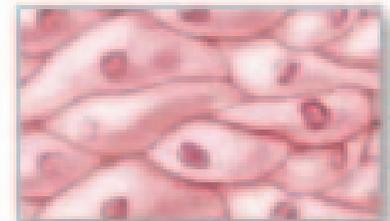




Tissue physiology



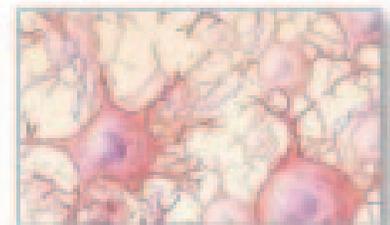
Connective tissue



Epithelial tissue



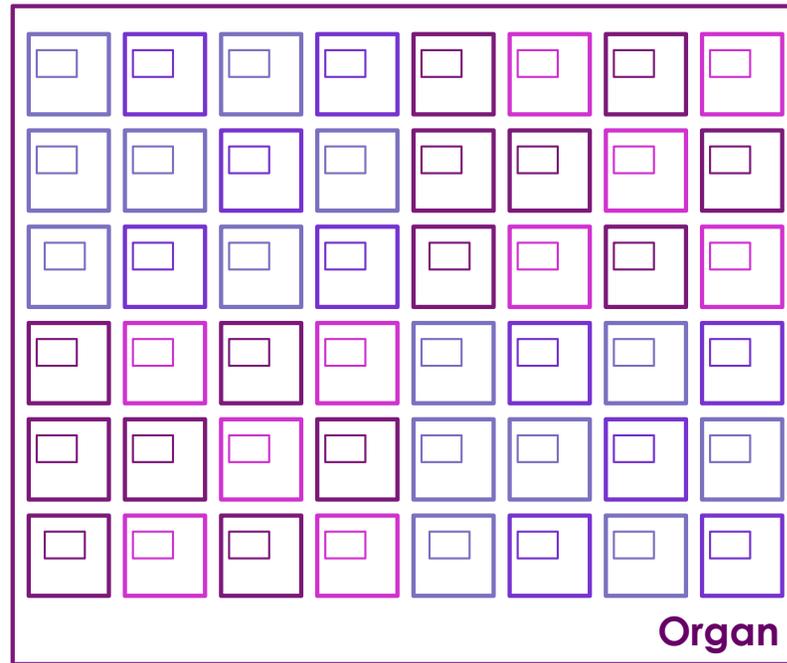
Muscle tissue



Nervous tissue

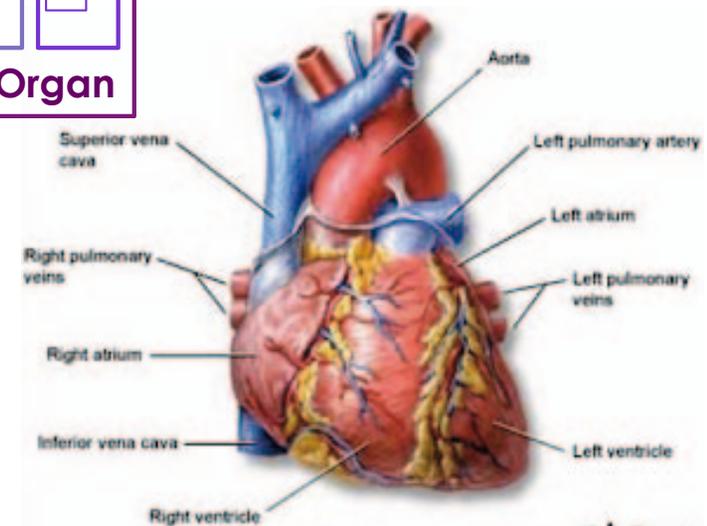
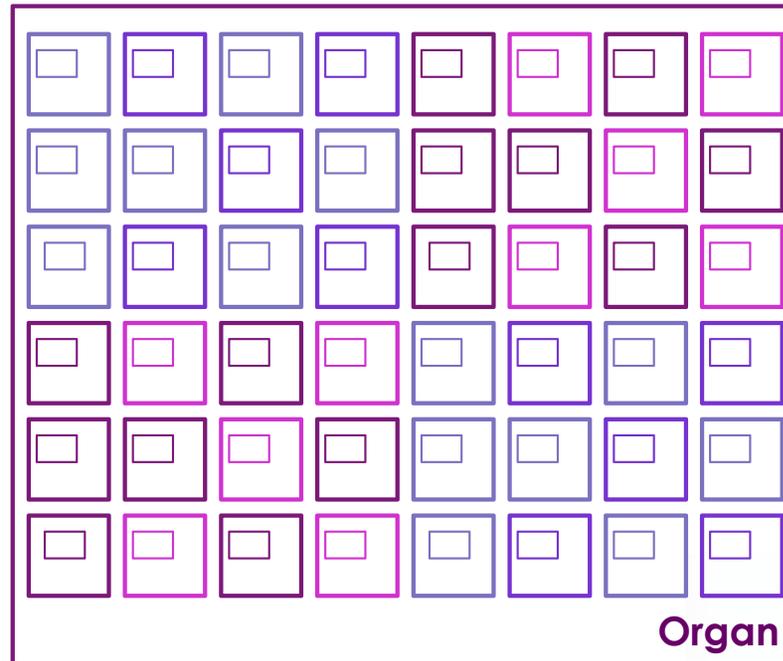


Organ physiology



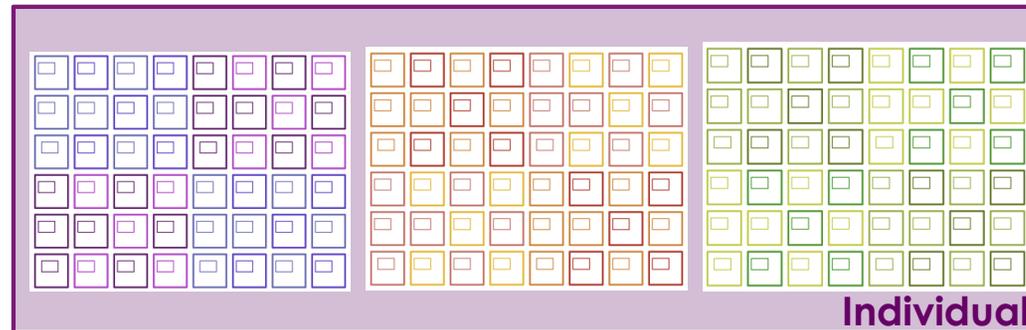


Organ physiology



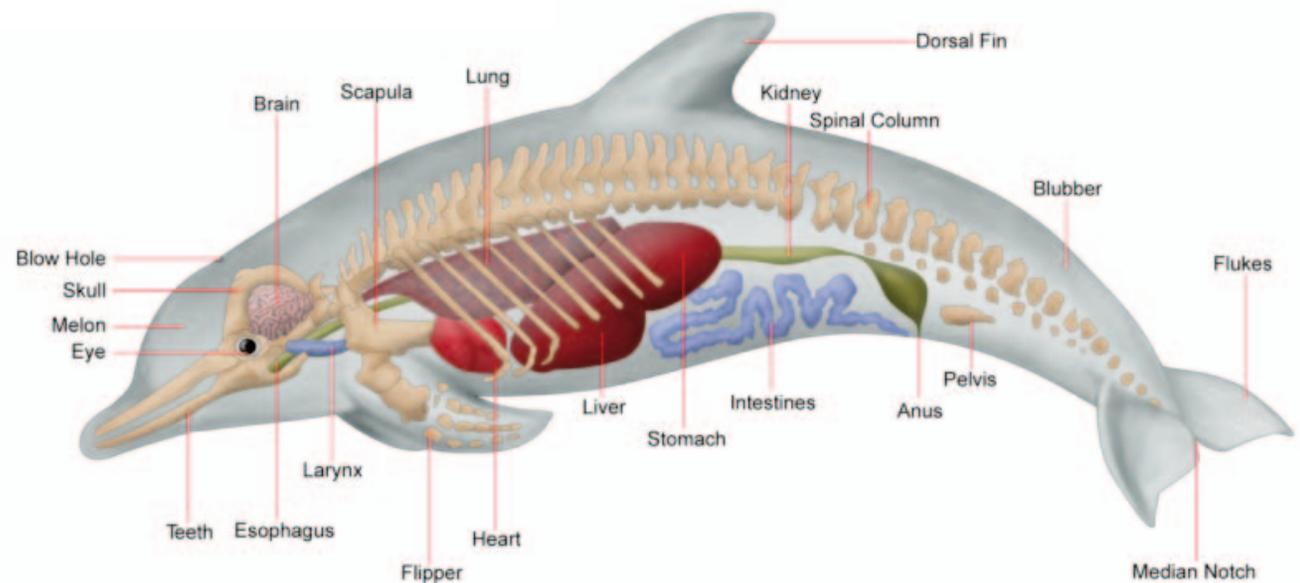
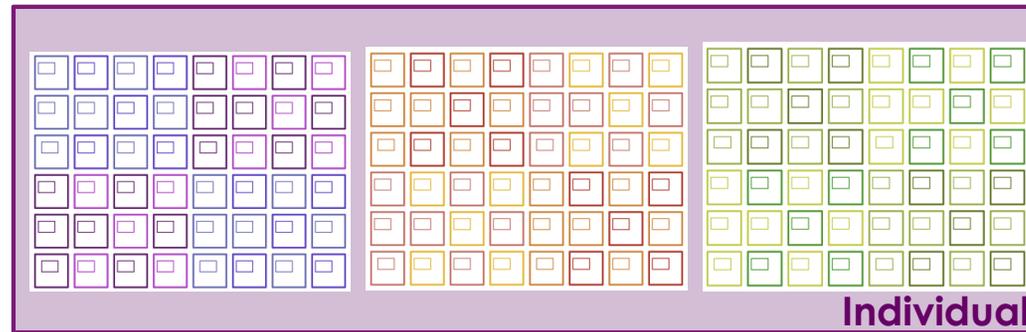


Organismal physiology



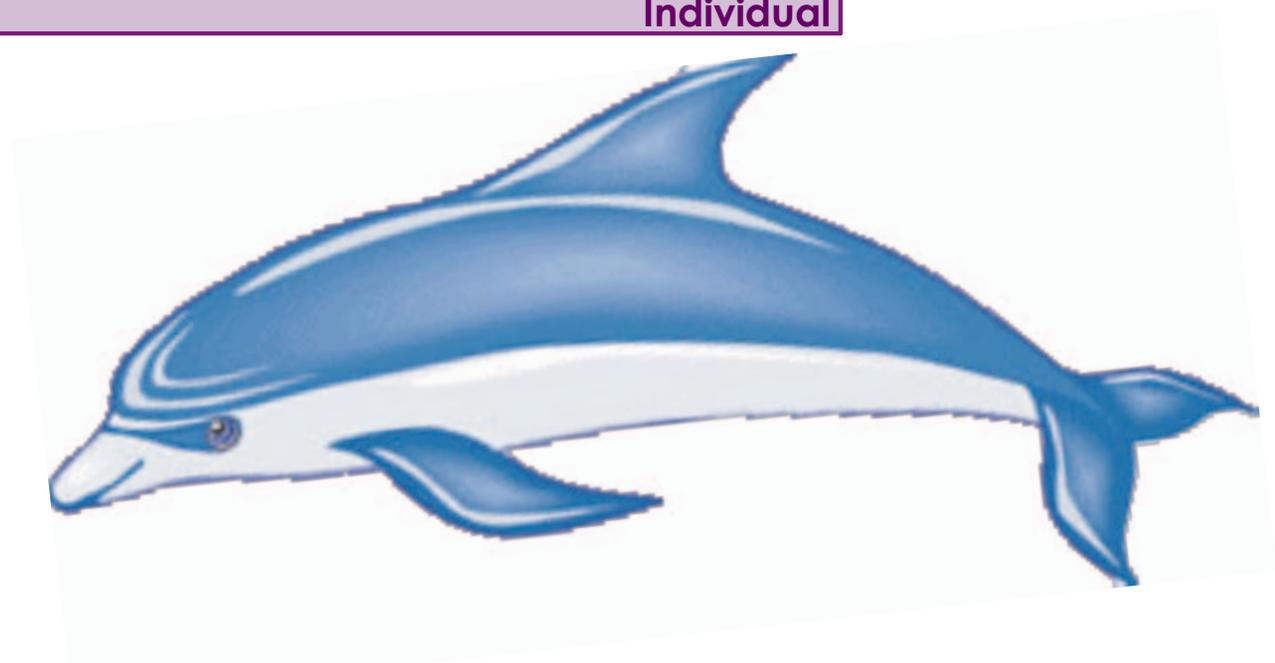
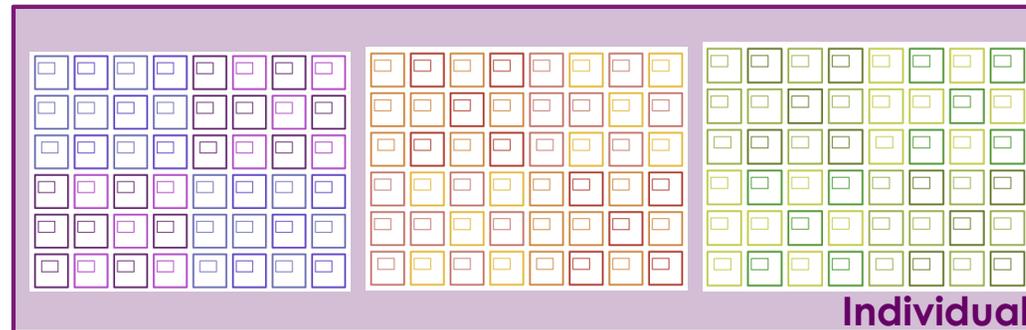


Organismal physiology



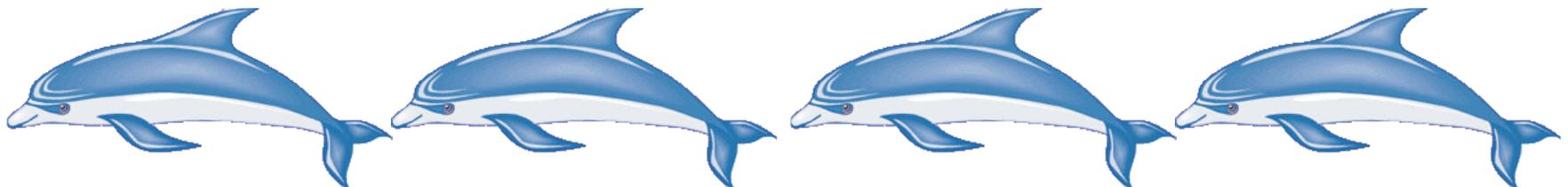
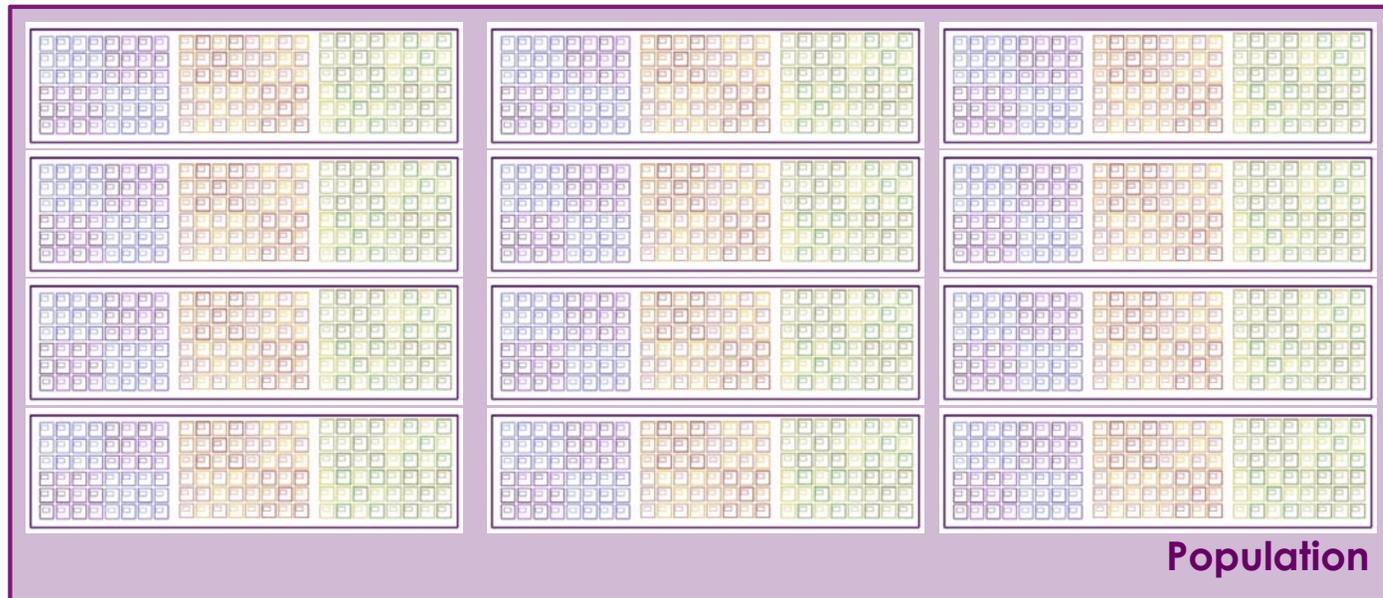


