Leis de Potência em Biologia

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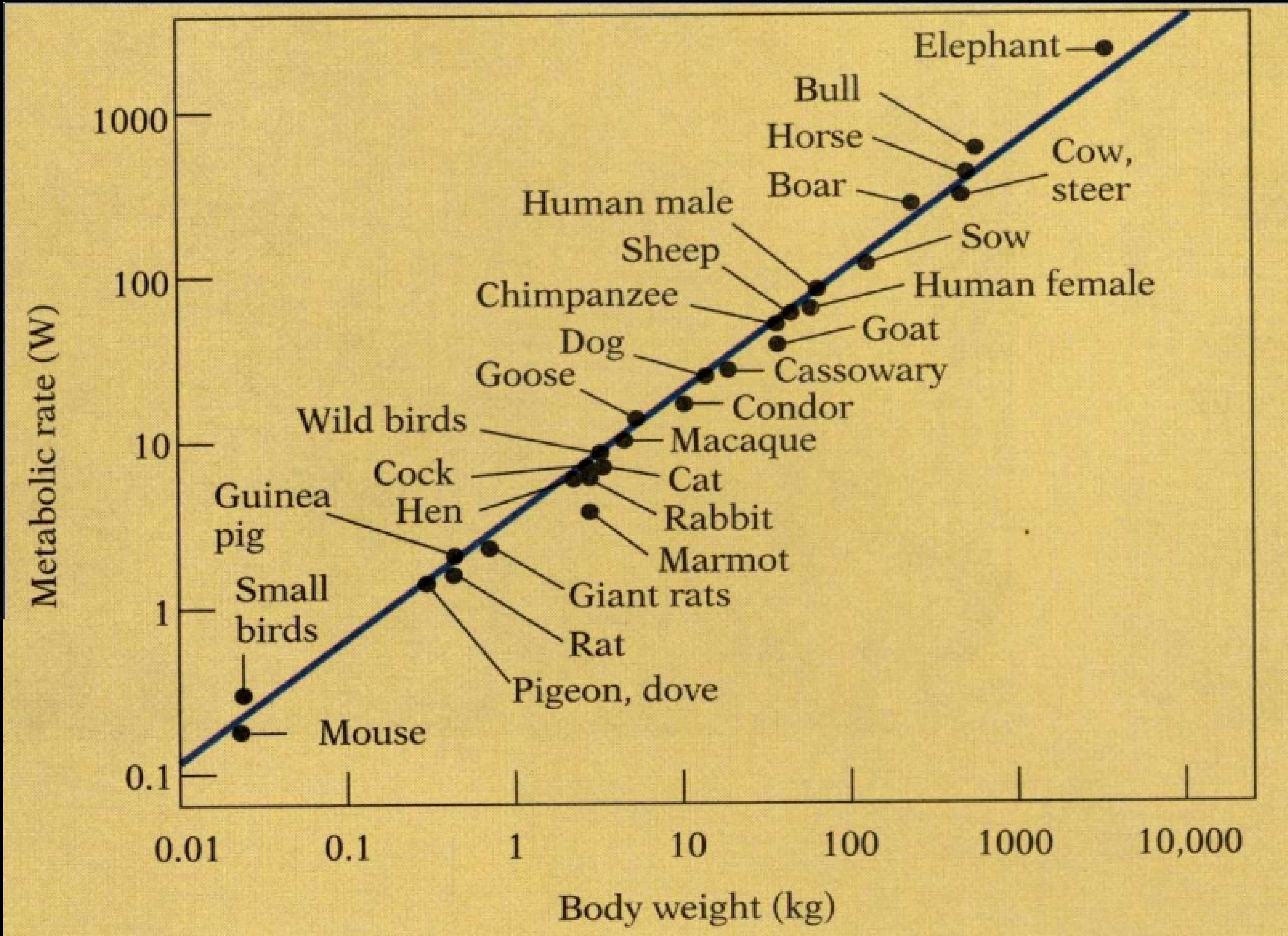
DEX- UFLA

Lei de Potência:

