Introduction to animal physiology

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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.

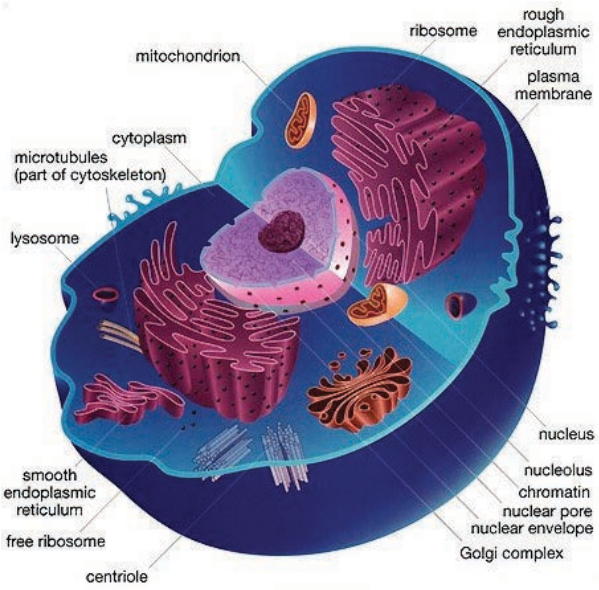
Cell physiology – molecular biology

Cell physiology – molecular biology

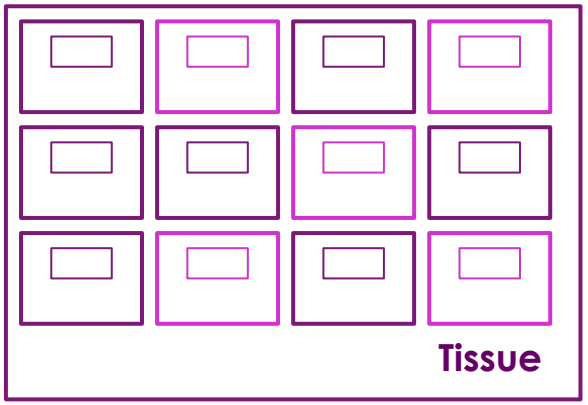
Genome

Proteins & Pathways

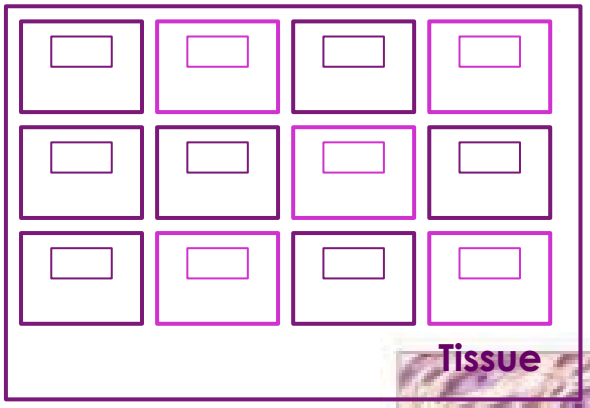
Cell



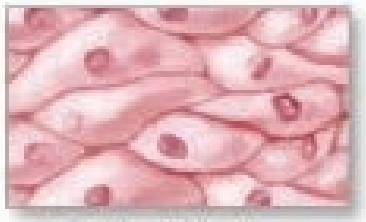
Tissue physiology



Tissue physiology



Connective tissue

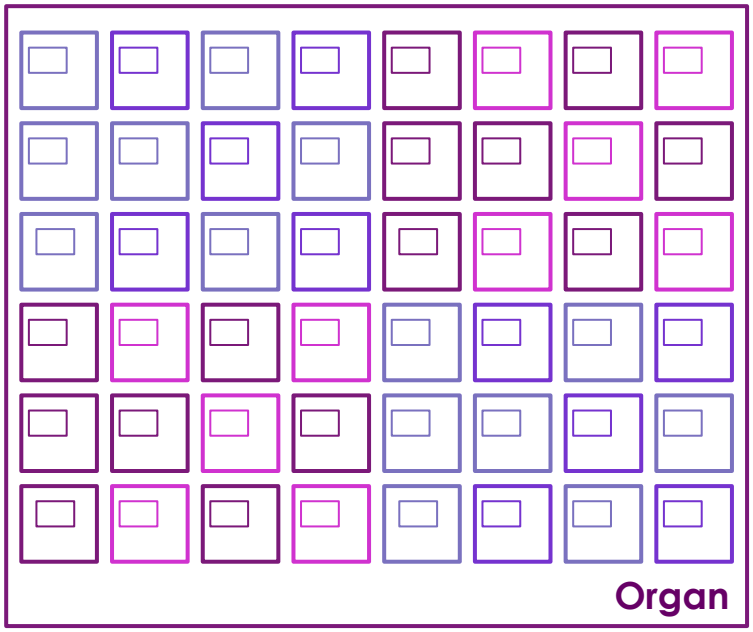


Epithelial tissue

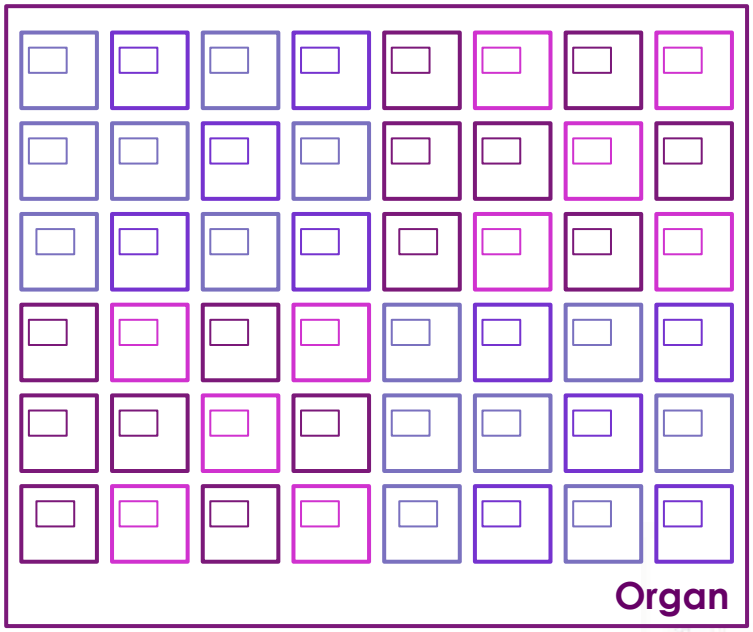
Muscle tissue

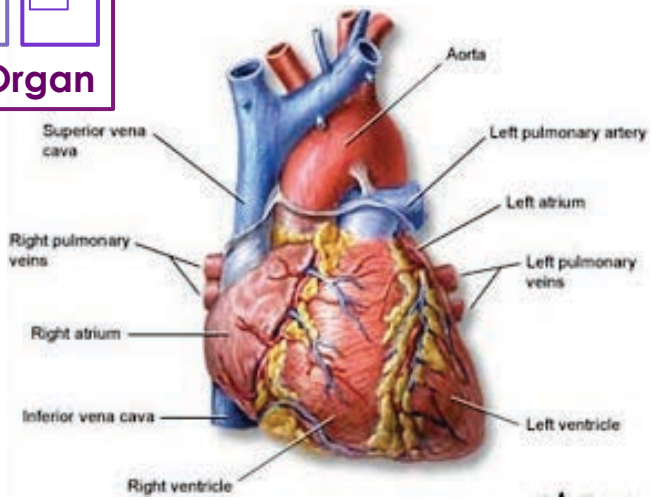
Nervous tissue

Organ physiology

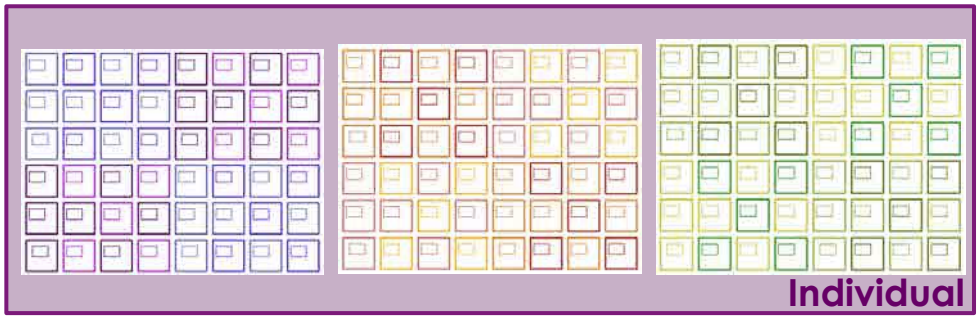


Organ physiology

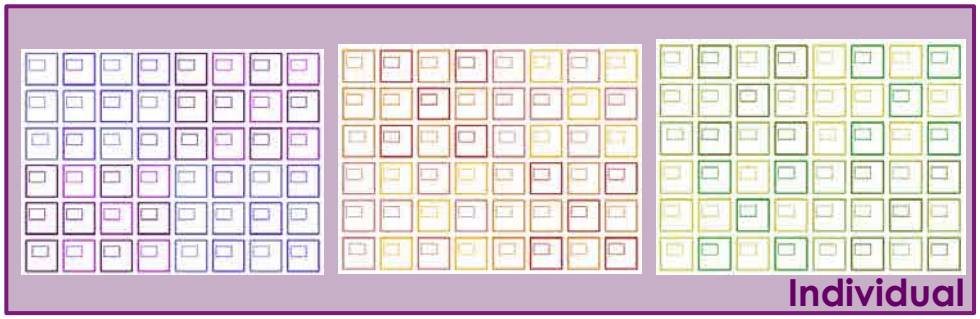


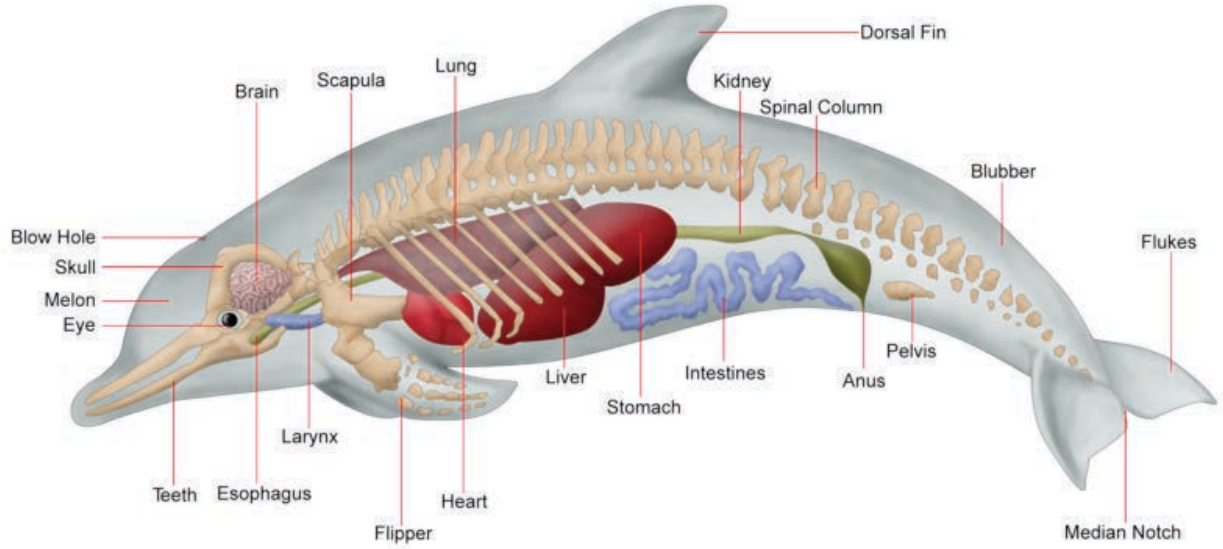


Organismal physiology

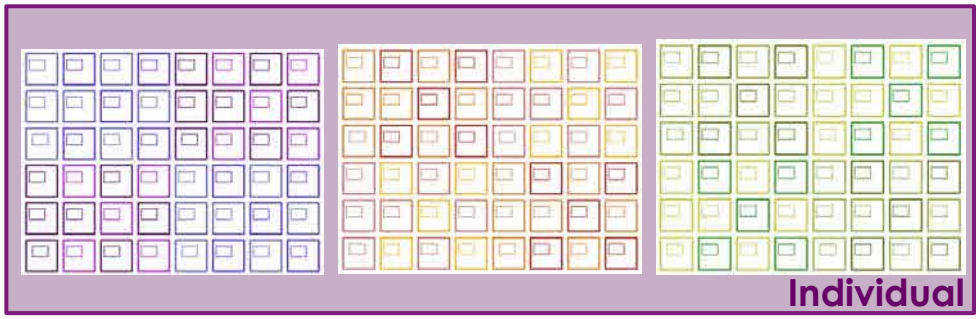


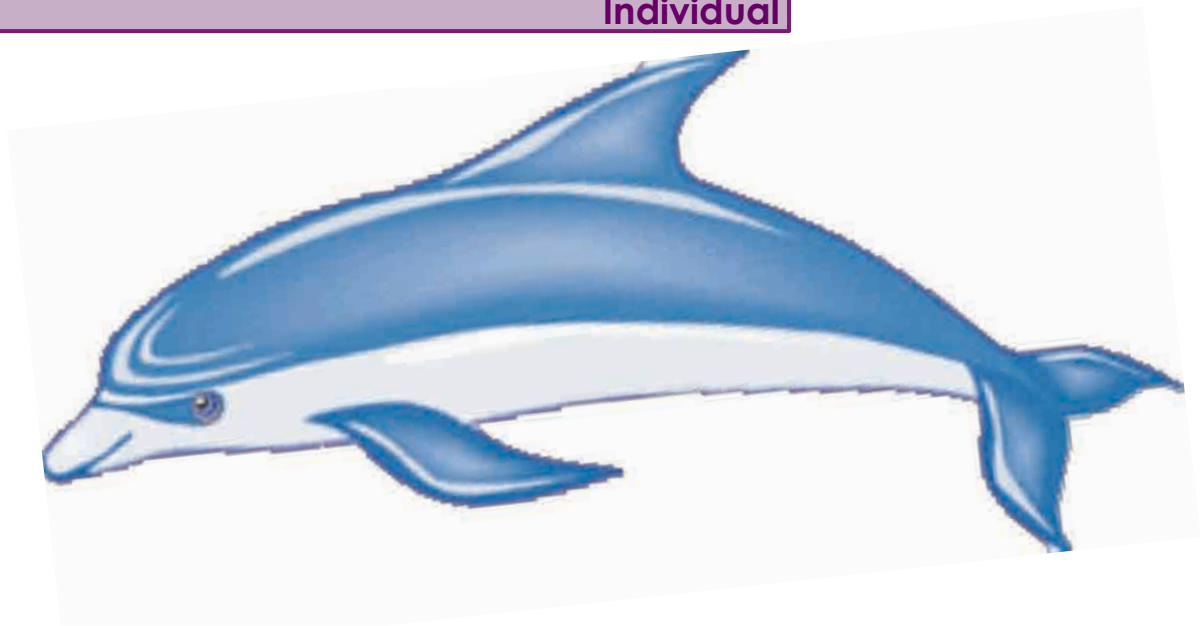
Organismal physiology



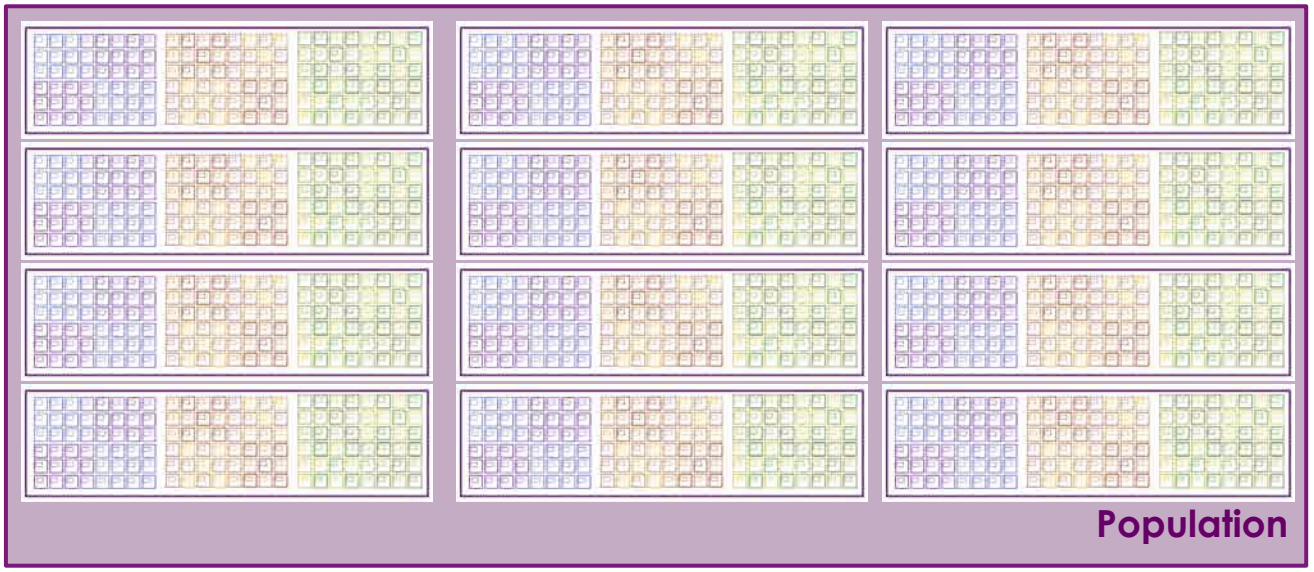


Organismal physiology

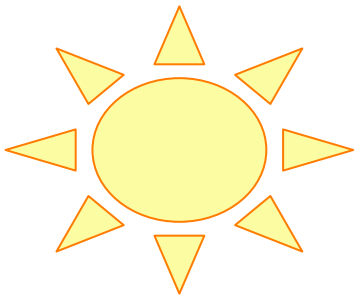


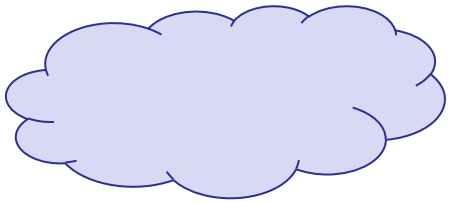


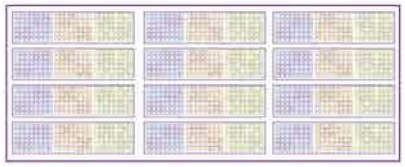
Population physiology - ecology

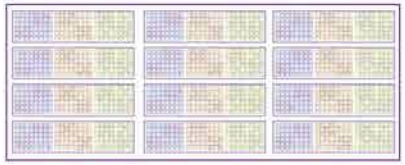


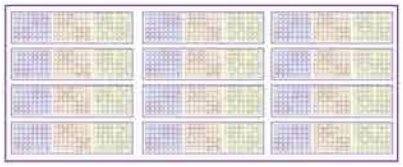
Ecophysiology





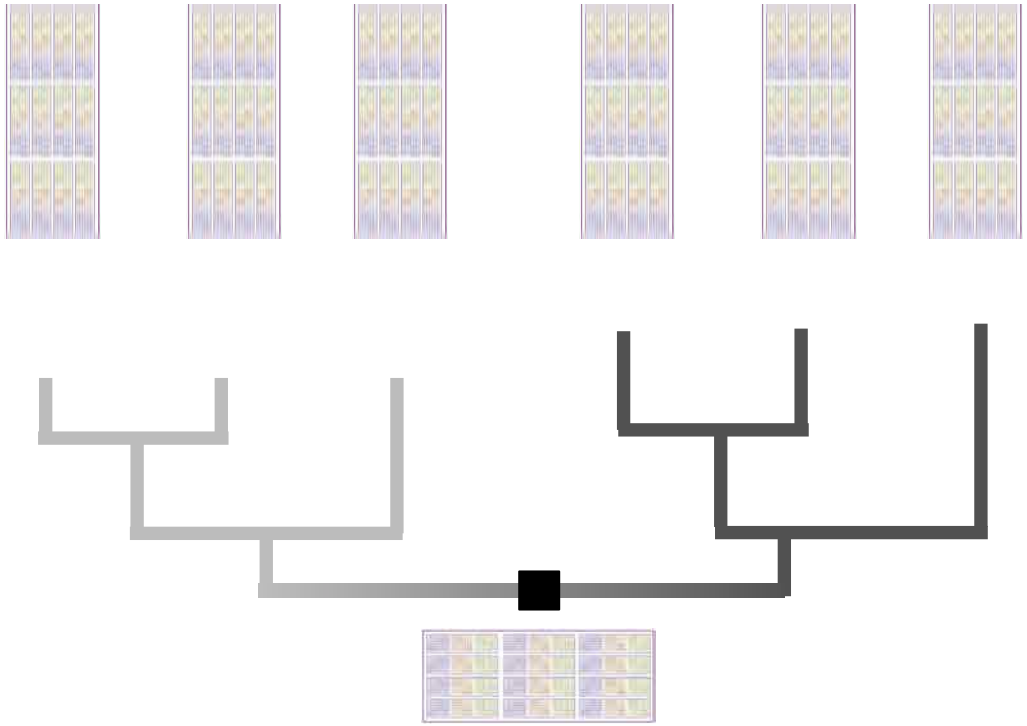




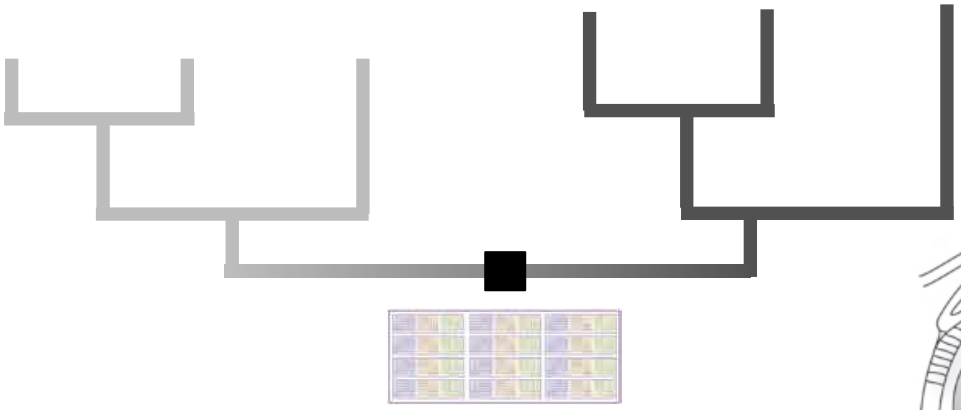


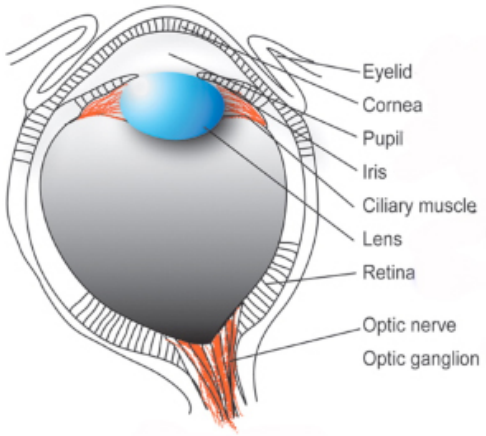
Ecosystem

Evolutionary physiology

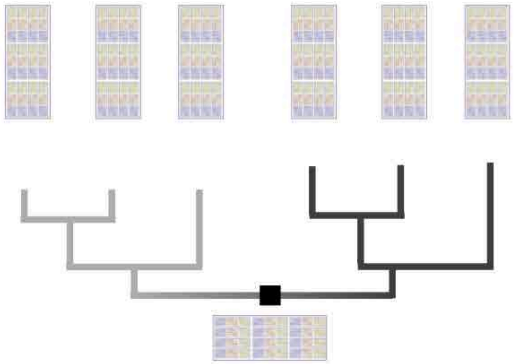


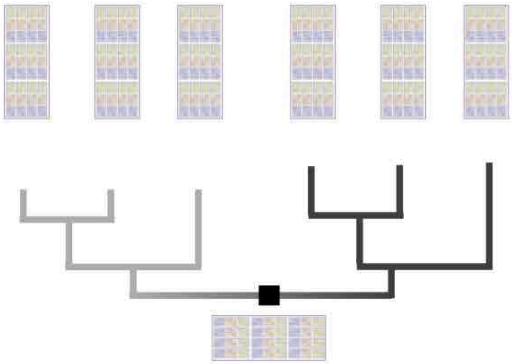
