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Variations in the Size of the African Grasscutter (*Thryonomys swinderianus*, Temminck, 1827) Brain during Normal Aging

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Abstract

Research Background: Aging in mammals is characterized by a gradual decline in the physiological functions and responses of organs and tissues. The African grasscutter (*Thryonomys swinderianus*) is the second largest rodent in sub-Saharan Africa. **Objectives:** The aim of this research was to record the brain sizes of African grasscutter across all age groups. **Methods:** Brain samples were collected from forty-two (42) male African grasscutter (AGC) using basic neuroanatomical techniques. Animals were divided into neonates (PND 6), peripubertal (PND 30), juveniles (PND 90), subadults (PND 240), young adults (PND 720), mid-adults (PND 1400), and older animals (PND 1800). The dimensions (length, width and height) of the brain, the cerebellum and olfactory bulb of each sample were examined with a one-way ANOVA ($P < 0.05$). **Results:** From neonates to the old adults, the length, width and height of the whole AGC brain increased respectively from 53.27 ± 0.04 mm to 64.28 ± 0.04 mm; 22.19 ± 0.03 mm to 31.11 ± 0.04 mm; and 1.28 ± 0.08 mm to 2.19 ± 0.03 mm. The dimensions of the olfactory bulb undergo a phase of growth and decline. The length, width and height of the olfactory bulb increased respectively from 7.23 ± 0.02 mm to 11.47 ± 0.02 mm; 0.23 ± 0.01 mm to 0.29 ± 0.02 mm and 0.16 ± 0.02 mm to 0.39 ± 0.03 mm. For the cerebellum, the dimensions increased from 16.56 ± 0.03 mm to 21.93 ± 0.05 mm for the length between 6 days of birth and 5 years, from 16.26 ± 0.03 mm to 25.22 ± 0.06 mm for the width between 6 days of birth and 4 years and 0.57 ± 0.03 mm to 1.04 ± 0.02 mm for the height between 6 days of birth and 2 years. Decreases were slight in older subjects. **Conclusions:** The current study concludes that the size of the whole brain, cerebellum and olfactory bulb varies with age and that brain maturation occurs between young and middle adults.

Keywords

African Grasscutter, Aging, Brain, Size

1. Introduction

Aging in mammals is characterized by a gradual decline in the physiological functions and responses of organs and tissues. With increasing age, a number of changes occur, including brain atrophy, oxidative stress and reduced antioxidant defense mechanisms, which contribute to impairments in learning, memory and physical activity [1]. Age is then the predominant risk factor for most diseases that impair quality of life and shorten lifespan, such as neurodegenerative diseases [2].

However, research into brain aging faces some difficulties, mainly related to experimental models. Animal experiments help us to understand human biology [3] and are important for understanding the pathophysiological and therapeutic basis of human diseases [4]. It is estimated that more than 115 million animals were used for research purposes in 2005 [5], and the number is increasing [6]. Rodents are the most commonly used animals in animal experiments [7] and account for approximately 80% of laboratory animals [8]. Studies with laboratory rodents have provided a wealth of information about age-related changes in the mammalian brain. Rodents are the largest group of placental mammals, accounting for more than half of all known mammals [9]. The African grasscutter (AGC) is a member of the suborder Hystricomorpha and the family Thryonomyidae. The African grasscutter is the second largest rodent in sub-Saharan Africa after the crested porcupine [10]. Studies have shown that AGC can be tamed and even used in laboratory animals [11], and recent work has been done to relate African grasscutter brain morphology to the functional aspects of different parts of the brain [12].

The aim of this research was to describe the change in brain morphometry in the aging African grasscutter. The results of the study will represent a significant addition to the AGC's growing brain anatomy database and provide new insights into neuroanatomical trajectories associated with normal aging.

2. Material and Method

2.1. Experimental Animal

This experimental study was conducted on 42 captured male AGC, including 6 neonates aged 6 days, 6 juveniles aged 30 days (1 month), 6 peripubertals aged 90 days (3 months), 6 subadults aged 240 days (8 months), 6 young adults aged 720 days (2 years), 6 middle adults aged 1400 days (4 years) and 6 old adults aged 1800 days (5 years). These animals were maintained at a temperature of 25 ± 2˚C, humidity of 50%, and natural photoperiod. Food and water were provided daily *ad libitum*. Veterinarians found no clinical signs of disease or behavioral problems in these animals.

2.2. Animal Cycle and Lifespan

AGC reaches sexual maturity at 5 months in females and 7 to 8 months in males [13]. Pregnancy lasts about 5 months, with two births per year. Litter size varies between 2 and 12, with an average of 4 and a sex ratio of about 1 [14]. Breastfeeding begins approximately thirty (30) minutes after the baby is born. Weaning occurs when the AGCs are one to one and a half months old [13]. Its average life expectancy in captivity varies between seven (7) and nine (9) years. Depending on the health care provided to the animals during their life, it can last up to 12 years [15].

2.3. Ethical Approval

All experimental procedures were carried out in accordance with the guidelines of the Togolese Bioethics Committee for Health Research (CBRS) and the 8th edition of the National Research Council Guide for the Care and Use of Laboratory Animals, USA.

2.4. Experimental Design

The animals were anesthetized with acepromazine and ketamine at the respective doses of 0.5 mg/kg body weight and 0.7 mg/kg until the first signs of anesthesia, including nystagmus, and myosis, were observed. The animals were then euthanized and their brains were removed. The dimensions—length, width, and height—were measured using the MG6001DC caliper (General Tools and Instruments Co., New York), which has a sensitivity of 0.01 cm, and the dimensions were converted to millimeters. **Figure 1** summarizes the different stages of the manipulation.

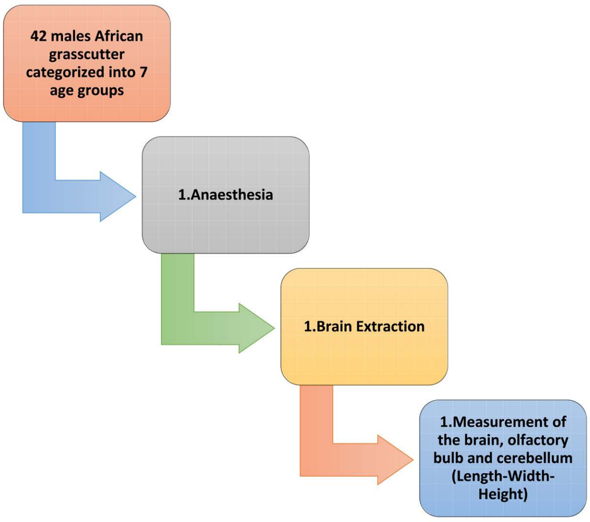


Figure 1. The major stages of manipulation.