Organismal physiology



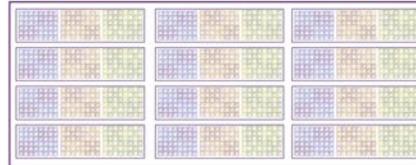
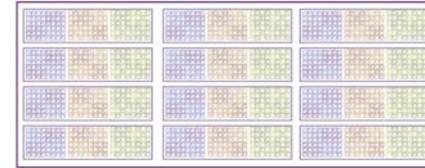
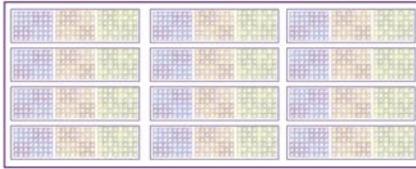
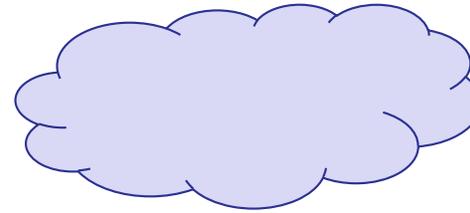
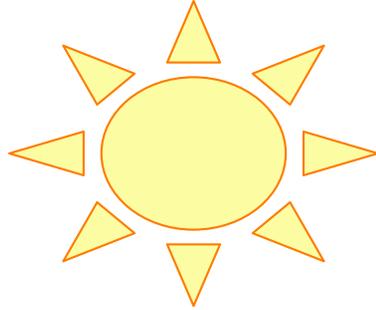


Population physiology - ecology





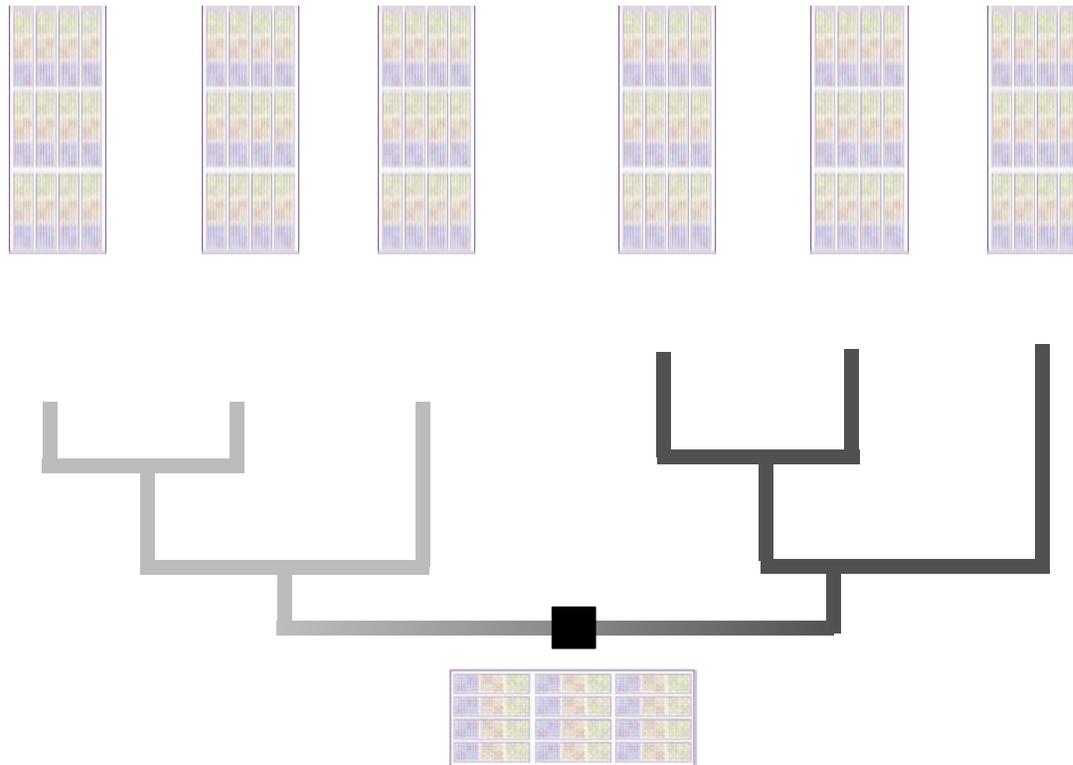
Ecophysiology



Ecosystem

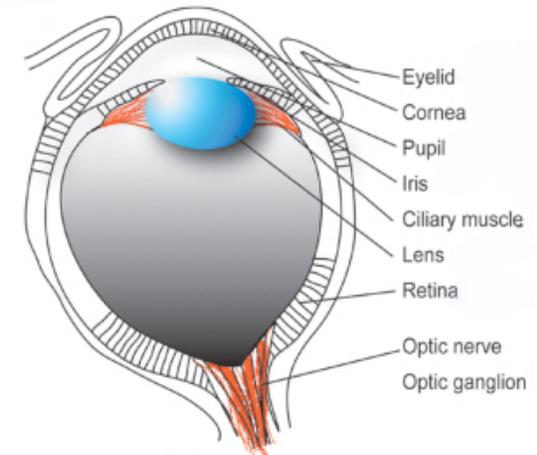
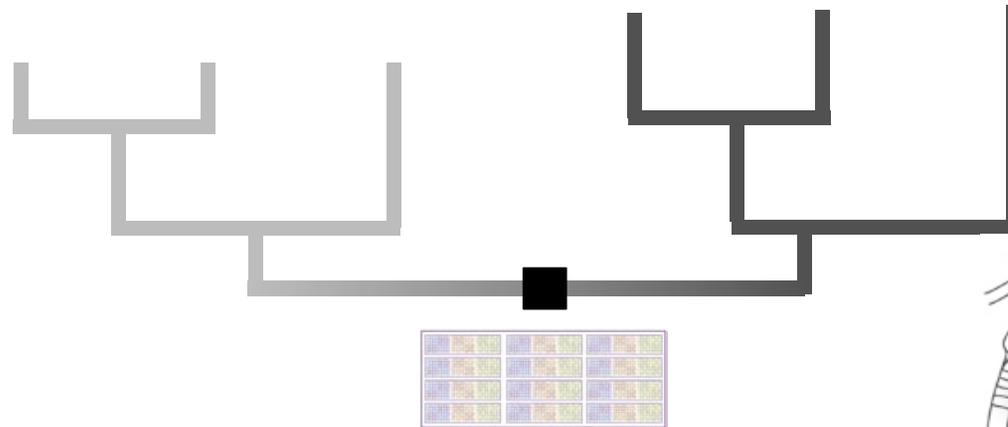
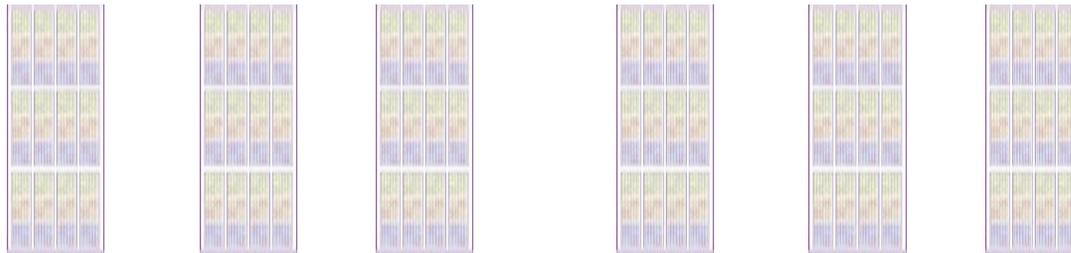


Evolutionary physiology



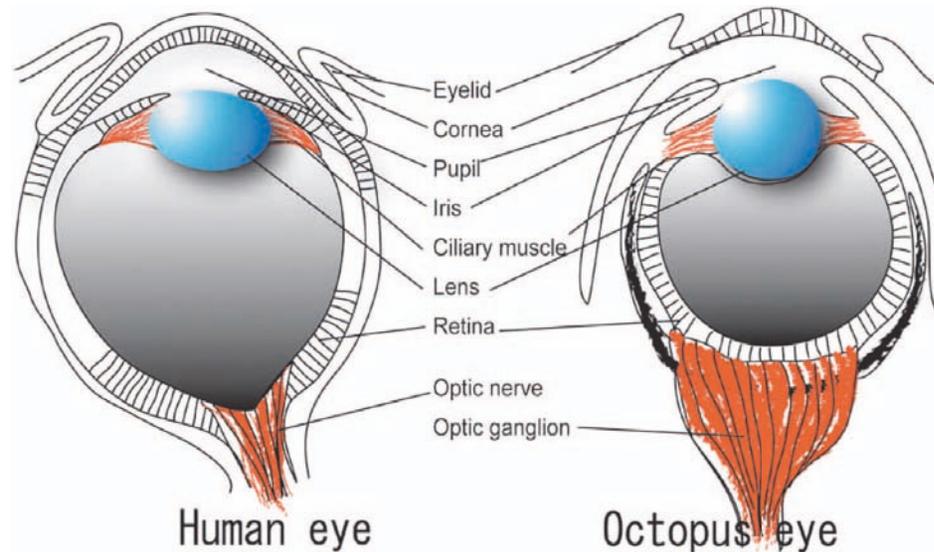
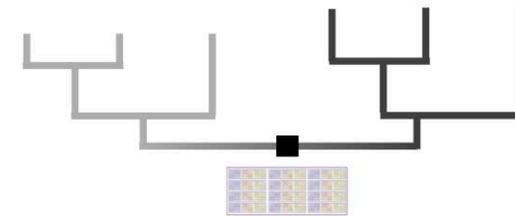
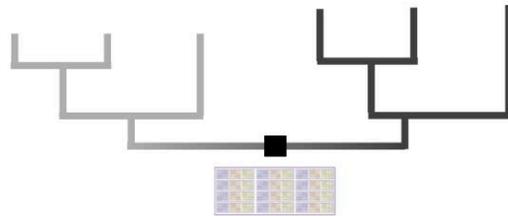
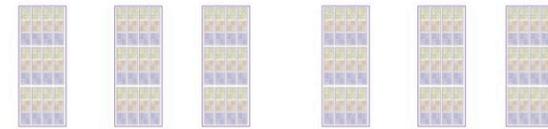
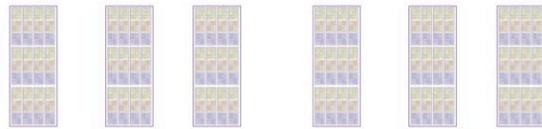


Basic function: synapomorphy





Basic function: parallel evolution





Basic functions

Cell

Organism



Basic functions

Cell

- Modulating enzyme and membrane properties

Homeostasis

Organism

- Neuroendocrine feedback, behavioural adjustment



Basic functions

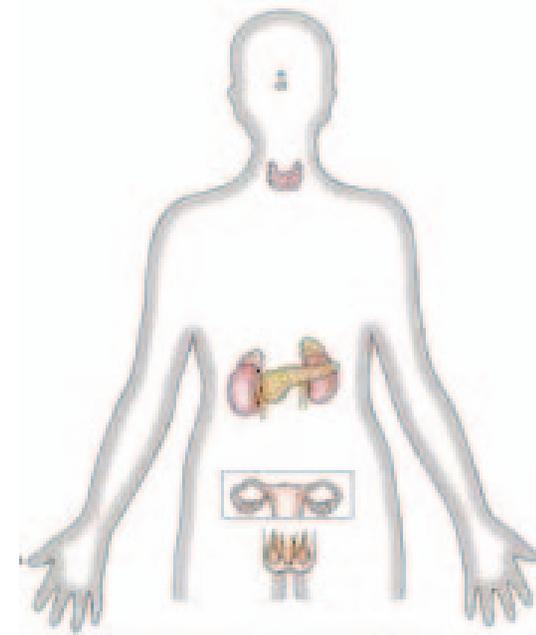
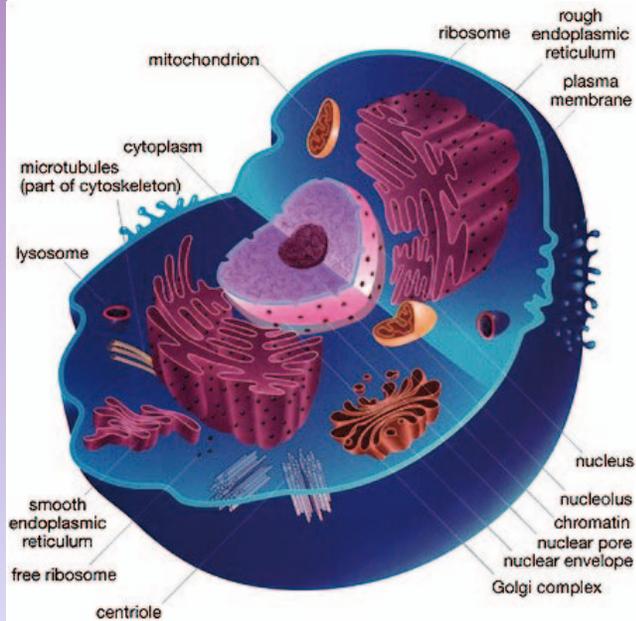
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Basic functions

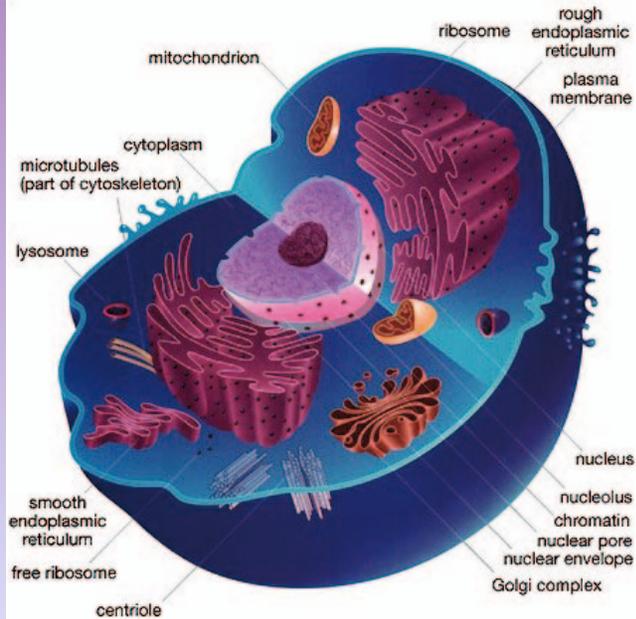
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Basic functions

Cell

- Modulating enzyme and membrane properties
- Carbon oxidization, CO_2 & H_2O production

Homeostasis
Gas exchange

Organism

- Neuroendocrine feedback, behavioural adjustment
- Ventilation (Lung, gills, tracheae)



Basic functions

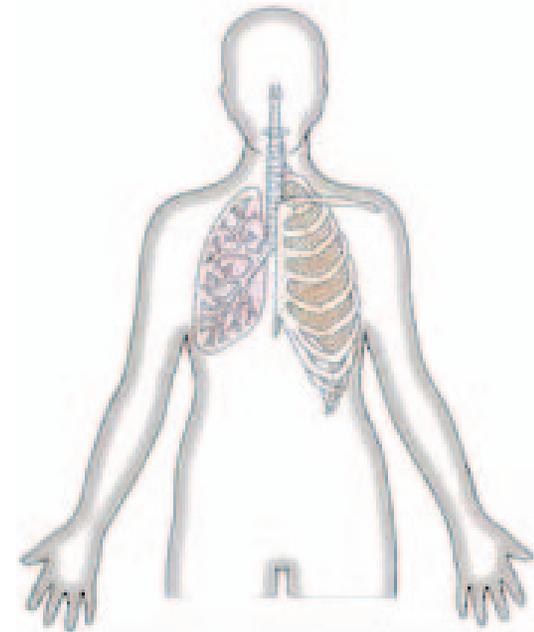
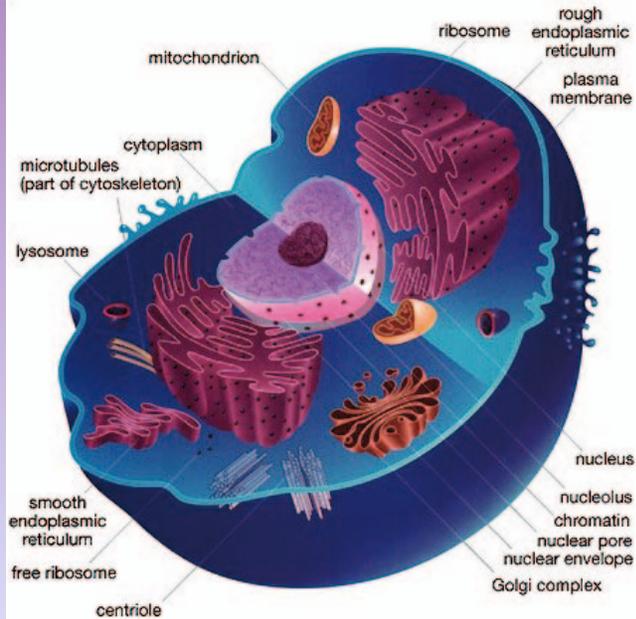
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Basic functions

Cell

- Modulating enzyme and membrane properties
- Carbon oxidization, CO_2 & H_2O production
- Diffusion, transport, pinocytosis, lysosomes

Homeostasis
Gas exchange
Nutrient supply

Organism

- Neuroendocrine feedback, behavioural adjustment
- Ventilation (Lung, gills, tracheae)
- Feeding, digestion, absorption, gastrointestinal tract, liver



