Bulgarian Journal of Veterinary Medicine (2005), 8, No 1, 13–22

ALLOMETRIC RELATIONSHIP BETWEEN THE LENGTH OF PREGNANCY AND BODY WEIGHT IN MAMMALS

A. T. ATANASOV

Department of Physics and Biophysics, Faculty of Medicine,
Trakia University, Stara Zagora, Bulgaria

Summary

Atanasov, A. T., 2005. Allometric relationship between the length of pregnancy and body weight in mammals. *Bulg. J. Vet. Med.*, **8**, No 1, 13–22.

The relationship between the length of pregnancy and the body weight in mammals – Metatheria and Placentalia, including 17 orders of animals with body weights ranging from 8 g to 15 t was investigated. It was found out that an allometric relationship existed, that could be described by the equation $T = 7.545 \times M^{0.2689}$, where T – pregnancy length in days, M – body weight in grammes, 7.545– allometric coefficient, 0.2689 – power allometric coefficient.

Key words: body weight, length of pregnancy, mammals

INTRODUCTION

There are numerous scientific reports about allometric relationships between animal body weight and a number of physiological parameters (Kleiber, 1961; Schmidt-Nielsen, 1984; McNab, 1988) – the rate and frequency as traits of physiological and biochemical processes, metabolism rate (Ballard *et al.*, 1969), the biological half-life of various drugs (Lashev & Pashov, 1992; Lashev *et al.*, 1992, 1995; Pashov *et al.*, 1997; West *et al.*, 2002) etc.

From the point of view of practical and theoretical medicine, allometric relationships regarding the innate processes in animals are particularly interesting. Having studied numerous birds with body weights ranging from 2.5 g (colibri) to 1000 kg (epiornis) Rann & Ar (1974) revealed an allometric relationship between the incubation time and egg weight whereas Rahn *et al.* (1975) showed the link between incubation time and the weight of parent birds.

The studies upon the pregnancy in large varieties of animal species are scarce (Atanasov, 2004, 2005). With this connection, we investigated the presence of an allometric relationship between the body weight of mammals and the length of pregnancy as well as the influence of genotype on such a correlation.

MATERIALS AND METHODS

The data for the studied mammal species, their body weight and pregnancy lengths were collected from review papers (Walker, 1968; Markov, 1980; Grant, 1980; Maurice, 1962; Naumov & Kuzyakina, 1971) and original articles. The present investigation included 105 animal species from the Mammalia class from Metatheria and Placentalia subclasses and the following orders: Marsupialia, Insectivora, Chiroptera, Edentata, Pholidota, Rodentia, Lagomorpha, Carnivora, Artiodactyla, Tylopoda, Perissodactyla, Hyracoidea, Proboscidea, Tubulidentata, Pinnipeda, Cetacea, Primates. The majority of data refer to wild animals living in their natural environement. Only for kangaroos, the sum of pregnancy length and the development of the joey in female's pouch is presented.

The relationships were calculated by means of a statistical software package (Statistica), licensed in the Space Research Institute (Bulgarian Academy of Sciences, Stara Zagora). The scaling exponents of functions were estimated using the least squares linear regression as well as the correlation coefficient between the length of pregnancy and parental body weight, the root mean square error and the level of significance of regression using the F-criterion and 95% confidence interval. A similar methodological approach was successfully used earlier in the study and modeling of the other allometric phenomena (Atanasov & Dimitrov, 2002, Hassard, 1991).

RESULTS

The data for body weights and pregnancy lengths in 105 mammal species are presented in Table 1.

The weights of mammals included in this study ranged from 8–15 g in the common shrew (*Sorex araneus*) to 12.5 t in the killer whale (*Orcinus orca*). The length of pregnancy varied from 19.5 days in the house mouse *(Mus musculus)* to 660 days in the African elephant (*Loxodonta africana*).

The calculations showed that the allometric relationship between pregnancy length and the body weight in studied 105 mammal species could be approximated by a logarithmic function as followed:

(1) $\log T = a + b \log M$

where T – length of pregnancy (days), M – body weight of animals (g).

The coefficients *a* and *b,* calculated by the least squares method were 0.878 ± 0.060 and 0.2689 ± 0.013, respectively.