2.5. Statistical Analysis

Statistical analysis was performed using Excel 2019 (Microsoft Office 2019) in conjunction with Graph Pad Prism 8.0 statistical software developed in San Diego, California, USA. Results were reported as mean and standard error of the mean (mean ± SEM). To determine statistical significance, a significance level of $P < 0.05$ was set. One-way analysis of variance (ANOVA) was used to assess differences between means, followed by Tukey's multiple comparison post hoc test. Each variable was examined statistically to identify correlations with age. To prevent confounding of outlier data without age-related factors, the relationships between age and the various parameters were analyzed using multiple regression analysis and assessed using Spearman's correlation coefficient (r) [16].

3. Results

3.1. Length

3.1.1. Brain Length

The mean length of the brain increased from 53.27 ± 0.04 mm to 64.28 ± 0.04 mm between the 6th birthday and the 5th year of life (Table 1). Statistical analyses were significant between age groups, except between neonates and peripubertals and between middle and old adults ($P < 0.05$).

Table 1. Length parameters according to the age of the AGC.

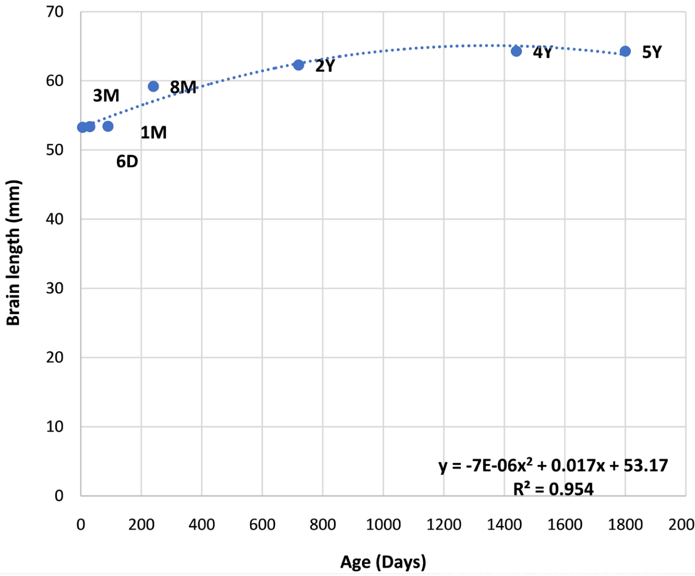
Length (mm)		Number of samples (n = 42)						
		6 days	1 month	3 months	8 months	2 years	4 years	5 years
Average ± SEM (mm)	BRL (mm)	53.27 ± 0.04^a	53.37 ± 0.04^a	53.43 ± 0.03^a	59.19 ± 0.07^b	62.29 ± 0.05^c	64.28 ± 0.03^d	64.28 ± 0.04^d
	OBL (mm)	7.23 ± 0.02^a	8.40 ± 0.03^b	9.44 ± 0.04^c	10.12 ± 0.06^d	10.49 ± 0.02^e	11.47 ± 0.02^f	11.42 ± 0.03^f
	CBL (mm)	16.56 ± 0.03^a	16.64 ± 0.04^a	17.67 ± 0.05^b	18.84 ± 0.03^c	20.90 ± 0.02^d	21.93 ± 0.05^e	21.93 ± 0.08^e

BRL: brain length. OBL: olfactory bulb length. CBL: cerebellum length. The means with the different superscript letters show a significant difference ($P \leq 0.05$) in the length of the brain, olfactory bulb, and cerebellum between age groups. Those with the same letters show no significant difference ($P > 0.05$) between age groups. The length of the brain, olfactory bulb, and cerebellum increases for up to 2 years and then decreases or stabilizes.

There was a significant positive correlation between brain length and age ($r = 0.90$; $P < 0.05$). Logarithmic regression analysis shows that age would explain 95.47% of the variability in brain length (Figure 2).

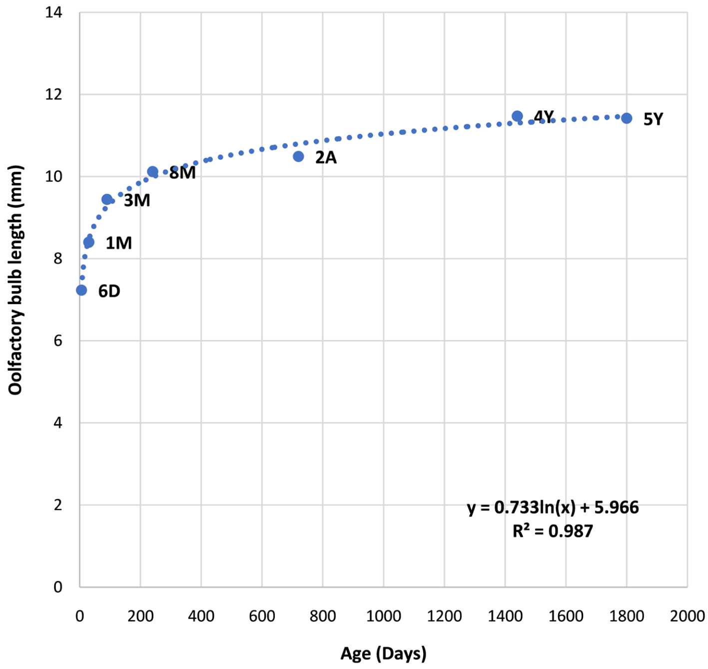
3.1.2. Olfactory Bulb Length

The mean length of the olfactory bulb increased from 7.23 ± 0.02 mm to 11.47 ± 0.02 mm between the 6th birthday and the 4th year of life (Table 1). It then decreases slightly between 4 and 5 years from 11.47 ± 0.02 mm to 11.42 ± 0.03 mm. Statistical analysis was significant between age groups, except for middle and old adults. There was a nonsignificant positive correlation between olfactory bulb length and AGC age (r = 0.8460; P < 0.05) (**Figure 3**). Logarithmic regression analysis shows that age would explain 98.79% of the variability in olfactory bulb length.



Positive quadratic relationship between brain length and age. By the age of 2, brain length increases. It stabilizes after 4 years. 6D: 6 days; 1M: 1 month; 3M: 3 months; 8M; 8 months; 2Y: 2 years; 4Y: 4 years; 5Y: 5 years.

Figure 2. Scatterplot of brain length versus age in AGC.