Basic functions

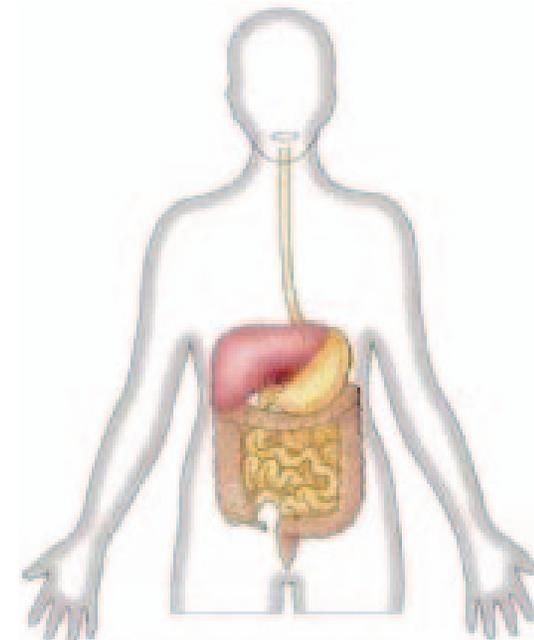
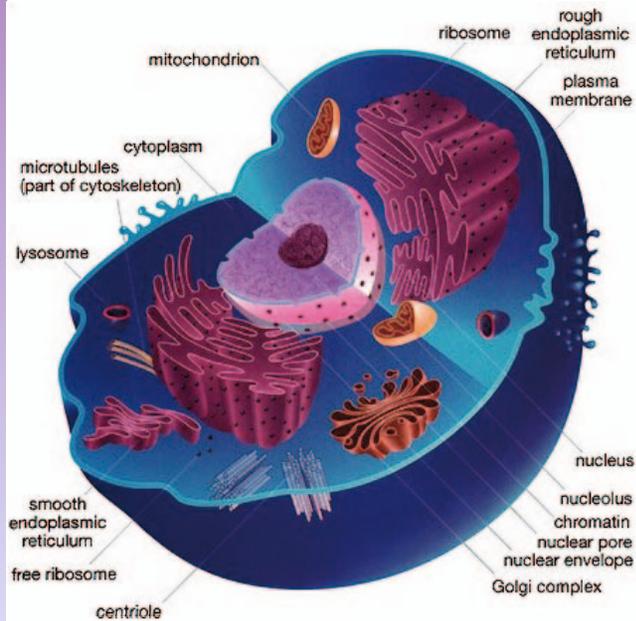
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Homeostasis
Gas exchange
Nutrient supply
Circulation

Organism

- Neuroendocrine feedback, behavioural adjustment
- Ventilation (Lung, gills, tracheae)
- Feeding, digestion, absorption, gastrointestinal tract, liver
 - Vascular system, heart



Basic functions

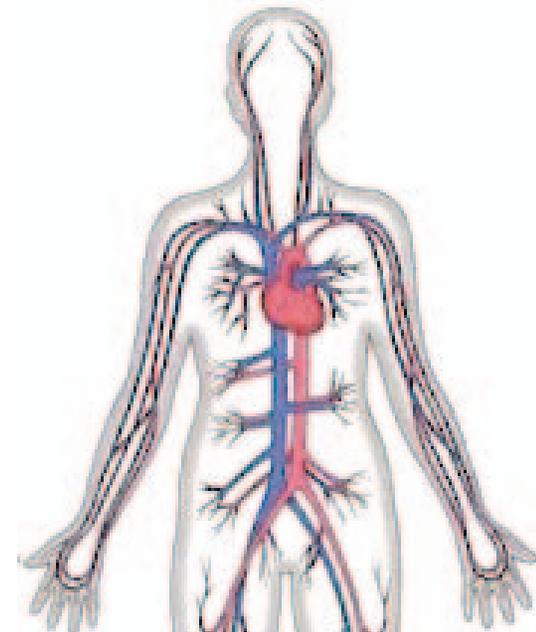
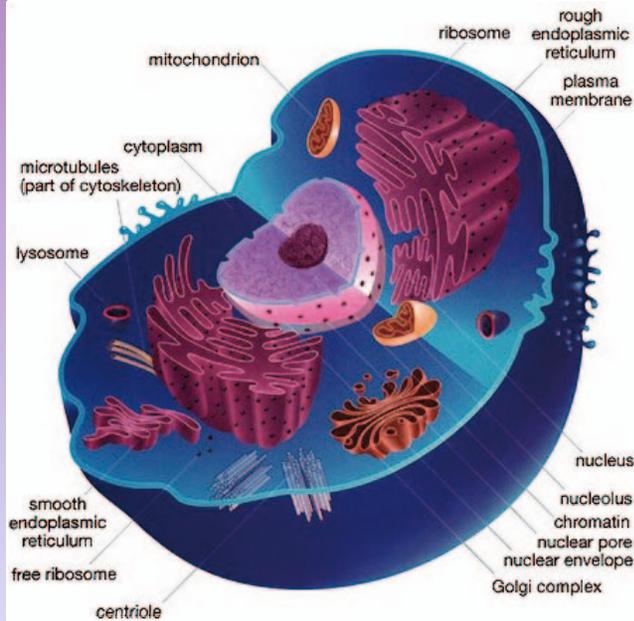
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Homeostasis
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- Digestive and urinary tract, kidneys, bladder



Basic functions

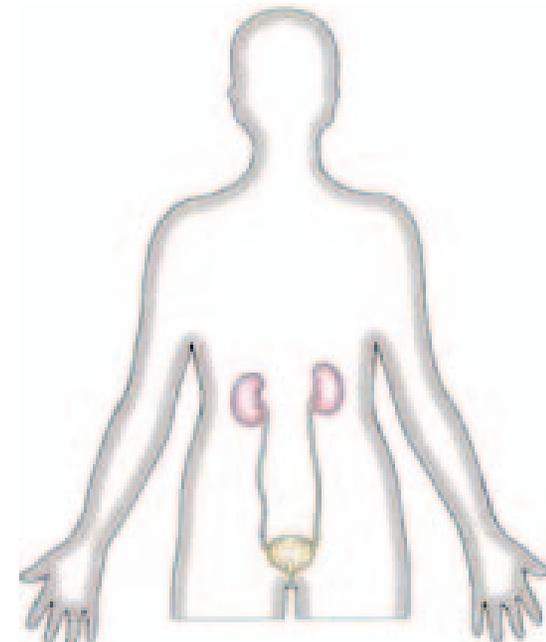
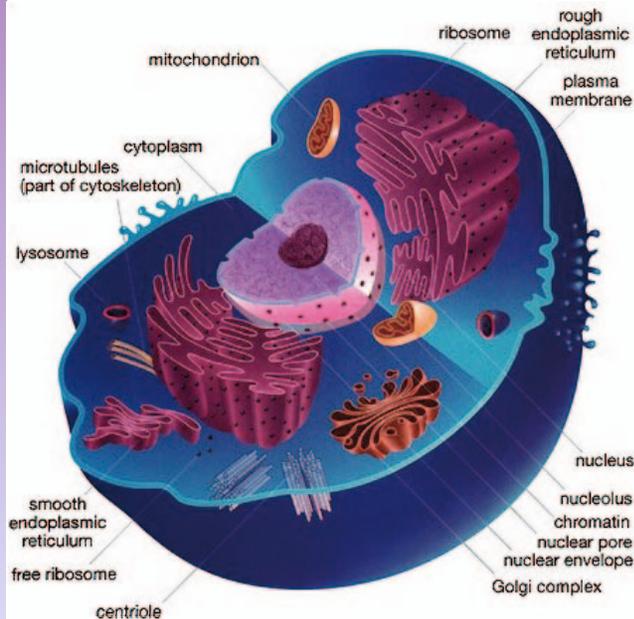
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- Diffusion, transport, pinocytosis, lysosomes
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- Tubulin, Actin/Myosine, amoeboid movement, cilia, flagellae

Homeostasis
Gas exchange
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Movement

Organism

- Neuroendocrine feedback, behavioural adjustment
- Ventilation (Lung, gills, tracheae)
- Feeding, digestion, absorption, gastrointestinal tract, liver
 - Vascular system, heart
- Digestive and urinary tract, kidneys, bladder
 - Musculoskeletal system



Basic functions

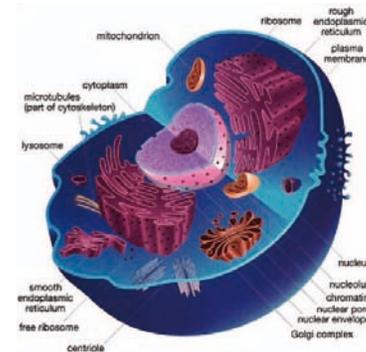
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- Receptors

Homeostasis
Gas exchange
Nutrient supply
Circulation
Excretion
Movement
Sensation

Organism

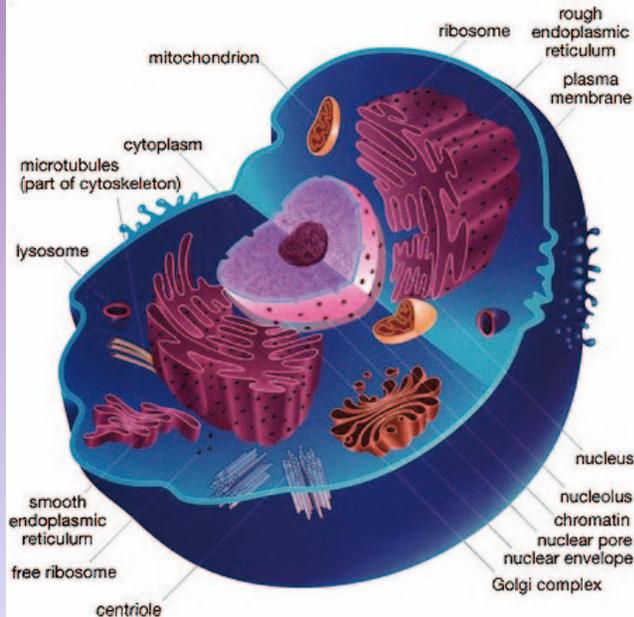
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 - Musculoskeletal system
- Sensory organs, nervous system



Basic functions

Cell

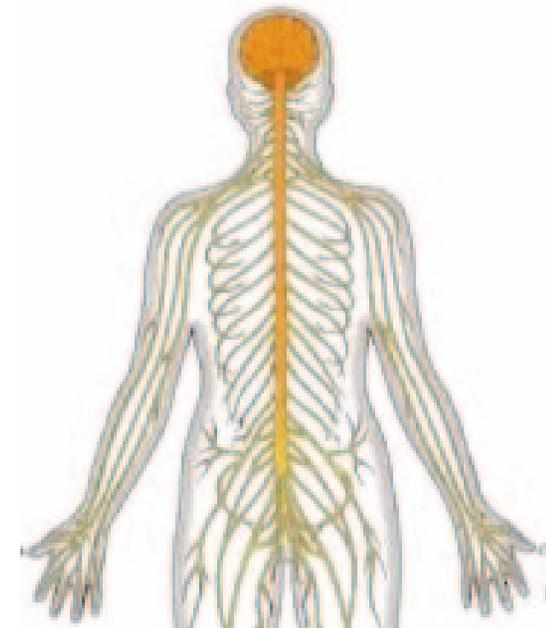
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Homeostasis
Gas exchange
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Basic functions

Cell

- Modulating enzyme and membrane properties
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- Diffusion, transport, pinocytosis, lysosomes
- Diffusion, cytoskeletal streaming, microtubules
- Vacuoles
- Tubulin, Actin/Myosine, amoeboid movement, cilia, flagellae
- Receptors
- Hypertrophy, mitosis, meiosis

Homeostasis
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Organism

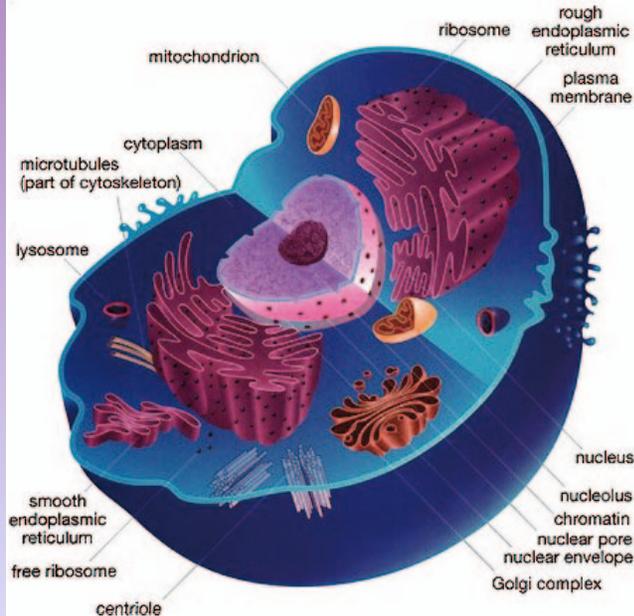
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- Digestive and urinary tract, kidneys, bladder
 - Musculoskeletal system
- Sensory organs, nervous system
- Sexual/asexual, reproductive organs



Basic functions

Cell

- Modulating enzyme and membrane properties
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Homeostasis
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Reproduction

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 - Vascular system, heart

FEMALE



MALE





Basic functions

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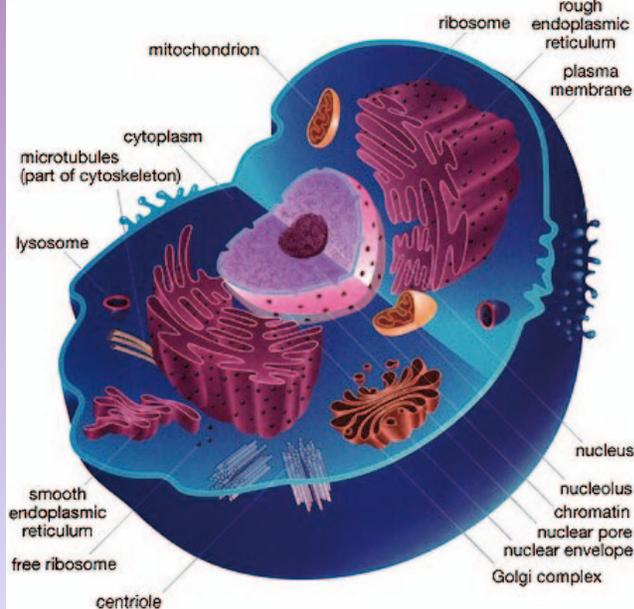
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Basic functions

Cell

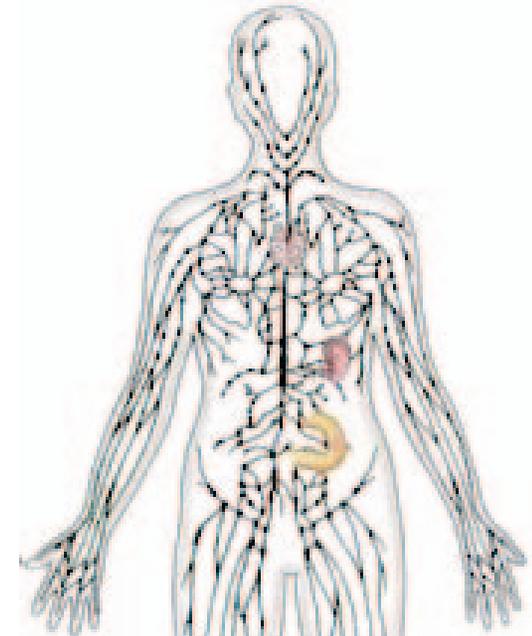
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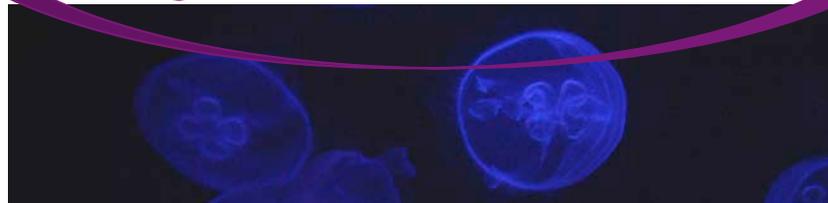
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single cells to whole animals





Basic functions

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 - Musculoskeletal system
- Sensory organs, nervous system
- Sexual/asexual, reproductive organs
 - Immune system

single cells to whole animals

compartmentalization of body into groups of specialized cells
control chemistry by building buffers between the uncontrolled environment and the controlled space within each cell



Basic functions: fundamental options

'conform'

no internal set point
large variation

'poikilo'



Homeostatic
control

'regulate'

internal set point
small variation

'homeo'





Basic functions: fundamental options

'conform'

Homeostatic
control

'regulate'

no internal set point
large variation

internal set point
small variation

'poikilo'



'homeo'



stable
'steno'