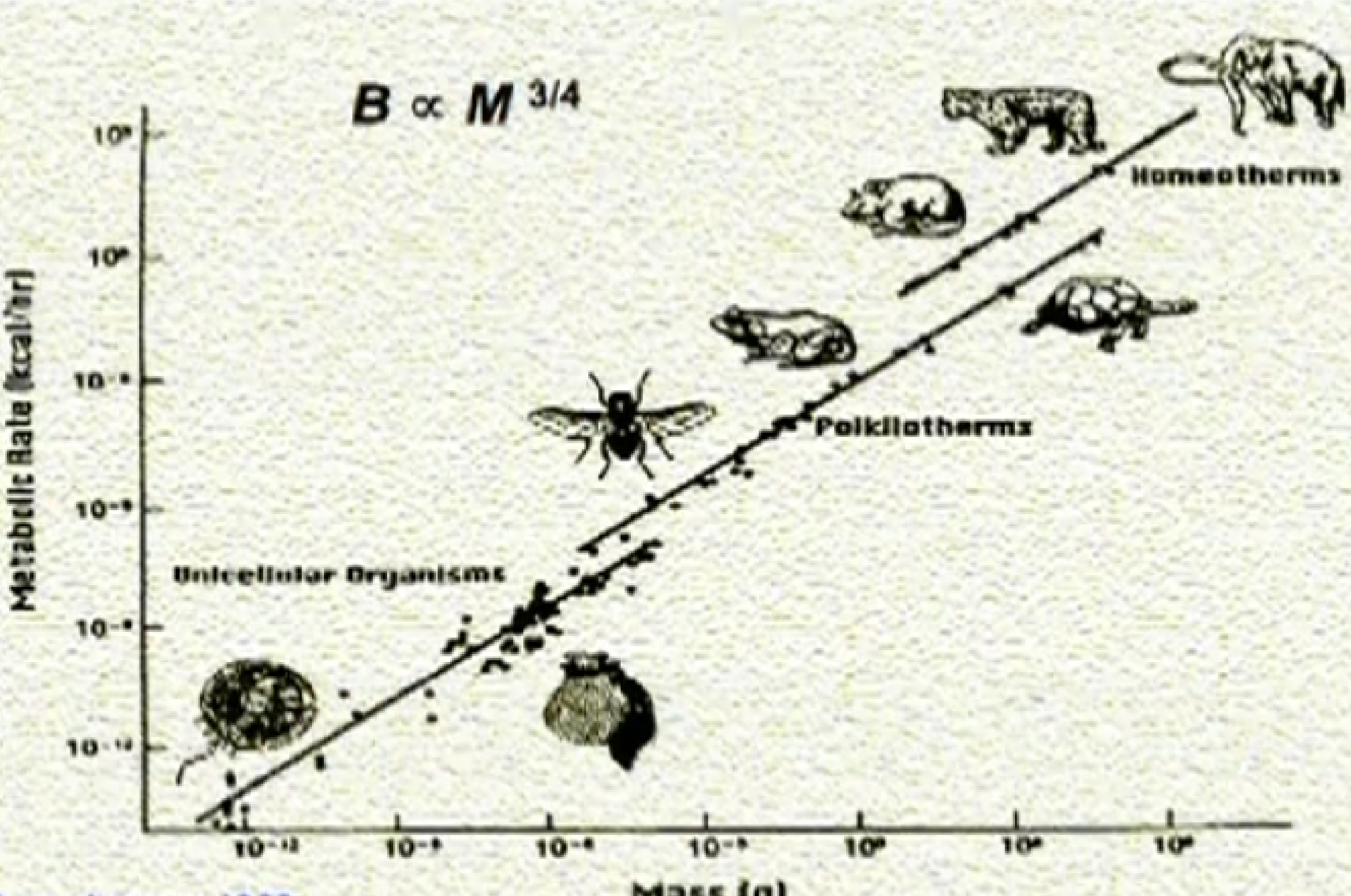
$$y(x)= a\, x^{\beta}$$

Mammals vary in size by 8 orders of magnitude

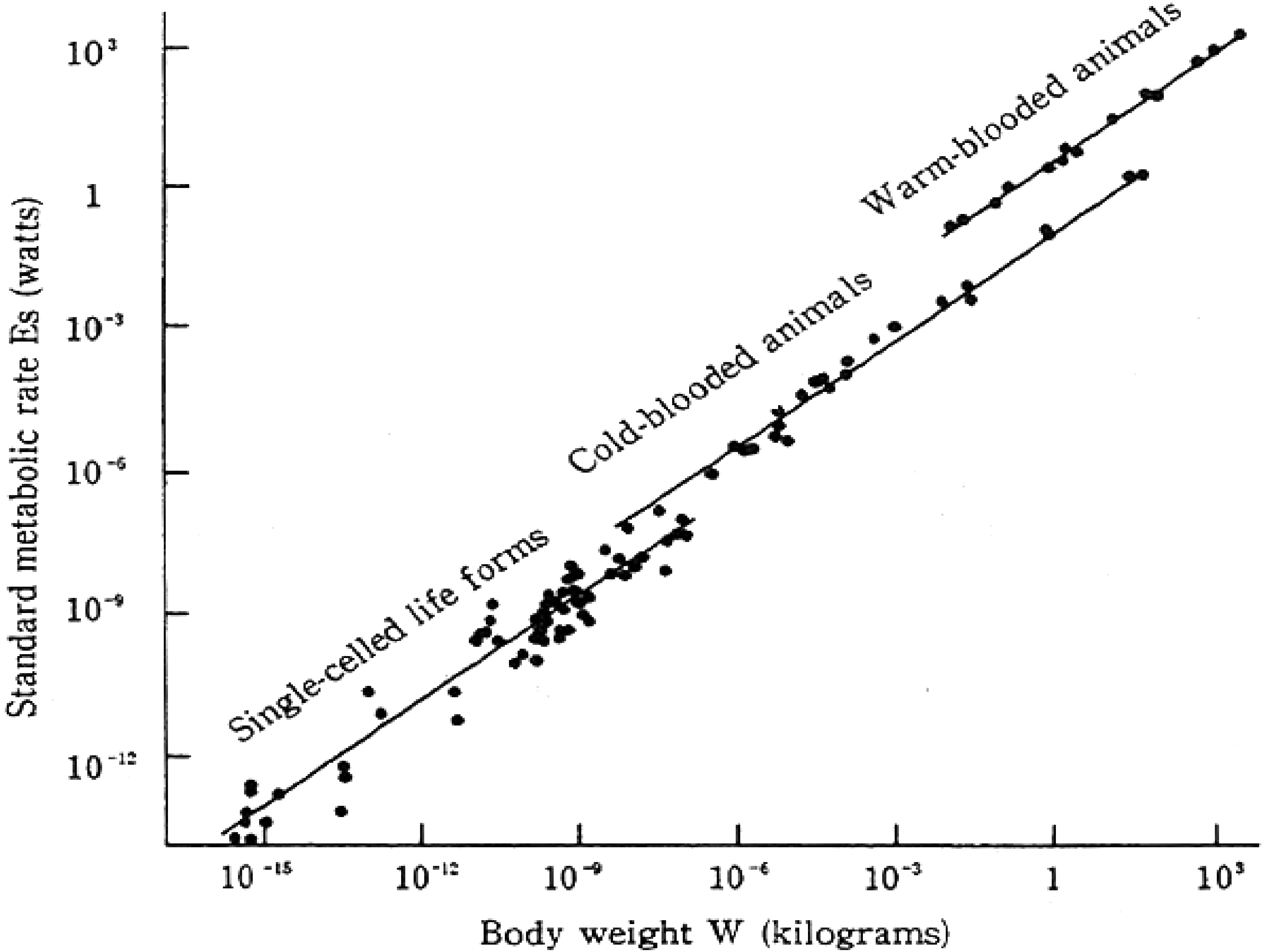


Elephant
Bull
Horse
Cow, steer
Boar
Human male
Sow
Sheep
Human female
Chimpanzee
Goat
Dog
Cassowary
Goose
Condor
Wild birds
Macaque
Cock
Cat
Hen
Rabbit
Guinea pig
Marmot
Giant rats
Small birds
Rat
Pigeon, dove
Mouse
1000
100
10
1
0.1
0.01
0.1
1
10
100
1000
10,000
Metabolic rate (W)
Body weight (kg)