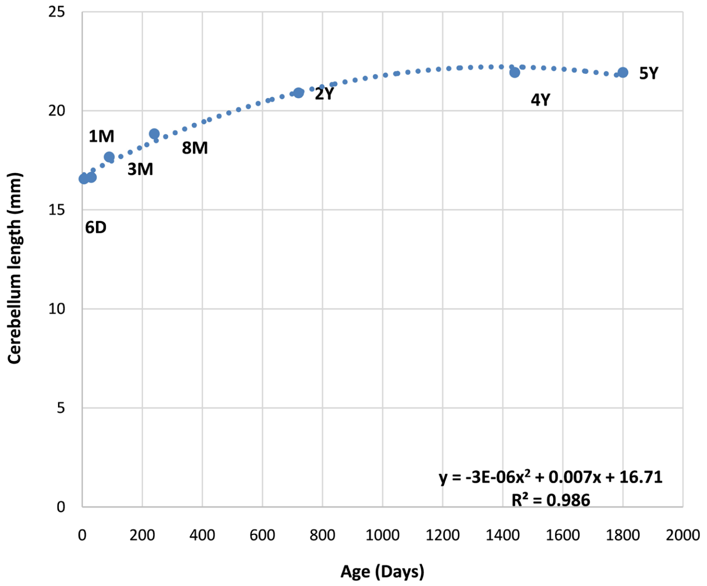


There is a positive logarithmic relationship between olfactory bulb length and age. The length of the olfactory bulb increases until age 2 and then stabilizes after age 4. 6D: 6 days; 1M: 1 month; 3M: 3 months; 8M; 8 months; 2Y: 2 years; 4Y: 4 years; 5Y: 5 years.

Figure 3. Scatterplot of olfactory bulb length versus age in AGC.

3.1.3. Cerebellum Length

The mean length of the cerebellum increased 16.56 ± 0.03 mm to 21.93 ± 0.05 mm between the 6th birthday and the 5th year of life (**Table 1**). Statistical analysis was significant between age groups, except for neonates and juveniles and middle to old adults. There was a significant positive correlation between cerebellum length and age of African grasscutter ($r = 0.93$; $P < 0.05$) (**Figure 4**). The quadratic regression analysis shows that age would explain 98.61% and 4.85% of the variability in cerebellar length.

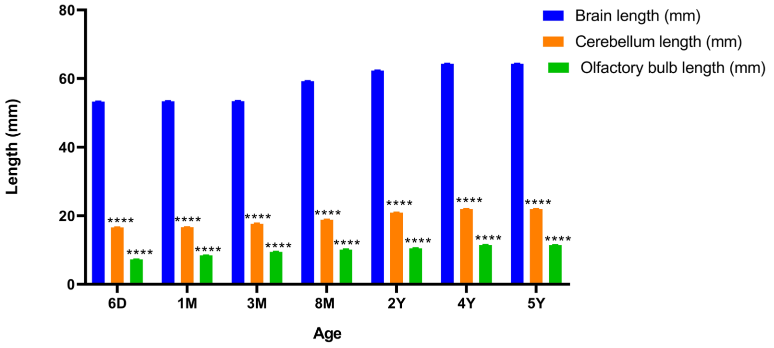


Quadratic relationship between cerebellar length and age. 6D: 6 days; 1M: 1 month; 3M: 3 months; 8M; 8 months; 2Y: 2 years; 4Y: 4 years; 5Y: 5 years.

Figure 4. Scatterplot of cerebellar length vs. AGC age.

3.1.4. Ration between Brain, Cerebellum and Olfactory Bulb Length

According to **Figure 5**, there is a significant difference ($P < 0.001$) between the length of the brain, cerebellum and olfactory bulb at each age.



There was a significant difference ($P < 0.0001$) between the lengths at each age. 6D: 6 days; 1M: 1 month; 3M: 3 months; 8M: 8 months; 2Y: 2 years; 4Y: 4 years; 5Y: 5 years.

Figure 5. Brain, olfactory bulb, and cerebellar lengths in relation to age in AGC.

3.2. Width

3.2.1. Brain Width

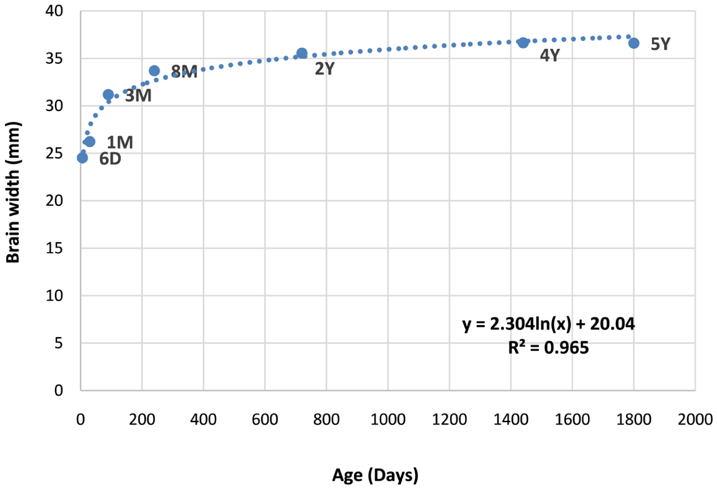
The mean width of the brain increased from 24.53 ± 0.17 mm to 36.64 ± 0.19 mm between the 6th birthday and the 4th year of life followed by a slight decrease at 5 years (36.60 ± 0.36 mm). Statistical analysis was significant between age groups ($P < 0.0001$) except for middle and old adults groups (Table 2).

Table 2. Width parameters according to the age of the AGC.

Width (mm)		Number of samples (n = 42)						
		6 days	1 month	3 months	8 months	2 years	4 years	5 years
Average ± SEM (mm)	BRW (mm)	24.53 ± 0.17^{a}	26.23 ± 0.30^{b}	31.19 ± 0.15^{c}	33.70 ± 0.16^{d}	35.55 ± 0.19^{e}	36.64 ± 0.19^{f}	36.60 ± 0.36^{f}
	OBW (mm)	0.23 ± 0.02^{a}	0.25 ± 0.02^{a}	0.28 ± 0.02^{a}	0.32 ± 0.01^{a}	0.34 ± 0.01^{a}	0.33 ± 0.01^{a}	0.33 ± 0.02^{a}
	CBW (mm)	16.26 ± 0.03^{a}	17.37 ± 0.02^{b}	22.45 ± 0.02^{c}	23.08 ± 0.02^{d}	24.70 ± 0.09^{e}	25.22 ± 0.06^{f}	25.21 ± 0.17^{f}

BRW: brain width; OBW: olfactory bulb width CBW: cerebellum width. The means with the different superscript letters show a significant difference ($P \le 0.05$) between the age groups. Those with the same letters show no significant age difference ($P > 0.05$). The width of the brain, olfactory bulb, and cerebellum increases with age and stabilizes between 2 and 5 years of age.