Basic function: synapomorphy

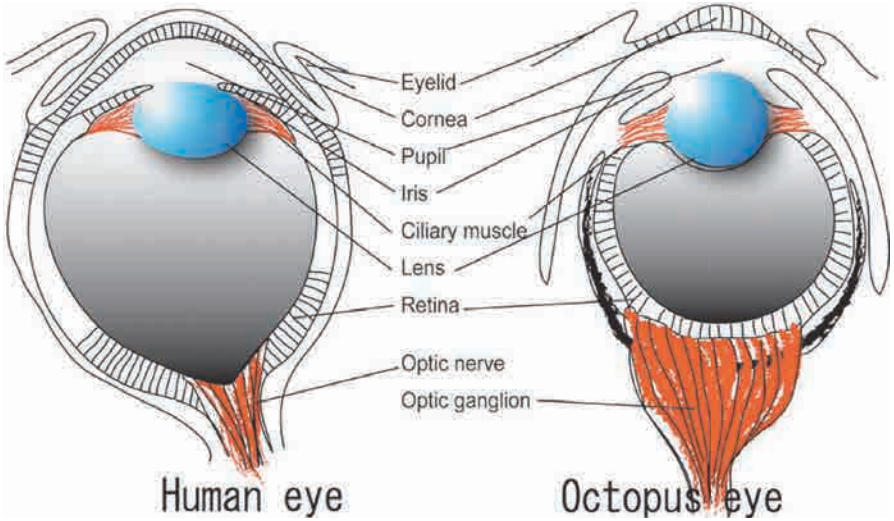




Basic function: parallel evolution







Basic functions

Cell

Organism

Basic functions

Cell

- Modulating enzyme and membrane properties

Homeostasis

Organism

- Neuroendocrine feedback, behavioural adjustment

Basic functions

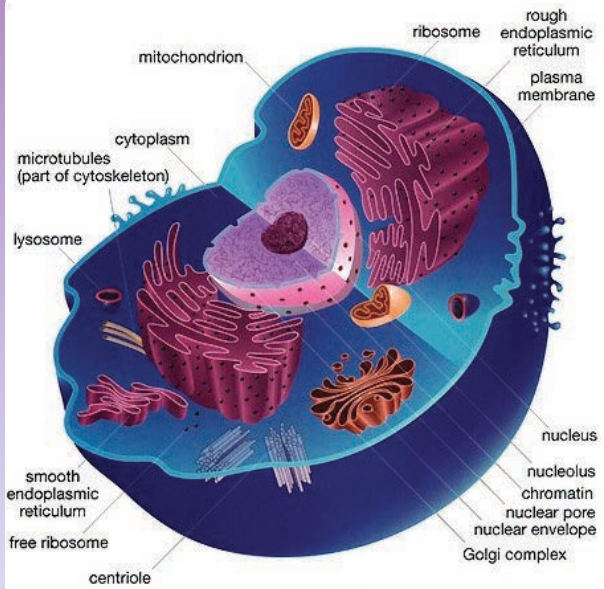
Cell

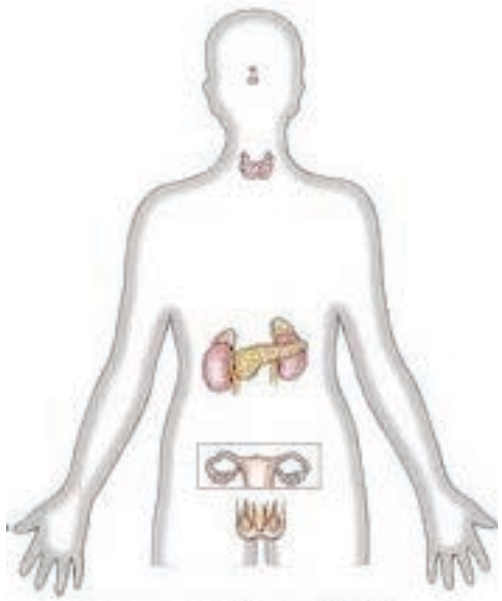
- Modulating enzyme and membrane properties

Homeostasis

Organism

- Neuroendocrine feedback, behavioural adjustment





Basic functions

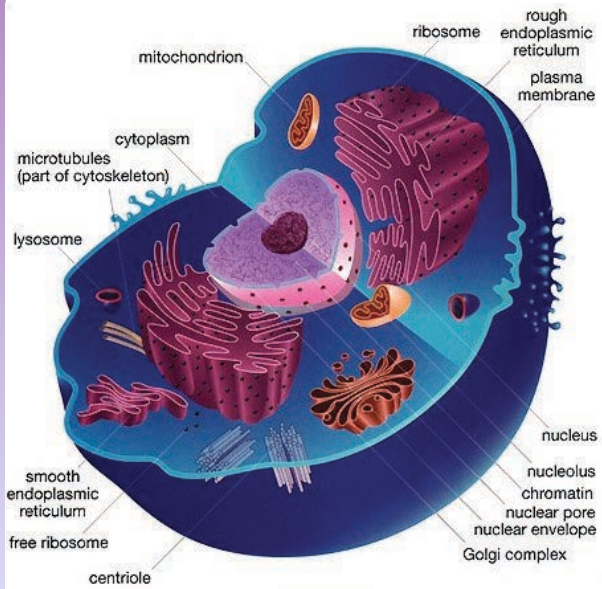
Cell

- Modulating enzyme and membrane properties

Homeostasis

Organism

- Neuroendocrine feedback, behavioural adjustment



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

Cell

- Modulating enzyme and membrane properties
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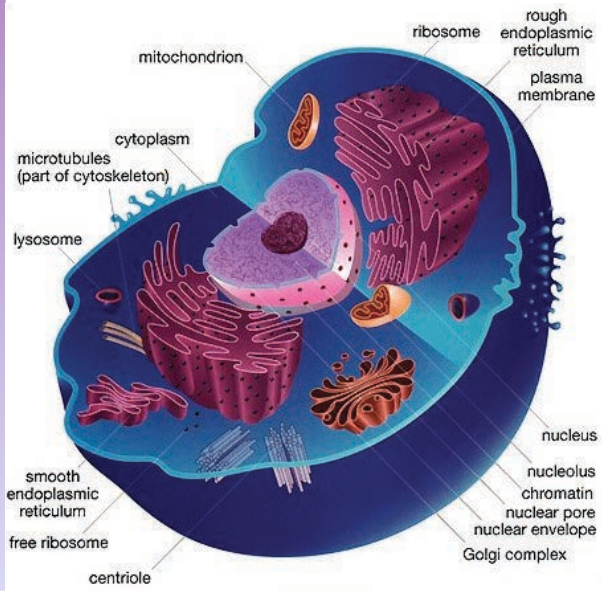

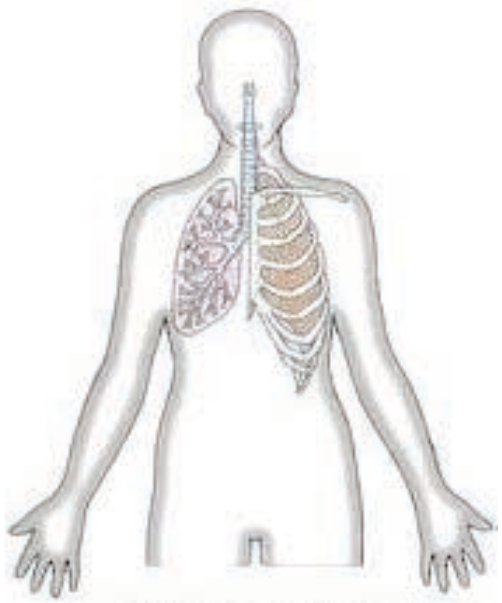

Basic functions

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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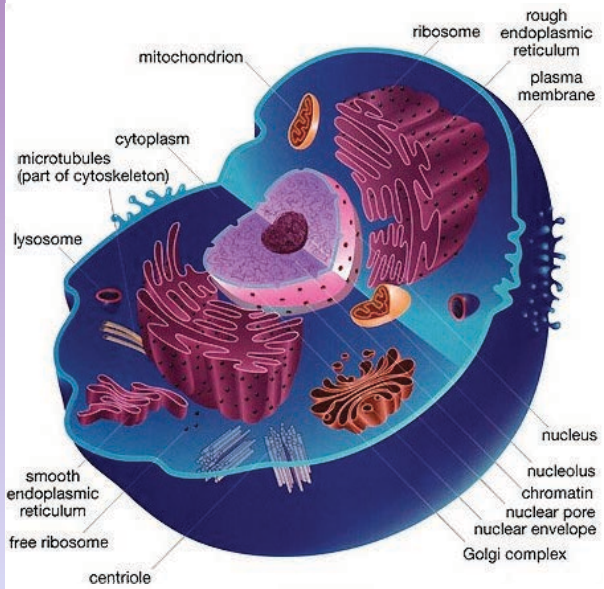

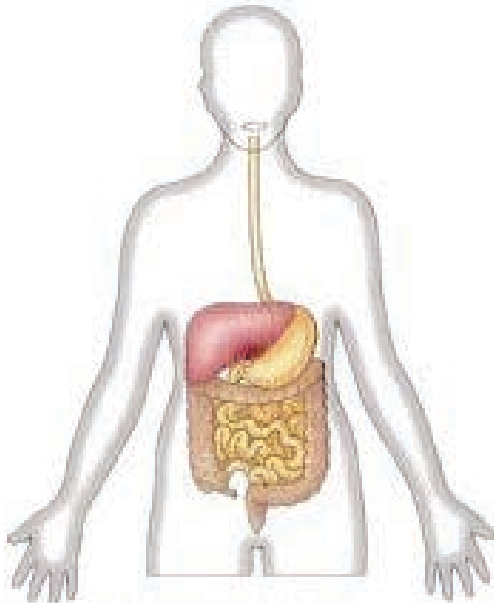

Basic functions

Cell

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

Homeostasis

Gas exchange

Nutrient supply

Circulation

Organism

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

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Homeostasis
Gas exchange
Nutrient supply
Circulation

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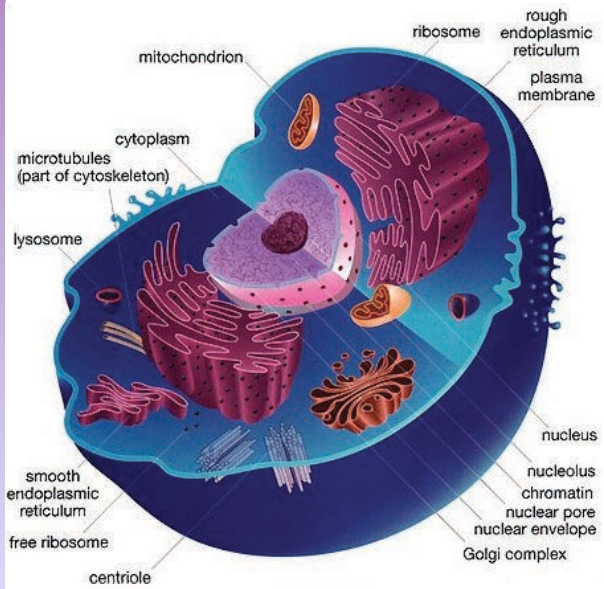