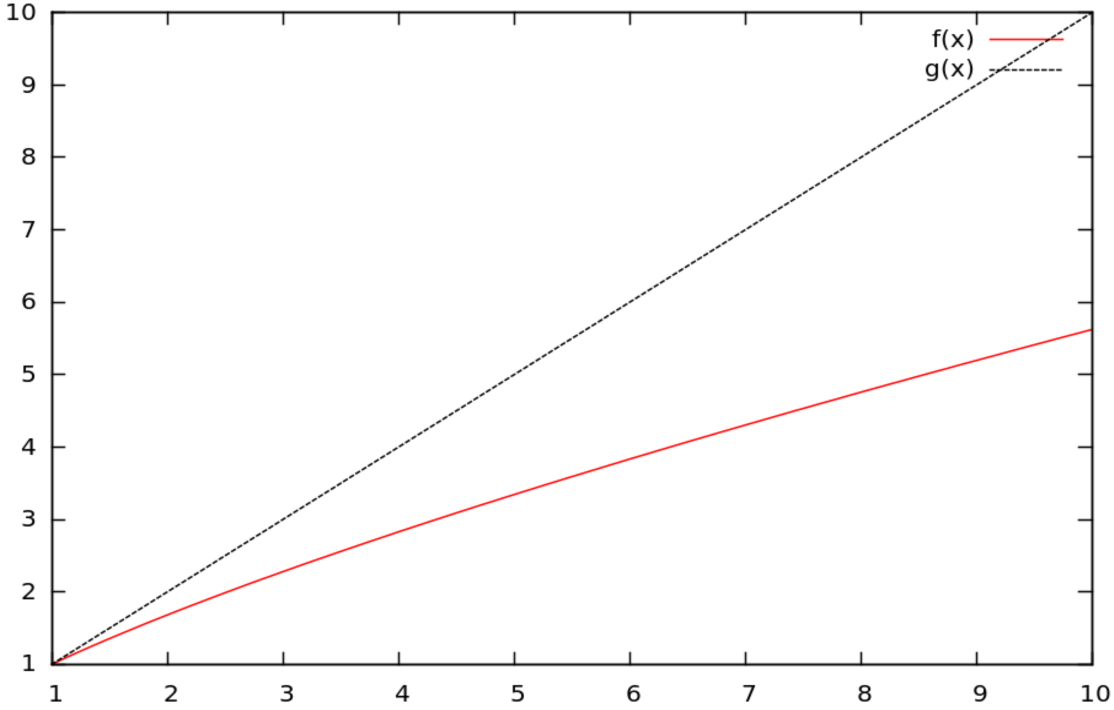
Whole-organism metabolic rate (*B*) scales as the 3/4 power of body mass (*M*)



Hemmingson 1960

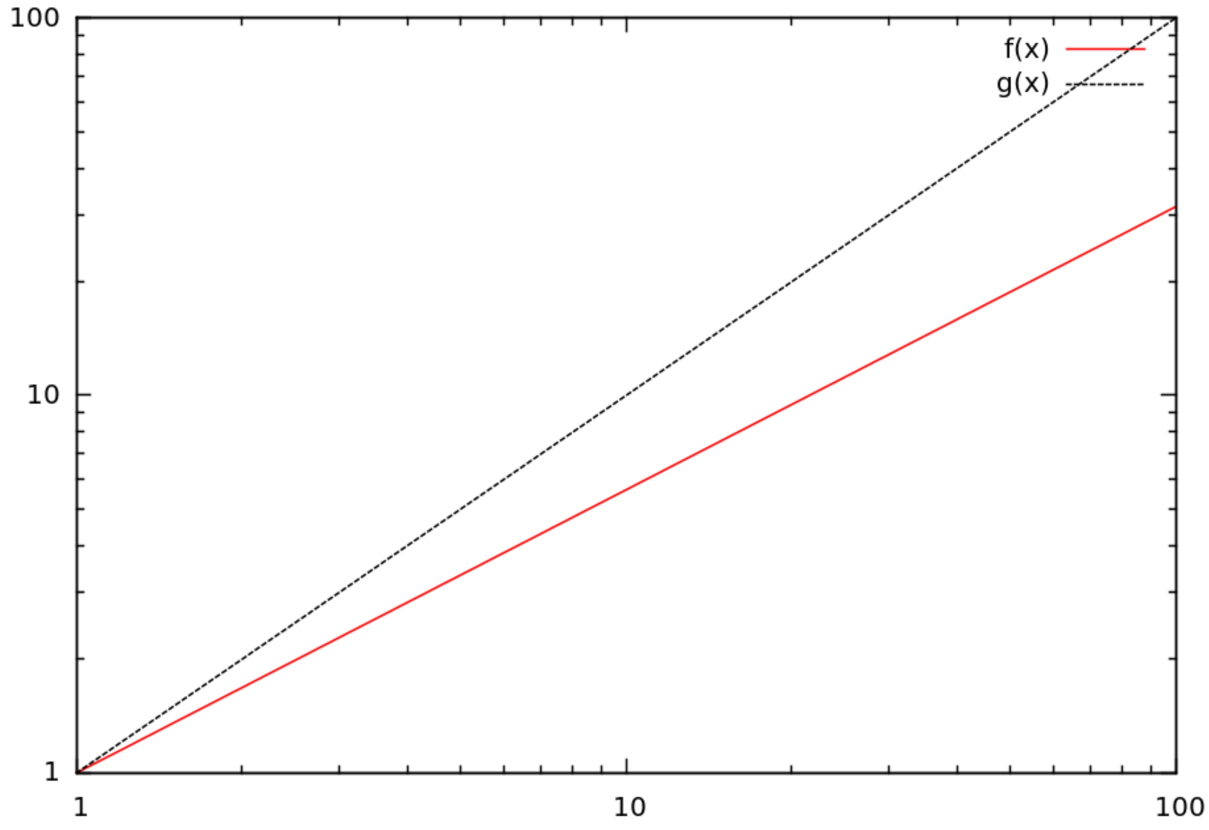


Standard metabolic rate Es (watts)
Body weight W (kilograms)
Warm-blooded animals
Cold-blooded animals
Single-celled life forms
10^3
1
10^{-3}
10^{-6}
10^{-9}
10^{-12}
10^{-15}
10^{-12}
10^{-9}
10^{-6}
10^{-3}
1
10^3