There was a very weak, nonsignificant positive correlation between brain width and AGC age ($r = 0.79$; $P < 0.05$). Logarithmic regression analysis shows that age would explain 96.52% of the variability in brain width (Figure 6).

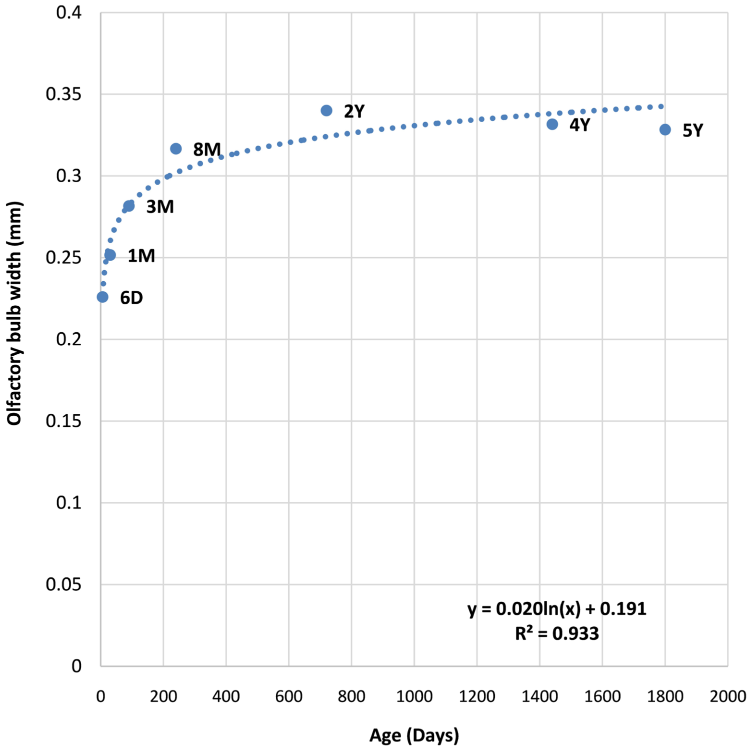


Positive logarithmic relationship between brain width and age. Brain width increases until age 2 years and stabilizes after 4 years. 6D: 6 days; 1M: 1 month; 3M: 3 months; 8M; 8 months; 2Y: 2 years; 4Y: 4 years; 5Y: 5 years.

Figure 6. Scatterplot of brain width versus AGC age.

3.2.2. Olfactory Bulb Width

The average width of the olfactory bulb increased from 0.23 ± 0.01 mm to 0.34 ± 0.01 mm between the 6th birthday and the 2nd year of life (**Table 2**). It then decreases significantly between 2 and 5 years from 0.34 ± 0.01 mm to 0.33 ± 0.02 mm. Statistical analysis revealed no significant differences between age groups. There was a non-significant positive correlation between olfactory bulb width and age (r = 0.72; P > 0.05). Logarithmic regression analysis shows that age would explain 93.31% of the variability in olfactory bulb width (**Figure 7**).



Logarithmic relationship between olfactory bulb width and age. 6D: 6 days; 1M: 1 month; 3M: 3 months; 8M; 8 months; 2Y: 2 years; 4Y: 4 years; 5Y: 5 years.

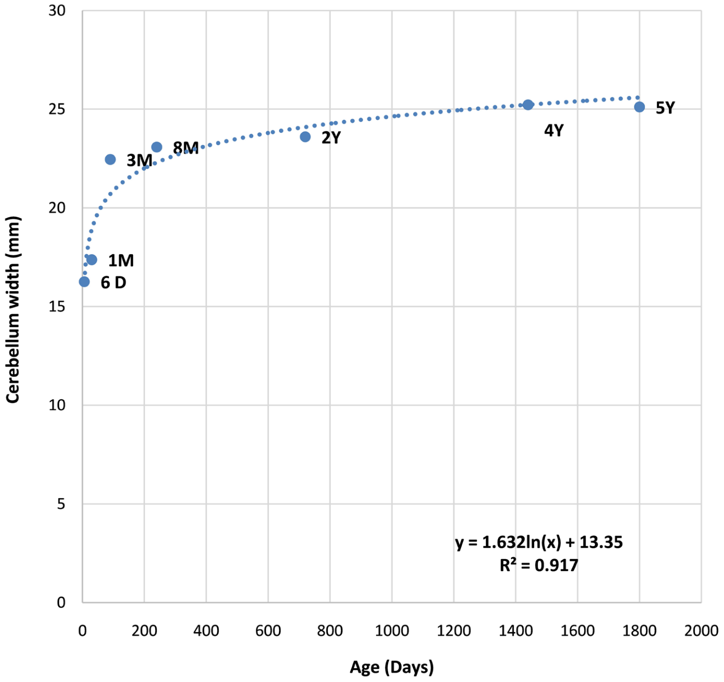
Figure 7. Scatterplot of olfactory bulb width versus age in AGC.

3.2.3. Cerebellum Width

The mean width of the cerebellum increased from 16.26 ± 0.03 mm to 25.22 ± 0.06 mm between the 6th birthday and the 4th year of life (**Table 2**). It then decreases slightly between 4 and 5 years from 25.22 ± 0.06 mm to 25.21 ± 0.17. Statistical analysis was significant between age groups (P < 0.05), except for middle and old adults. There was a nonsignificant positive correlation between cerebellar width and AGC age (r = 0.74; P > 0.05). Logarithmic regression analysis shows that age would explain 92.57% of the variability in cerebellar width (**Figure 8**).

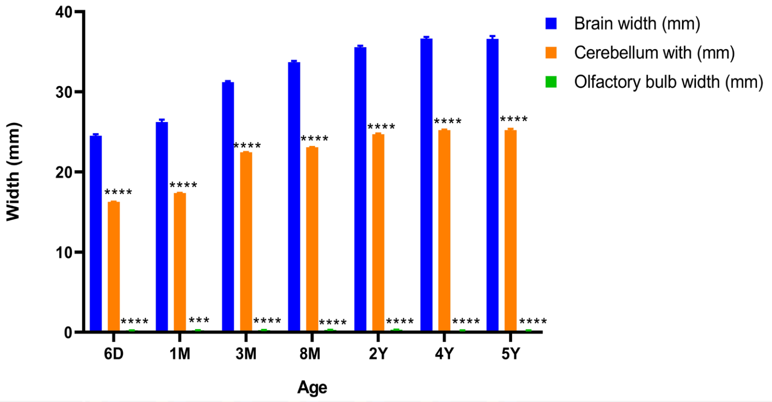
3.2.4. Ration between Brain, Cerebellum and Olfactory Bulb Width

According to **Figure 9**, there is a significant difference (P < 0.001) between the width of the brain, cerebellum and olfactory bulb at each age.