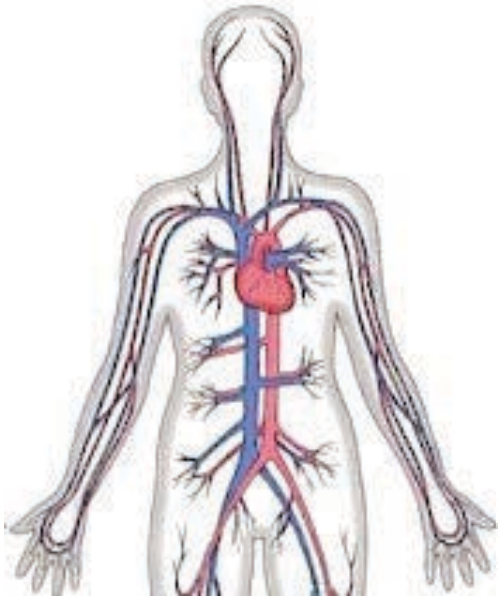

Basic functions

Cell

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

Homeostasis

Gas exchange

Nutrient supply

Circulation

Excretion

Organism

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

Basic functions

Cell

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Homeostasis
Gas exchange
Nutrient supply
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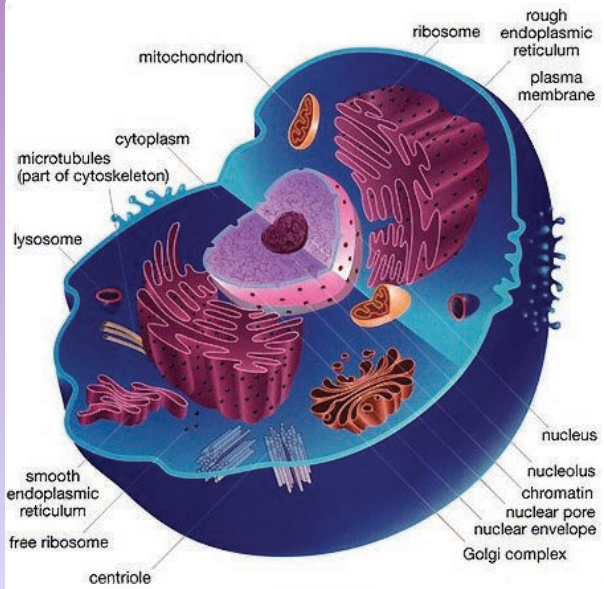
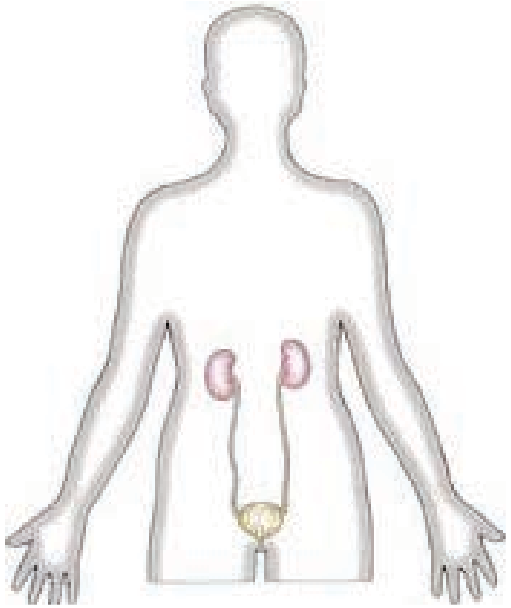




Basic functions

Cell		Organism
▪ Modulating enzyme and membrane properties ▪ Carbon oxidization, CO_2 & H_2O production	Homeostasis Gas exchange	▪ Neuroendocrine feedback, behavioural adjustment ▪ Ventilation (Lung, gills, tracheae)
▪ Diffusion, transport, pinocytosis, lysosomes ▪ Diffusion, cytoskeletal streaming, microtubules	Nutrient supply	▪ Feeding, digestion, absorption, gastrointestinal tract, liver ▪ Vascular system, heart
▪ Vacuoles	Circulation Excretion	▪ Digestive and urinary tract, kidneys, bladder
▪ Tubulin, Actin/Myosine, amoeboid movement, cilia, flagellae	Movement	▪ Musculoskeletal system

Basic functions

Cell

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

Homeostasis

Gas exchange

Nutrient supply

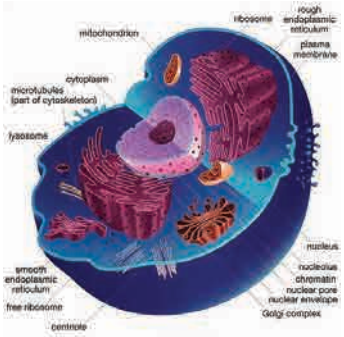
Circulation

Excretion

Movement

Organism

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



Basic functions

Cell

- Modulating enzyme and membrane properties
- Carbon oxidization, CO_2 & H_2O production
- Diffusion, transport, pinocytosis, lysosomes
- Diffusion, cytoskeletal streaming, microtubules
- Vacuoles
- Tubulin, Actin/Myosine, amoeboid movement, cilia, flagellae
- Receptors

Homeostasis

Gas exchange

Nutrient supply

Circulation

Excretion

Movement

Sensation

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
- Sensory organs, nervous system

Basic functions

Cell

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

Homeostasis

Gas exchange

Nutrient supply

Circulation

Excretion

Movement

Sensation

Organism

- Neuroendocrine feedback, behavioural adjustment
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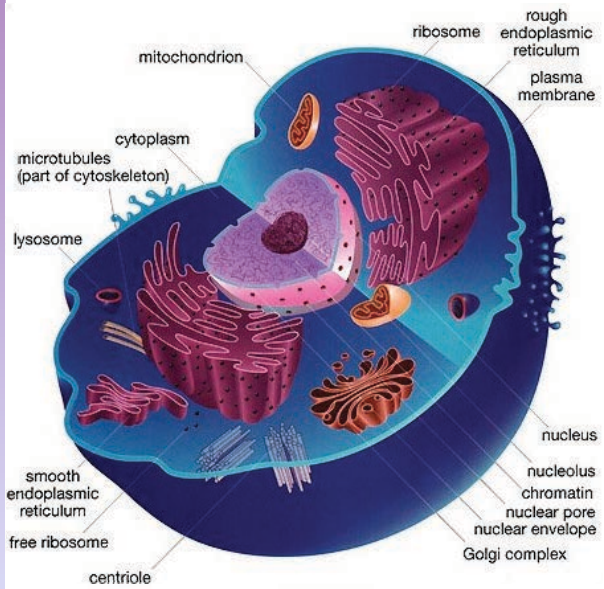

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▪ Vacuoles	Excretion	▪ Digestive and urinary tract, kidneys, bladder
▪ Tubulin, Actin/Myosine, amoeboid movement, cilia, flagellae	Movement	▪ Musculoskeletal system
▪ Receptors	Sensation	▪ Sensory organs, nervous system
▪ Hypertrophy, mitosis, meiosis	Reproduction	▪ Sexual/asexual, reproductive organs

Basic functions

Cell

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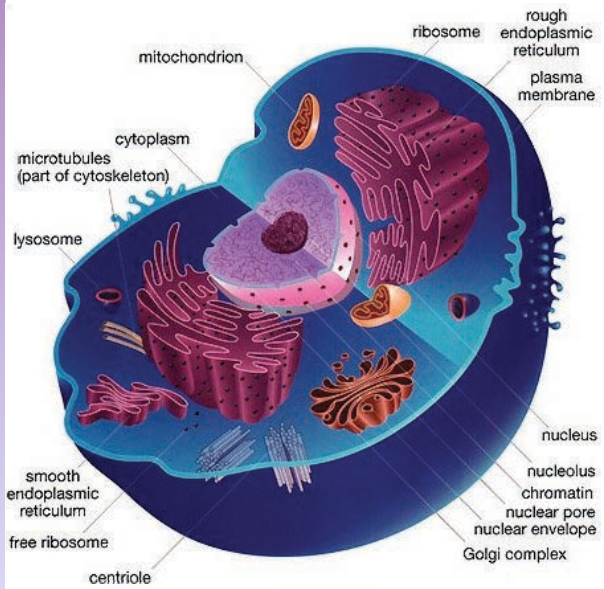


Homeostasis

Gas exchange

Nutrient supply

Circulation

Excretion

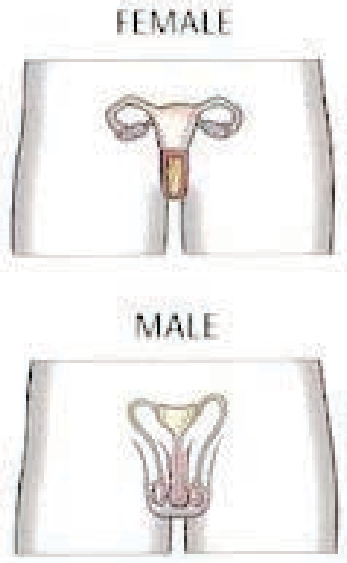
Movement

Sensation

Reproduction

Organism

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



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▪ Tubulin, Actin/Myosine, amoeboid movement, cilia, flagellae	Movement	▪ Musculoskeletal system
▪ Receptors	Sensation	▪ Sensory organs, nervous system
▪ Hypertrophy, mitosis, meiosis	Reproduction	▪ Sexual/asexual, reproductive organs
▪ Lysosomes	Defence	▪ Immune system

Basic functions

Cell

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

Gas exchange

Nutrient supply

Circulation

Excretion

Movement

Sensation

Reproduction

Defence

Organism

- Neuroendocrine feedback, behavioural adjustment
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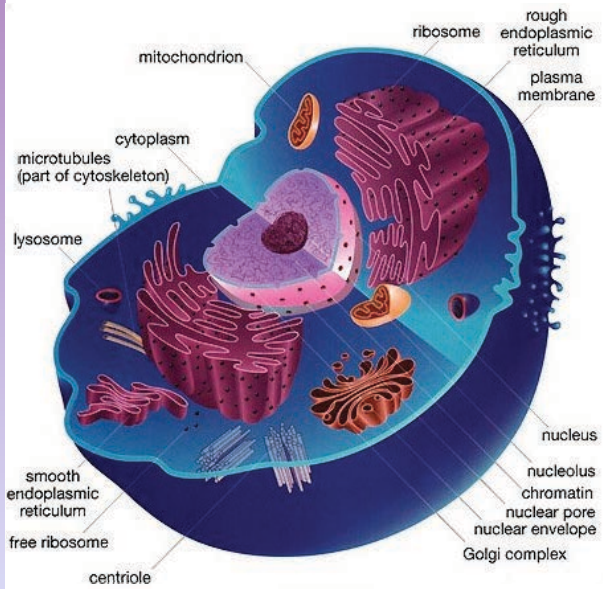

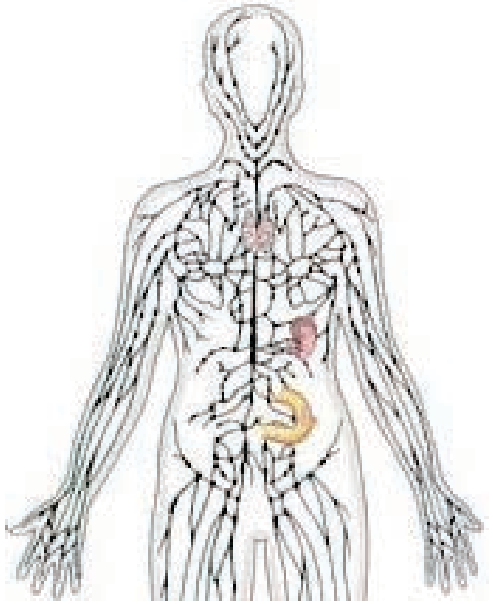

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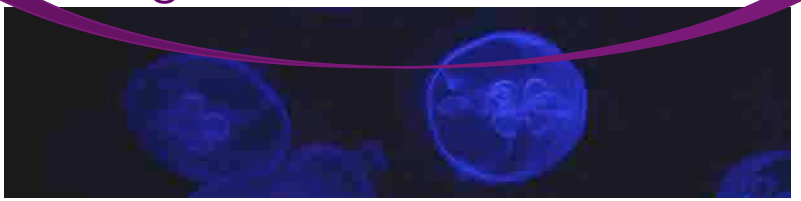
▪ Receptors	Movement	▪ Musculoskeletal system
	Sensation	▪ Sensory organs, nervous system
▪ Hypertrophy, mitosis, meiosis	Reproduction	▪ Sexual/asexual, reproductive organs
▪ Lysosomes	Defence	▪ Immune system

single cells to whole animals



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Cell		Organism
▪ Modulating enzyme and membrane properties ▪ Carbon oxidization, CO_2 & H_2O production	Homeostasis Gas exchange	▪ Neuroendocrine feedback, behavioural adjustment ▪ Ventilation (Lung, gills, tracheae)
▪ Diffusion, transport, pinocytosis, lysosomes ▪ Diffusion, cytoskeletal streaming, microtubules	Nutrient supply Circulation	▪ Feeding, digestion, absorption, gastrointestinal tract, liver ▪ Vascular system, heart
▪ Vacuoles	Excretion	▪ Digestive and urinary tract, kidneys, bladder
▪ Tubulin, Actin/Myosine, amoeboid movement, cilia, flagellae	Movement	▪ Musculoskeletal system
▪ Receptors	Sensation	▪ Sensory organs, nervous system
▪ Hypertrophy, mitosis, meiosis ▪ Lysosomes	Reproduction Defence	▪ Sexual/asexual, reproductive organs ▪ Immune system

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

Homeostasic control

‘conform’

‘regulate’

no internal set point
large variation

internal set point
small variation

‘poikilo’

‘homeo’

Basic functions: fundamental options

Homeostasic control

'conform'

'regulate'

no internal set point
large variation

internal set point
small variation

'poikilo'

'homeo'

External conditions

stable
'steno'

variable
'eury'

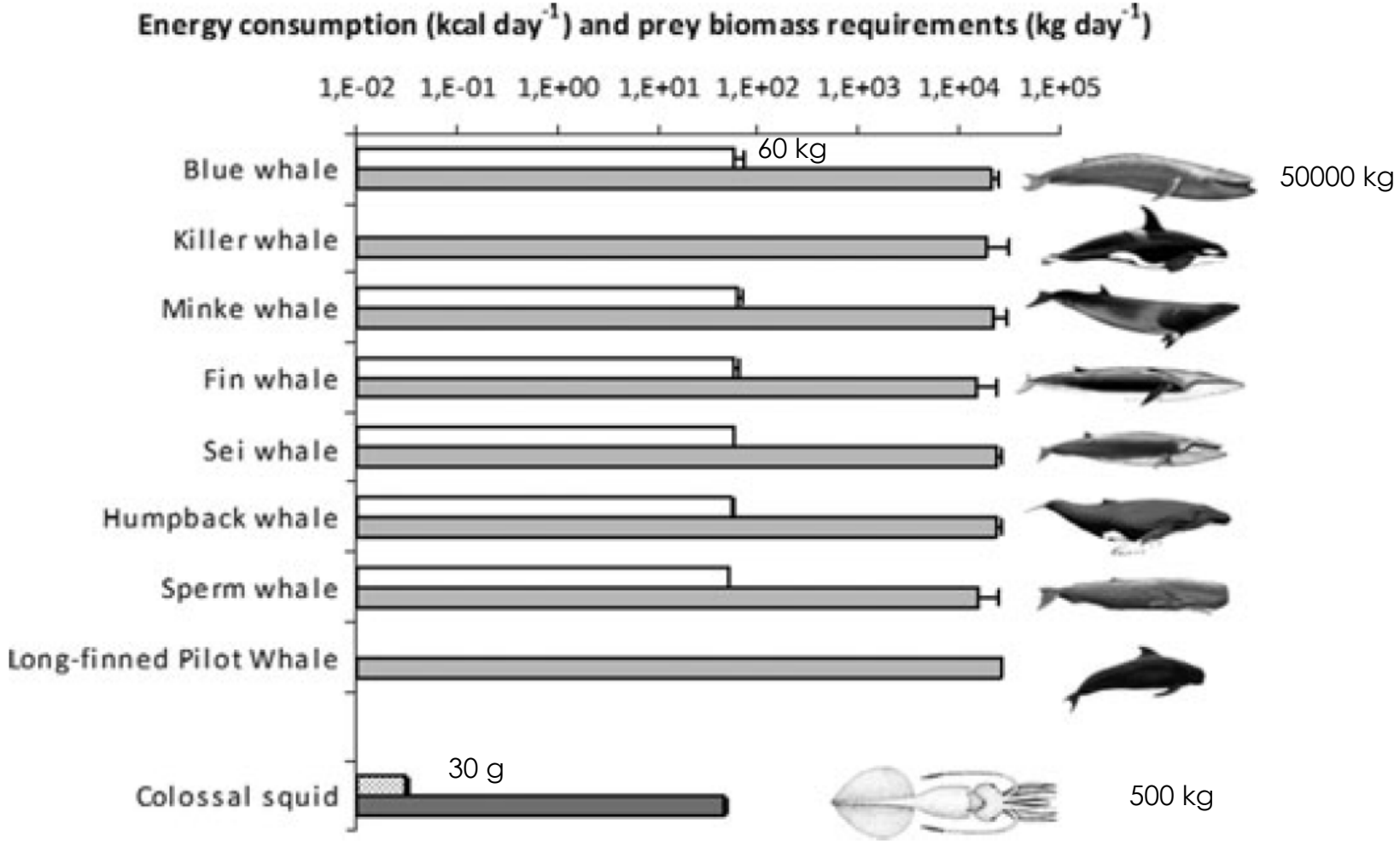
poikilotherms are often stenotherms

homeotherms are often eurytherms

Slow pace of life of the Antarctic colossal squid

RUI ROSA[1] AND BRAD A. SEIBEL[2]