The correlation coefficient (r = 0.899 ± 0.043) was high and thus indicated a

Table 1. Body weight and pregnancy length in mammals. The species are arranged in ascending weight order

Animals	Body mass, kg	Pregnancy, days	Reference
1. Common shrew (*Sorex araneus*)	0.008–0.015	20	Searle, 1984
2. Mouse (*Mus musculus*)	0.021	19–20	Goodwin *et al.*, 1980
3. Chinese hamster (*Cricetulus migratorius*)	0.021	20	Sato *et al.*, 1984
4. Golden mouse (*Ochrotomys nuttali*)	0.015–0.030	30	Markov, 1980
5. Masked hunter (*Myomimus personatus*)	0.024–0.025	20–25	Markov, 1980
6. White-footed mouse (*Peromyscus leucopus*)	0.020–0.060	21–28	Markov, 1980
7. Grasshopper mouse (*Onychomys leucogaster*)	0.040–0.060	30–35	Markov, 1980
8. Squirrel (*Citellus citellus*)	0.150–0.350	25–28	Markov, 1980

Table 1 (continued)

Animals	Body mass, kg	Pregnancy, days	Reference
9. Woodrat (*Neotoma cinerea*)	0.190–0.430	30–37	Olsen, 1968
10. Rat (*Rattus rattus*)	0.250–0.380	20–24	Grant, 1980
11. Chinchilla (*Chinchilla laniger*)	0.300–0.600	108–112	Kuroiwa & Imamichi, 1977
12. Norway rat (*Rattus norvegicus*)	0.384	21–22	Grant, 1980
13. Hamster (*Cricetus cricetus*)	0.400	30	Lee *et al.*, 1975
14. Guinea pig (*Cavia porcellus*)	0.510	68	Grant, 1980
15. Red squirrel (*Sciurus vulgaris*)	0.180–1.0	38–44	Naumov & Kuzjakina, 1971
16. Steppe polecat (*Mustela lutreola*)	0.550–0.800	42–46	Mead *et al.*, 1990
17. Hedgehog (*Erinaceus europaeus*)	0.700–0.800	49	Naumov & Kuzjakina, 1971
18. Musk rat (*Ondatra zibethica*)	0.950	25	Widayati *et al.*, 2003
19. Suslik (*Citellus major*)	1.050	30	Markov, 1980
20. Mink (*Mustela vison*)	1.500	34–78	Markov, 1980
21. Rabbit (*Lepus tolai*)	3.0–4.0	50	Markov, 1980
22. Red panda (*Ailurus fulgens*)	3.0–4.5	90–150	Markov, 1980
23. Bobac burrow (*Marmota bobac*)	4.5–6.0	30	Concannon *et al.*, 1983
24. Marmot (*Marmota marmota*)	4.0–8.0	35	Markov, 1980
25. Brown hare (*Lepus europaeus*)	4.0–5.0	44	Caillol *et al.*, 1991
26. Mountain hare (*Lepus timidus*)	3.0–5.0	47–55	Caillol *et al.*, 1991
27. Blue fox (*Alopex lagopus*)	6.0	52	Osadchuk & Shurkalova, 1992
28. Armadillo (*Dasypus novemcinctus*)	6.0	120	Walker, 1968
29. Feral coypu (*Myocastor coypus*)	up to 6.0	130	Walker, 1968
30. Domestic cat (*Felis familiaris*)	up to 6.0	60–63	Walker, 1968
31. Grey fox (*Urocyon cinereoargentus*)	7.0	63	Walker, 1968
32. Gibbon (*Hylobater lar*)	6.0–10.0	210	Walker, 1968
33. Fox (*Vulpes vulpes*)	6.0–10.0	49–58	Marks *et al.*, 2001
34. Cat (*Felis libyca*)	5.0	60	Naumov & Kuzjakina, 1971
35. Raccoon (*Procyon lotor*)	7.0–8.0	63	Naumov & Kuzjakina, 1971
36. Raccoon dog (*Nyctereutes procyonides*)	6.0–10	65	Naumov & Kuzjakina, 1971
37. Wildcat (*Felis silvestris*)	6.0–10	63–68	Naumov & Kuzjakina, 1971
38. Golden jackal (*Canis aureus*)	7.0–13	60–63	Naumov & Kuzjakina, 1971
39. Coyote (*Canis latrans*)	13	60–65	Naumov & Kuzjakina, 1971
40. Indian wild dog (*Cuon alpinus*)	14–21	62–64	Naumov & Kuzjakina, 1971
41. African wild dog (*Lycaon pictus*)	16–23	63–80	Naumov & Kuzjakina, 1971
42. Wolf (*Chrysocyon jubatus*)	18	63	Naumov & Kuzjakina, 1971
43. Collored peccary (*Tayassu tajacu*)	18–25	142–149	Naumov & Kuzjakina, 1971
44. Muntjac (*Muntiacus muntjak*)	15–35	180	Naumov & Kuzjakina, 1971
45. Roe deer (*Capreolus capreolus*)	20–37	165	Naumov & Kuzjakina, 1971