Positive logarithmic relationship between cerebellar width and age. The width of the cerebellum increases until the age of 2 and stabilizes after the age of 4.6D: 6 days; 1M: 1 month; 3M: 3 months; 8M; 8 months; 2Y: 2 years; 4Y: 4 years; 5Y: 5 years.

Figure 8. Scatterplot of cerebellar width versus age in AGC.



The widths increase with age. There is a significant difference (P < 0.0001) between the width at each age. 6D: 6 days; 1M: 1 month; 3M: 3 months; 8M; 8 months; 2Y: 2 years; 4Y: 4 years; 5Y: 5 years.

Figure 9. Widths of the brain, olfactory bulb, and cerebellum in relation to age in AGC.

3.3. Height

3.3.1. Brain Height

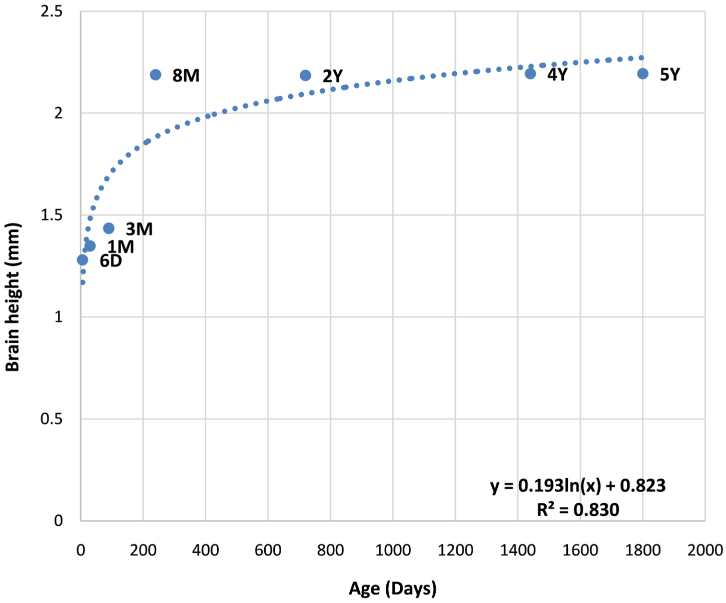
The mean brain height (EH) increased from 1.28 ± 0.08 mm to 2.19 ± 0.03 mm between the sixth day of birth and five years of age with a stabilization observed between eight months and five years. The statistical analysis yielded significant results between ages, except the comparisons between the sixth day of birth to months and eight months to five years.

Table 3. Height parameters according to the age of the AGC.

Height (mm)		Number of samples (n = 42)						
		6 days	1 month	3 months	8 months	2 years	4 years	5 years
Average ± SEM (mm)	BRH (mm)	1.28 ± 0.08^{a}	1.35 ± 0.09^{a}	1.44 ± 0.06^{a}	2.19 ± 0.1^{b}	2.19 ± 0.03^{b}	2.19 ± 0.04^{b}	2.19 ± 0.03^{b}
	OBH (mm)	0.16 ± 0.02^{a}	0.19 ± 0.02^{a}	0.33 ± 0.01^{b}	0.38 ± 0.02^{b}	0.39 ± 0.03^{b}	0.23 ± 0.01^{a}	0.22 ± 0.00^{a}
	CBH (mm)	0.57 ± 0.03^{a}	0.77 ± 0.03^{b}	0.80 ± 0.01^{b}	0.88 ± 0.03^{b}	1.04 ± 0.02^{c}	0.98 ± 0.03^{c}	0.71 ± 0.02^{b}

BRH: brain level. OBH: olfactory bulb level. CBH: cerebellar level. The different heights develop according to the age of the alders and stabilize between 2 and 5 years. The means with the different superscript letters show a significant difference ($P \leq 0.05$) between the age groups. Those with the same letters show no significant difference ($P > 0.05$) between age groups.

There was a non-significant positive correlation between brain height and AGC age ($r = 0.73$; $P > 0.05$). Logarithmic regression shows that age would explain 83.02% of the variability in brain height (**Figure 10**).



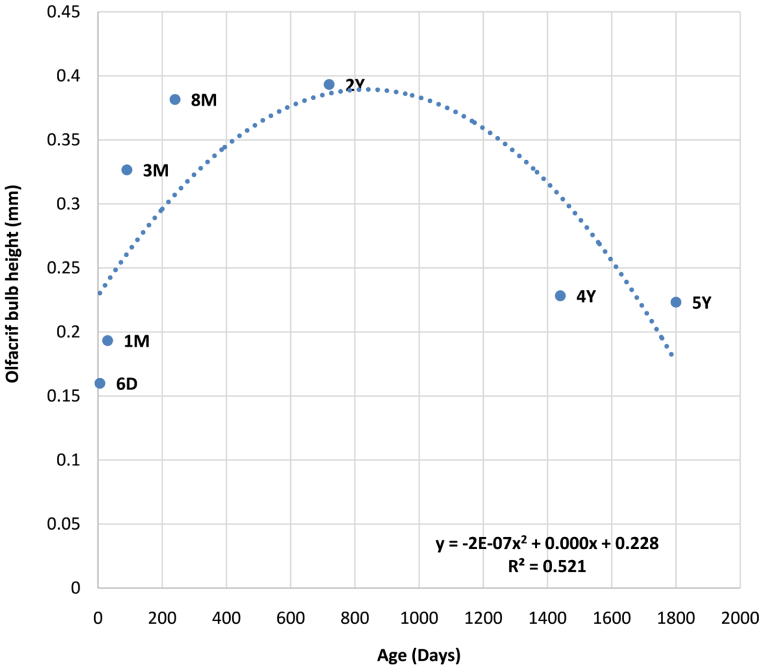
Positive logarithmic relationship between brain height and age. Brain height increases up to 5 years of age and stabilizes between 4 and 5 years of age. 6D: 6 days; 1M: 1 month; 3M: 3 months; 8M; 8 months; 2Y: 2 years; 4Y: 4 years; 5Y: 5 years.

Figure 10. Scatterplot of brain height versus age in AGC.