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



Basic functions: tradeoffs

Life history

'slow' **'fast'**

Basic functions: tradeoffs

Life history

'**slow**'
low

Metabolism

'**fast**'
high

Basic functions: tradeoffs

Life history

'**slow**'
low
long

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

'**fast**'
high
short

Basic functions: tradeoffs

‘**slow**’	**Life history**	‘**fast**’
low	Metabolism	high
long	Times (gestation, longevity, growth, time to 1st reproduction)	short
few, precocial	Young	many, altricial

Basic functions: tradeoffs

‘**slow**’	**Life history**	‘**fast**’
low	Metabolism	high
long	Times (gestation, longevity, growth, time to 1st reproduction)	short
few, precocial	Young	many, altricial
low	Mortality	high

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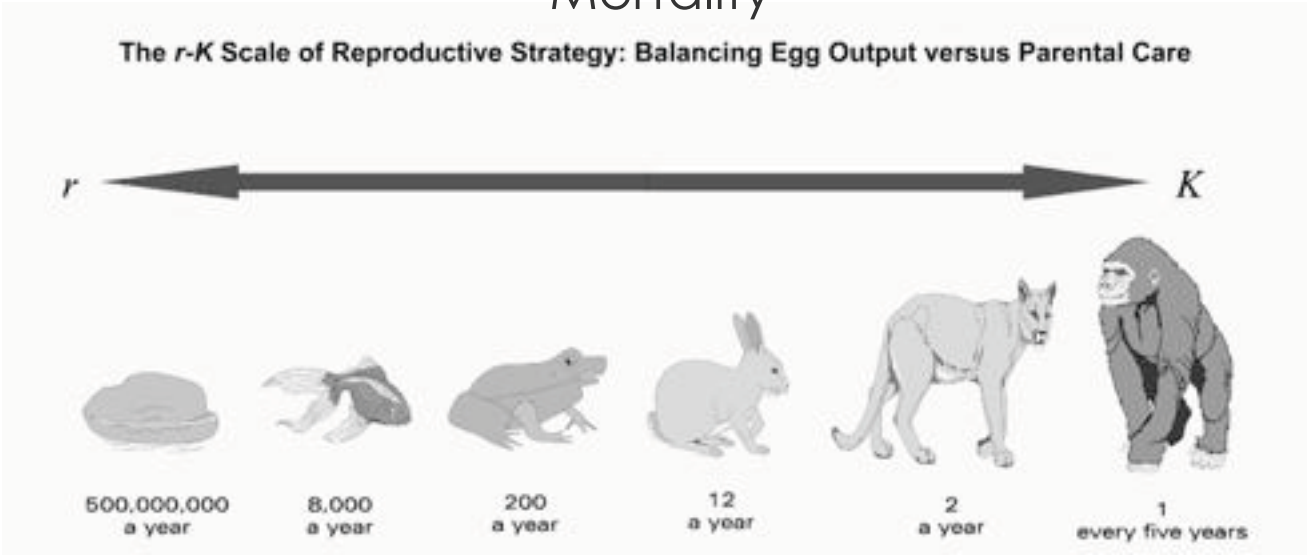


Basic functions: tradeoffs

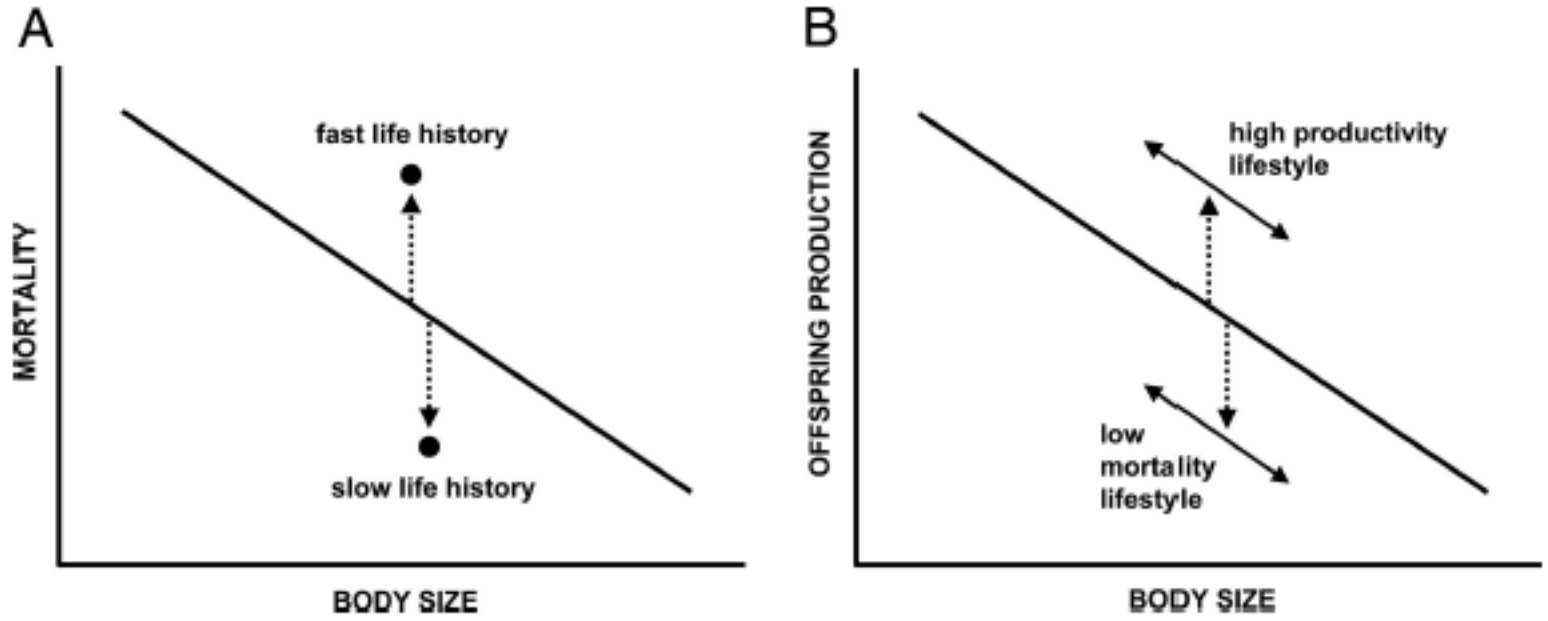
Life history

'slow' **'fast'**

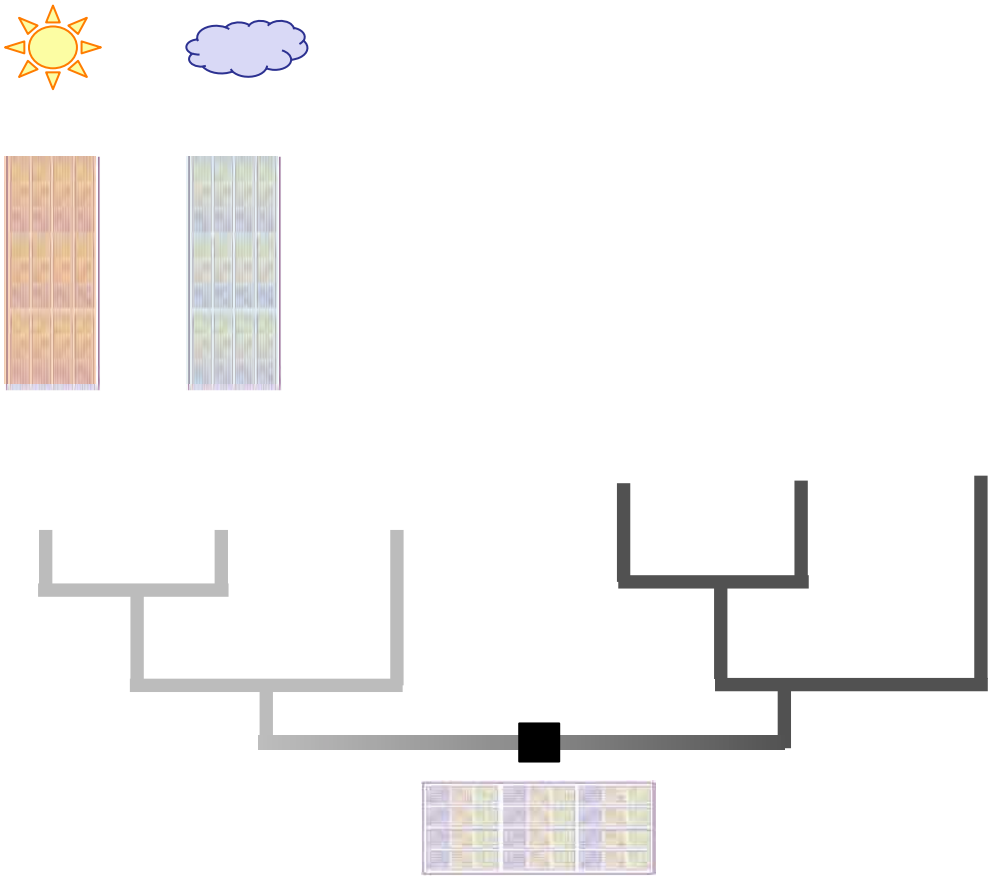
A lifestyle view of life-history evolution

F. Stephen Dobson*

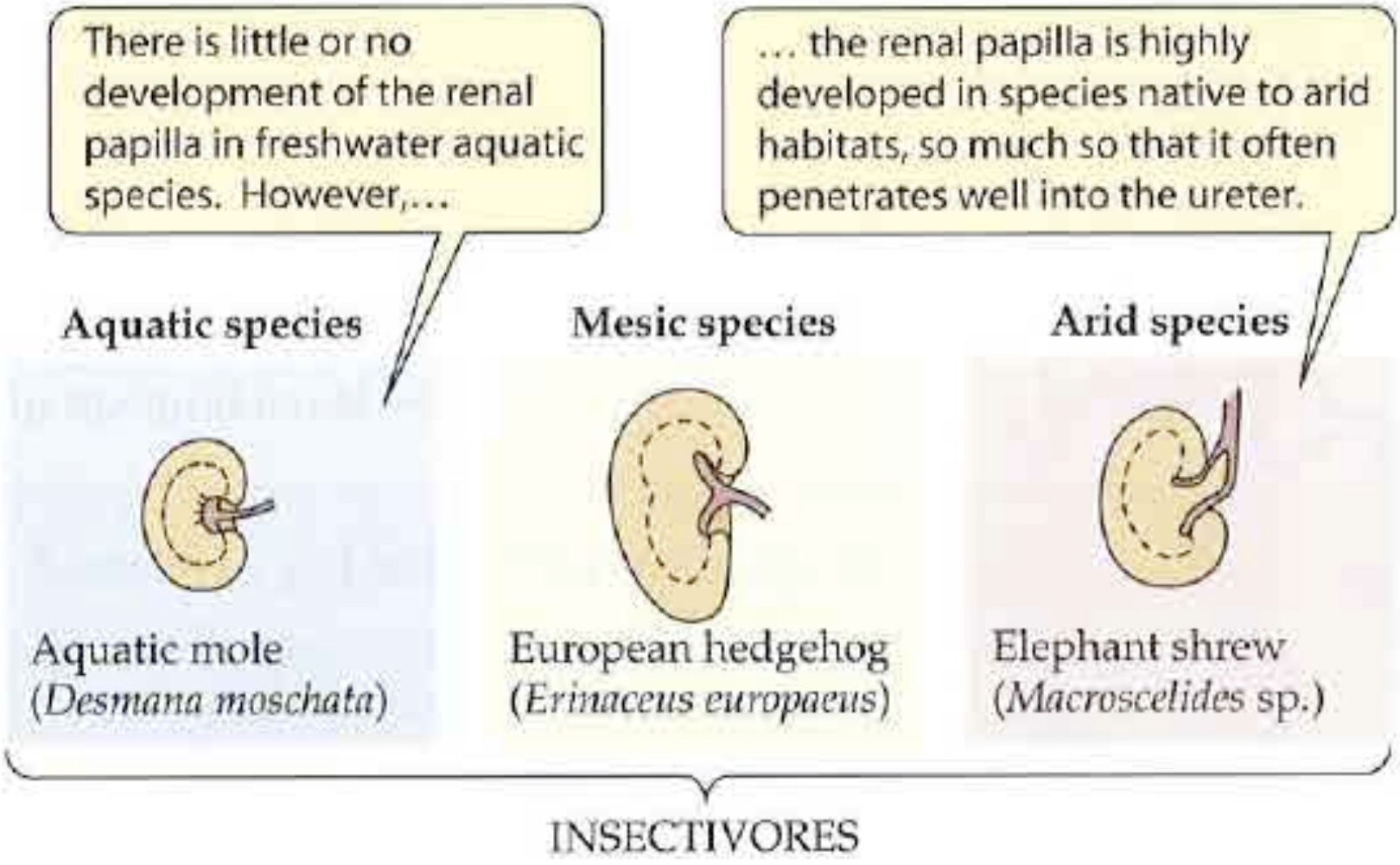
PNAS | November 6, 2007 | vol. 104 | no. 45 | 17565–17566



Detailed function: adaptation/apomorphy



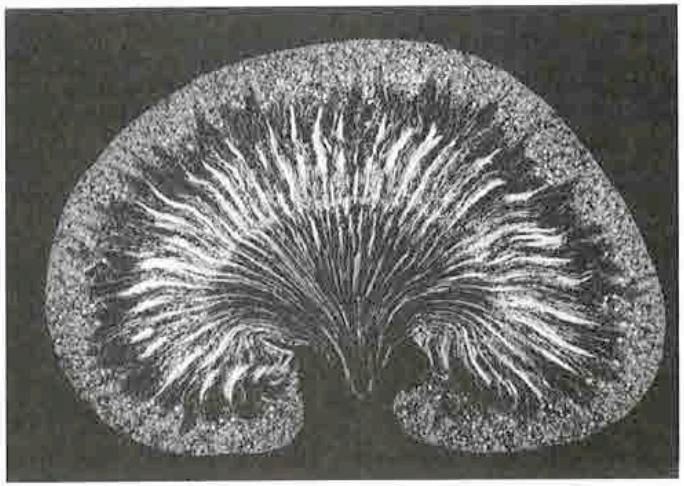
Detailed function: adaptation/apomorphy



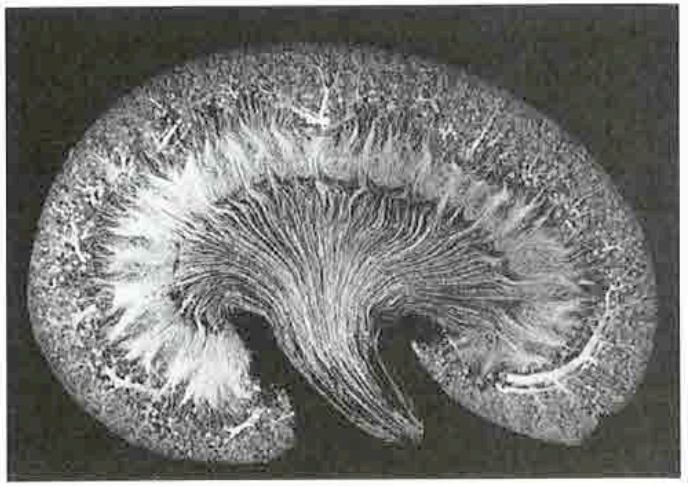
from Hill et al. (2004)