External
conditions

variable
'eury'

poikilotherms are
often stenotherms

homeotherms are
often eurytherms

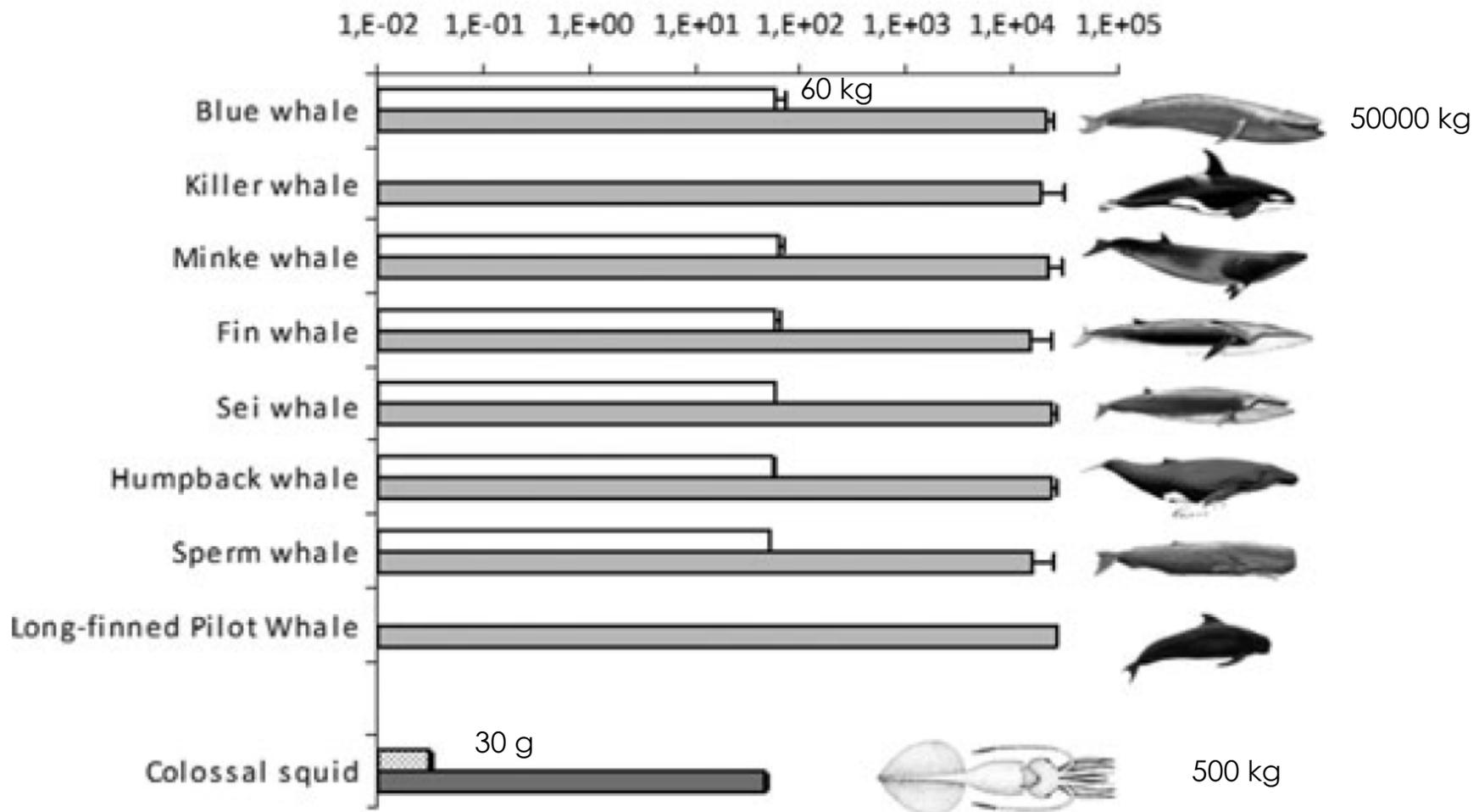


Slow pace of life of the Antarctic colossal squid

RUI ROSA¹ AND BRAD A. SEIBEL²

Journal of the Marine Biological Association of the United Kingdom, 2010, 90(7), 1375–1378.

Energy consumption (kcal day^{-1}) and prey biomass requirements (kg day^{-1})





Basic functions: tradeoffs

Life history

'slow'

'fast'





Basic functions: tradeoffs

'slow'
low

Life history

Metabolism

'fast'
high





Basic functions: tradeoffs

'slow'

low
long

Life history

Metabolism
Times
(gestation,
longevity, growth,
time to 1st
reproduction)

'fast'

high
short





Basic functions: tradeoffs

Life history

'slow'

low
long

few, precocial



Metabolism
Times
(gestation,
longevity, growth,
time to 1st
reproduction)
Young

'fast'

high
short

many, altricial





Basic functions: tradeoffs

Life history

'slow'

low
long

few, precocial
low



Metabolism
Times
(gestation,
longevity, growth,
time to 1st
reproduction)

Young
Mortality

'fast'

high
short

many, altricial
high





Basic functions: tradeoffs

Life history

'slow'

low
long

few, precocial
low



'fast'

high
short

many, altricial
high





Basic functions: tradeoffs

Life history

'slow'

low
long

Metabolism
Times
(gestation,
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Young
Mortality

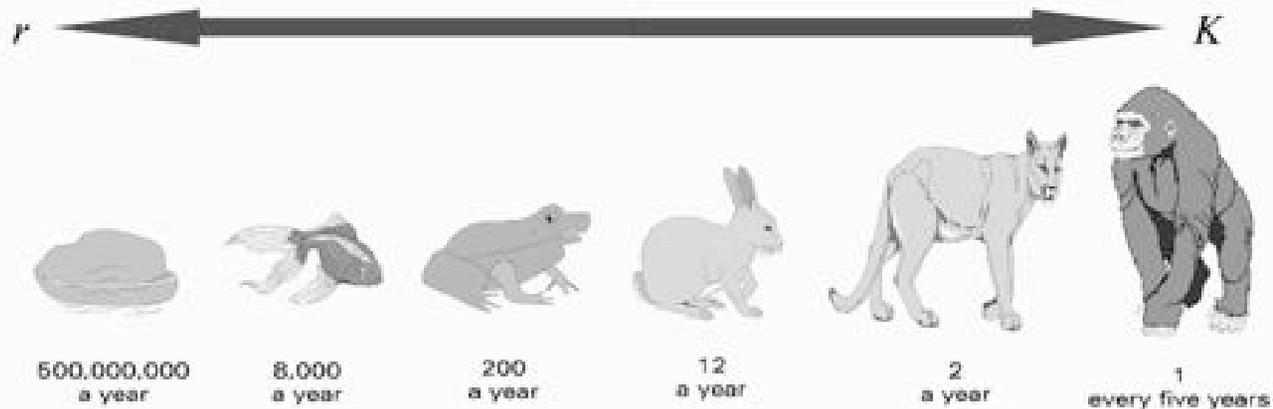
'fast'

high
short

few, precocial
low

many, altricial
high

The *r*-*K* Scale of Reproductive Strategy: Balancing Egg Output versus Parental Care





Basic functions: tradeoffs

Life history

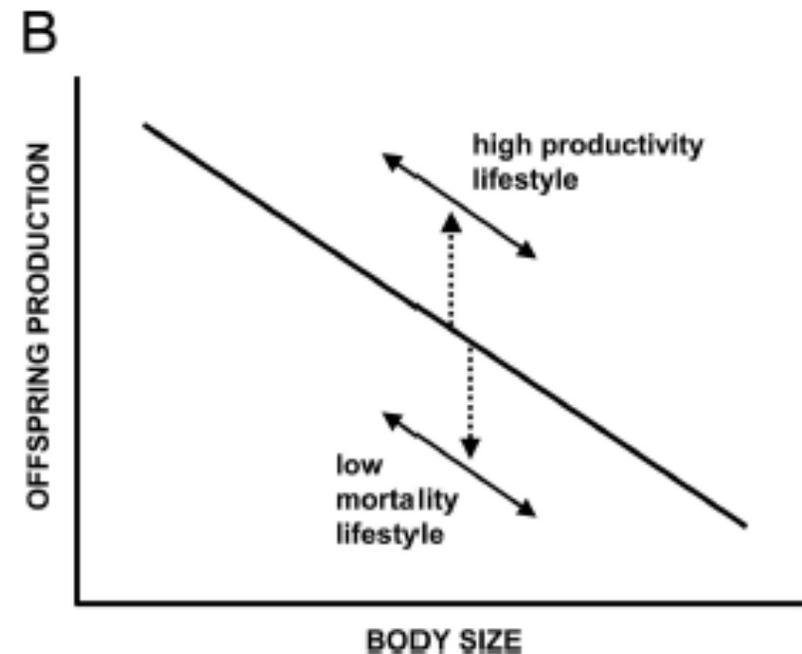
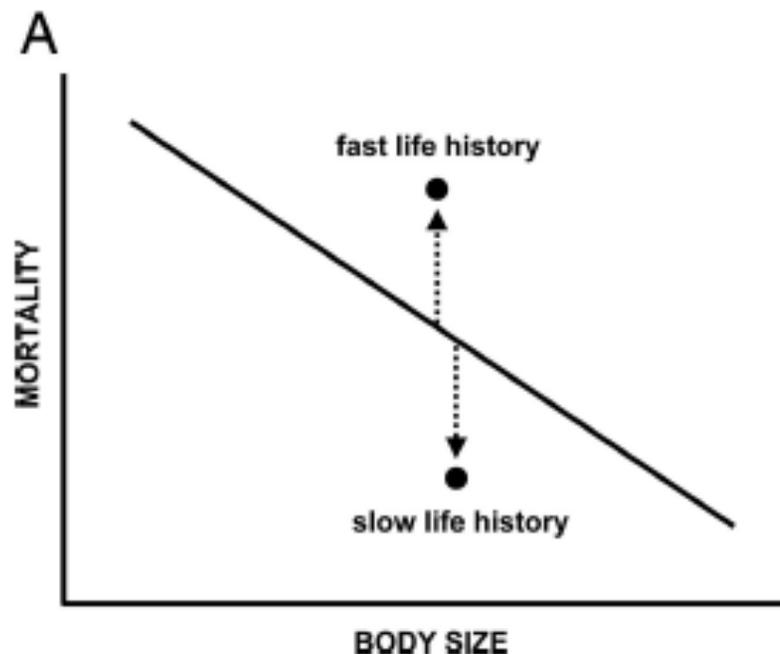
'slow'

'fast'

A lifestyle view of life-history evolution

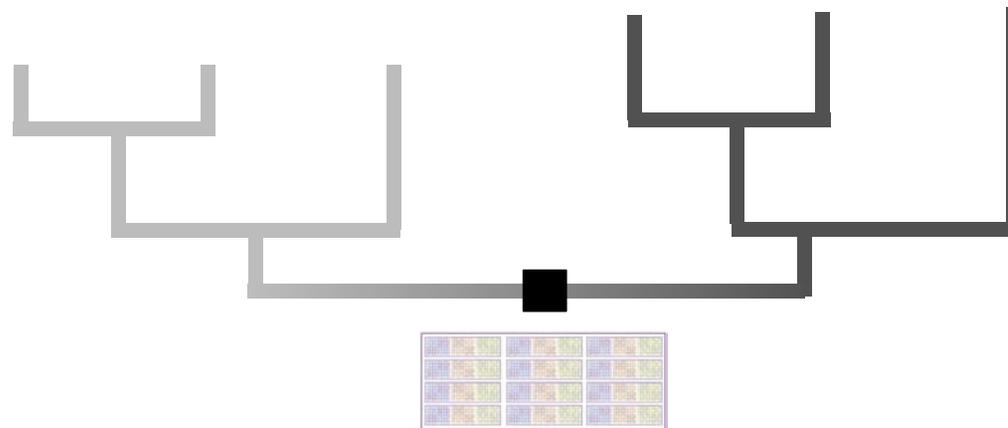
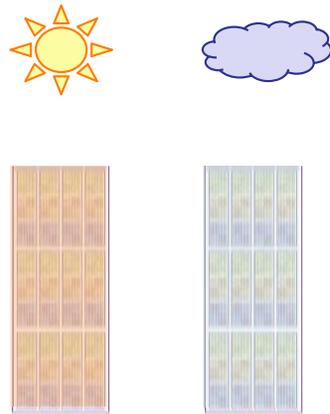
F. Stephen Dobson*

PNAS | November 6, 2007 | vol. 104 | no. 45 | 17565–17566





Detailed function: adaptation/apomorphy





Detailed function: adaptation/apomorphy

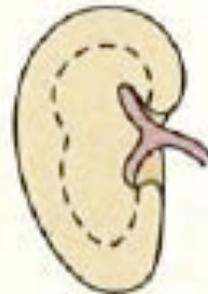
There is little or no development of the renal papilla in freshwater aquatic species. However,...

... the renal papilla is highly developed in species native to arid habitats, so much so that it often penetrates well into the ureter.

Aquatic species

Mesic species

Arid species



Aquatic mole
(*Desmana moschata*)

European hedgehog
(*Erinaceus europaeus*)

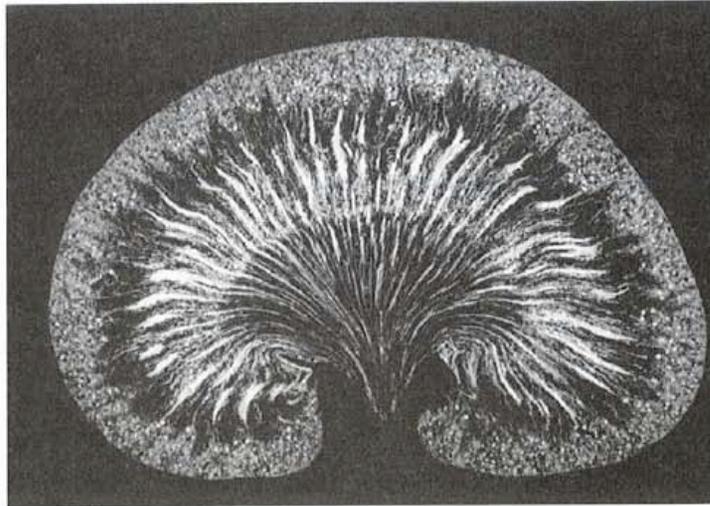
Elephant shrew
(*Macroscelides* sp.)

INSECTIVORES

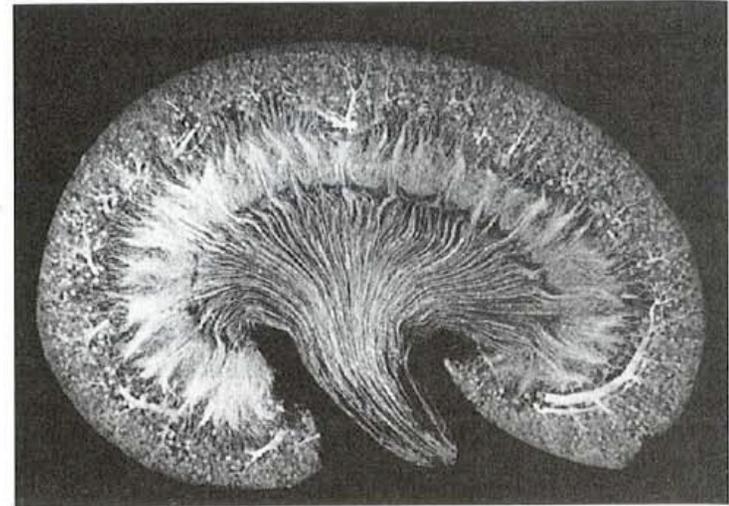


Detailed function: adaptation/apomorphy

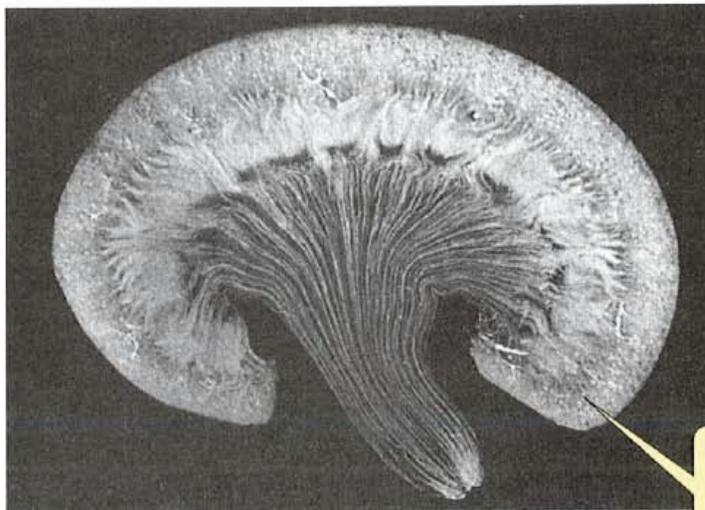
(a) Laboratory rat



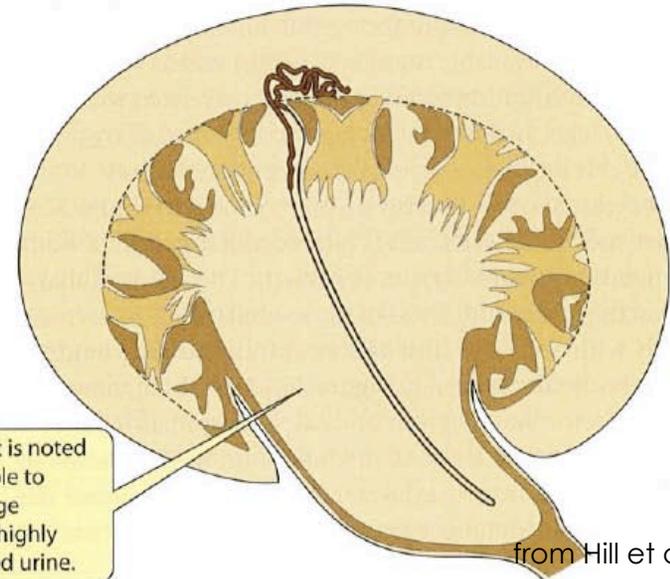
(b) Mongolian gerbil



(c) Sand rat



(d) A long-looped nephron in the sand rat kidney



The sand rat is noted for being able to produce large volumes of highly concentrated urine.