3.3.2. Olfactory Bulb Height

The mean height of the olfactory bulb increased from 0.16 ± 0.02 mm to 0.39 ±

0.03 mm between the 6th birthday and the 2nd year of life (Table 3). It decreases significantly between 2 and 5 years from 0.39 ± 0.03 mm to 0.22 ± 0.00 mm. Statistical analysis was significant between age groups ($P < 0.05$), except for neonates, juveniles, middle adults and old age and between juveniles and young adults. There is a very weak, nonsignificant negative correlation between olfactory bulb height and AGC age ($r = -0.08$; $P > 0.05$). The quadratic regression analysis shows that age would explain 52.19% of the variability in olfactory bulb height (Figure 11).



Quadratic relationship between olfactory bulb height and age. After 1000 days of growth, the height of the olfactory bulb decreases. 6D: 6 days; 1M: 1 month; 3M: 3 months; 8M; 8 months; 2Y: 2 years; 4Y: 4 years; 5Y: 5 years.

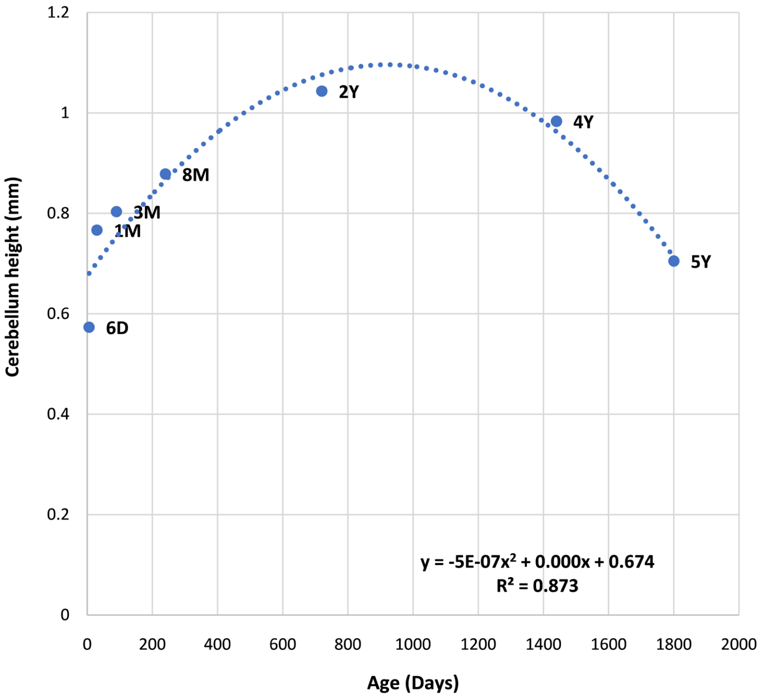
Figure 11. Scatter plot of olfactory bulb height versus age in AGC.

3.3.3. Cerebellum Height

The mean height of the cerebellum increased from 0.57 ± 0.03 mm to 1.04 ± 0.02 mm between the 6th birthday and the 2nd year of life (Table 3). It then decreases significantly between 4 and 5 years from 0.98 ± 0.03 mm to 0.71 ± 0.02 mm. The difference was significant ($P < 0.05$) between age groups, except between juveniles, subadults and old age, and between young adults and middle adults. There is a very weak, nonsignificant positive correlation between cerebellar size and AGC age ($r = 0.26$; $P > 0.05$). The quadratic regression analysis shows that age would explain 87.34% of the variability in cerebellar height (Figure 12).

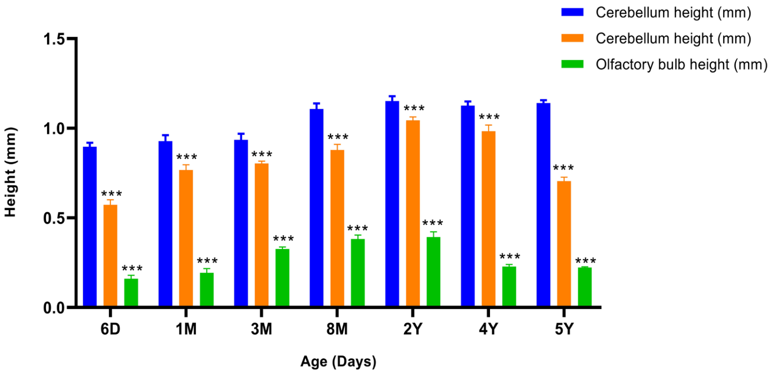
3.3.4. Ration between Brain, Cerebellum and Olfactory Bulb Height

According to Figure 13, there is a significant difference ($P < 0.001$) between the height of the brain, cerebellum and olfactory bulb at each age.



Quadratic relationship between cerebellar height and age. After 900 days of growth. there is a decrease in cerebellar height.6D: 6 days; 1M: 1 month; 3M: 3 months; 8M; 8 months; 2Y: 2 years; 4Y: 4 years; 5Y: 5 years.

Figure 12. Scatterplot of cerebellar height versus age in AGC.



Height increases with age. There is a significant difference ($P < 0.001$) between the lengths at each age.

Figure 13. Height of brain, olfactory bulb and cerebellum in relation to age in AGC.

4. Discussion

4.1. Brain Dimensions

The current study shows a significant increase in mean brain length (BL) from 6 days to 5 years, specifically from 53.27 ± 0.04 mm to 64.28 ± 0.04 mm. These results are consistent with the observations of Broalet *et al.* [12], who similarly found brain length progression in AGC from 1.5 months to 8 months of age. Likewise, Ibe *et al.* [16] documented an increase in brain length in AGC from 6 days to 450 days and reported mean lengths of 39.12 ± 0.46 mm; 53.18 ± 0.52 mm and 63.74 ± 1.47 mm for ages of 3 days, 72 days and 450 days respectively.

Mean brain width (BRW) results showed a progression from 24.53 ± 0.17 mm at 6 days after birth to 36.60 ± 0.36 mm at 5 years of age. These observations are consistent with the research of Broalet *et al.* [12], who documented an increase in AGC from 1.5 to 8 months of age. Their data revealed AGC values of 3.04 ± 0.17 cm at 1.5 months; 3.25 ± 0.81 cm at 4 to 5 months and 3.35 ± 0.59 cm at 7 to 8 months. Additionally, Byanet *et al.* [17] documented an increase in brain width from 23 mm to 28 mm in AGC for weights ranging from 380 g to 2050 g.