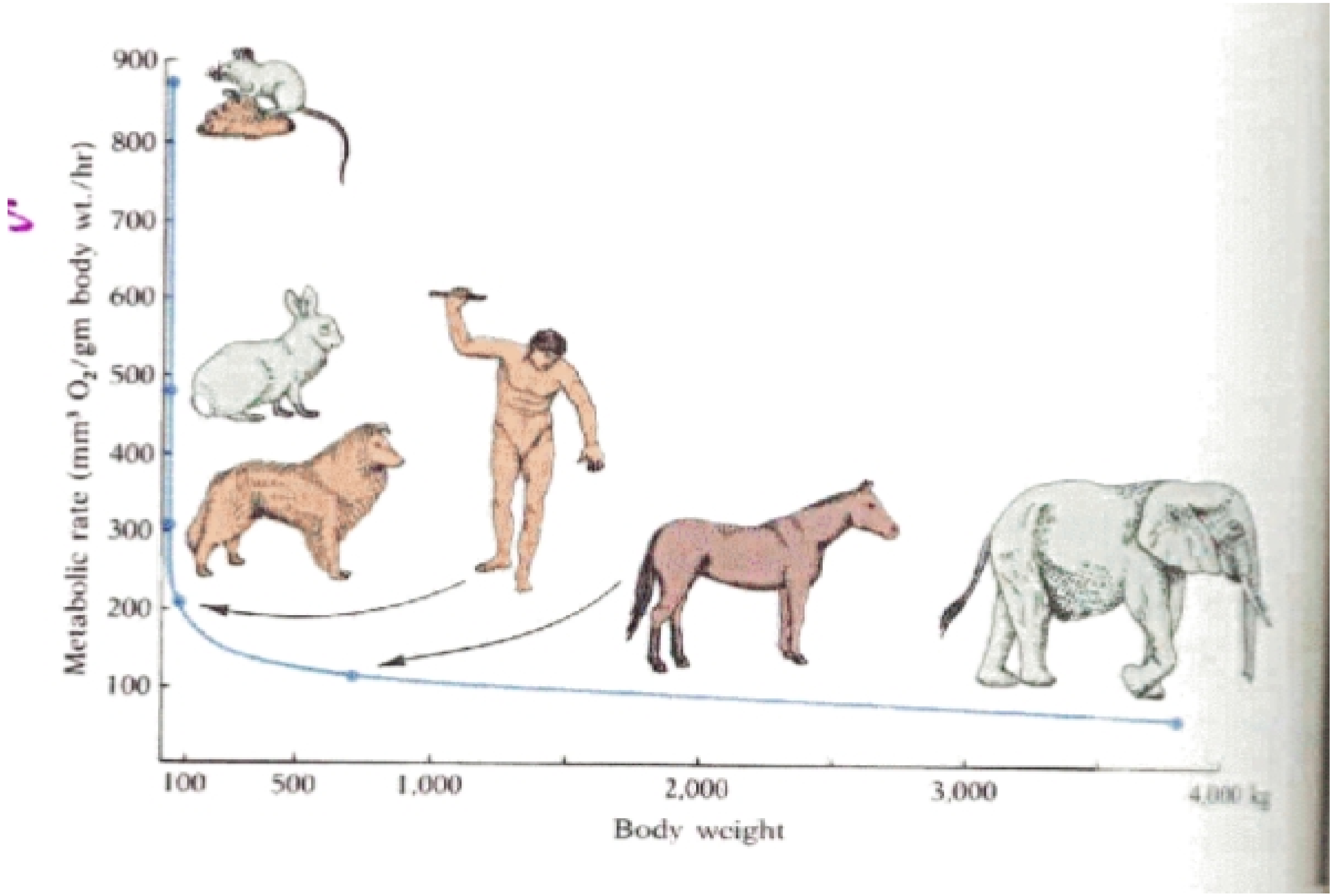
$$g(x)= x$$

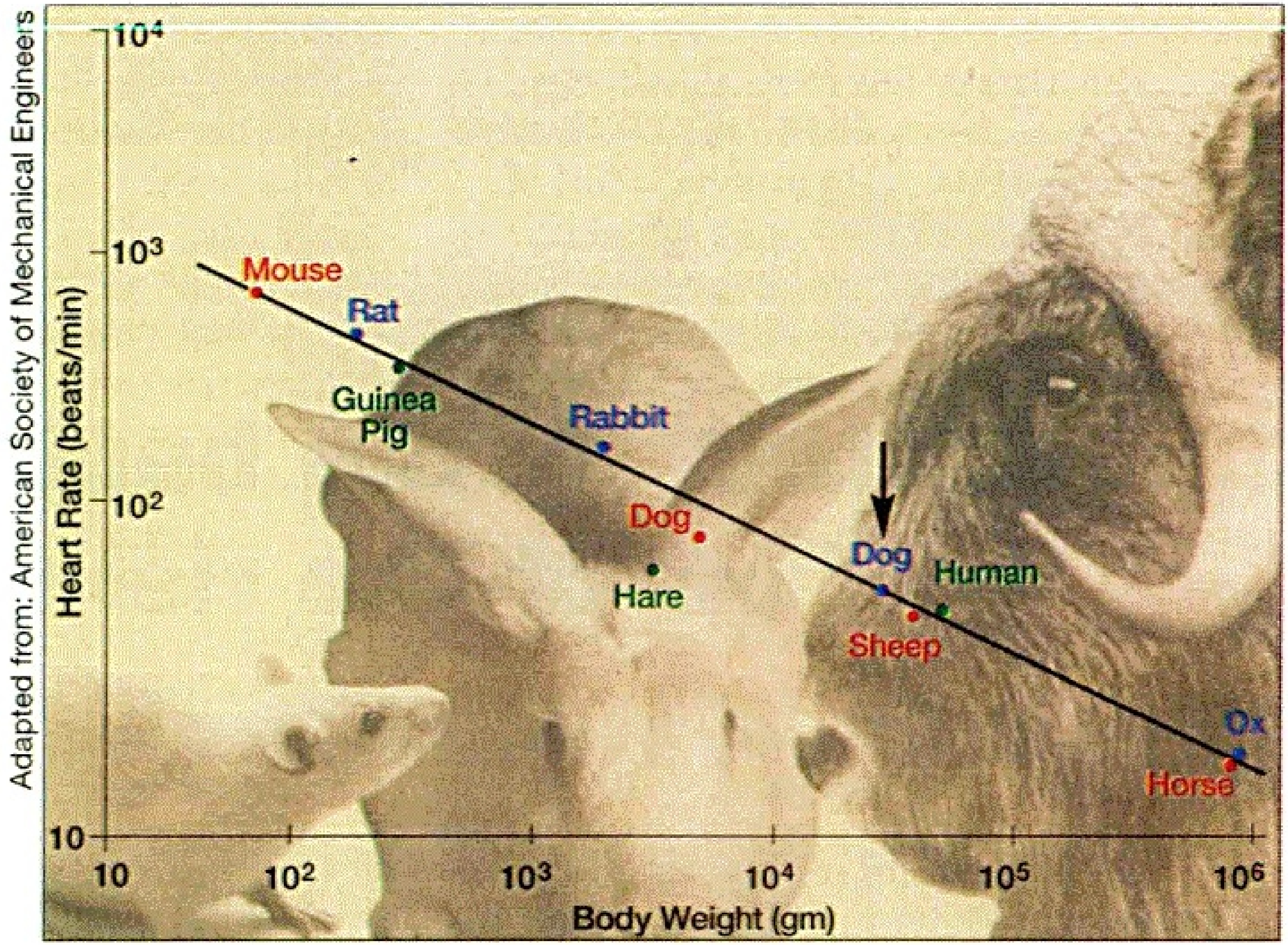
$$f(x)=x^{3/4}$$



Economia Energética com a Escala!

Economia Energética com a Escala!





Small mammals live fast and die young compared to big ones. Because heart rate tracks weight by a 1/4-power law, a dog (arrow) about 1/16 as heavy as a horse has a pulse about twice as fast as the horse's, not 16 times faster.