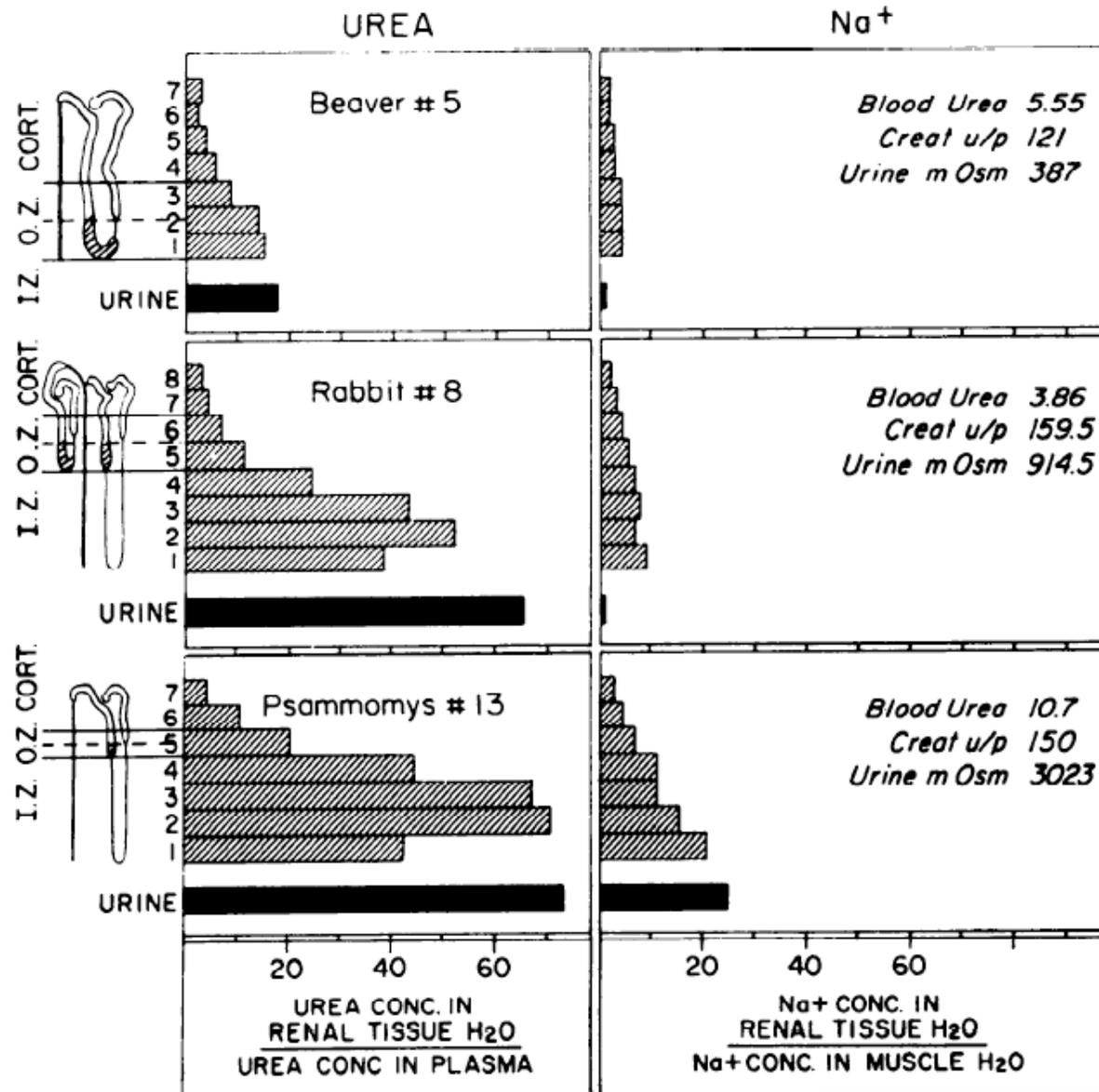
from Hill et al. (2004)



Structure and concentrating mechanism in the mammalian kidney¹

BODIL SCHMIDT-NIELSEN² AND ROBERTA O'DELL³

Am. J. Physiol. (1961)

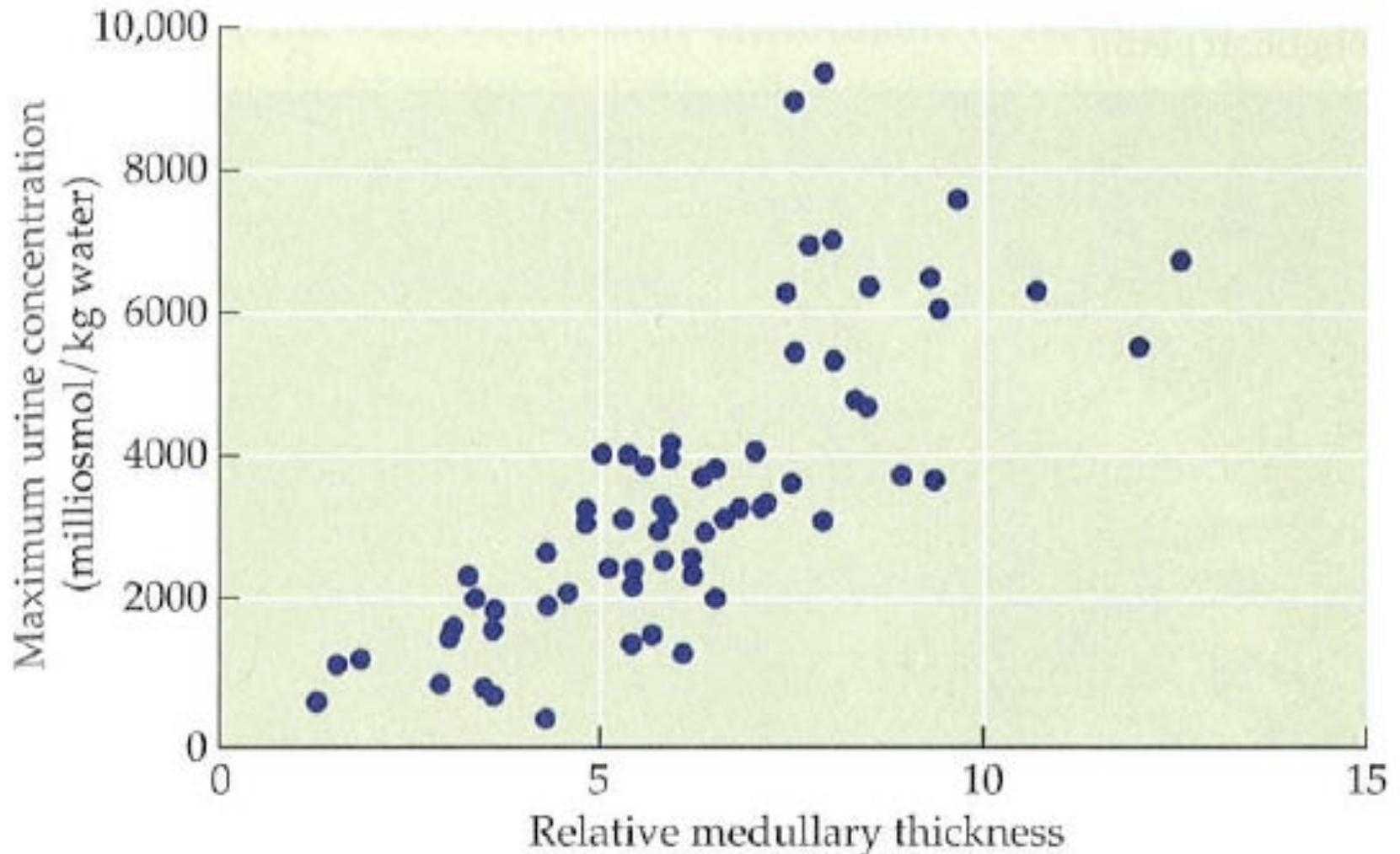




Body size, medullary thickness, and urine concentrating ability in mammals

CAROL A. BEUCHAT

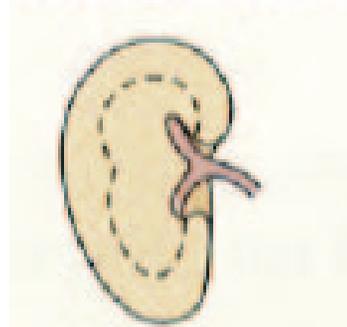
Am. J. Physiol. (1990)





Two basic modes of adaptation

Mesic species



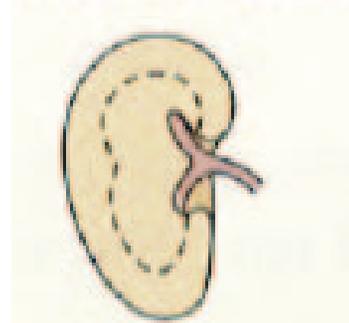


Two basic modes of adaptation

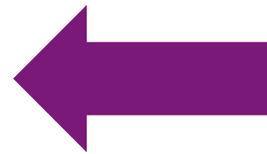
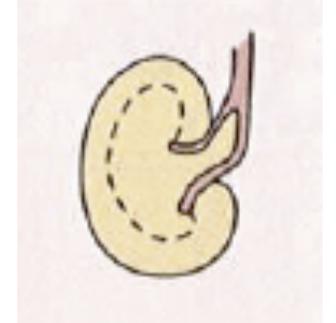
Aquatic species



Mesic species



Arid species



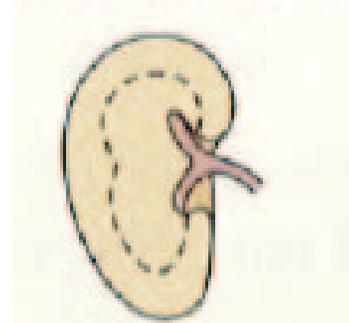


Two basic modes of adaptation

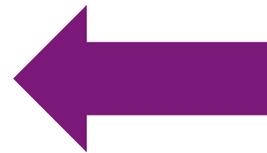
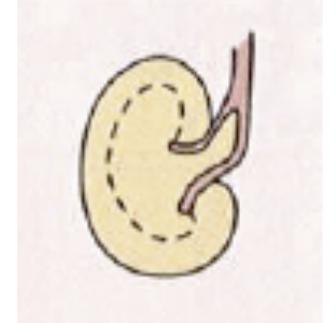
Aquatic species



Mesic species



Arid species



Ecological
challenge

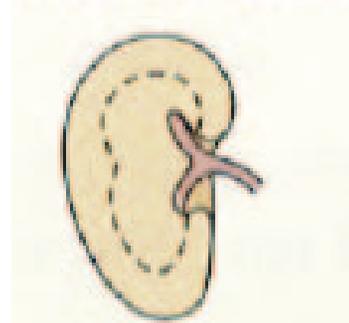


Two basic modes of adaptation

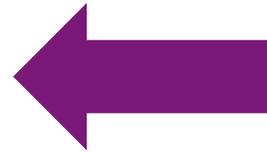
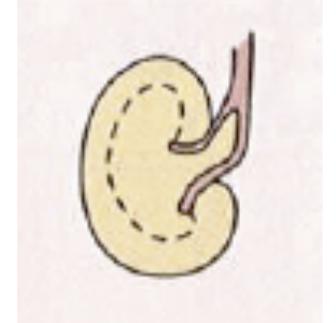
Aquatic species



Mesic species



Arid species



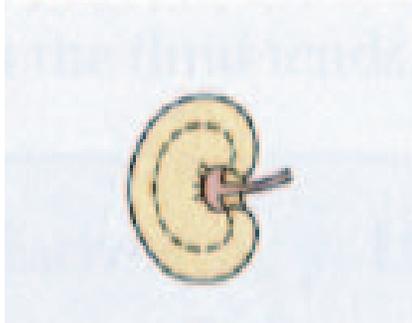
Ecological
opportunity

Ecological
challenge

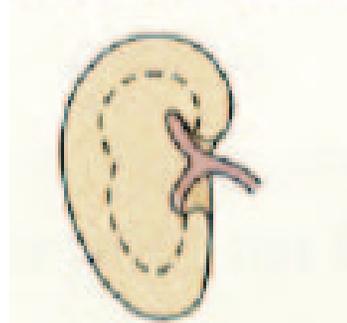


Two basic modes of adaptation

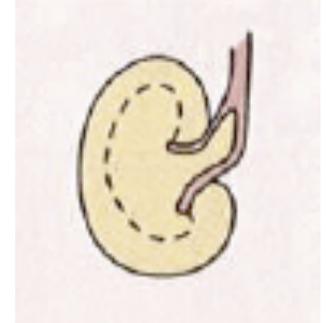
Aquatic species



Mesic species



Arid species



Ecological
opportunity

- reduction (saving)

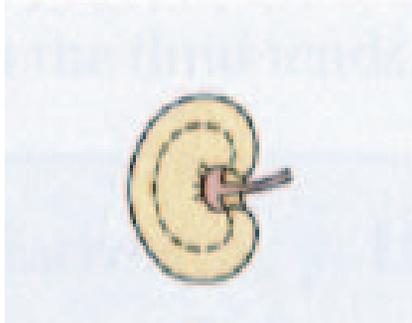
Ecological
challenge

- addition (cost)

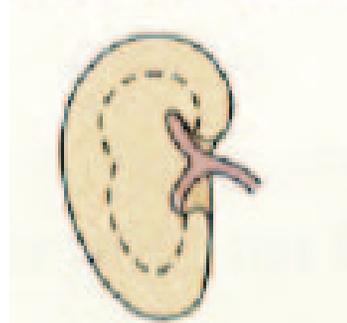


Two basic modes of adaptation

Aquatic species



Mesic species



Arid species



Ecological
opportunity

- reduction (saving)

Ecological
challenge

- addition (cost)

*high efficiency that is
often not able to use
high resource availability
competitively*

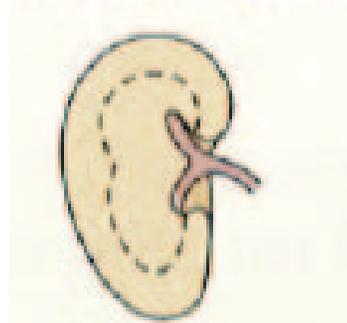


Two basic modes of adaptation

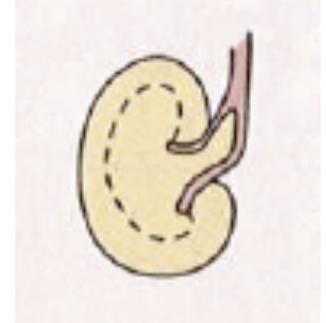
Aquatic species



Mesic species



Arid species



Ecological
opportunity

- reduction (saving)



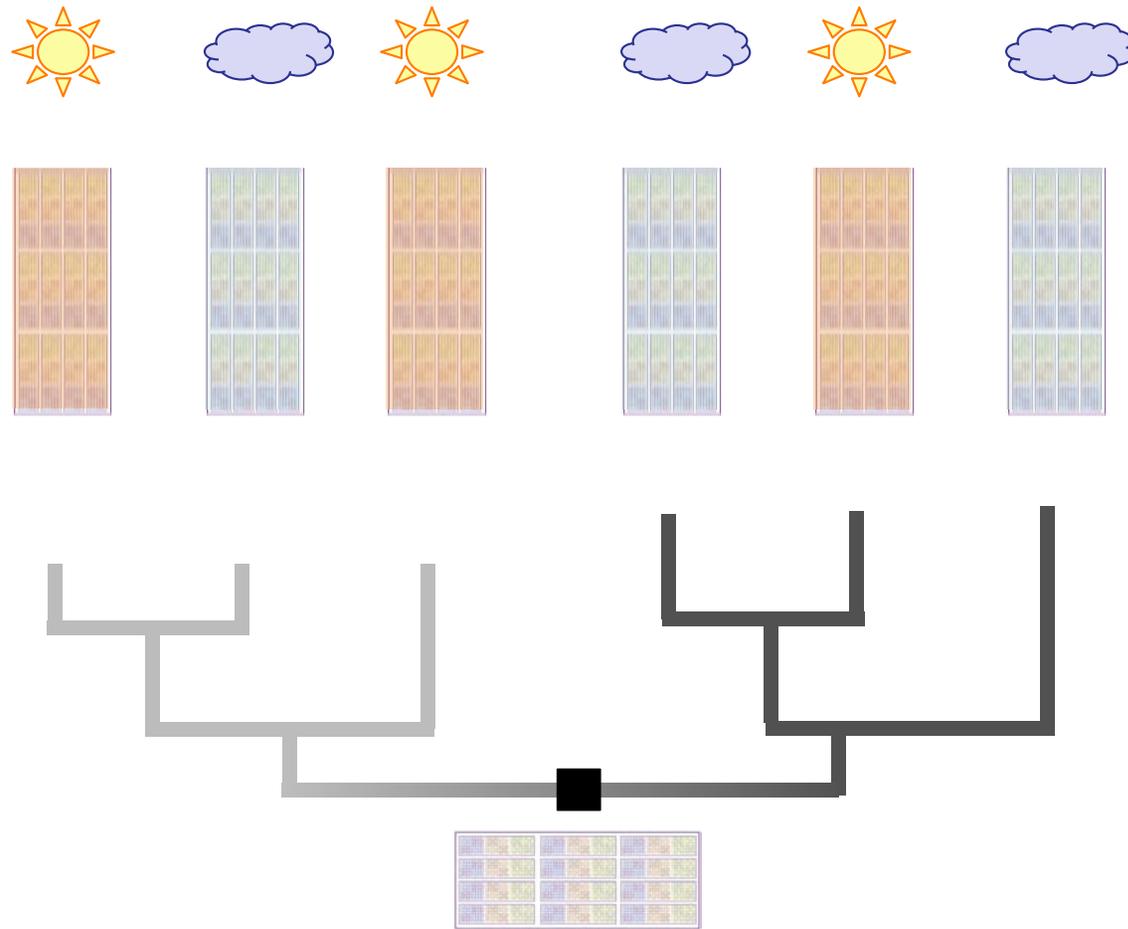
Ecological
challenge

- addition (cost)