Table 1 (continued)

Animals	Body mass, kg	Pregnancy, days	Reference
46. Domestic dog (*Canis familiaris*)	29	60–64	Scantlebury *et al.*, 2000
47. Giant anteater (*Myrmecophaga tridactyla*)	30–35	180	Walker, 1968
48. Wolverine (*Gulo gulo*)	30	120	Walker, 1968
49. Eurasian lynx (*Lynx lynx*)	32	63–70	Walker, 1968
50. Gazelle (*Gazella subgutturosa*)	33	150–180	Pickard *et al.*, 2001
51. Chamois (*Rupicapra rupicapra*)	25–45	180	Walker, 1968
52. Angora goat (*Capra aegagrus*)	up to 38	150	Walker, 1968
53. Leopard (*Panthera pardus*)	32–40	90	Walker, 1968
54. Wolf (*Canis lupus*)	32–50	65–75	Walker, 1968
55. Merino sheep (*Ovis aries*)	49	148	Buckrell *et al.*, 1990
56. Tufted deer (*Elaphodus cephalophus*)	40–50	180	Naumov & Kuzjakina, 1971
57. Deer (*Cervus danka*)	40–80	225–240	Naumov & Kuzjakina, 1971
58. Man (*Homo sapiens*)	60	280	Markov, 1980
59. Saiga antelope (*Saiga tatarica*)	60	150	Markov, 1980
60. Sheep (*Ovis orientali*)	46–79	150	Markov, 1980
61. Dog (*Canis lupus familiaris*)	65	64–68	Markov, 1980
62. Spotted hyena (*Crocuta crocuta*)	59–82	110	Holekamp *et al.*, 1996
63. Sika deer (*Cervus nippon*)	73–84	225	Holekamp *et al.*, 1996
64. Red kangaroo (*Macropus rufus)*	80–150	275	Holekamp *et al.*, 1996
65. Chimpanzee (*Pan troglodytes*)	up to 70	270	Holekamp *et al.*, 1996
66. Spotted deer (*Cervus axi*)	75–100	210–225	Holekamp *et al.*, 1996
67. Puma (*Felis concolor*)	up to 105	90	Holekamp *et al.*, 1996
68. Swine (*Sus scrofa*)	60–150	124–140	Mauget, 1972
69. Goat (*Capra falconeti*)	109	150–180	Naumov & Kuzjakina, 1971
70. Ibex kid (*Capra ibex*)	110	154–161	Naumov & Kuzjakina, 1971
71. Warthog (*Phacochoerus aethiopicus*)	50–150	171–175	Naumov & Kuzjakina, 1971
72. Siberian ibex (*Capra sibirica*)	100–130	170–180	Naumov & Kuzjakina, 1971
73. Harbur seal (*Phoca vitulina*)	150	270–300	Naumov & Kuzjakina, 1971
74. Llama (*Lama glama*)	up to 110	330–397	Naumov & Kuzjakina, 1971
75. Argali sheep (*Ovis ammon*)	100–170	150–180	Naumov & Kuzjakina, 1971
76. Lion (*Panthera leo*)	180–240	105–112	Schmidt *et al.*, 1979
77. Gorilla (*Gorilla gorilla*)	110–300	270	Naumov & Kuzjakina, 1971
78. South American tapir (*Tapirus terrestris*)	200	390–400	Naumov & Kuzjakina, 1971
79. Sambar deer (*Cervus unicolo*)	150–315	249–284	Naumov & Kuzjakina, 1971
80. Tiger (*Panthera tigri*)	227–272	95–154	Donohue *et al.*, 1990
81. Brown bear (*Ursus arctos*)	250	180–240	Markov, 1980
82. Orangutan (*Pongo pygmaeus*)	up to 250	270	Markov, 1980