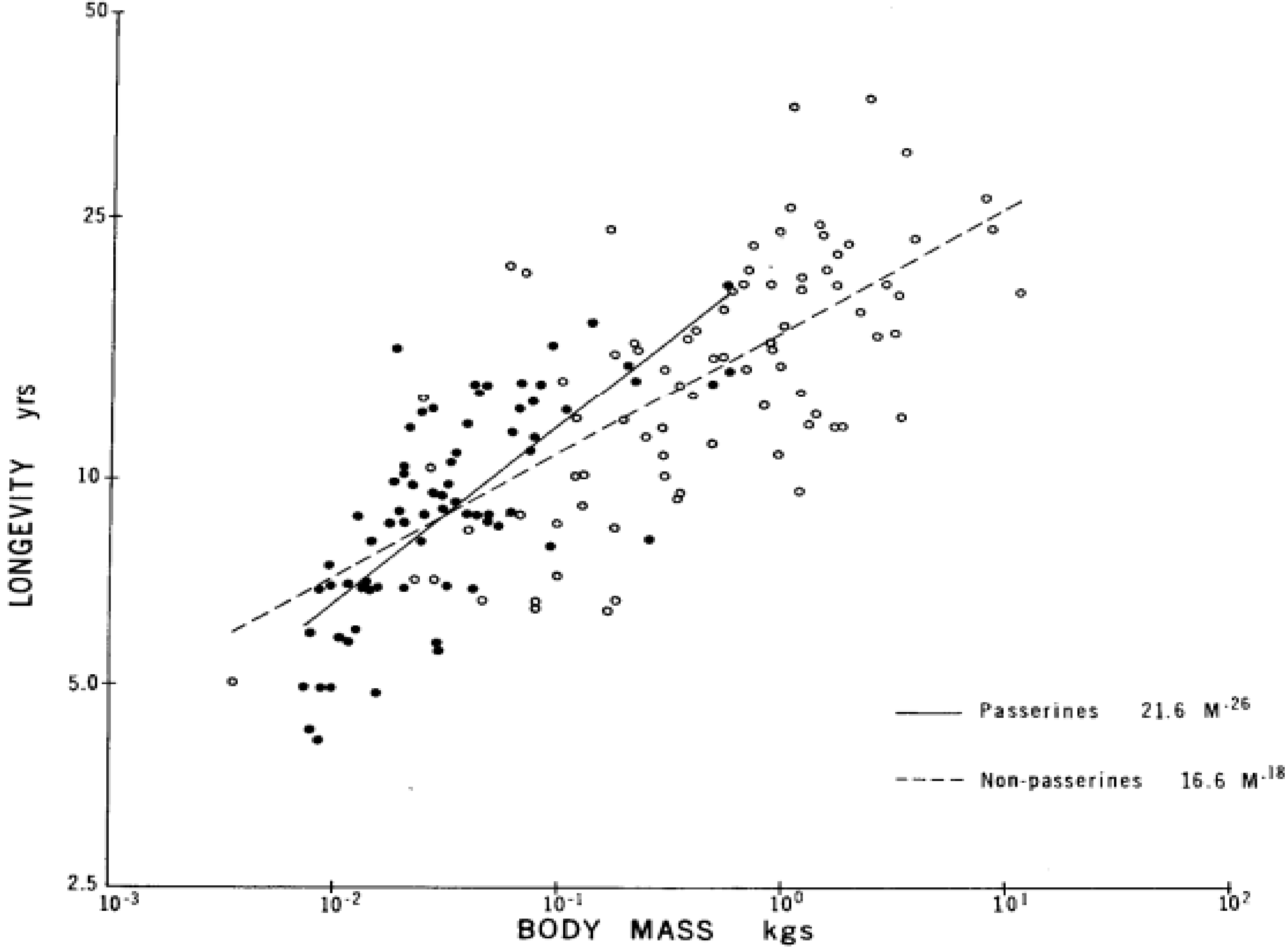


FIGURE 1. The relation of maximum longevity and body weight in wild birds, showing separate lines for passerine (solid circles) and nonpasserine (open circles) species.