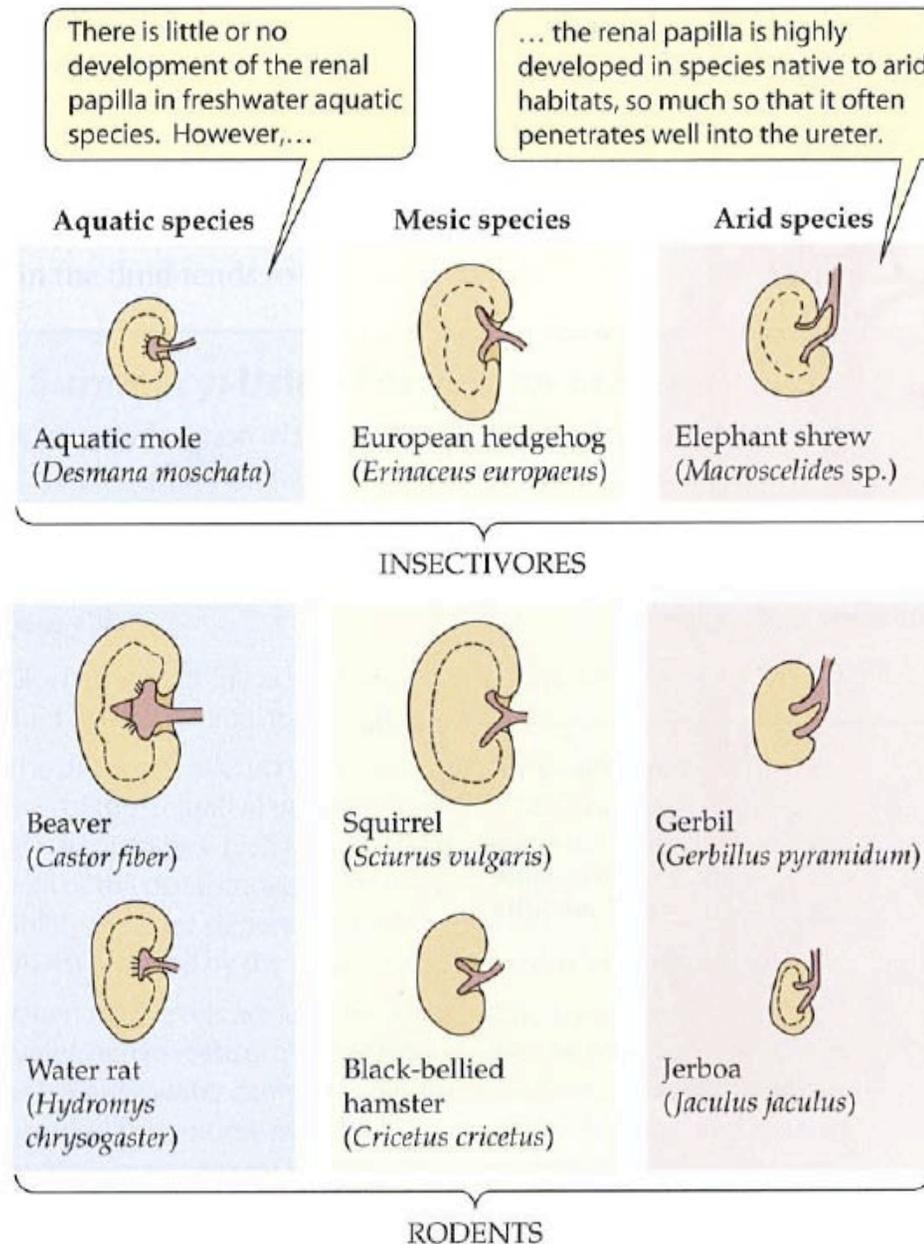


Detailed function: convergence/homoplasy





Detailed function: convergence/homoplasy

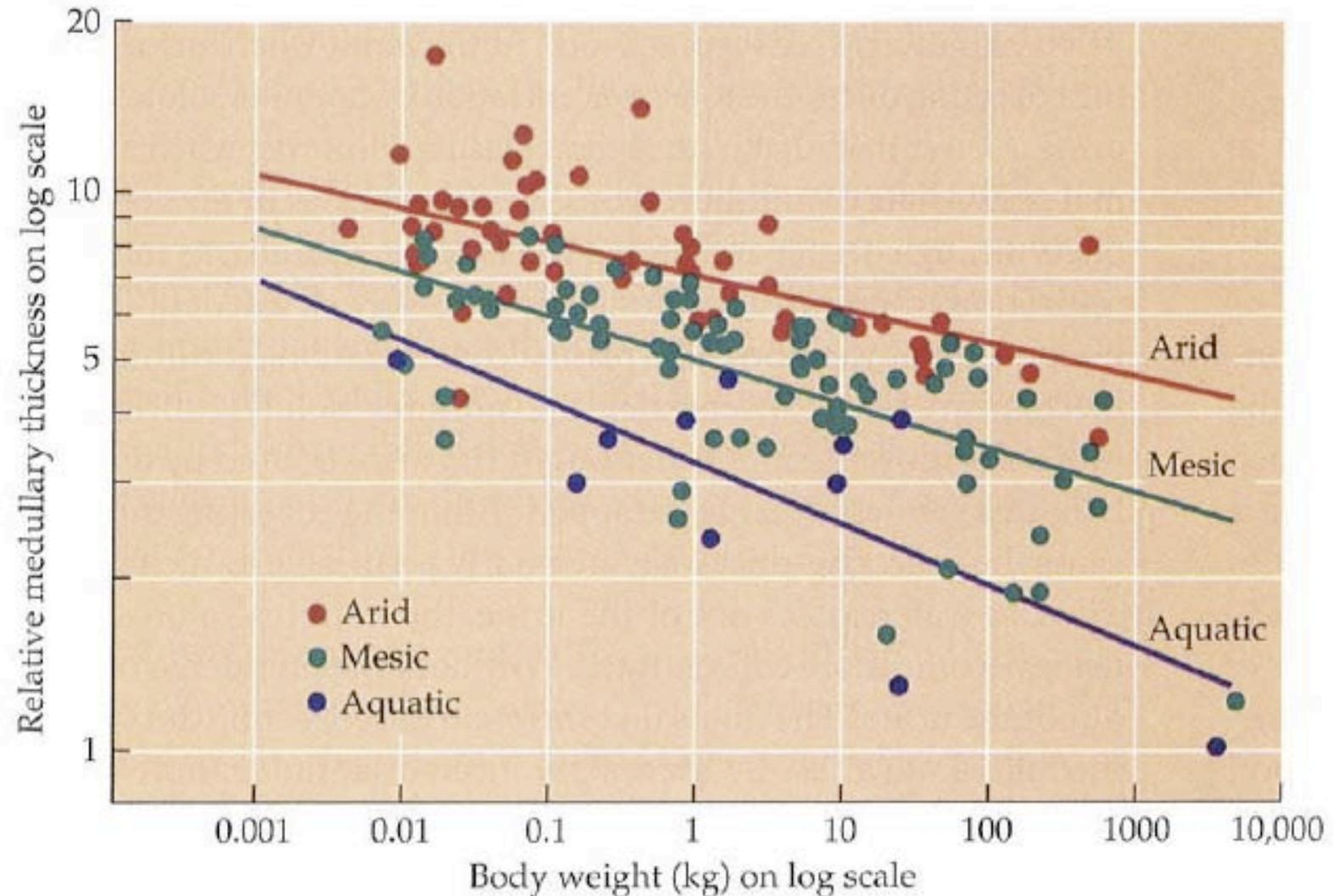




Structure and concentrating ability of the mammalian kidney: correlations with habitat

CAROL A. BEUCHAT

Am. J. Physiol.
(1996)



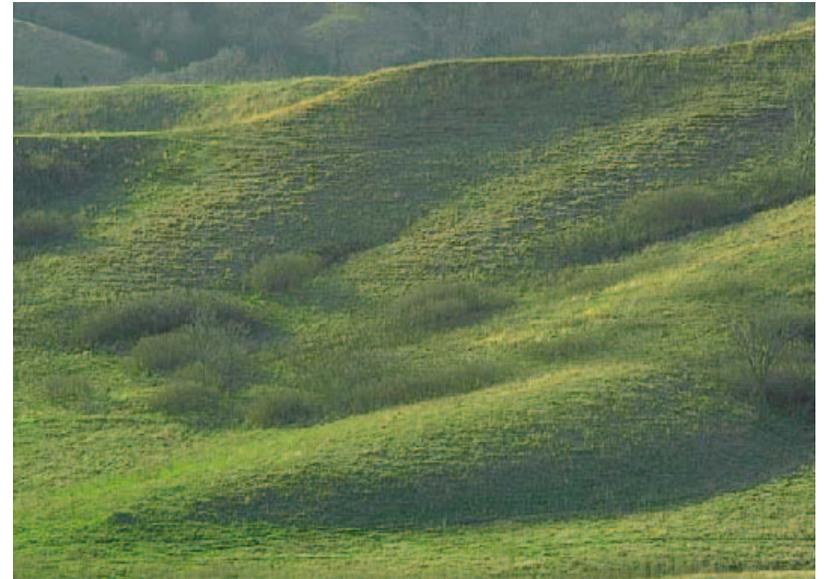


Characterising basic condition

Marine



Terrestrial





Characterising basic condition

Marine
viscous

Medium

Terrestrial
thin





Characterising basic condition

Marine
viscous
buoyancy

Medium
Support

Terrestrial
thin
gravity





Characterising basic condition

Marine
viscous
buoyancy
high

Medium
Support
Pressure

Terrestrial
thin
gravity
low



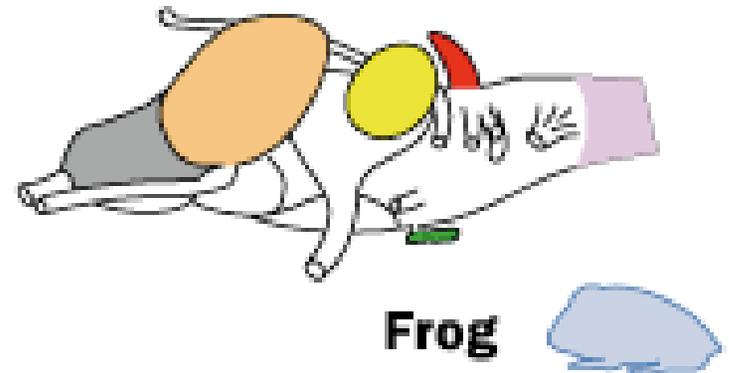
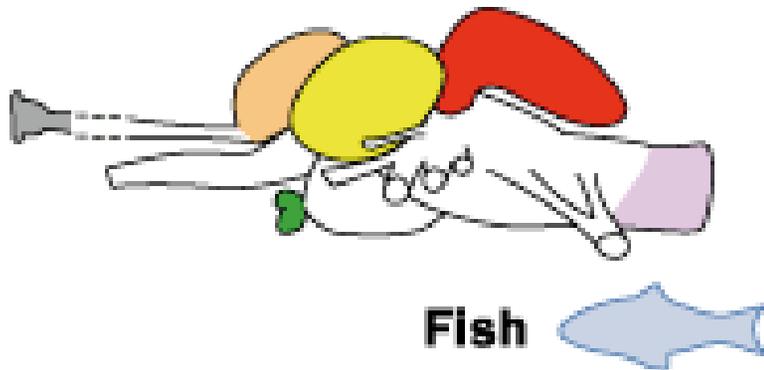


Characterising basic condition

Marine
viscous
buoyancy
high
3 D

Medium
Support
Pressure
Dimensionality

Terrestrial
thin
gravity
low
mostly 2 D





Characterising basic condition

Marine

viscous

buoyancy

high

3 D

high

Medium

Support

Pressure

Dimensionality

Conductance

Terrestrial

thin

gravity

low

mostly 2 D

low





Characterising basic condition

Marine

viscous

buoyancy

high

3 D

high

high

Medium

Support

Pressure

Dimensionality

Conductance

Thermal stability

Terrestrial

thin

gravity

low

mostly 2 D

low

low





Characterising basic condition

Marine

viscous

buoyancy

high

3 D

high

high

low

Medium

Support

Pressure

Dimensionality

Conductance

Thermal stability

Oxygen

Terrestrial

thin

gravity

low

mostly 2 D

low

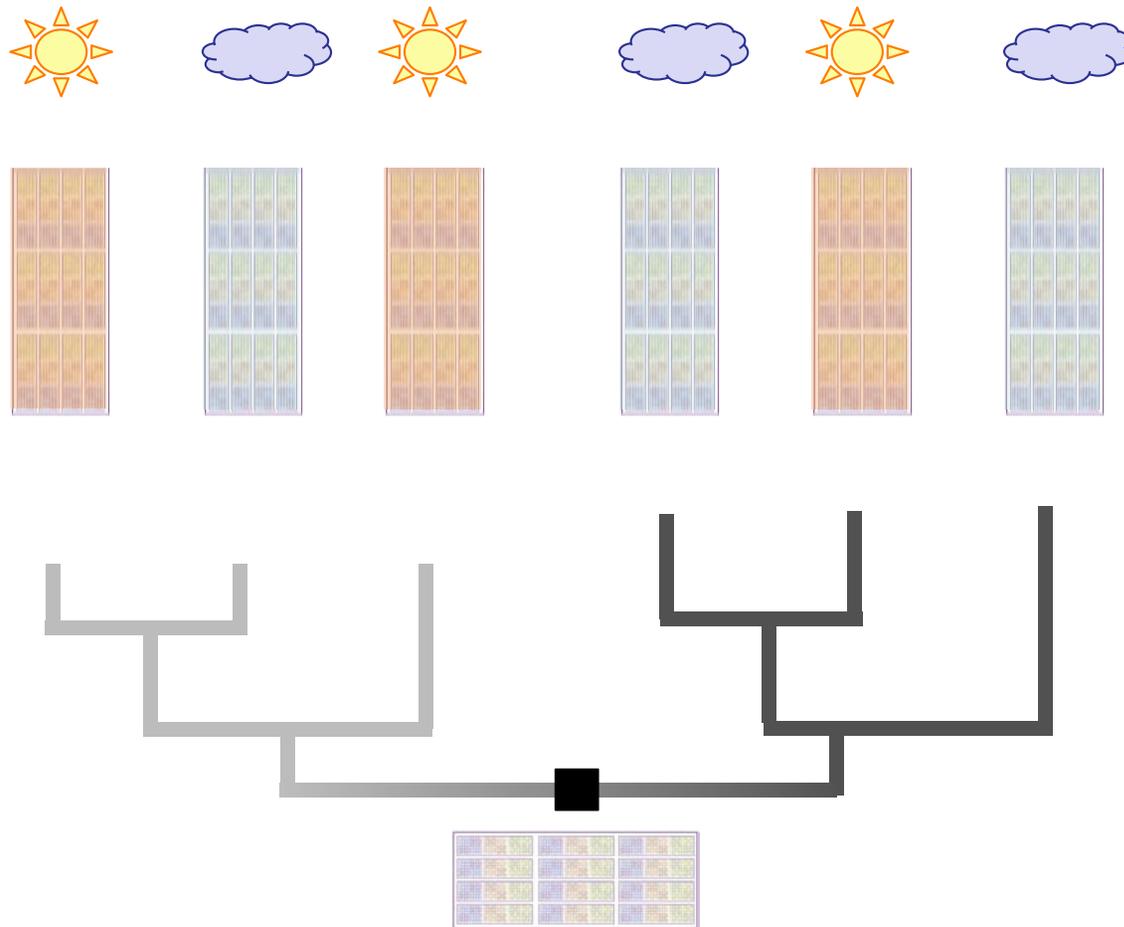
low

high



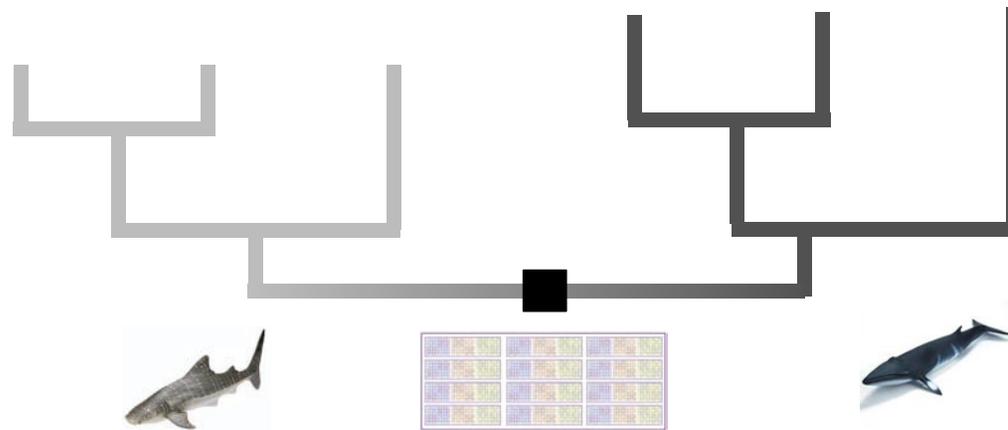


Detailed function: constraints by evolutionary history ('contingency')