Table 1 (continued)

Animals	Body mass, kg	Pregnancy, days	Reference
83. Red deer (*Cervus elaphus*)	300–340	165–224	Markov, 1980
84. Muskox (*Ovibos moschatus*)	up to 300	270	Markov, 1980
85. Zebra (*Equus burchelli*)	up to 350	361–390	Markov, 1980
86. Camel (*Camelus bactrianus*)	450–490	365–440	Markov, 1980
87. Polar bear (*Ursus maritimus*)	700	230–250	Markov, 1980
88. European bison (*Bison bonasus*)	600–800	270	Roden *et al.*, 2003
89. Yak bos grunniens (*Poephagus gruniens*)	up to 720	255–304	Naumov & Kuzjakina, 1971
90. Horse (*Equus caballus*)	up to 700	350	Naumov & Kuzjakina, 1971
91. Alaskan grizzly (*Ursus horribilis*)	up to 800	250	Naumov & Kuzjakina, 1971
92. Buffalo (*Bubalus caffer*)	800–1000	270–280	Grimstell, 1973
93. Giraffe (*Giraffa camelopardalis*)	1000	420–446	Naumov & Kuzjakina, 1971
94. Bison (*Bison bison*)	up to 1000	265–270	Naumov & Kuzjakina, 1971
95. Beluga whale (*Delphinapterus leucas*)	up to 1000	330–360	Naumov & Kuzjakina, 1971
96. Buffalo (*Bubalus arnee*)	1000–1200	300–328	Naumov & Kuzjakina, 1971
97. African buffalo (*Syncerus caffer*)	1000–1200	330	Naumov & Kuzjakina, 1971
98. Malayan tapir (*Tapirus indicus*)	1500	390–395	Naumov & Kuzjakina, 1971
99. Black rhinoceros (*Diceros bicornis*)	up to 2000	450–548	Radcliffe *et al.*, 2001
100. Indian rhinoceros (*Rhinoceros unicornis*)	up to 2000	419–550	Radcliffe *et al.*, 2001
101. Hippopotamus (*Hippopotamus amphibius*)	3000–3200	210–240	Walker, 1968
102. White rhinoceros (*Ceratotherium simum*)	3000	540	Markov, 1980
103. Asian elephant (*Elephas maximum*)	5000	607–641	Hodges, 1998
104. African elephant (*Loxodonta africana*)	7500	660	Hodges, 1998
105. Killer whale (*Orcinus orca*)	10000–15000	480	Markov, 1980

strong relationship between pregnancy length and parental body weight.

The root mean square error of deviation of points from regression line was $\sigma_{reg} = 0.177$.

For the *length of pregnancy/body weight* data, we found a very large and highly significant F value – 435.45 ($P<0.000001$), confirming that the relationship linking pregnancy length and body weight was a real one and not just a product of random variation (Hassard, 1991).

The equation (1) could be transformed into (2):

$$(2) \quad T = 10^a \times M^b = 10^{0.878} \times M^b = 7.545 \times M^{0.2689},$$

where 7.545 – allometric coefficient; 0.2689 – allometric scaling exponent.

DISCUSSION

The body weight of studied mammalian species comprised 6 orders of magnitude: from 8–15 g in common shrews (*Sorex araneus*) to 15.10^6 g in killer whales (*Orcinus orca*). Similar investigations in birds with differences in body weights amounting to 6 orders of magnitude are also reported (Rahn & Ar, 1974; Rahn *et al.*, 1975). The allometric relationship obtained in those studies between the period of egg incubation in days and the body weight of parental birds in grammes is described by the equation $T = 9.105 \times M^{0.176}$. The scaling exponent (0.176) in this function is considerably lower than that, obtained by us in mammalian allometric relationship (0.2689). This fact suggests that in mammals, the correlation between pregnancy length and parental body weight was stronger than that in birds. The values of linear allometric coefficients in both equations are comparable (9.105 and 7.454 in birds and mammals respectively). They could be compared because of the equal dimensions (grammes and days), used in both allometric functions.