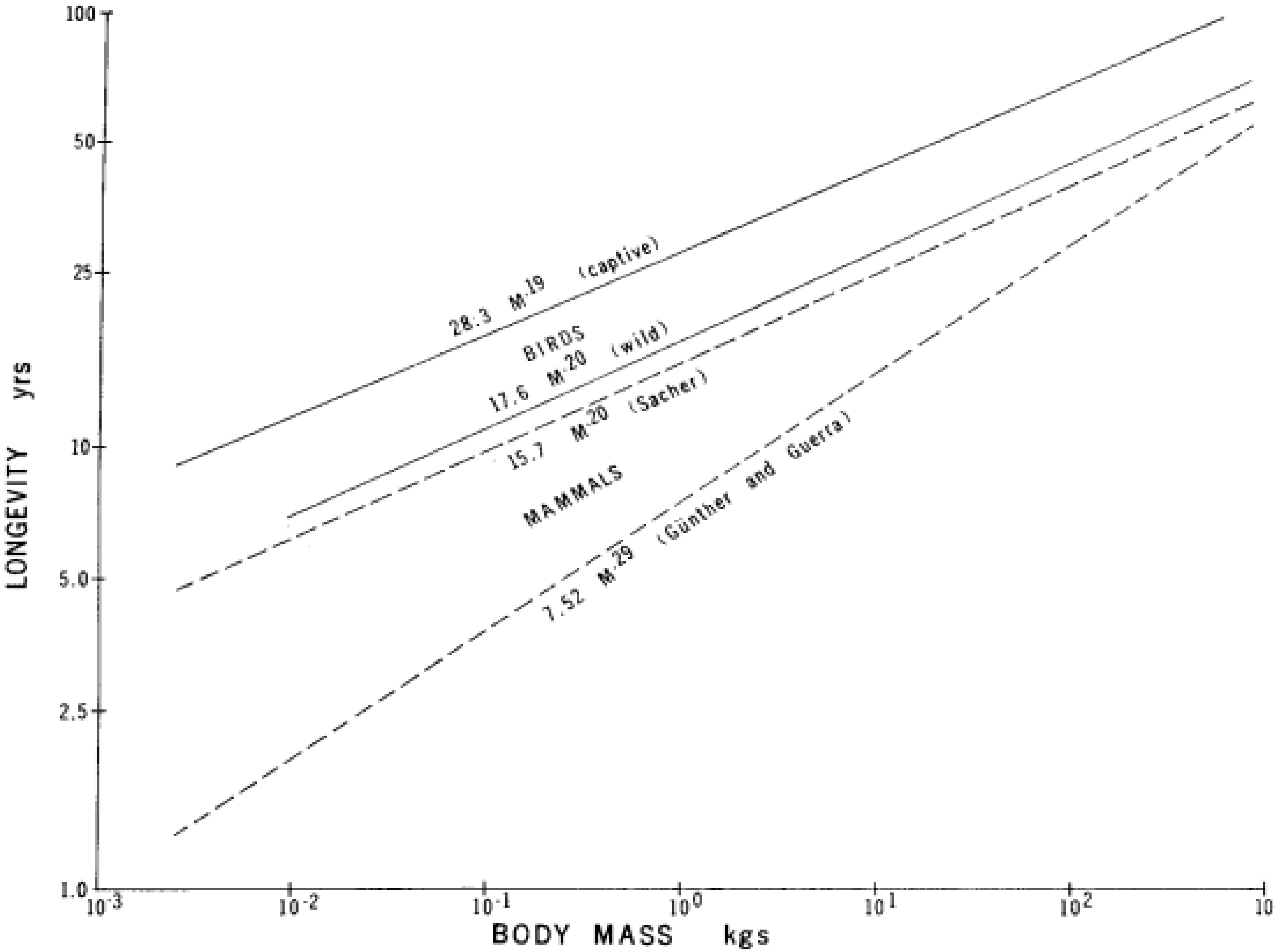
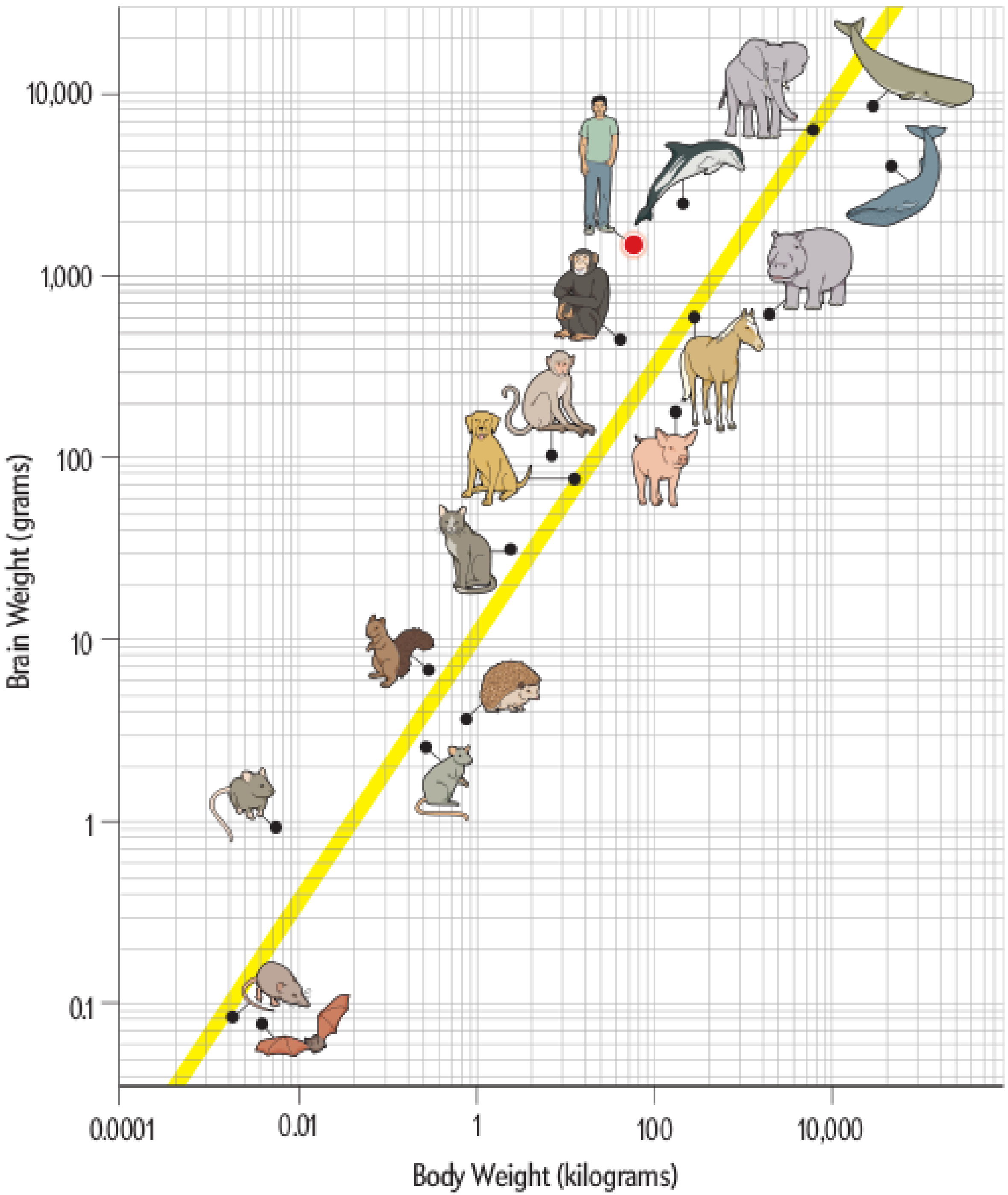


FIGURE 2. The relation of longevity and body weight in wild and captive birds compared with lines for mammals from equations by Günther and Guerra (1955) and Sacher (1959).



10,000
1,000
100
10
1
0.1
Brain Weight (grams)
0.0001
0.01
1
100
10,000
Body Weight (kilograms)