Detailed function: adaptation/apomorphy

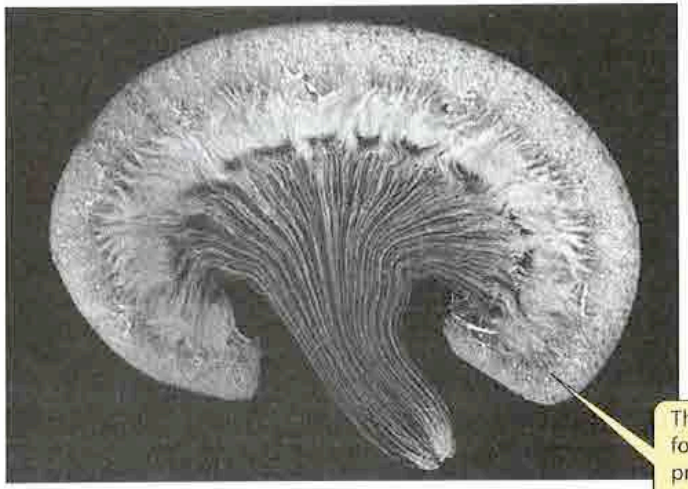
(a) Laboratory rat



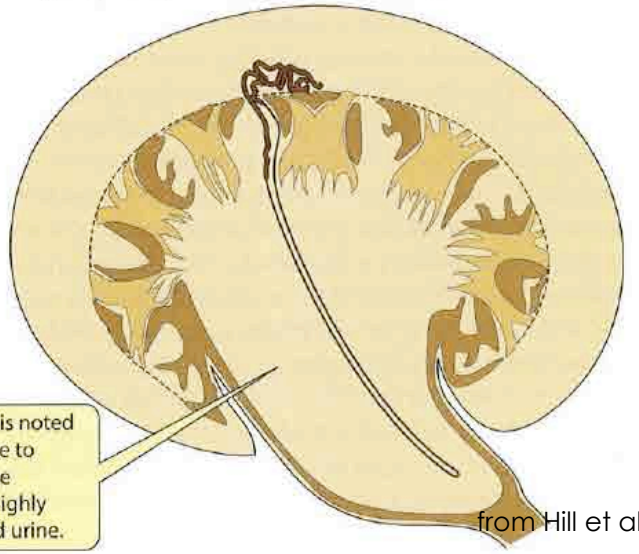
(b) Mongolian gerbil



(c) Sand rat



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

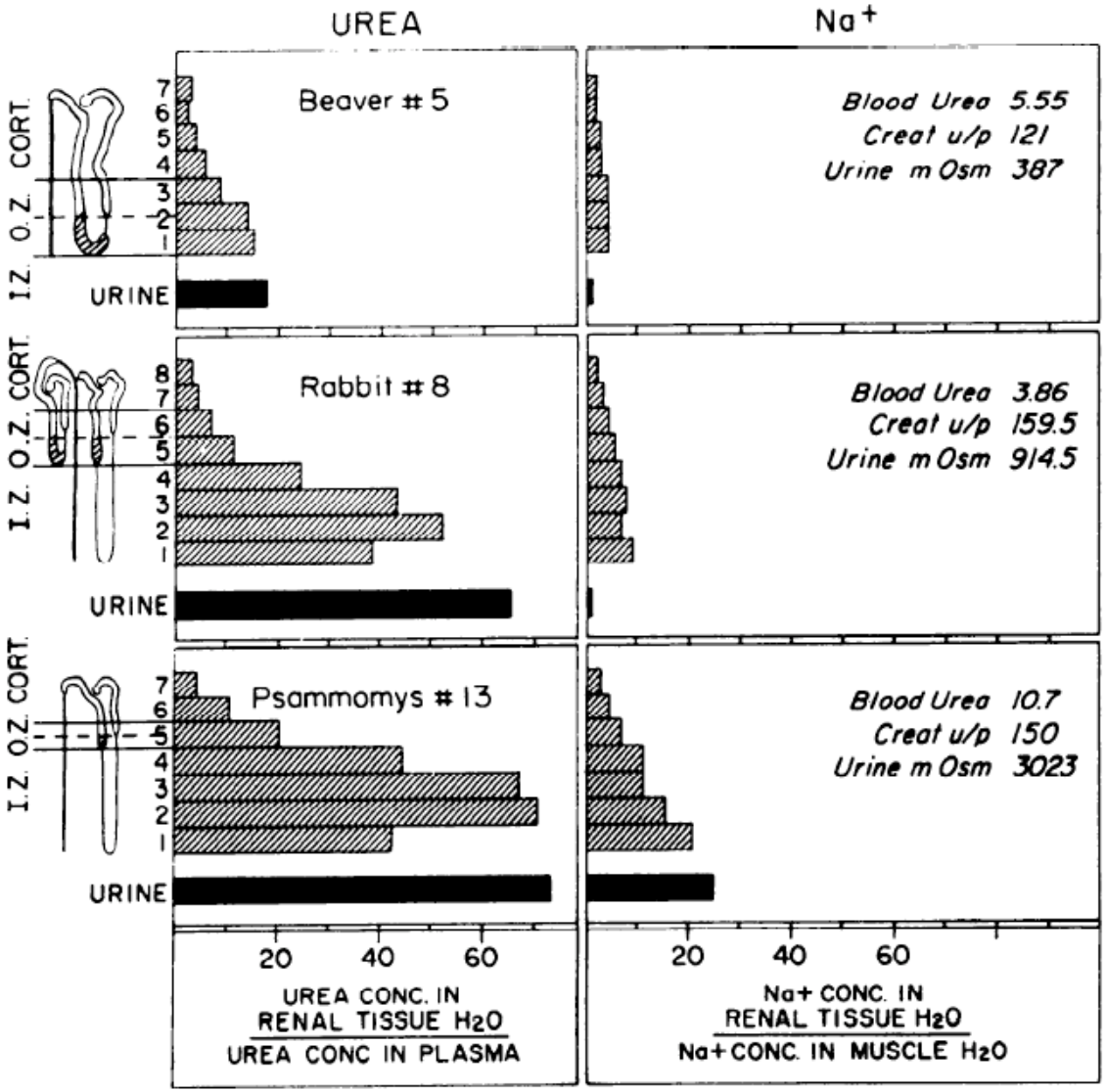


from Hill et al. (2004)

Structure and concentrating mechanism in the mammalian kidney[1]

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

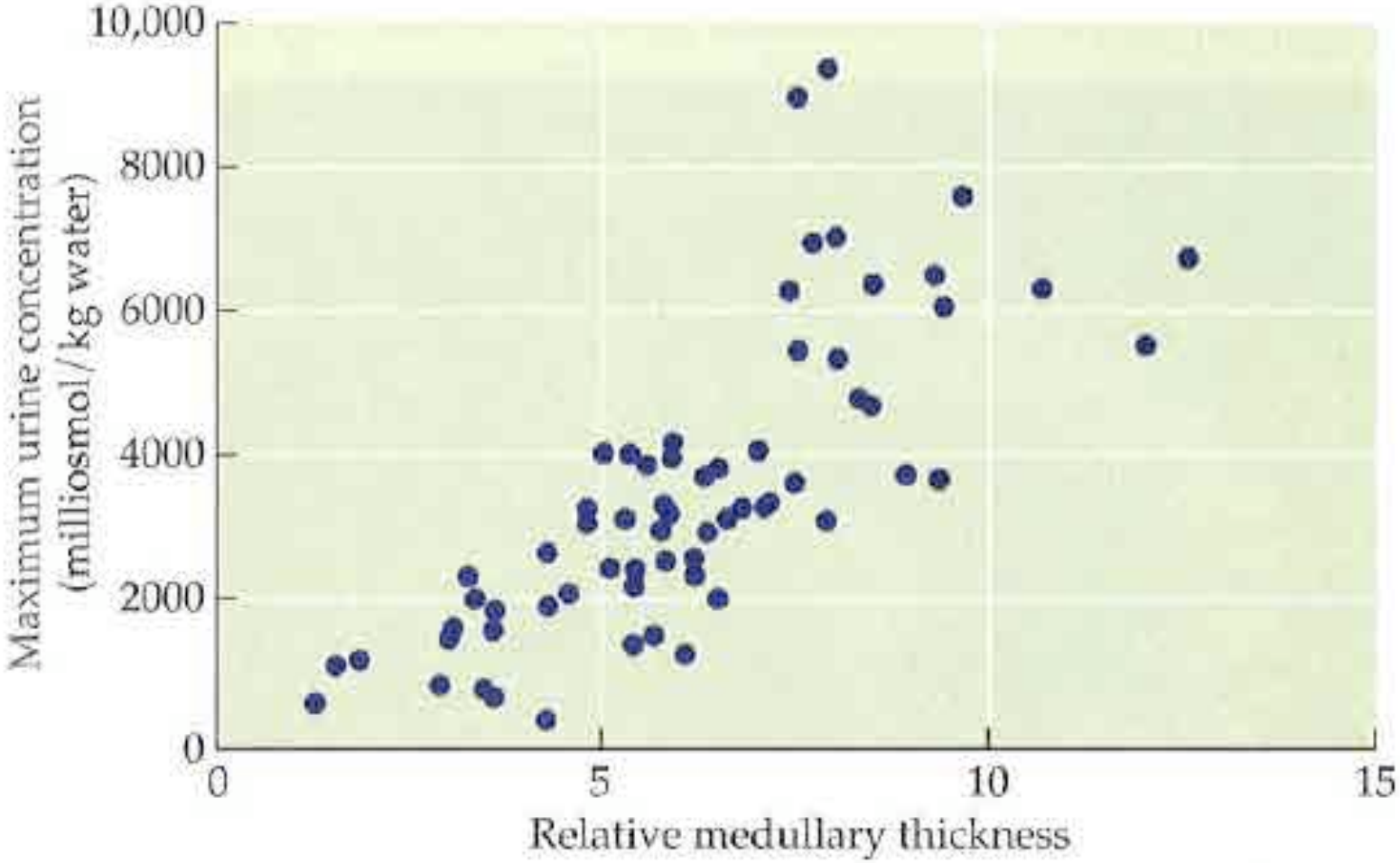
Am. J. Physiol. (1961)



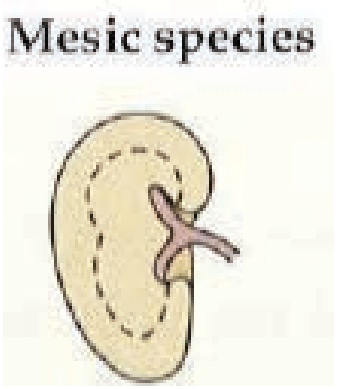
Body size, medullary thickness, and urine concentrating ability in mammals

CAROL A. BEUCHAT

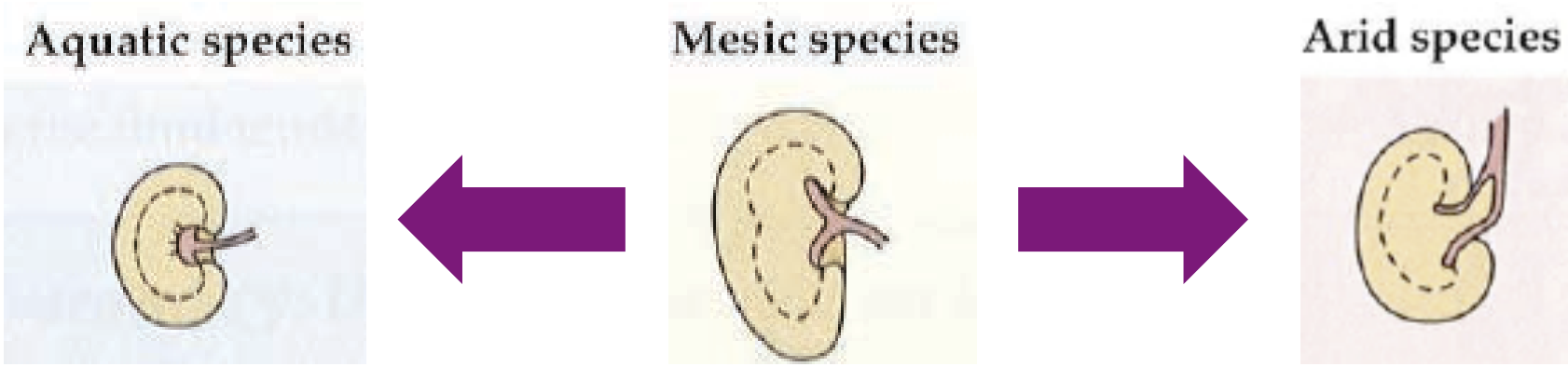
Am. J. Physiol. (1990)



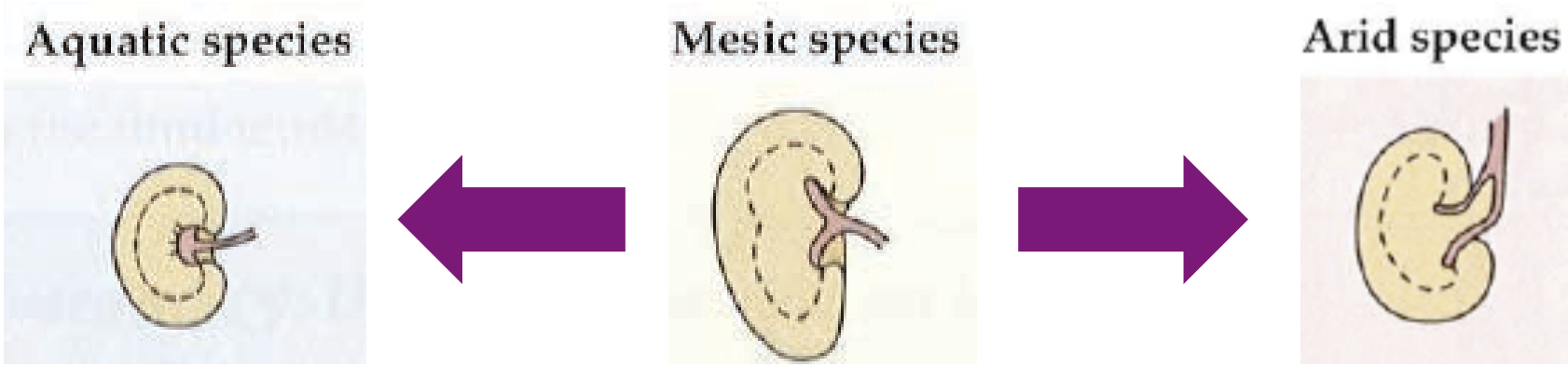
Two basic modes of adaptation



Two basic modes of adaptation

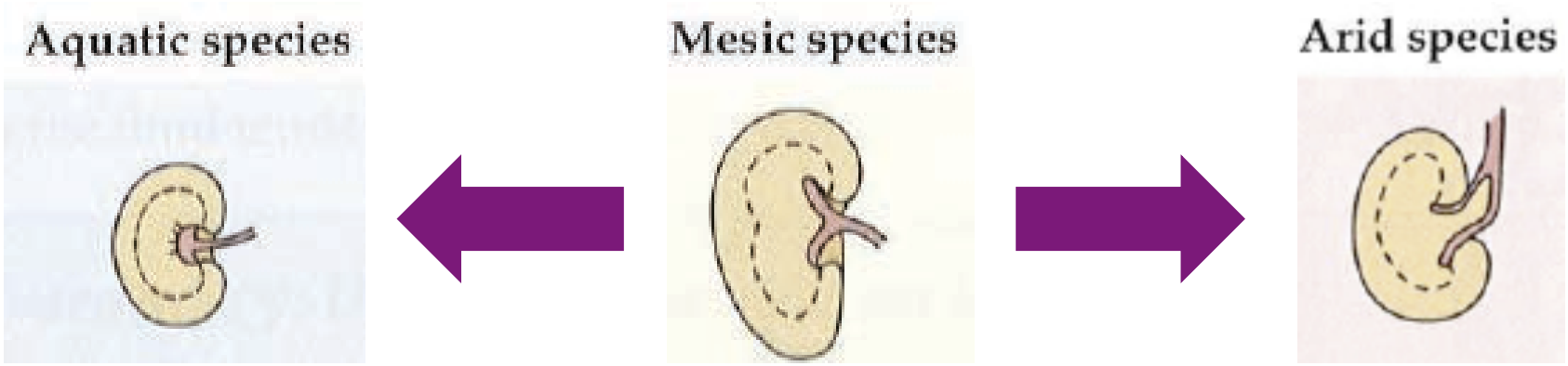


Two basic modes of adaptation



Ecological challenge

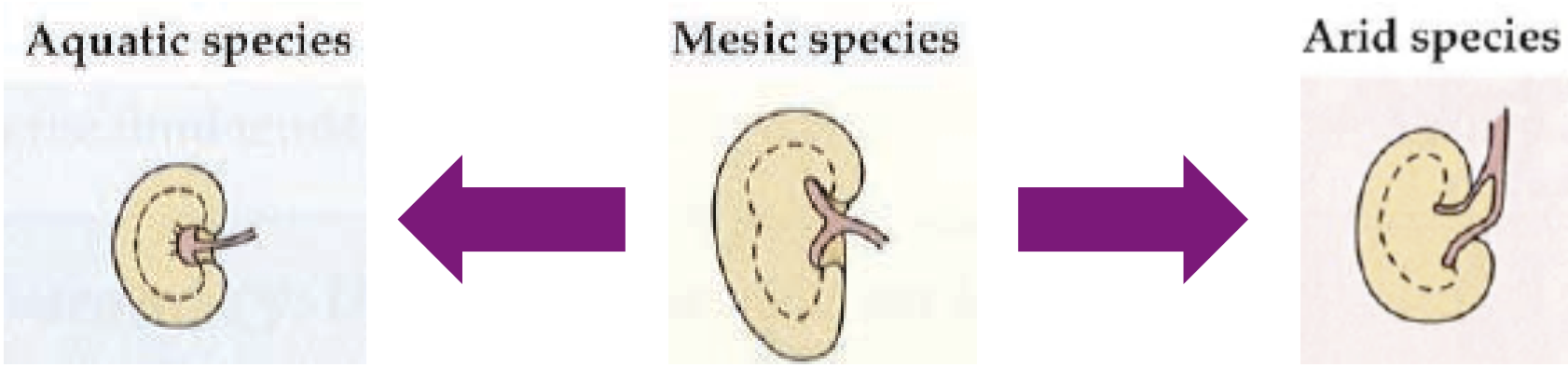
Two basic modes of adaptation



Ecological opportunity

Ecological challenge

Two basic modes of adaptation



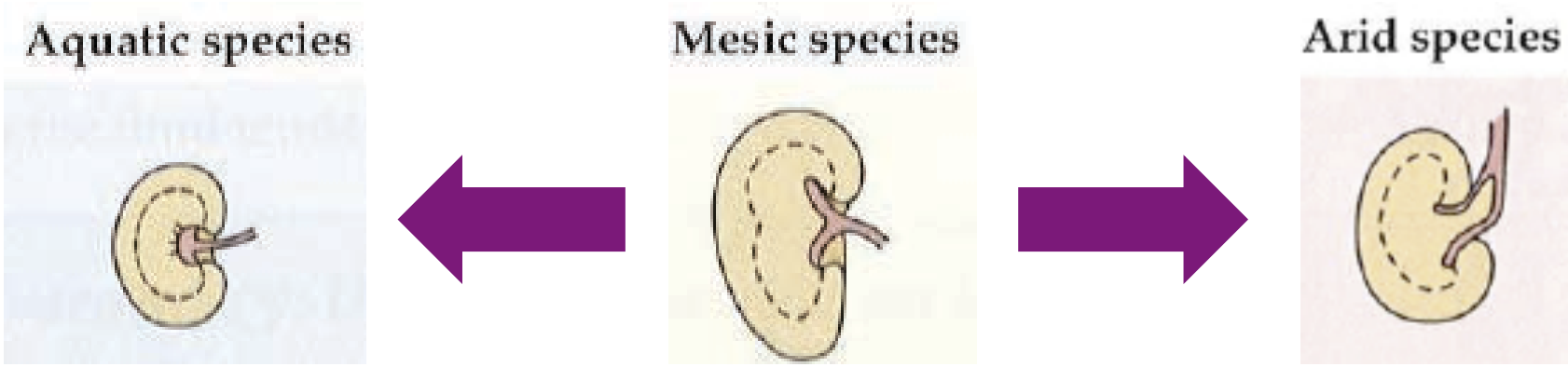
Ecological opportunity

- reduction (saving)

Ecological challenge

- addition (cost)