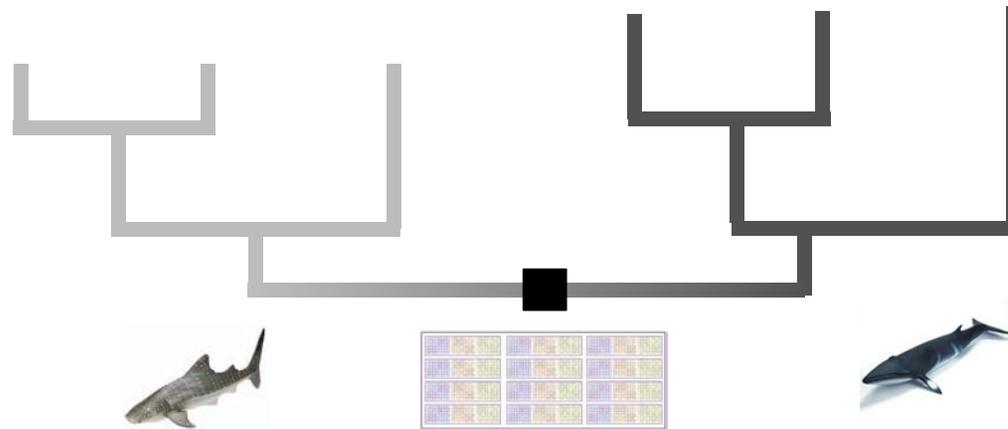
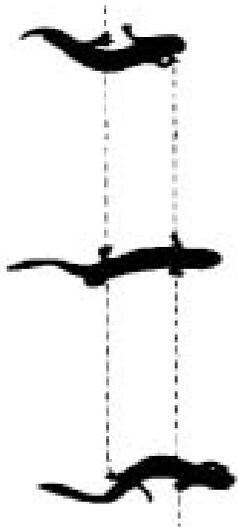


Detailed function: constraints by evolutionary history ('contingency')



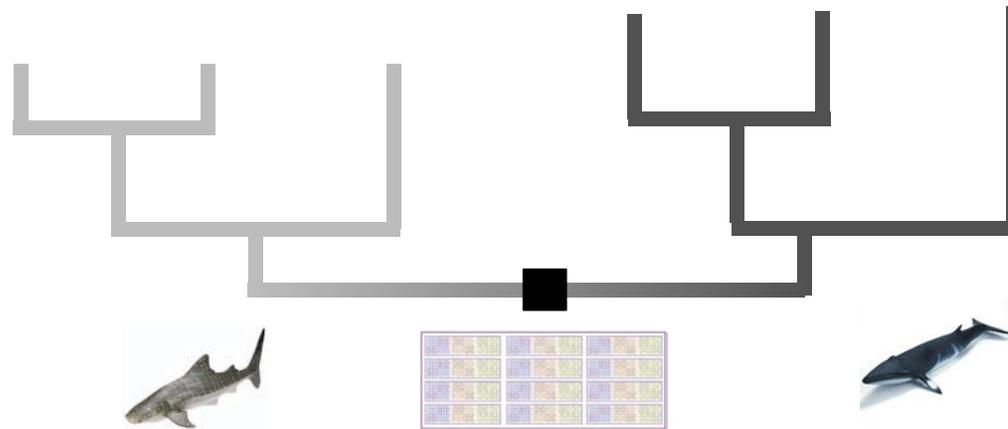
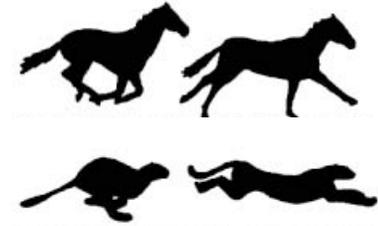
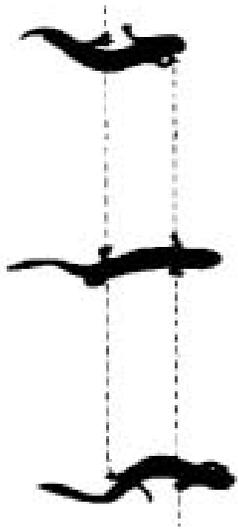


Detailed function: constraints by evolutionary history ('contingency')



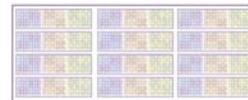
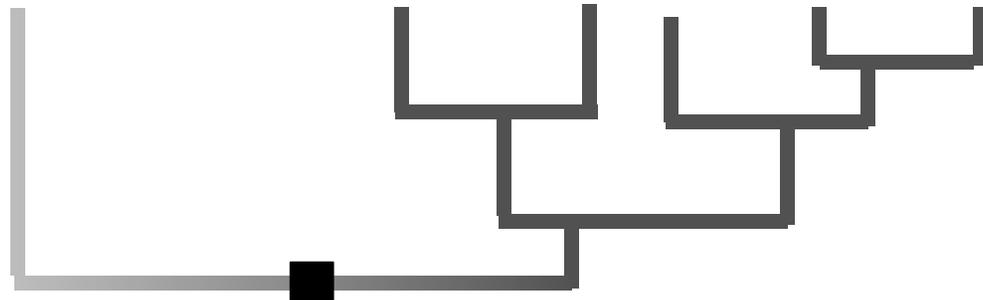
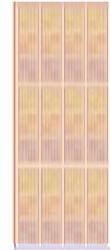


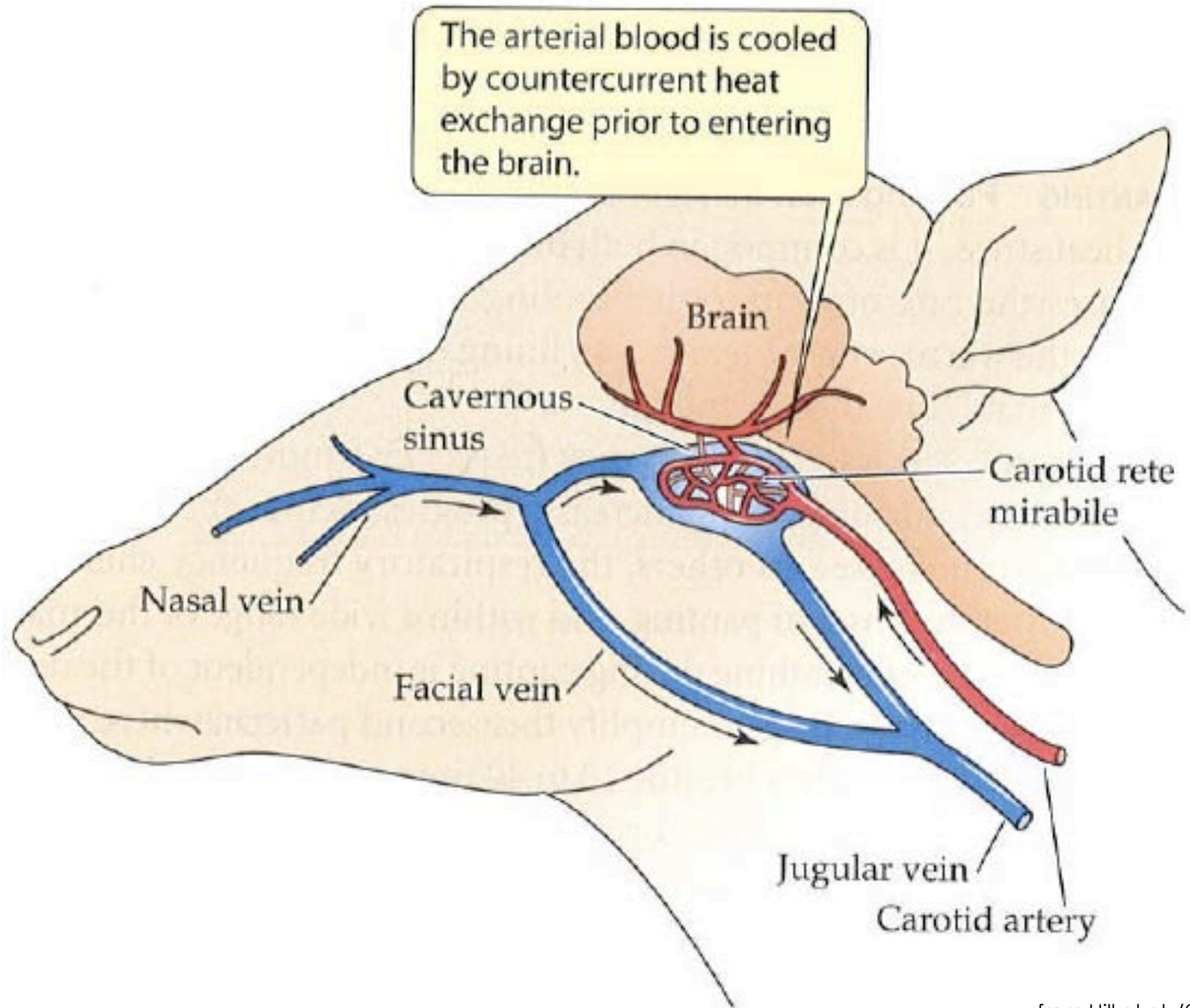
Detailed function: constraints by evolutionary history ('contingency')