Fig. 1. shows that mammals with differences in body weight of 2 orders of magnitude (100 times) have almost identical pregnancy length. For instance, the pregnancy in the common shrew (*Sorex araneus*) weighing 8–15 g and the Russet ground squirrel (*Citellus major*) weighing 1000 g is 20 and 25 days, respectively. The house mouse (*Mus musculus*) weighing 21 g and the black rat (*Rattus rattus*) weighing 250–380 g have a comparable pregnancy length of 19–24 days. Most probably, the similar pregnancy length in

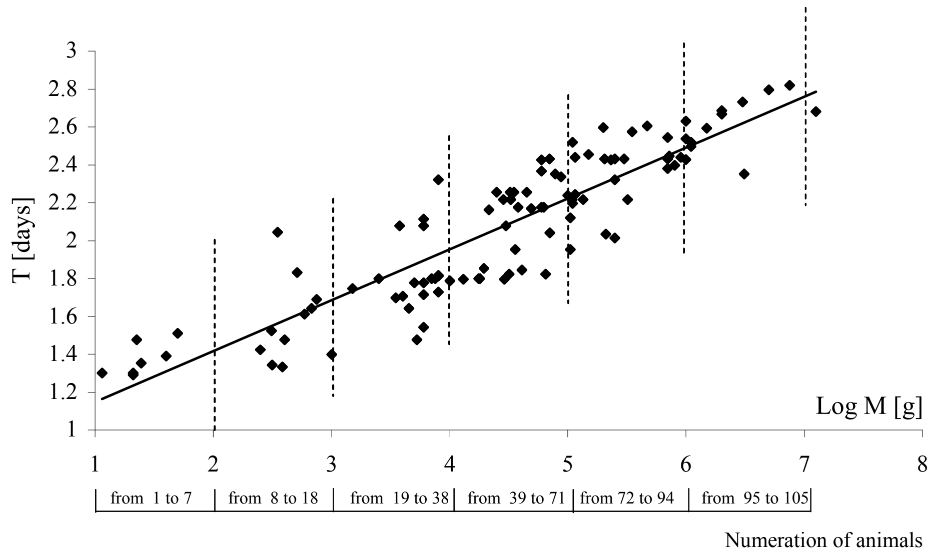

Fig. 1. Allometric relationship between pregnancy length (T, days) and body weight (M, g) of mammalian parents (continuous line). The average data about body weights and pregnancy lengths from Table 1 are plotted. The vertical dotted lines differentiate the dots' numbering, that is corresponding to the numeration of species in Table 1.

those animals is genetically coded despite the different number of chromosomes in the house mouse (*Mus musculus*) and the black rat (*Rattus rattus*) (40 and 42 respectively) (Leninger, 1982).

A similar duration of gestation, possibly due to the identical chromosome set is observed in the different dog breeds. In 60 dog breeds weighing from 0.5−1 kg (Manchester terrier and Chi-hua-hua) to 100 kg (Saint Bernard), the pregnancy lasts from 58 days in small to 65 days in large breeds (68−70 days in multiple pregnancy). If the least pregnancy length is accepted as 100%, the increase in pregnancy length with 12 days to 70 days, due to the higher weight amounts to 20.7% from the minimum coded pregnancy length. Fig. 1. also shows that there is an increase by about 20% in species from different orders with weights ranging within 2 orders of magnitude. For example, the difference in pregnancy lengths between the African wildcat (*Felis libyca*) having a body weight of 5 kg and pregnancy of 60 days and the domestic guinea pig (*Gavia porcellus*) with body weight of 510 g and pregnancy length of 68 days is 13−14%. The span between the minimum gestation length in the common shrew (20 days) and the maximum gestation length in the African elephant (660 days) is 33 times and the difference in their body weights − ~10^6 times.