Mean brain height (BRH) increased from 1.28 ± 0.08 mm to 2.19 ± 0.03 mm from 6 months to 5 years of age, with stabilization from 8 months to 5 years of age. These results are consistent with those of Broalet *et al.* [12], who also found an increase in AGC of 1.34 ± 0.22 cm; 1.41 ± 0.47 cm and 1.4 ± 0.46 cm from 1.5 to 8 months of age. Byanet *et al.* [17] also showed an increase in brain size from 1.1 mm to 2 mm in AGC with a weight increase from 380 g to 2050 g.

Schoenemann [18] demonstrated a correlation between brain size and both body size and lean body mass across various animal groups. Some experimental studies have highlighted the effects of abiotic and biotic environmental complexity on brain development [19] [20]. Rodents exposed to enriched abiotic environments (rich in stimuli) had larger brains compared to those living in low-stimulus environments [21]. Additionally, it has been observed that captive breeding can lead to a reduction in brain size, as well as in the sizes of the olfactory bulb and telencephalon [22]-[24]. Various biotic environmental factors have also been shown to influence brain development. For example, the social environment, the risk of predation or competition can alter brain development [25]. Other investigations have indicated that brain size varies according to the behavioral patterns of mammals; it tends to be larger in arboreal species and those that consume vertebrates seeds, or fruits, as well as in terrestrial species that primarily feed on grasses or the foliage of small woody plants [26]. Consequently, variations in brain size are associated with differences in habitat type, dietary habits, zonation and temporal activity patterns [27].

4.2. Olfactory Bulb Dimensions

The present study found an increase in mean olfactory bulb length (OBL) between 6 days and 2 years (7.23 ± 0.02 mm to 11.47 ± 0.02 mm), followed by a slight. Non-significant decrease at 5 years (11.42 ± 0.03 mm). These results are in agreement with those of Ibe *et al.* (2018) [28] who also found an increase in olfactory bulb length between AGCs aged 6 days to 450 days. They found mean lengths of 7.30 ± 0.09 mm; 9.30 ± 0.06 mm; 11.20 ± 0.09 mm for 6-day-old. 72-day-old and 450-day-old AGC. Byanet *et al.* [17] showed a variation in brain length (0.5 cm to 0.66 cm) in AGC weighing 380 g to 2050 g. On the other hand, Olude *et al.* [29] found an increase in mean olfactory bulb length between neonates and juveniles (3.19 ±

0.21 mm; 7.68 ± 0.57 mm) with a decrease in adulthood (6.46 ± 0.28 mm).

The mean width of the olfactory bulb (lBo) increased from 0.23 ± 0.01 mm to 0.34 ± 0.01 mm between the 6th birthday and the 2nd year of life (**Table 2**). It then decreases significantly between 2 and 5 years from 0.34 ± 0.01 mm to 0.33 ± 0.02 mm. Research conducted by George *et al.* [30] indicated that the widths of the right and left olfactory bulbs in adult *Thryonomys swinderianus* and *Cricetomys gambianus* were recorded at 0.623 ± 0.01 cm and 0.506 ± 0.012 cm respectively. Furthermore. Kavoi and Jameela [31] reported that the olfactory bulb width in adult humans was 5.50 ± 0.71 cm. These values are higher than those found in AGC in this study.

The mean height of the olfactory bulb (OBH) changes from 0.16 ± 0.02 mm to 0.39 ± 0.03 mm between the 6th birthday and the 2nd year of life. It decreases significantly from 0.39 ± 0.03 mm to 0.22 ± 0.00 mm between the ages of 2 and 5 years. Lee *et al.* [32] have also shown that the height of the olfactory bulb is higher in adults humans (2 mm) than in elderly (1.6 mm). Schiff *et al.* [33] showed that age is a significant factor affecting the size of the olfactory bulb and that odor recognition progressively declines with age. Murphy *et al.* [34] showed that the prevalence of olfactory disorders is high in older people and increases with age. Lee *et al.* [32] showed that the height of the olfactory bulb can be used to detect olfactory disorders regardless of age.

The olfactory bulb is part of the olfactory brain. It provides a connection between the brain and the environment [35]. The study by Kavoi *et al.* [36] showed that the size of the olfactory bulb reflects the degree of survival dependence of a given species on the sense of smell. Veyseller *et al.* [37] showed that in humans the size of the olfactory bulb correlates with olfactory function. In AGC, vision is relatively poor, so communication and recognition rely heavily on hearing and a well-developed sense of smell [38]. Thus, the high values of olfactory bulb size in juveniles and adults could explain their stronger smell production, which is related to their nocturnal nature.

4.3. Cerebellum Dimensions

The current investigation revealed a notable increase in mean cerebellar length (CBL) from 16.56 ± 0.03 mm to 21.93 ± 0.05 mm between 5 and 6 years of age. with a period of stabilization observed between 4 and 5 years of age. This progression of mean cerebellar length into adulthood is consistent with the findings of Ibe *et al.* [16], who reported measurements of 10.74 ± 0.05 mm, 17.37 ± 0.07 mm and 20.39 ± 0.20 mm for AGC at 3, 72 and 450 days of age respectively. The measurements obtained in this study for AGC at 8 and 24 months (18.84 ± 0.03 mm and 20.90 ± 0.02 mm) exceed those reported by Obadiah *et al.* [39], who documented a cerebellar length of 14.79 ± 0.15 mm in adult AGC. In addition, Byanet *et al.* [17] reported that cerebellar length in AGC ranged from 0.94 cm to 1.4 cm in individuals weighing between 380 g and 2050 g.

The mean cerebellar width (CBW) increased significantly from 16.26 ± 0.03

mm to 25.22 ± 0.06 mm between the 6th birthday and the 4th year of life. Between the ages of 4 and 5 years it then decreases very slightly and not significantly from 25.22 ± 0.06 mm to 25.21 ± 0.17 mm. These results are consistent with those of Ibe *et al.* [16], who found values of 16.66 ± 0.15 mm, 21.58 ± 0.13 mm and 24.76 ± 0.16 mm in AGC at 3 days, 72 days and 450 days of age respectively. The results found in this study in 8 months and 2 years old are consistent with those of Obadiah *et al.* [39], who showed that the mean cerebellar width in adult AGC was 22.43 ± 0.72 mm. Likewise, the results of Byanet *et al.* [40] in adult males (20.83 ± 0.91 mm) and females (21.17 ± 1.14 mm) AGCs are consistent with those in this study. In contrast, Sultan and Braitenberg [41] reported higher cerebellar width values in adult chinchilla, guinea pig, squirrel, macaque and human specimens (27 mm, 17 mm, 41 mm, 51 mm and 237 mm).