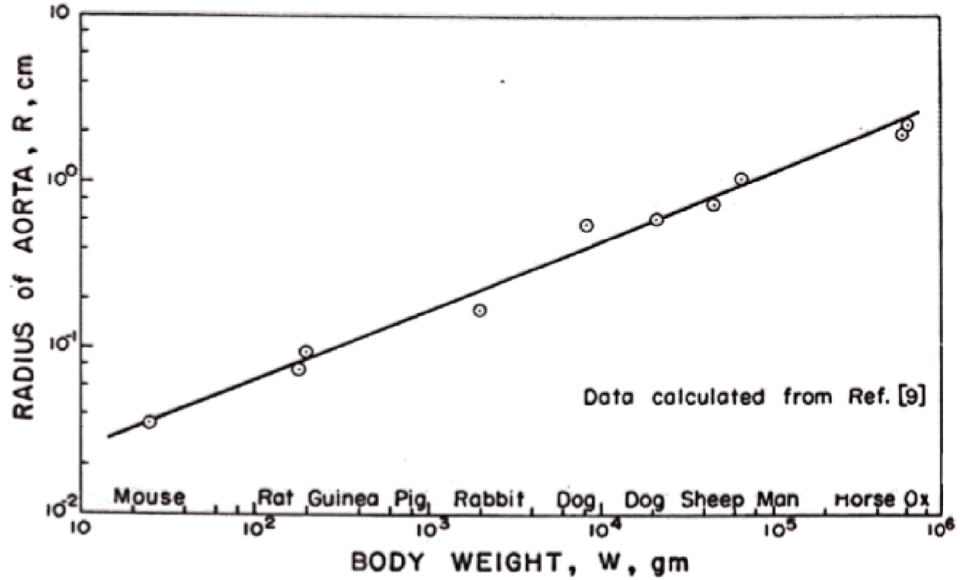


FIG. 4 – VARIATION IN RADIUS OF AORTA WITH BODY WEIGHT

$r \sim M^{3/8}$

SAME SCALING FOR TREE TRUNKS

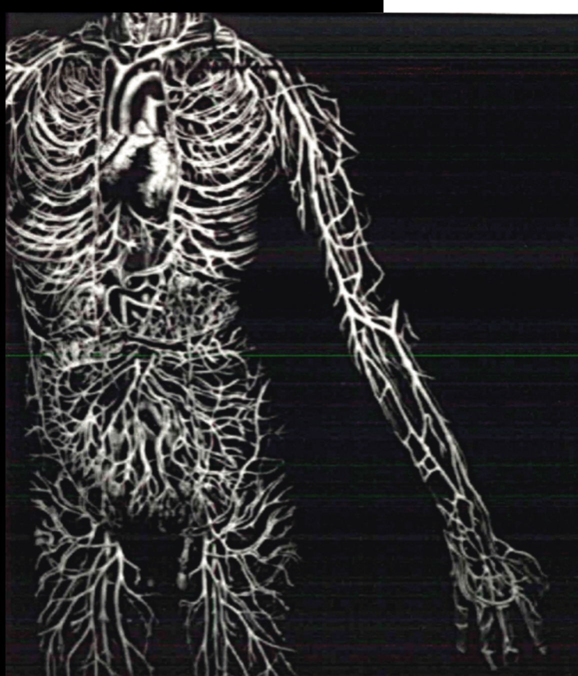


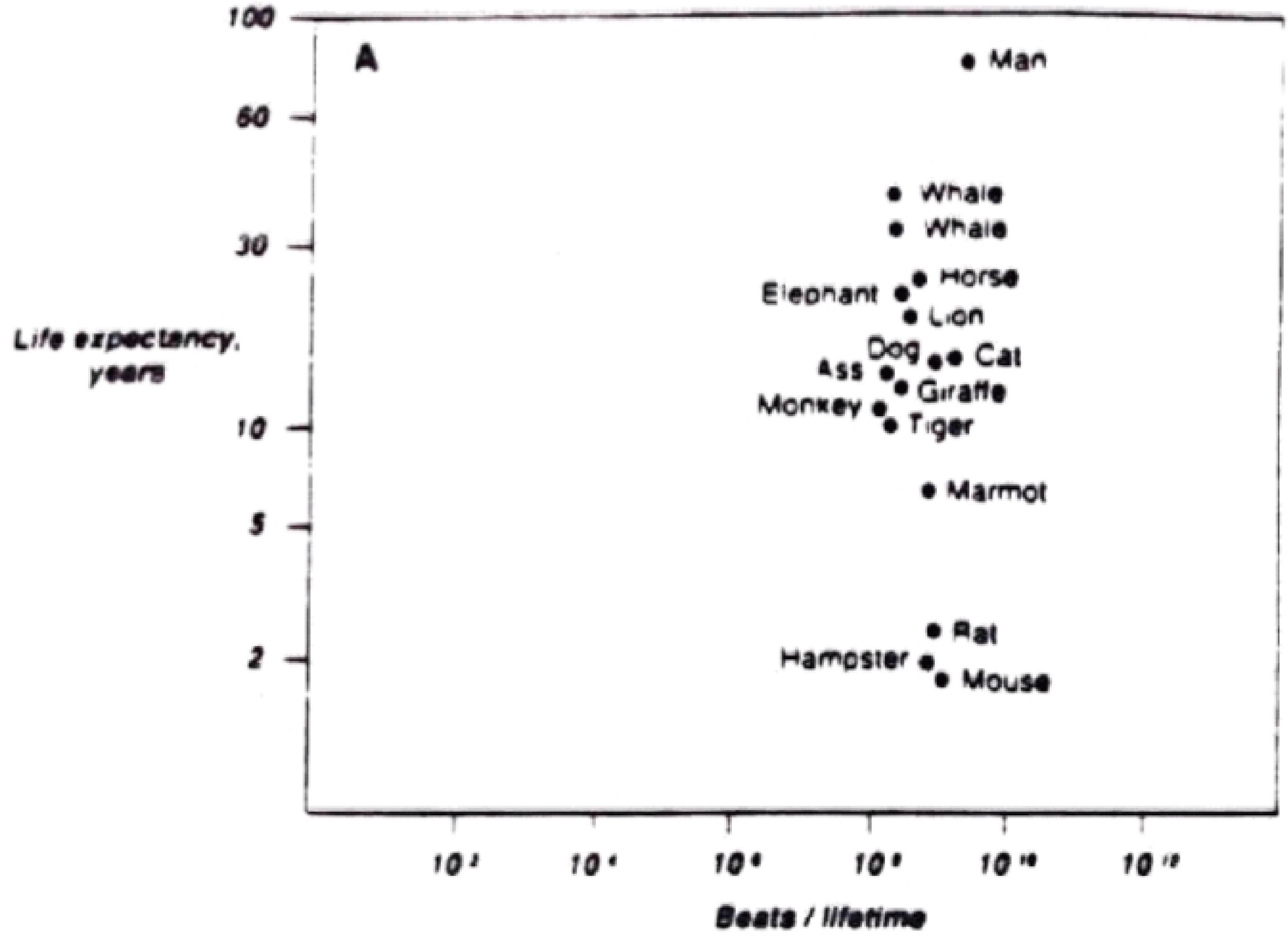
TABLE II. Values of allometric exponents for variables of the mammalian respiratory system predicted by the model compared with empirical observations. References not cited above can be found in refs. 2 and 3.