It could be also noticed (Fig. 1) that animals with similar body weights could have pregnancy periods differing from 2 to 4.5−5 times. For example, the Siberian ibex (*Capra sibirica*) and the llama (*Lama glama*) are weighing about 100 kg, but the pregnancy period in llamas is twice longer. The difference in gestation lengths in the black rat (*Rattus rattus*) and the chinchilla (*Chinchilla laniger*) weighing 250−380 g and 300−600 g respectively is 4.5 times. In other instances, animals with body weight differences of 2 orders of magnitude have a similar pregnancy length as is the case with the chinchilla (*Chinchilla laniger*) and the spotted hyaena (*Crocuta crocuta*) whose pregnancies last 100 days but their body weights are 300−600 g and 59−82 kg respectively.

Having studied the metabolism rates and the weights of mammals in the "from mouse to elephant" range, Brody *et al.* (1934) obtain the allometric relationship $P=a\times M^{0.734}$ between metabolism rate (P) and the body weight (P). The same dependence, related to metabolism rate per unit weight (P/M=P* − intensity of metabolism) when presenting the weight in grammes is $P^*= 0.442\times M^{-0.266}$. The absolute value of the scaling exponent (−0.266) in this relationship is similar to that obtained in our study (+0.2689) for the relationship "pregnancy length vs body weight" in mammals. As the absolute values of both scaling exponents are equal, if both functions are equalized, the theoretical relationship between metabolism intensity and pregnancy length (T) could be obtained: $P^* \times T = 3.335$. The value 3.335 is a theoretical constant, product of allometric coefficients in the metabolism function (0.442) and in the pregnancy length function (7.545). The relationship between P* and T evidences that the duration of pregnancy is connecter with metabolism intensity of the parent. In allometric equations obtained by different investigators in birds, such a relationship does not exist. The scaling exponent in the relationship "metabolism rate vs body weight" in all birds is +0.668 (Lasiewski & Dawson, 1967) and when expressed through the intensity of metabolism in birds is –0.332. This scaling exponent is twice bigger than the respective value in the allometric equation presenting the relationship between egg incubation time and body weight of parental birds (Rahn *et al.*, 1975).

Some general conclusions could be deducted about the correlation of pregnancy length with genome, metabolism and the body weight. First, the pregnancy length is genetically coded. Given that the animals from a species could have a maximum differences in body weights of about 100 times and their gene set determines pregnancy lengths ranging within 10 days, the same is also valid for animals with similar differences in body weights of about 2 orders of magnitude, but belonging to different orders. Second, the pregnancy length depends on metabolism intensity of mammalian parents and on their body weight. The relationships $T = 7.545 \times M^{0.2689}$ and $P^* = 0.442 \times M^{-0.266}$ show that both parameters could be mutually more closely related than to parental body weight.

ACKNOWLEDGEMENTS

I would like to thank Dimitar Valev from the Space Research Institute (Bulgarian Academy of Sciences, Stara Zagora, Bulgaria) for his kind assistance in performing statistical analyses.

REFERENCES

Atanasov, A. T. & B. D. Dimitrov, 2002. Changes of the power coefficient in the 'metabolism-mass' relationship in the evolutionary process of animals. *Biosystems*, **66**, 65–71.

Atanasov, A. T., 2004. The allometric relationships between length of pregnancy, body mass and metabolism of mammals. In: *Proceedings of Ninth Conference on Biomedical Physics and Engineering,* 14–16 October, Sofia, Bulgaria, pp. 333–335.

Atanasov, A. T., 2005. Possible metabolism-body weight effect on prolongation and reduction of pregnancy duration. *Medical Hypotheses* (in press).

Ballard, F. J., R. W. Hanson & D. S. Kronfeld, 1969. Gluconeogenesis and lipogenesis in tissue from ruminant and nonruminant animals. *Federation Proceedings*, **28**, 218–231.

Brody, S., R. I. Procter & U. S. Ashworth, 1934. Basal metabolism, endogenous nitrogen, creatinine and neutral sulphur excretions as functions of body weight. *University Missoury Agricultural Sta. Research Bulletin*, **220**, 1– 40.

Buckrell, B. C., C. J. Gartley, K. G. Mehren, G. J Crawshaw, W. H. Johnson, I. K. Barker, J. Balke, C. Coghill, J. R. Challis & K. L. Goodrowe, 1990. Failure to maintain interspecific pregnancy after transfer of Dall's sheep embryos to domestic ewes. *Journal of Reproduction and Fertility*, **90**, 387–394.