Detailed function: solutions of different efficiency



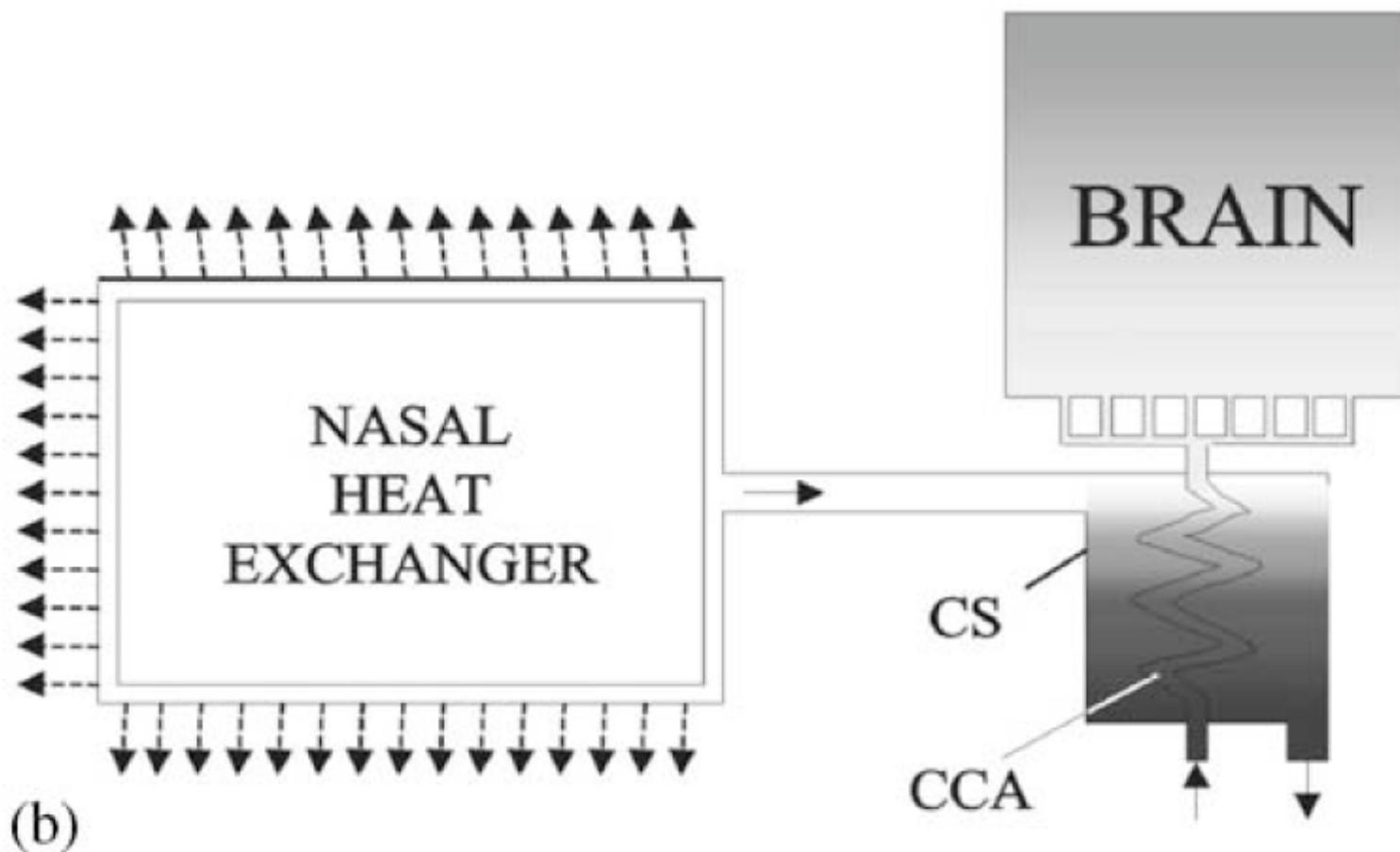




Selective brain cooling: a multiple regulatory mechanism

Michał Caputa*

Journal of Thermal Biology 29 (2004) 691–702

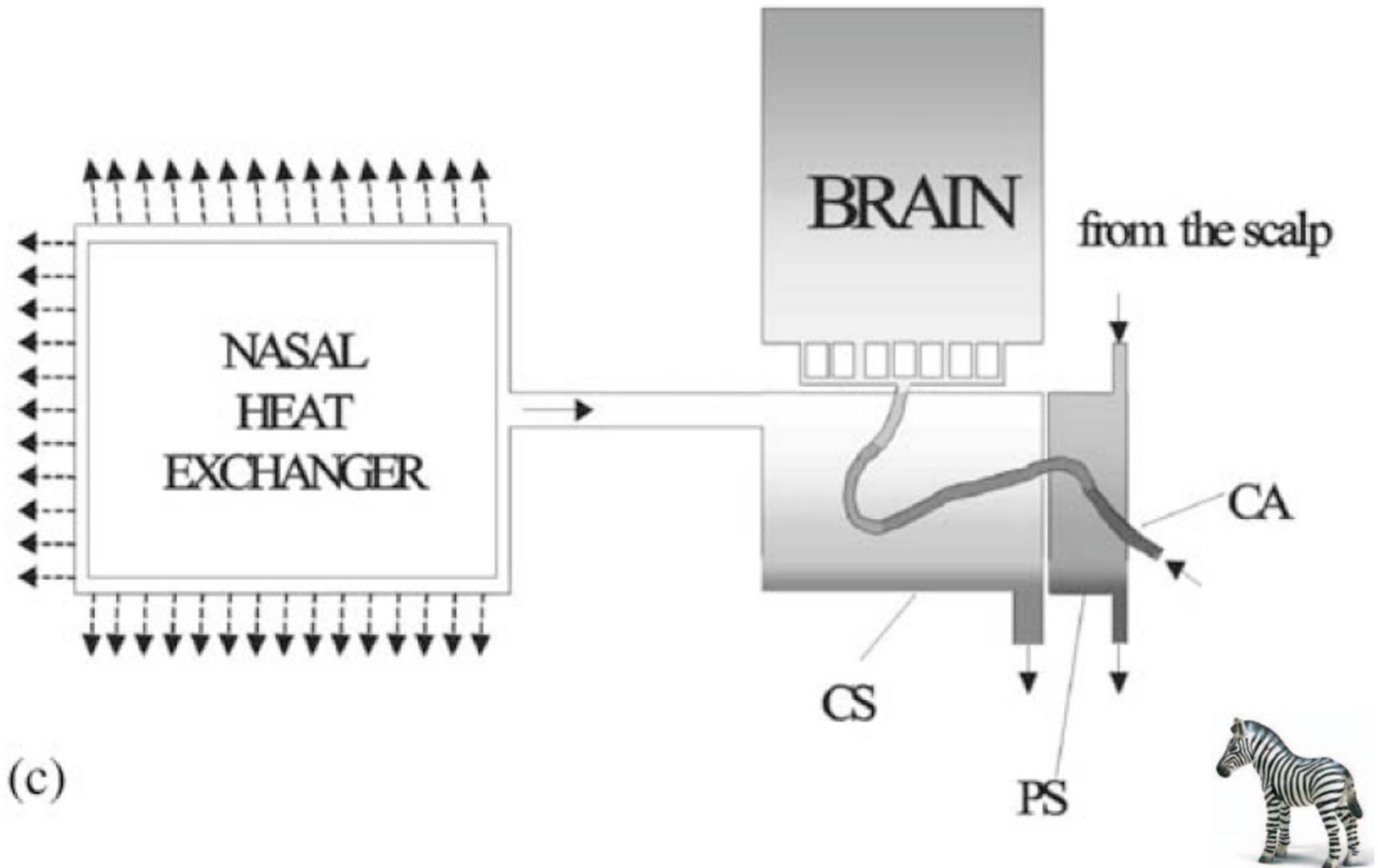




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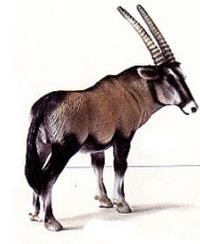
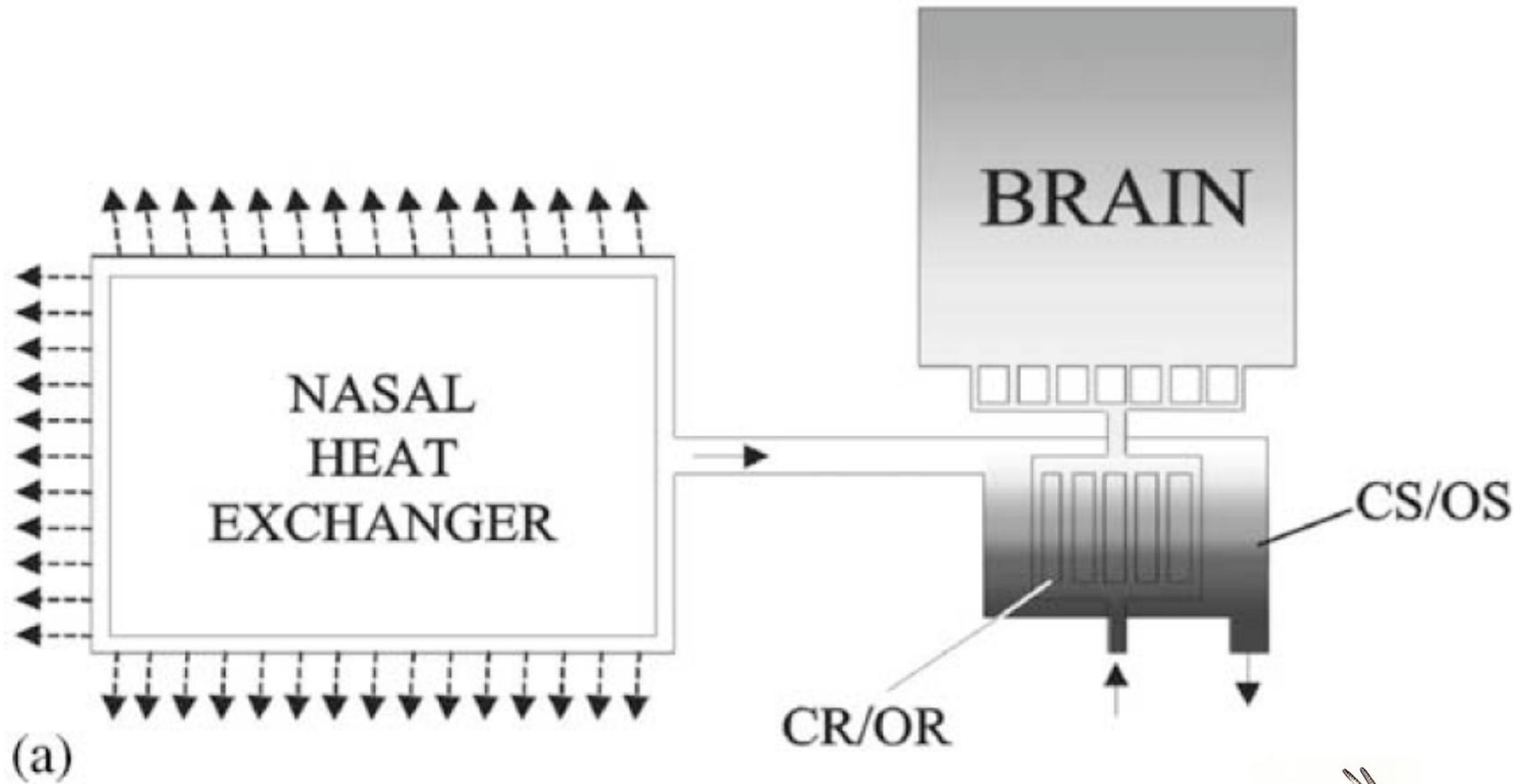
(c)



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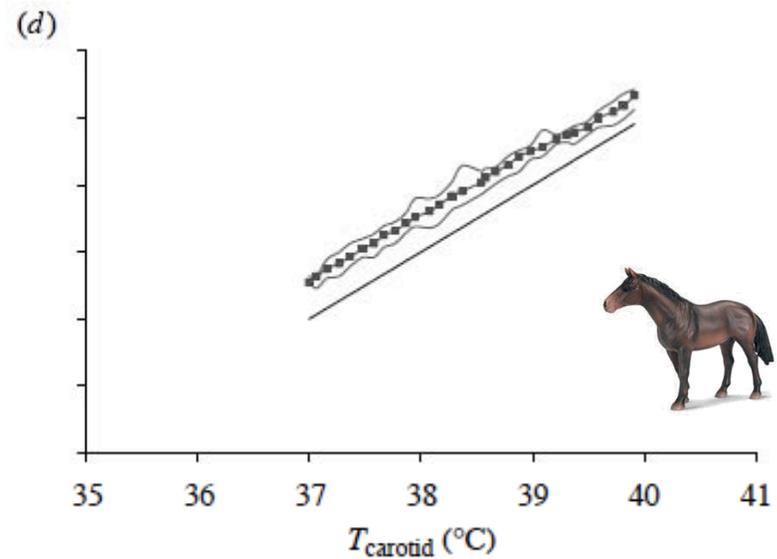
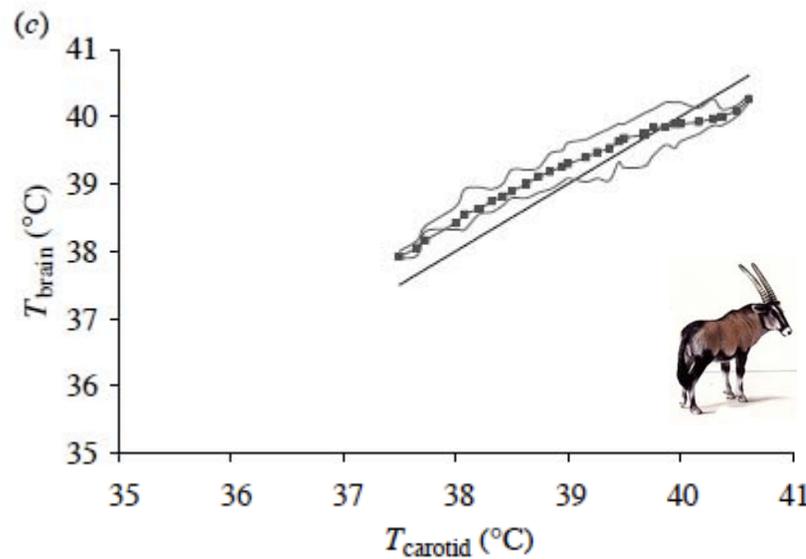
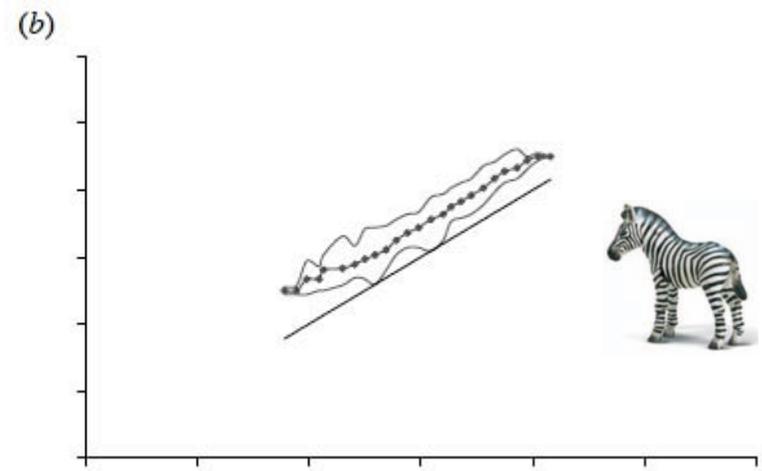
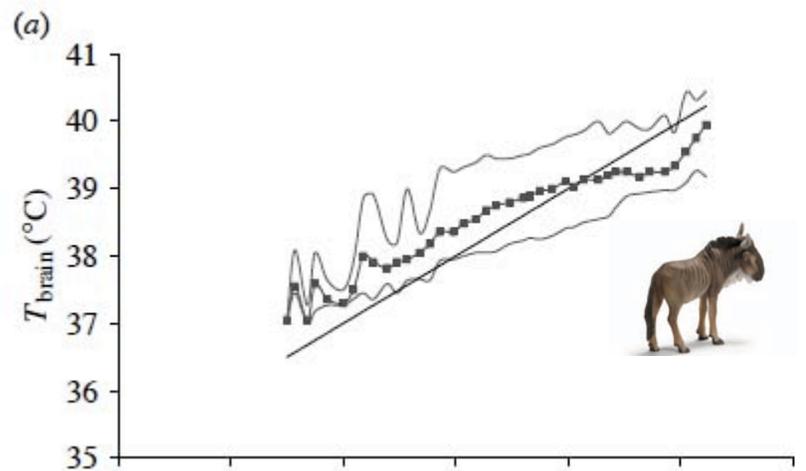




The carotid rete and artiodactyl success

G. Mitchell* and A. Lust

Biol. Lett. (2008) 4, 415–418

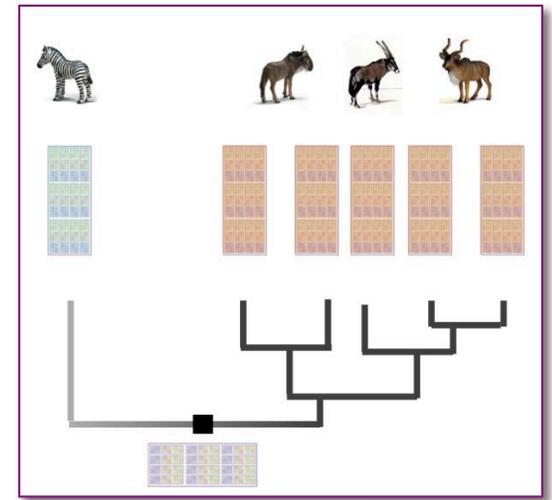
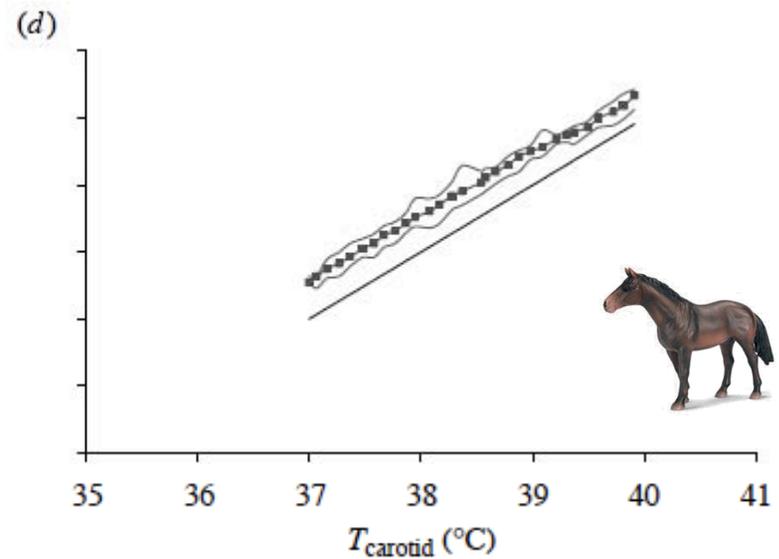
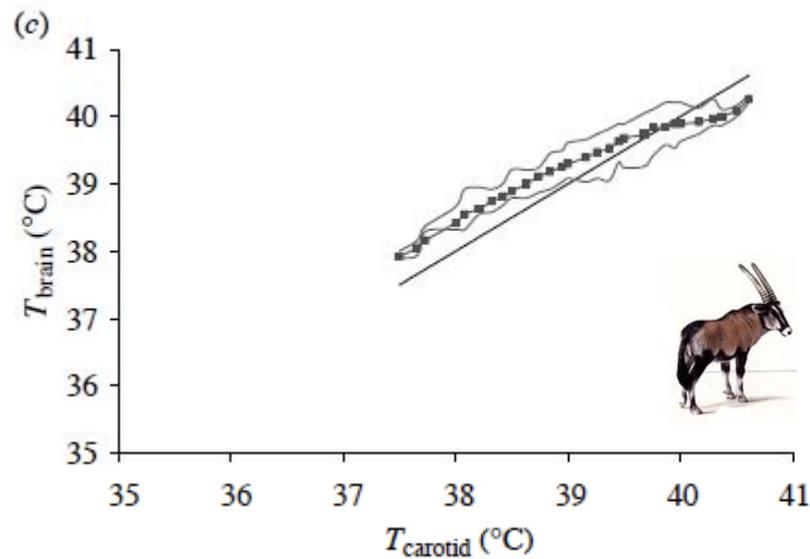
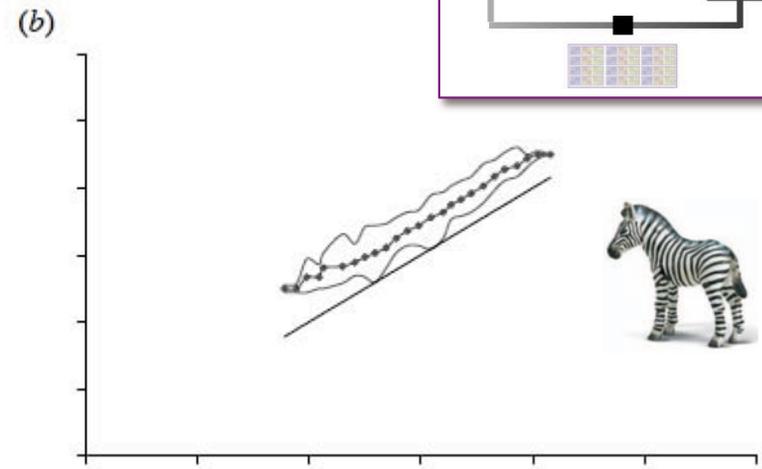
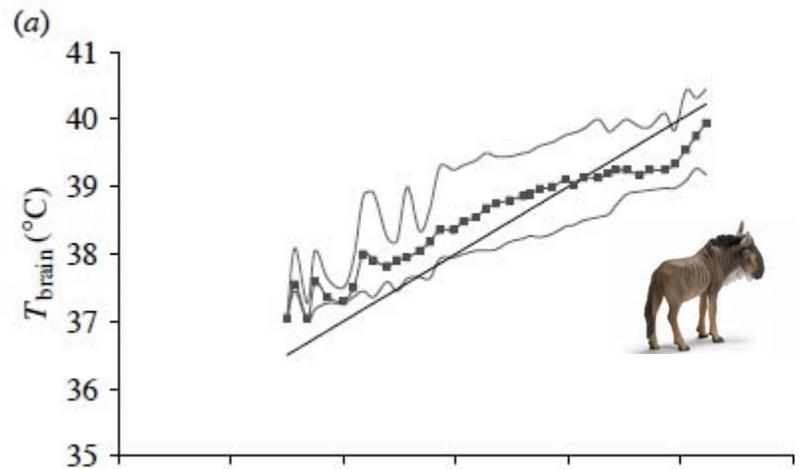




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biology
letters

Physiology

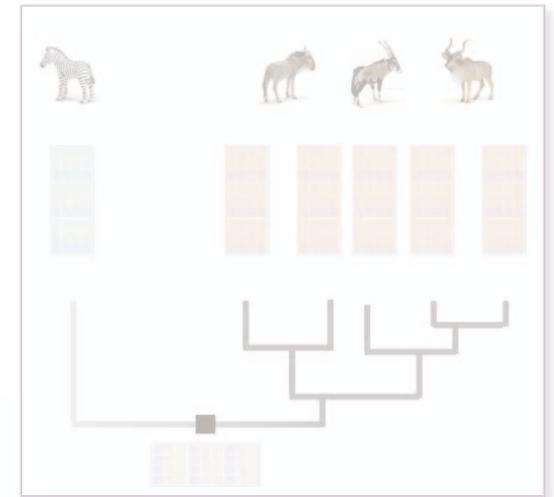
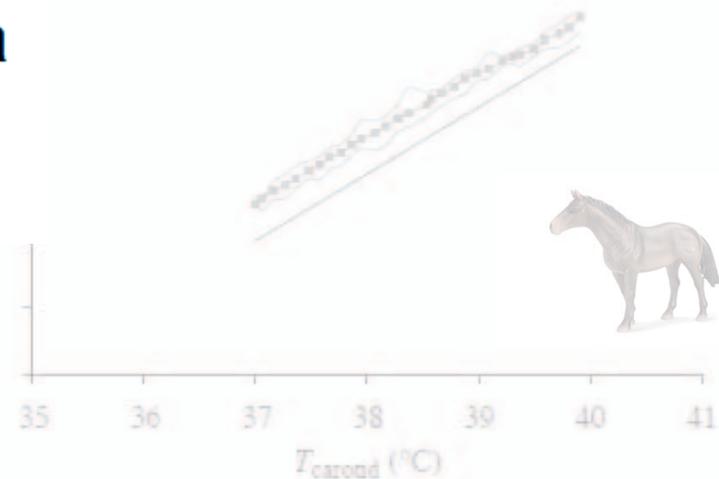
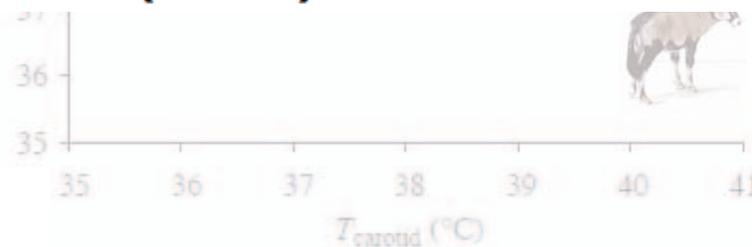
Biol. Lett. (2009) 5, 97–98

doi:10.1098/rsbl.2008.0429

Published online 7 October 2008

Comment

Artiodactyl ‘success’ over perissodactyls in the late Palaeogene unlikely to be related to the carotid rete: a commentary on Mitchell & Lust (2008)





Physiology

- describes rules that determine function of biological units of varying complexity
- is linked to physical and biochemical principles
- describes the link between the environment and the biological unit
- is linked, by describing different or similar solutions to the same challenges, to evolutionary history



Physiology

- especially when done in a comparative approach is utterly fascinating because of the amazing variety of life and the possibility to categorize/catalogue it