Two basic modes of adaptation



Ecological opportunity

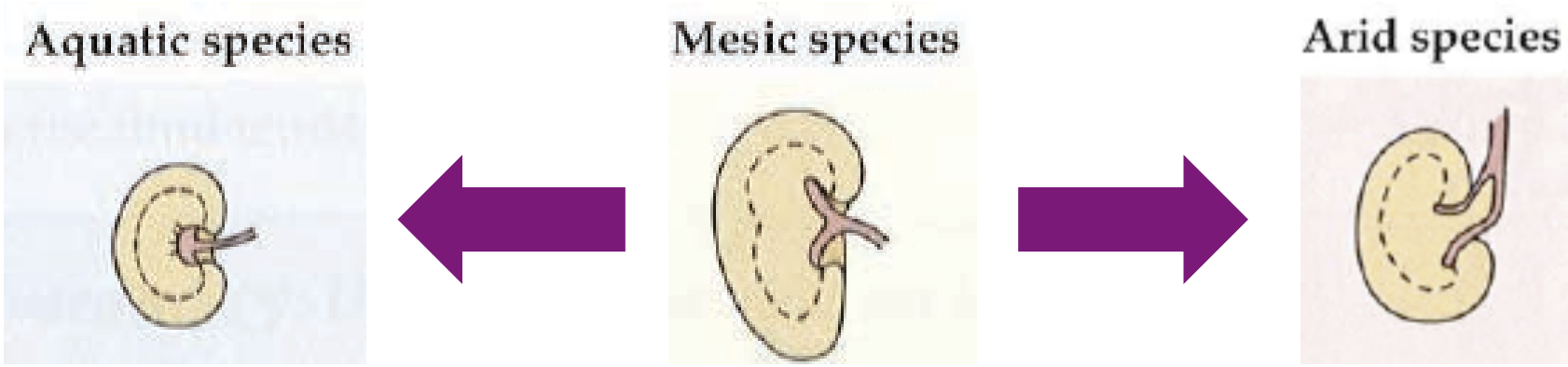
- reduction (saving)

Ecological challenge

- addition (cost)

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

Two basic modes of adaptation



Ecological opportunity

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Ecological challenge

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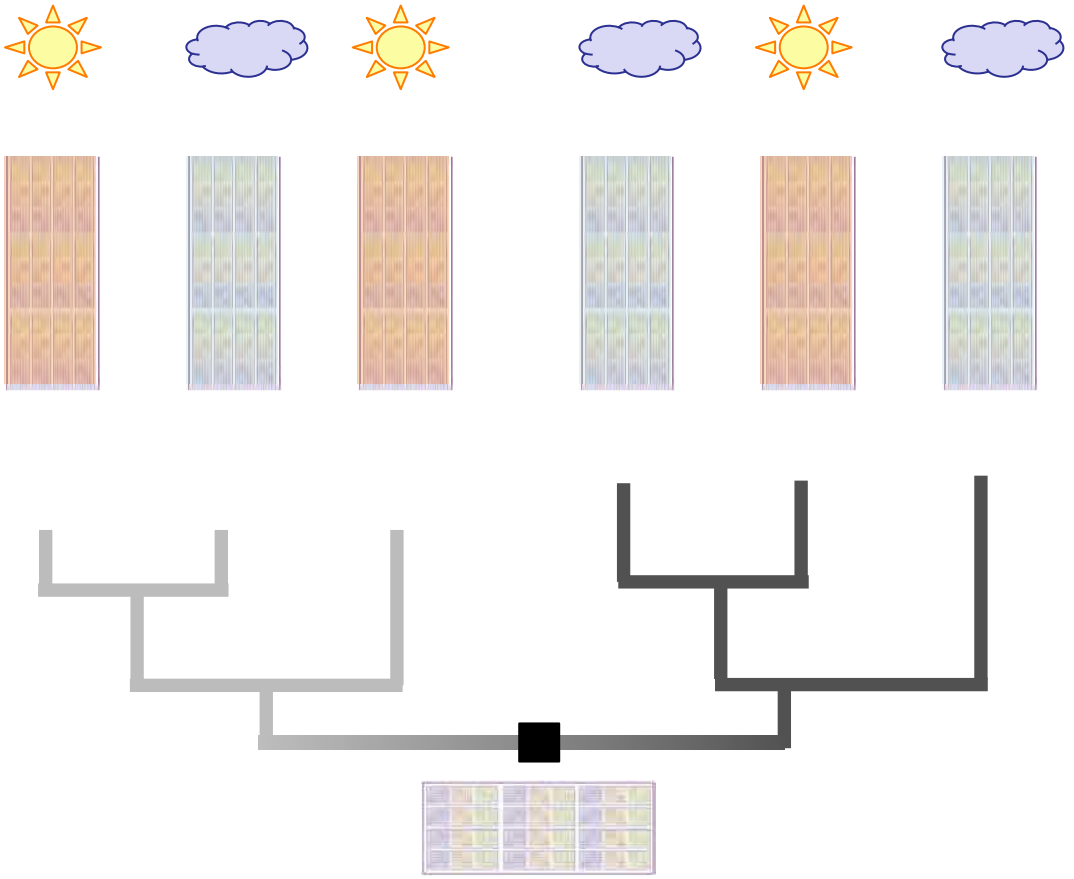
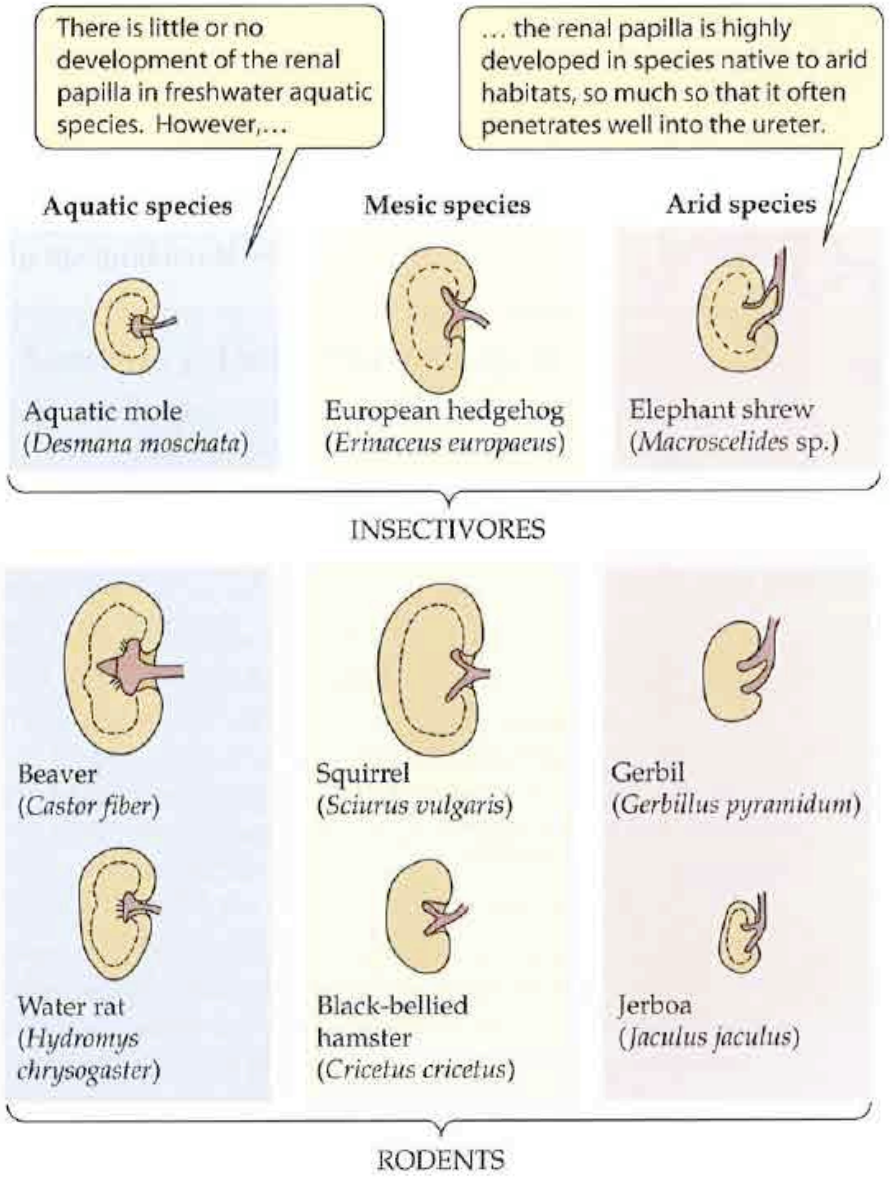
Detailed function: convergence/homoplasy



Detailed function: convergence/homoplasy

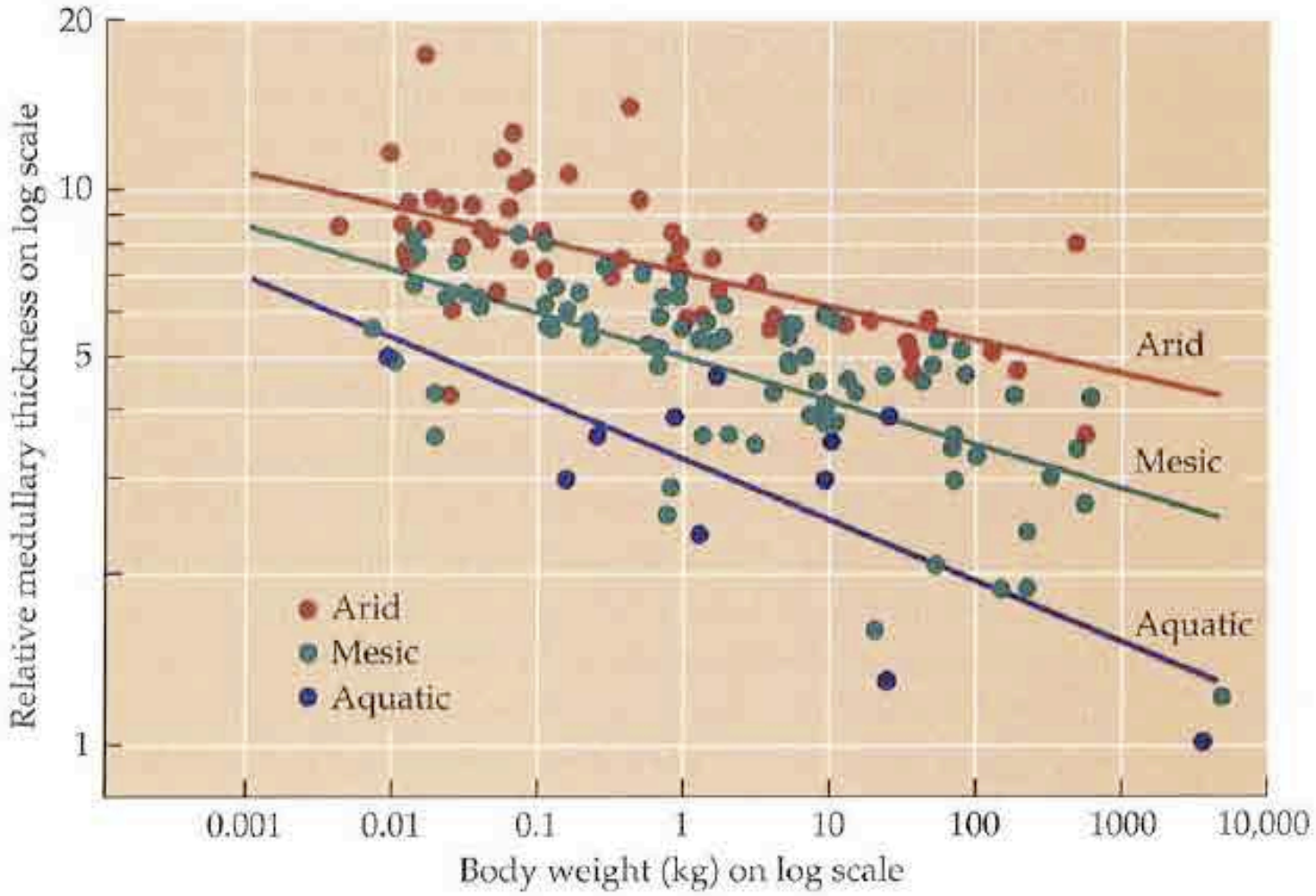


from Hill et al. (2004)

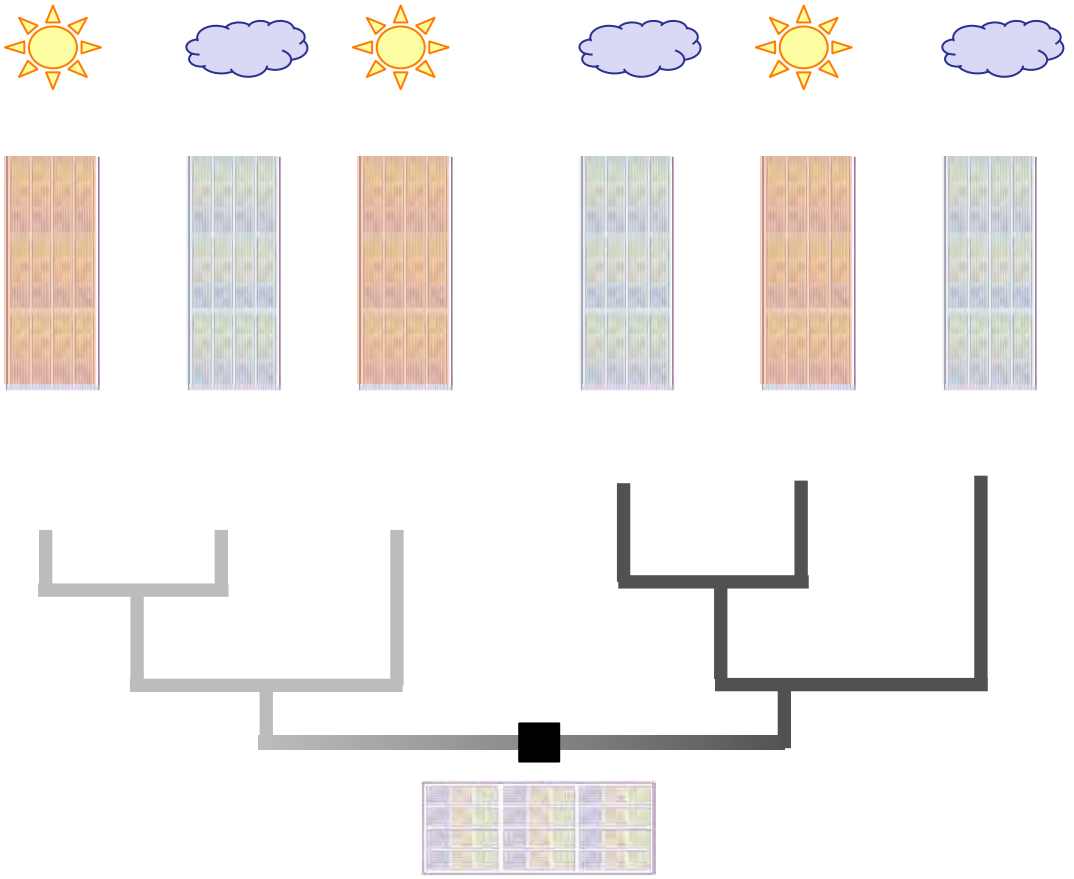
Structure and concentrating ability of the mammalian kidney: correlations with habitat

CAROL A. BEUCHAT

Am. J. Physiol.
(1996)



Detailed function: different solutions to the same problems



Characterising basic condition

Marine

Terrestrial

Characterising basic condition

Marine
viscous

Medium

Terrestrial
thin

Characterising basic condition

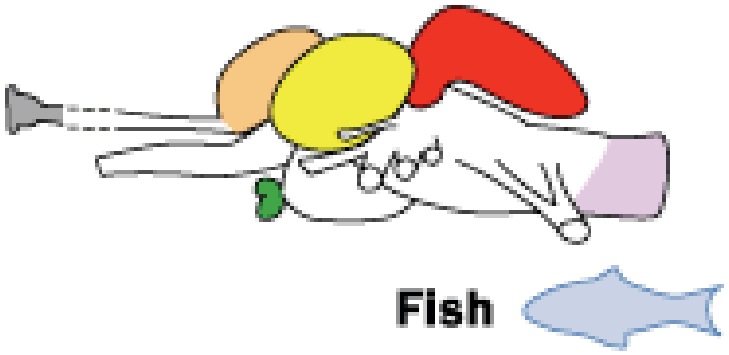
Marine		Terrestrial
viscous	Medium	thin
buoyancy	Support	gravity

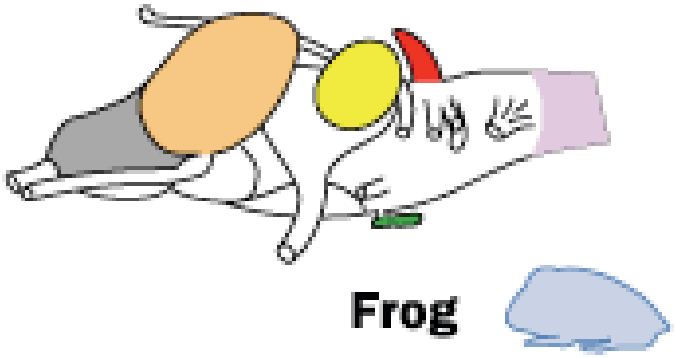
Characterising basic condition

Marine		Terrestrial
viscous	Medium	thin
buoyancy	Support	gravity
high	Pressure	low

Characterising basic condition

Marine		Terrestrial
viscous	Medium	thin
buoyancy	Support	gravity
high	Pressure	low
3 D	Dimensionality	mostly 2 D





Characterising basic condition

Marine		Terrestrial
viscous	Medium	thin
buoyancy	Support	gravity
high	Pressure	low
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high	Conductance	low