Caillol, M., M. Mondain-Monval & B. Rossano, 1991. Gonadotrophins and sex steroids during pregnancy and natural superfoetation in captive brown hares (*Lepus europaeus*). *Journal of Reproduction and Fertility*, **92**, 299–306.

Concannon, P., B. Baldwin, J. Lawless, W. Hornbucke & B. Tennant, 1983. Corpora lutea of pregnancy and elevated serum progesterone during pregnancy and postpartum anestrus in woodchuck (*Marmota monax*). *Biology of Reproduction,* **29**, 1128–1134.

Donohue, A. M., L. A. Johnston, U. S. Seal, D. L. Armstrong, R. L. Tilson, P. Wolf, K. Petrini, L. G. Simmons, T. Gross & D. E. Wildt, 1990. In vitro fertilization and embryo development *in vitro* and *in vivo* in the tiger (*Panthera tigris*). *Biology of Reproduction*, **43**, 733–744.

Goodwin, P. J., V. J. Perez, J. C. Eatwell, J. L. Palet & M. T. Jaworski, 1980. Phencyclidine: Effect of chronic administration in the female mouse on gestation, maternal behaviour and neonates. *Psychopharmacology (Berlin)*, **69**, 63–67.

Grant, V., 1980. Evolution of Organisms. Mir, Moscow, Russia.

Grimsdell, J. J., 1973. Reproduction in the African buffalo, *Syncerus caffer*, in Western Uganda. *Journal of Reproduction and Fertility,* Supplement, **19**, 303–318.

Hassard, Th. H., 1991. Understanding Biostatistics. Mosby-Year Book, Inc, St. Louis, Missouri, USA.

Hodges, J. K., 1998. Endocrinology of the ovarian cycle and pregnancy in the Asian (*Elephas maximus*) and African (*Loxodontia africana*) elephant. *Animal Reproduction Science*, **53**, 3–18.

Holekamp, K. E., L. Smale & M. Szykman, 1996. Rank and reproduction in the female spotted hyaena. *Journal of Reproduction and Fertility*, **108**, 229–237.

Kleiber, M., 1961. The Fire of Life. Wiley, New York.

Kuroiwa, J. & T. Imamichi, 1977.Growth and reproduction of the chinchills – age at vaginal opening, oestrous cycle, gestation period, litter size, sex ratio and dieases frequently encountered (Japanese). *Jikken Dobutsu. Experimental animals*, **26**, 213–222.

Lashev, L. D. & D. A. Pashov, 1992. Interspecies variations in plasma half-life of ampicillin, amoxycillin, sulphadimidine and sulphacetamide related to variations in body mass. *Research in Veterinary Science*, **53**, 160–164.

Lashev, L. D., D. A. Pashov & T. Marinkov, 1992. Interspecies differences in the pharmacokinetics of kanamycin and apramycin. *Veterinary Research Communications*, **16**, 293–300.

Lashev, L. D., D. A. Pashov & I. Kanelov, 1995. Species specific pharmacokinetics of rolitetracycline. *Zentralblatt für Veterinär Medizin*, **42**, 201–208.

Lasiewski, R.C. & W.R. Dawson, 1967. A reexamination of the relation between standard metabolic rate and body weight in birds. *The Condor*, **69**, 13–23.

Lee, C.S., T. Nishida & K. Mochizuki, 1975. Normal prenatal growth of the golden hamster. *Jikken Dobutsu. Experimental animals*, **24**, 53–60.

Leninger, A. L., 1982. Principles of Biochemistry. Worth Publishers, Inc., The John Hopkins University, School of Medicine.

MacNab, B. K., 1988. Complications inherent in scaling the basal rate of metabolism in mammals.*The Quarterly Review of Biology*, **63**, 25–63.

Markov, G., 1980. Animals. 2nd edn, Nauka i izkustvo, Sofia, Bulgaria (BG).

Marks, C. A., L. Jalkanen, R. Savolainen & R.V. Short, 2001. Control of red fox (*Vulpes vulpes*) fertility with cabergoline: Dose response and timing of intervention. *Reproduction (Cambridge, England)*, **122**, 147–154.