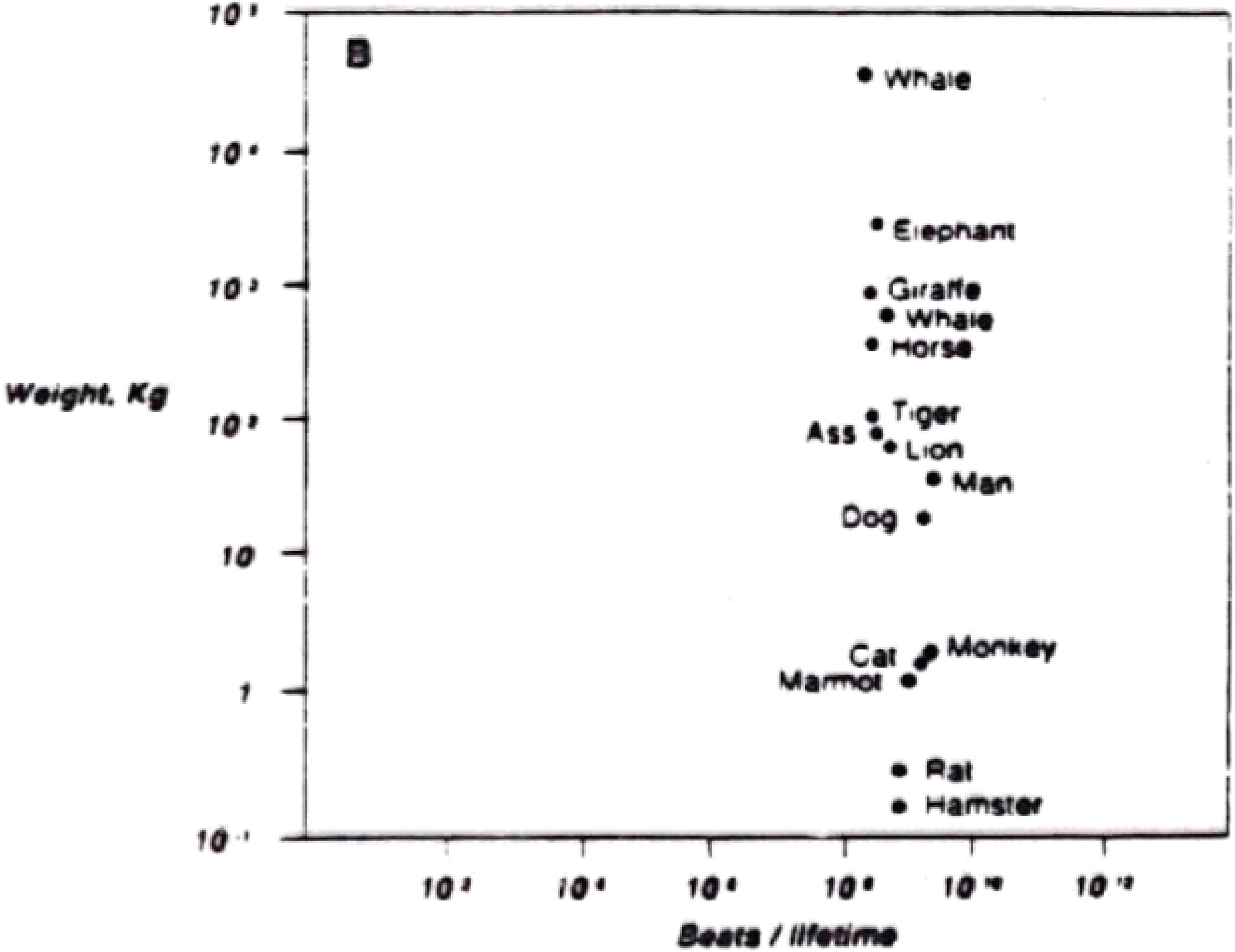
VARIABLE	SCALING EXPONENT		REFERENCE
RESPIRATORY SYSTEM	PREDICTED	OBSERVED	
Lung Volume	$1 = 1.00$	1.05	Weibel, 1973
Respiratory Frequency	$-\frac{1}{4} = -0.25$	−0.26	Stahl, 1967
Volume Flow to Lung	$\frac{3}{4} = 0.75$	0.80	Stahl, 1967
Interpleural Pressure	$0 = 0.00$	0.004	Gunther & de la Barra, 1966
Diameter of Trachea	$\frac{3}{8} = 0.375$	0.39	Tenney & Bartlett, 1967 and pers. comm. in Calder, 1984
Air Velocity in Trachea	$0 = 0.00$	0.02	Calder (calculated), 1984
Tidal Volume	$1 = 1.00$	1.041	Maina & Settle, 1982
Power Dissipated	$\frac{3}{4} = 0.75$	0.78	Stahl, 1967
Number of Alveoli, N_A	$\frac{3}{4} = 0.75$	Not Available	-
Volume of Alveolus, V_A	$\frac{1}{4} = 0.25$	Not Available	-
Radius of Alveolus, r_A	$\frac{1}{12} = 0.083$	0.13	Tenney & Remmers, 1963
Surface Area of Alveolus, A_A	$\frac{1}{6} = 0.083$	Not Available	
Surface Area of Lung, A_L	$\frac{11}{12} = 0.92$	0.95	Gehr et al., 1981
Oxygen Diffusing Capacity	$1 = 1.00$	0.99	Gehr et al., 1981
Total Airway Resistance	$-\frac{3}{4} = -0.75$	0.70	Stahl, 1967
Oxygen Consumption Rate	$\frac{3}{4} = 0.75$	0.76	Stahl, 1967

TABLES

TABLE I. Values of allometric exponents for variables of the mammalian circulatory system predicted by the model compared with empirical observations. The radius, length and velocity of blood in the capillary are all assumed to be independent of M. References not cited above can be found in refs. 2 and 3.

VARIABLE	SCALING EXPONENT		REFERENCE
CIRCULATORY SYSTEM	PREDICTED	OBSERVED	
Radius of Aorta, r_0	$\frac{3}{8} = 0.375$	0.36	Holt et al. 1981
Pressure in Aorta, Δp_0	$0 = 0.00$	0.032	Gunther & de la Barra, 1966
Velocity of Blood in Aorta, u_0	$0 = 0.00$	0.07	Milnor, 1979
Blood Volume, V_b	$1 = 1.00$	1.00	Prothero, 1980
Circulation Time	$\frac{1}{4} = 0.25$	0.25	Schmidt-Nielsen, 1984
Circulation Distance, l	$\frac{1}{4} = 0.25$	Not Available	-
Cardiac Stroke Volume	$1 = 1.00$	1.03	Gunther, 1975
Cardiac Frequency, ω	$-\frac{1}{4} = -0.25$	−0.25	Stahl, 1981
Cardiac Output, $\dot{E}$	$\frac{3}{4} = 0.75$	0.74	Gunther, 1975
Number of Capillaries, N_c	$\frac{3}{4} = 0.75$	Not Available	-
Supply Radius of Cells	$\frac{1}{12} = 0.083$	Not Available	
Radius of Krogh Cylinder	$\frac{1}{8} = 0.125$	Not Available	-
Density of Capillaries	$-\frac{1}{12} = -0.083$	−0.095	Hoppeler et al., 1981
Oxygen Affinity of Blood, P_{50}	$-\frac{1}{12} = -0.083$	−0.089	Dhindsa et al., 1971
Total Peripheral Resistance, Z	$-\frac{3}{4} = -0.75$	0.76	Gunther, 1975
Womersley Number, α	$\frac{1}{4} = 0.25$	0.25	-
Metabolic Rate, B	$\frac{3}{4} = 0.75$	0.75	Stahl, 1967


A
100
60
30
10
5
2
Life expectancy, years
Man
Whale
Whale
Horse
Elephant
Lion
Dog
Cat
Ass
Giraffe
Monkey
Tiger
Marmot
Rat
Hampster
Mouse
10^{2}
10^{4}
10^{6}
10^{8}
10^{10}
10^{12}
Beats / lifetime


B
Whale
Elephant
Giraffe
Whale
Horse
Tiger
Ass
Lion
Man
Dog
Cat
Monkey
Marmot
Rat
Hamster
Weight, Kg
10
1
Beats / lifetime