Characterising basic condition

Marine		Terrestrial
viscous	Medium	thin
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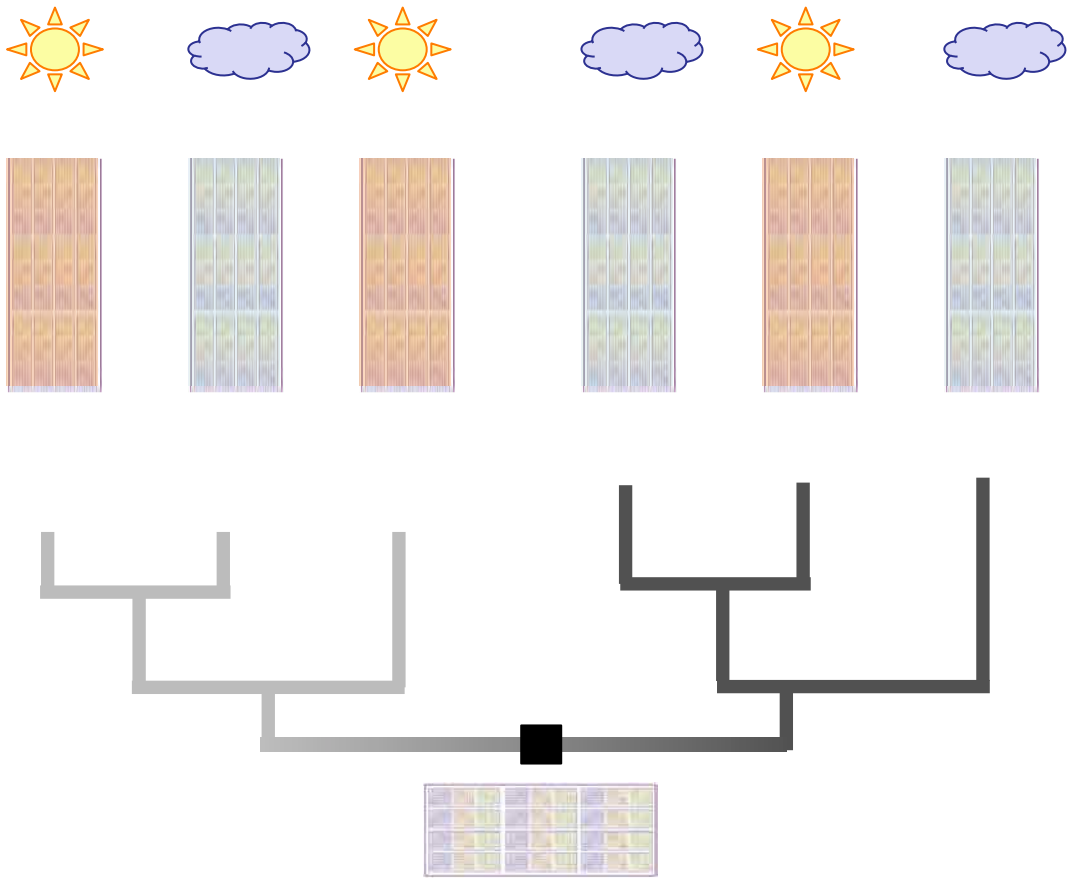
3 D	Dimensionality	mostly 2 D
high	Conductance	low
high	Thermal stability	low

Characterising basic condition

Marine		Terrestrial
viscous	Medium	thin
buoyancy	Support	gravity
high	Pressure	low
3 D	Dimensionality	mostly 2 D
high	Conductance	low
high	Thermal stability	low
low	Oxygen	high

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



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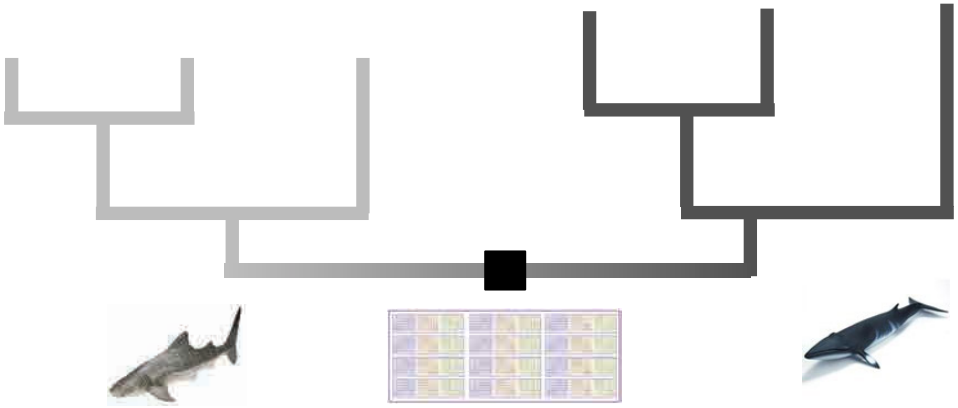
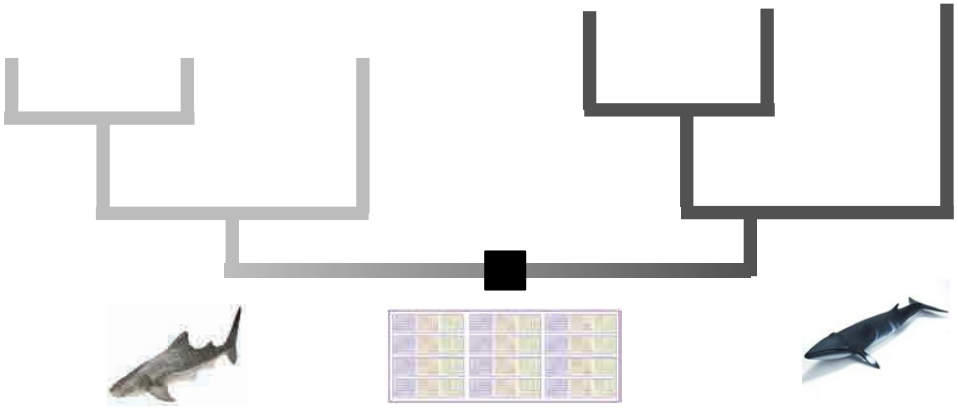


Detailed function: constraints by evolutionary history ('contingency')



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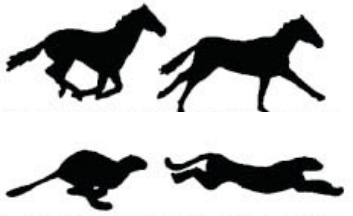
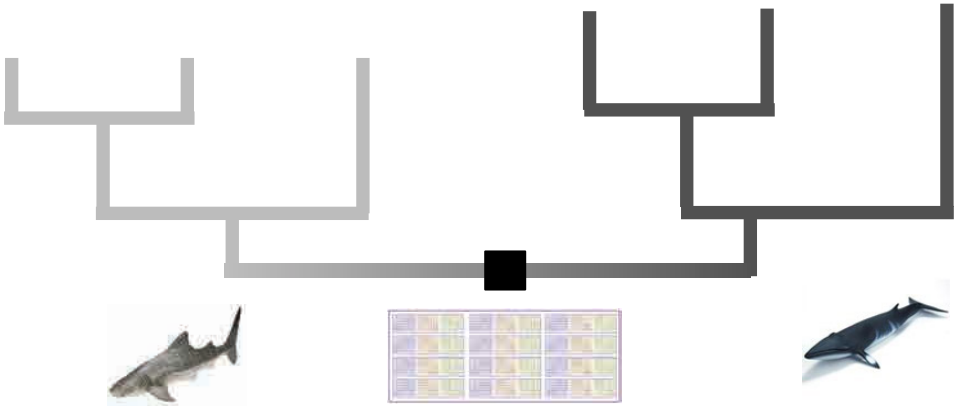
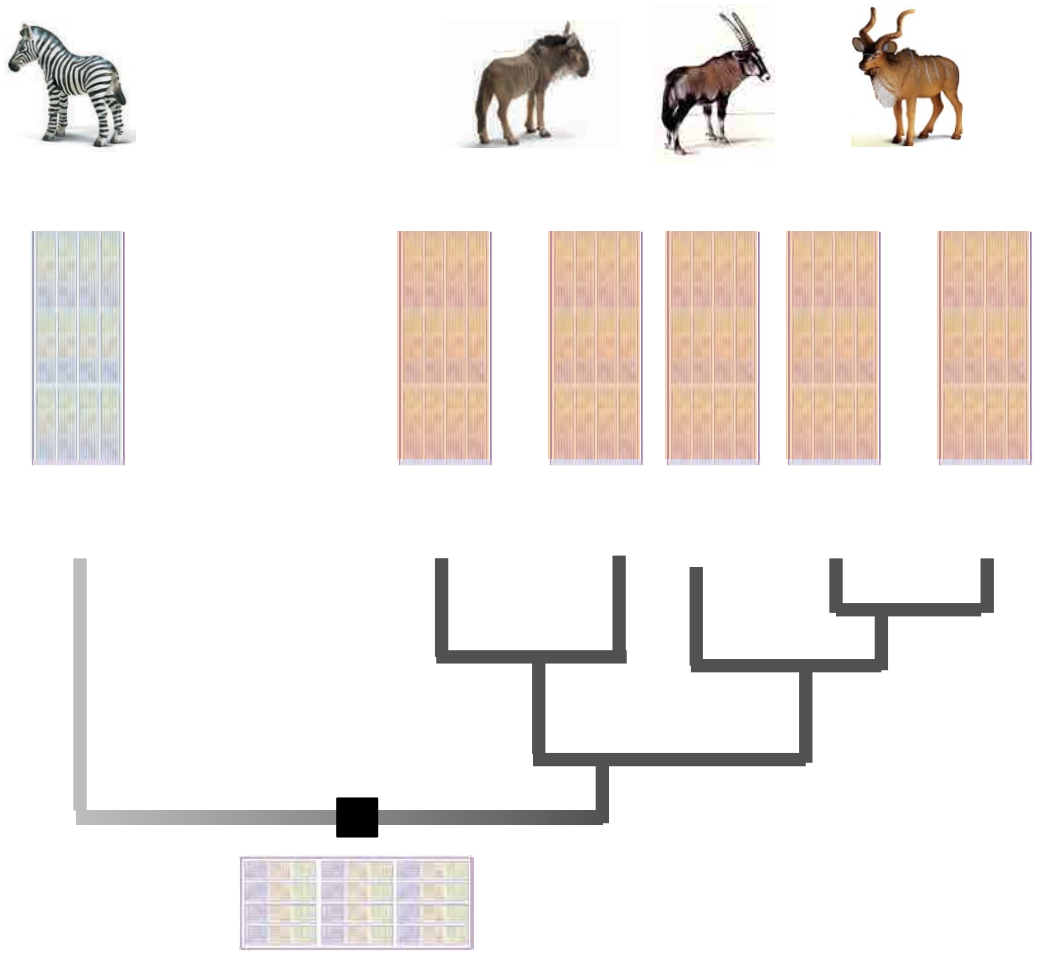
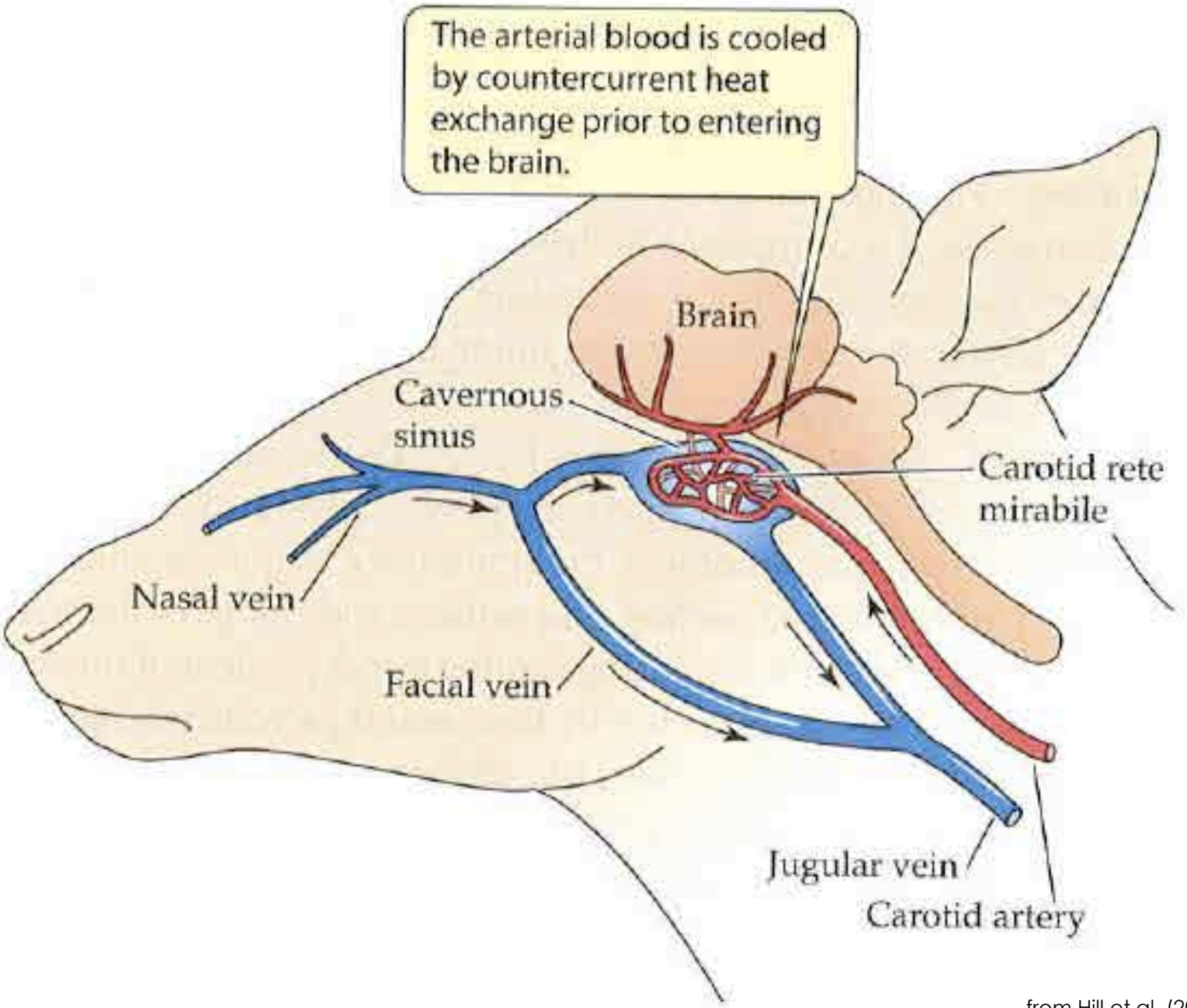




Detailed function: solutions of different efficiency



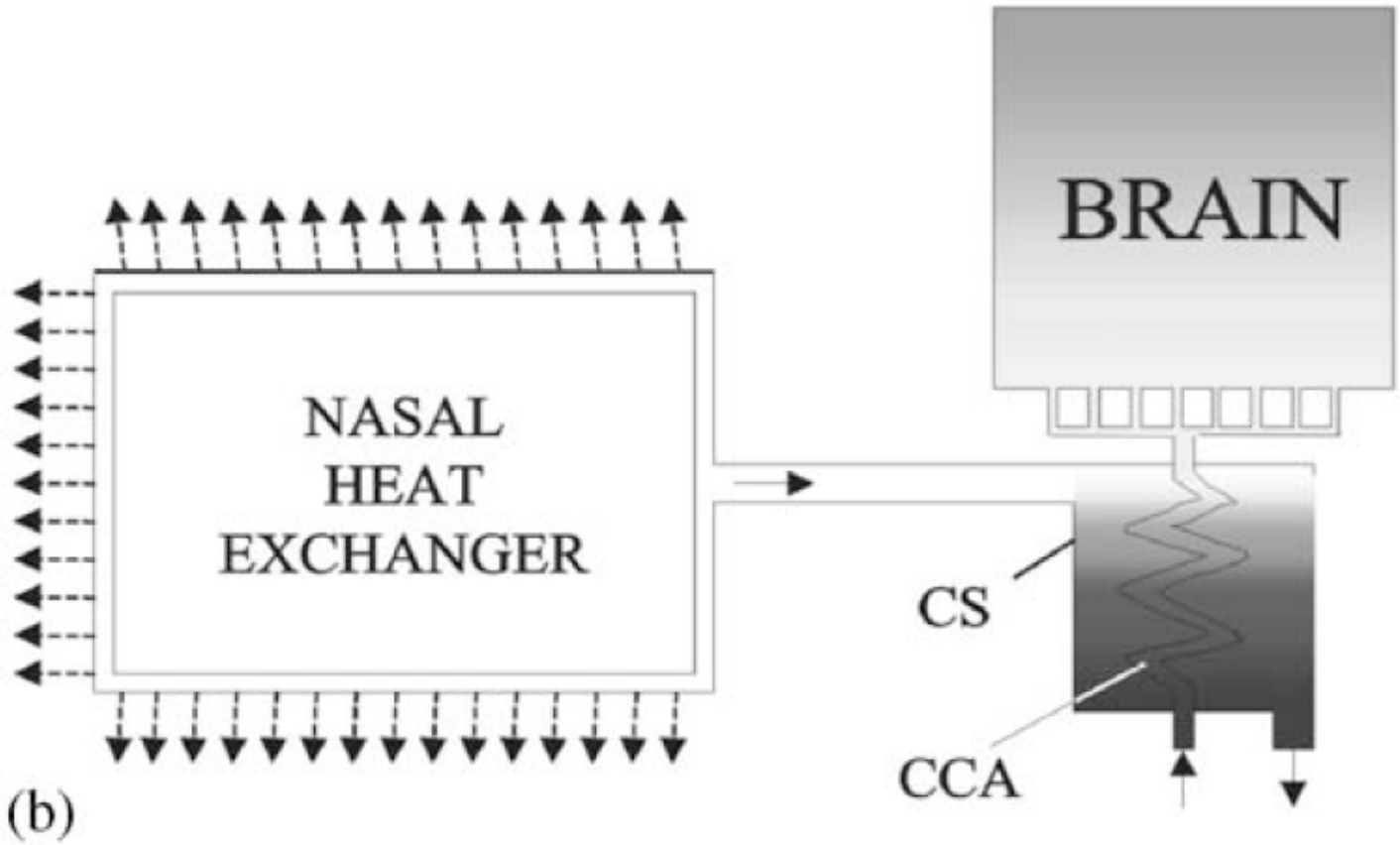


from Hill et al. (2004)