Mauget, R., 1972. Observations on reproduction in wild swine (*Sus scrofa* L.). *Annales de biologie animale, biochimie, biophysique*, **12**, 195–202.

Maurice, B., 1962. Systematic Dictionary of Mammals of the World. Museum Press, London.

Mead, R. A., S. Neirinckx & N. M. Czekala, 1990. Reproductive cycle of the steppe polecat (*Mustela eversmanni*). *Journal of Reproduction and Fertility*, **88**, 353–360.

Naumov, S. P. & A. P. Kuzjakina, 1971. Life of Animals, vol 6. Prosveshtenie, Moscow, Russia.

Olsen, R. W., 1968. Gestation period in *Neotoma mexicana*. *Journal of Mammals*, **49**, 533–534.

Osadchuk, L. V. & T. A. Shurkalova, 1992. The testosterone level in the testes of silver foxes during prenatal development. *Ontogenez*, **23**, 385–389.

Pashov, D. A., L. D. Lashev, Matev I. V. & I. N. Kanelov, 1997. Interspecies comparison of plasma half-life of trimethoprim in relation to body mass. *Journal of Veterinary Pharmacology and Therapeutics*, **20**, 48–53.

Pickard, A. R., T. Abaigar, D. I. Green, W. V. Holt & M. Cano, 2001. Hormonal characterization of the reproductive cycle and pregnancy in the female Mohor gazella (*Gazella dama mhorr*). *Reproduction (Cambridge, England)*, **122**, 571–580.

Radcliffe, R. W., A. I. Eyres, M. L. Patton, N. M. Czekala & R.H. Emslie, 2001. Ultrasonographic characterization of ovarian events and fetal gestation parameters in two southern black rhinoceros (*Diceros bocornis minor*) and correlation to fecal progesterone. *Theriogenology,* **55**, 1033–1049.

Rahn, H. & A. Ar, 1974. The avian egg: Incubation time and water loss. *The Condor*, **76**, 147–152.

Rahn, H., C. V. Paganelli & A. Ar, 1975. Relation of avian egg to body weight. *The Auk*, **92**, 750–765.

Sato, T., K. Komeda & K. Shirama, 1984. Plasma progesterone concentrations during the estrous cycle, pregnancy and lactation in the Chinese hamster *Cricetulus gricens*. *Jikken Dobutsu. Experimental animals*, **33**, 501–508.

Scantlebury, M., R. Butterwick & J. R. Speakmen, 2000. Energetics of lactation in domestic dog (*Canis familiaris*) breeds of two size. *Comparative Biochemistry and Physiology. Part A, Molecular and Integrative Physiology*, **125**, 197–210.

Schmidt, A. M., L. A. Nadal, M. J. Schmidt & N. B. Beamer, 1979. Serum concentrations of oestradiol and progesterone during the normal oestrus cycle and early pregnancy in the lion (*Panthera leo*). *Journal of Reproduction and Fertility*, **57**, 267–272.

Schmidt-Nielsen, K., 1984. Scaling. Why is Animal Size so Important? Cambridge University Press, Cambridge, London, New York, New Rochelle, Melbourne, Sydney.

Searle, J. B., 1984. Breeding the common shrew (*Sorex araneus*) in captivity. *Laboratory animals*, **18**, 359–363.

Walker, E. P., 1968. Mammals of the World, 2nd edn, vol. I–II. Baltimore, Hopkins.

West, G. B., W. H. Woodruff & J. H. Brown, 2002. Allometric scaling of metabolic rate from molecules and mitochondria to cells and animals. *Proceedings of the National Academy of Sciences of the United State of America*, Suppl. 1, 2473–2478.

Widayati, D. T., U. Mekada, S. Oda, E. Zholnerovskaya, S. M. Zakiyan & K. Fukuta, 2003. Reproductive features of the Russian vole in laboratory breeding. *Experimental Animals*, **52**, 329–334.

Paper received 17.05.2004; accepted for publication 26.01.2005

Correspondence:

Atanas Todorov Atanasov
Department of Physics and Biophysics,
Faculty of Medicine,
Trakia University,
11 Armeiska str.,
6000 Stara Zagora, Bulgaria.
E-mail: atanastod@abv.bg