Selective brain cooling: a multiple regulatory mechanism

Michał Caputa*

Journal of Thermal Biology 29 (2004) 691–702



(b)

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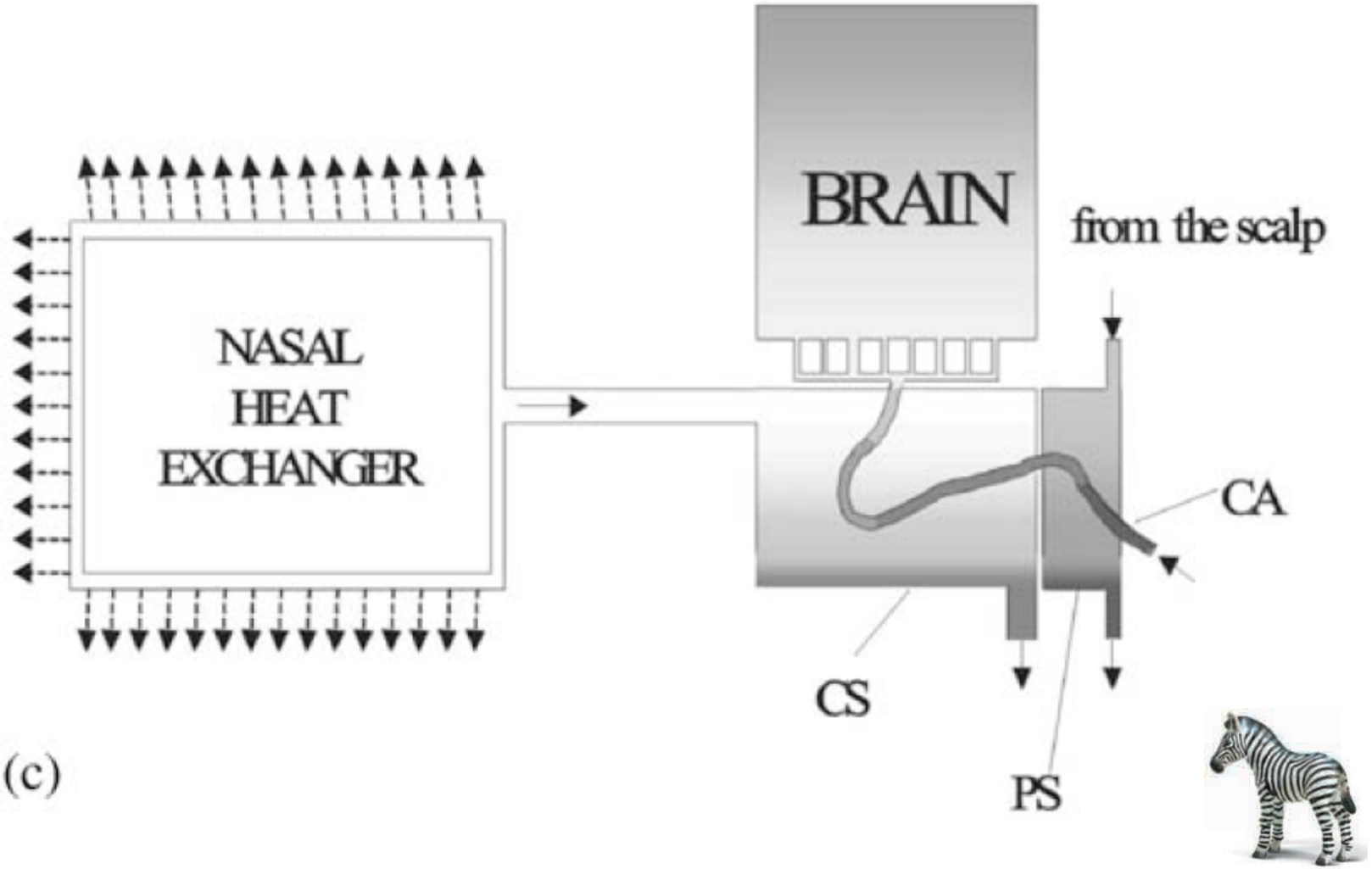

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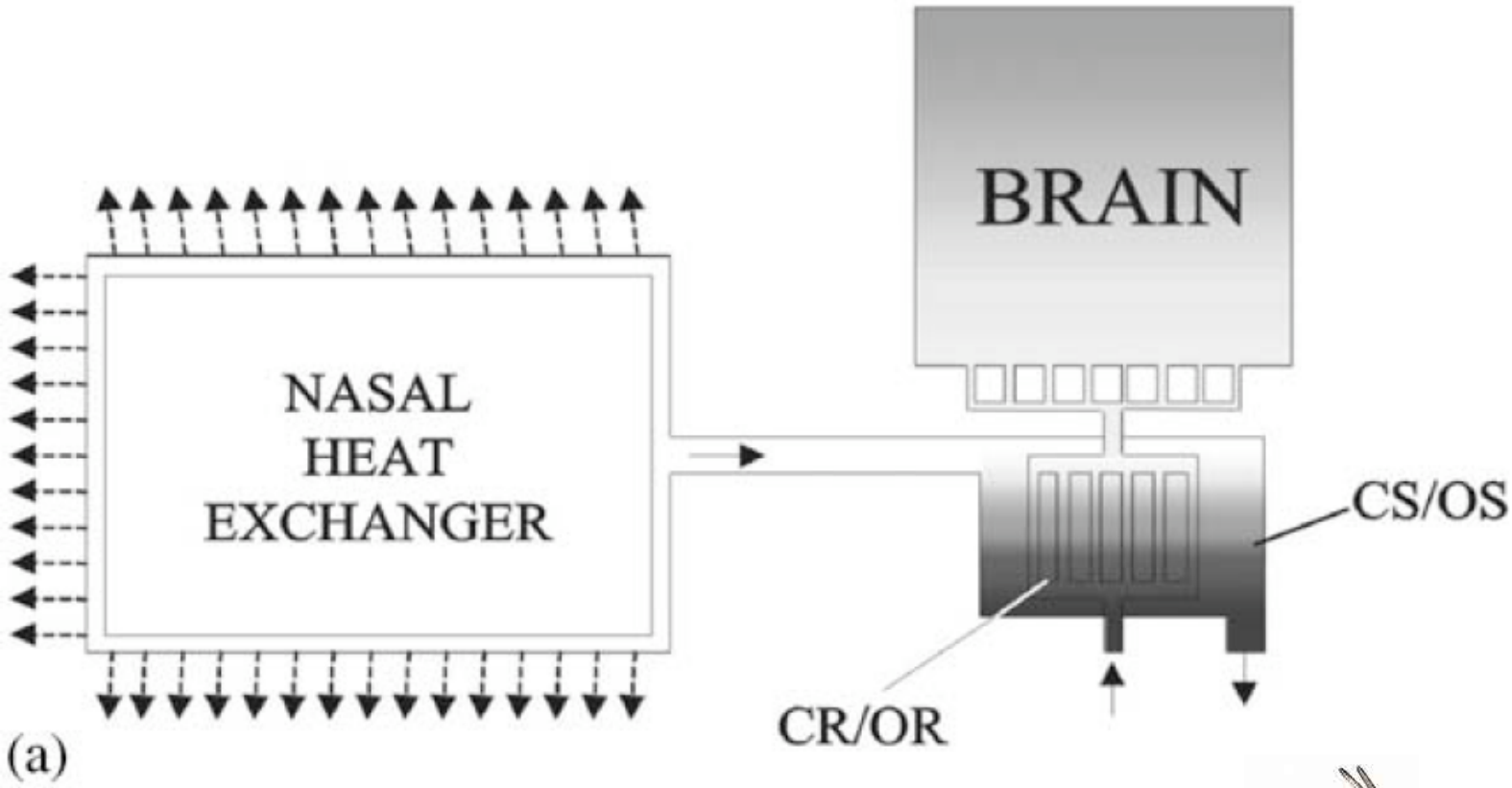
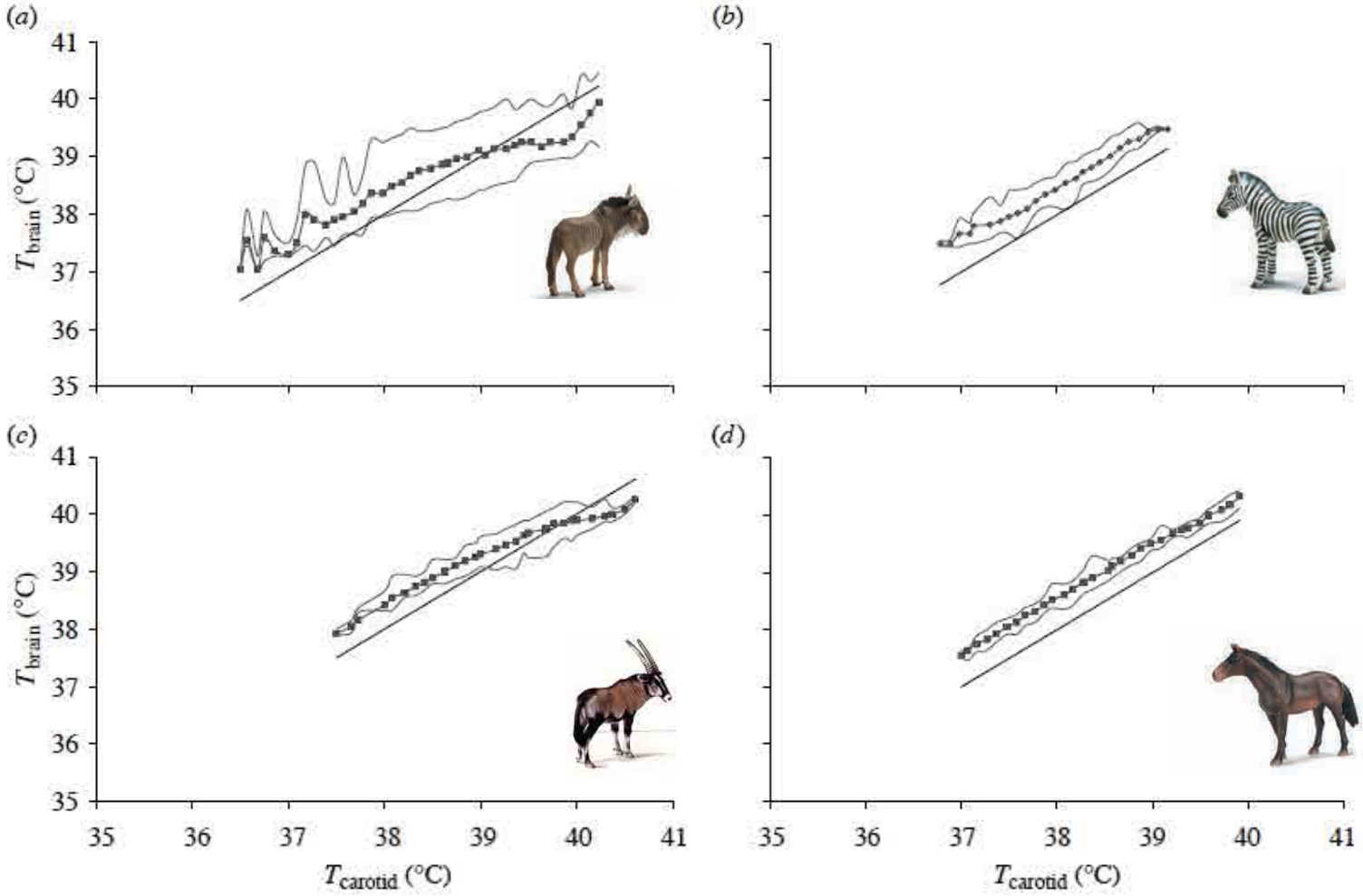


The carotid rete and artiodactyl success

G. Mitchell* and A. Lust

Biol. Lett. (2008) 4, 415–418



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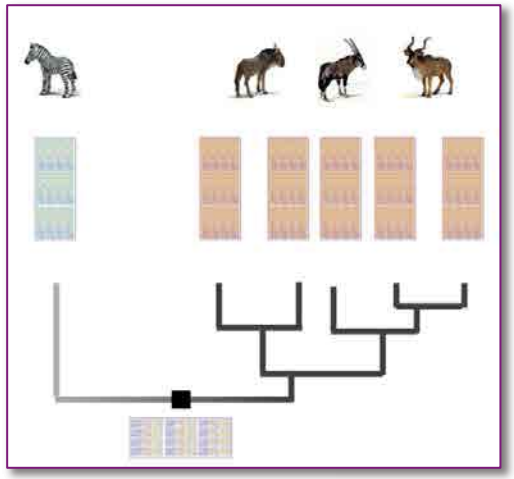

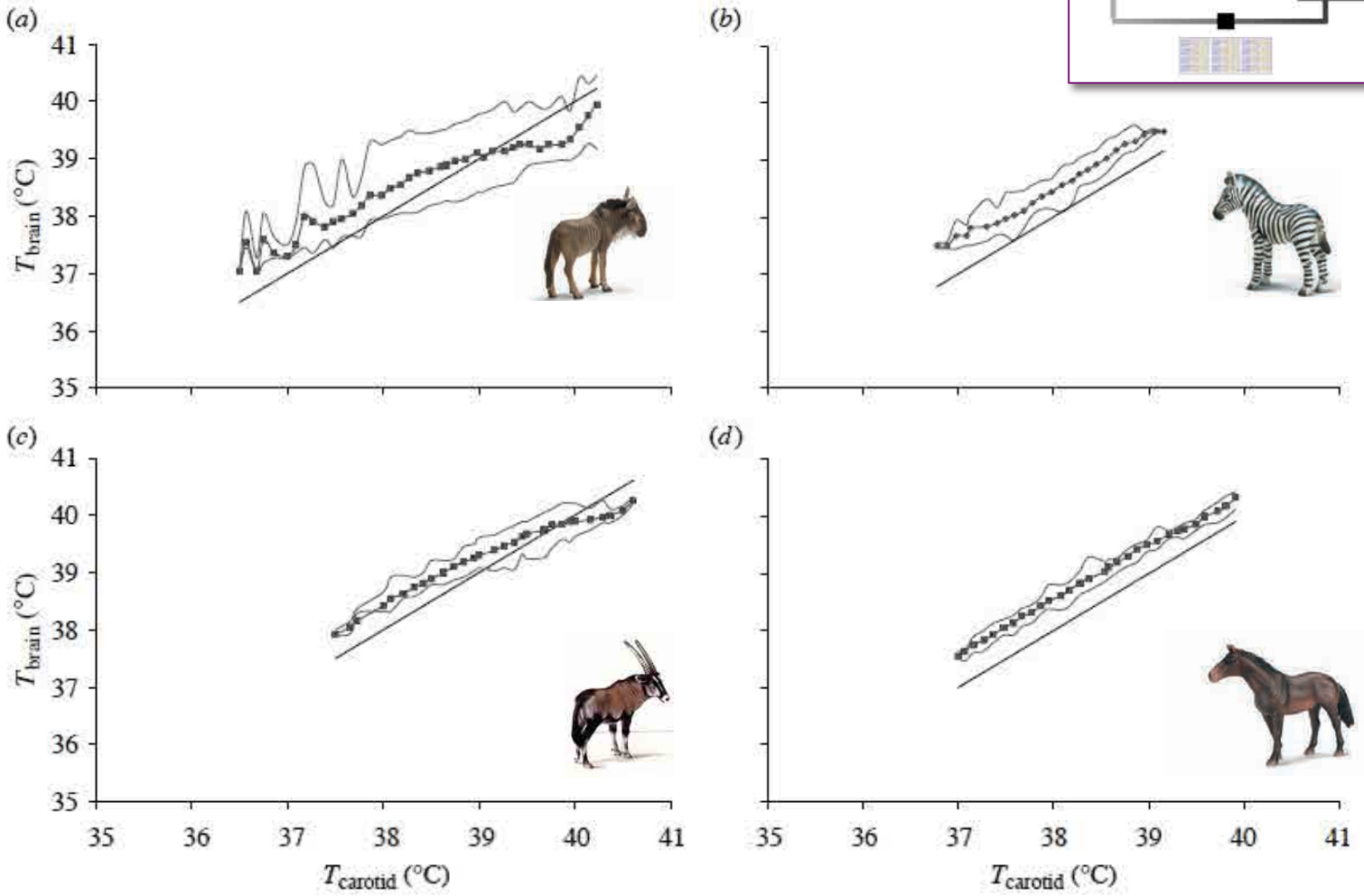

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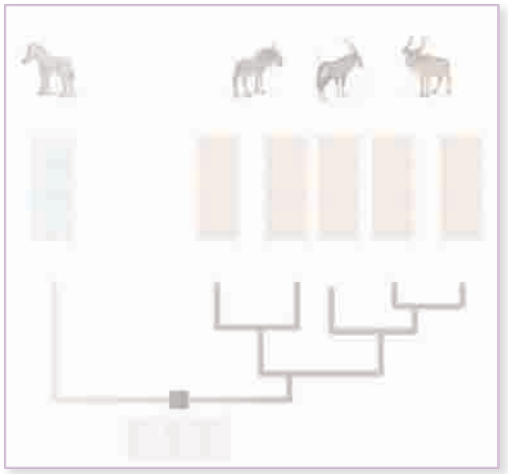

biology letters

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