The mean cerebellar height (CBH) increases from 0.57 ± 0.03 mm to 1.04 ± 0.02 mm between the 6th birthday and the 2nd year of life. Between the ages of 4 and 5 years it then decreases significantly from 0.98 ± 0.03 mm to 0.71 ± 0.02 mm. In contrast, research conducted by Kalinichenko [42] indicates that adult males have cerebellar heights of 58.32 ± 0.65 mm in the coronal plane and 45.81 ± 0.55 mm in the sagittal plane. These findings suggest a significant increase in cerebellar height in humans when compared to AGC.

The cerebellum is involved in a variety of functions that are important for everyday functioning [43]. It plays an important role in balance and motor activities [44]. Studies in humans and monkeys have also demonstrated the importance of the cerebellum in several cognitive and affective domains [45] [46]. Thus, the cerebellum plays an essential role in balance and psychomotor speed as well as speech production, time estimation, rhythm production, inhibition, attention and associative memory [47]. In addition to the well-known declines in cognitive performance that occur with increasing age, deficits in the motor area are also observed [48]. Increasing age is associated with deterioration in gait and balance [49] and older adults learn sensorimotor adaptation tasks [50] and motor sequence learning [51] less well. Animal studies have shown the effects on cerebellar development of an adverse intrauterine environment affected by toxic substances, environmental influences, infections, inflammation, hypoxia, vitamin or hormonal disorders [52].

5. Conclusion

The present study provided information about the brain size of African grasscutters in old age. The study determined and reported increased whole brain length, width and height across all age groups. The length of the olfactory bulb and cerebellum increases with age, but the width and height decrease after two (2) or four (4) years of growth. The significance of this study lies in the availability of a natural rodent model of brain aging for African laboratories. The results of the present study, which complement existing information on the neurobiology of the African grasscutter, will serve as a guide for studies of brain aging.

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Highlights

- The length, width and height of the brain increased with age.
- The length, width and height of the olfactory bulb change with age and the volume increases with age.
- The length, width and height of the cerebellum increase with age.

Authors' Contribution

HMA and ON contributed to the writing of this manuscript; ON, EMYB, and ANT contributed to revising the manuscript. EMYB and ANT contributed to the study design; KA helped with the manipulations; YJ and AS supported and provided facilities to conduct this research. HMA performed all data analysis.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Taridi, N.M., Abd Rani, N., Abd Latiff, A., Wan Ngah, W.Z. and Mazlan, M. (2014) Tocotrienol Rich Fraction Reverses Age-Related Deficits in Spatial Learning and Memory in Aged Rats. *Lipids*, **49**, 855-869. https://doi.org/10.1007/s11745-014-3919-2

[2] Picq, J. (2007) Aging Affects Executive Functions and Memory in Mouse Lemur Primates. *Experimental Gerontology*, **42**, 223-232. https://doi.org/10.1016/j.exger.2006.09.013

[3] Cabeza, R., Albert, M., Belleville, S., Craik, F.I.M., Duarte, A., Grady, C.L., *et al.* (2018) Maintenance, Reserve and Compensation: The Cognitive Neuroscience of Healthy Ageing. *Nature Reviews Neuroscience*, **19**, 701-710. https://doi.org/10.1038/s41583-018-0068-2

[4] Potvin, O., Mouiha, A., Dieumegarde, L. and Duchesne, S. (2016) Normative Data for Subcortical Regional Volumes over the Lifetime of the Adult Human Brain. *NeuroImage*, **137**, 9-20. https://doi.org/10.1016/j.neuroimage.2016.05.016

[5] Bethlehem, R.A.I., Seidlitz, J., White, S.R., Vogel, J.W., Anderson, K.M., Adamson, C., *et al.* (2022) Brain Charts for the Human Lifespan. *Nature*, **604**, 525-533. https://doi.org/10.1038/s41586-022-04554-y

[6] Ingram, D.K. (1985) Analysis of Age-Related Impairments in Learning and Memory in Rodent Models. *Annals of the New York Academy of Sciences*, **444**, 312-331. https://doi.org/10.1111/j.1749-6632.1985.tb37599.x

[7] Aydin, A., Yilmaz, S., ÖZkan, Z.E. and Ilgün, R. (2008) Morphological Investigations on the Circulus Arteriosus Cerebri in Mole-Rats (*Spalax leucodon*). *Anatomia, Histologia, Embryologia*, **37**, 219-222. https://doi.org/10.1111/j.1439-0264.2007.00834.x

[8] Taylor, K., Gordon, N., Langley, G. and Higgins, W. (2008) Estimates for Worldwide

Laboratory Animal Use in 2005. *Alternatives to Laboratory Animals*, **36**, 327-342. https://doi.org/10.1177/026119290803600310

[9] Hudson-Shore, M. (2016) Statistics of Scientific Procedures on Living Animals Great Britain 2015—Highlighting an Ongoing Upward Trend in Animal Use and Missed Opportunities for Reduction. *Alternatives to Laboratory Animals*, **44**, 569-580. https://doi.org/10.1177/026119291604400606

[10] Mensah, G.A., Koudande, O.D. and Mensah, E.R.C.K.D. (2007) Captive Breeding and Improvement Program of the Larger Grasscutter (*Thryonomys swinderianus*). *Bulletin de la Recherche Agronomique du Bénin*, **56**, 18-23.

[11] Addo, P.G. (1997) Domesticating the Wild Grasscutter (*Thryonomys swinderianus* Temminck, 1827) under Laboratory Conditions. Ph.D. Thesis, University of Ghana Legon.

[12] Broalet, E., Tako, A., Soro, D., Zunon-Kipré, Y., Kakou, M. and Fantodji, A. (2014) L'encéphale de l'aulacode (*Thryonomys swinderianus*, Temminck): Aspects morphologiques et microstructure. *Morphologie*, **98**, 129-130. https://doi.org/10.1016/j.morpho.2014.04.073

[13] Fantodji, A. and Soro, D. (2004) L'élevage d'aulacodes. Expérience en Côte d'Ivoire. Edition Gret, Ministère des Affaires étrangères, programme Agridoc.

[14] Parasido, J.L. (1968) Walker Mammals of the World. 2nd Edition, John Hopkins Press.

[15] Opara, M.N. (2010) Department of Animal Science and Technology, Fedral University of Technology, PMB 1526, Owerri, Imo State, Nigeria. *Research Journal of Forestry*, **4**, 119-135.

[16] Ibe, C.S., Ojo, S.A., Salami, S.O., Ayo, J.O. and Ikpegbu, E. (2019) Cerebellar Gross Anatomy of the African Grasscutter (*Thryonomys swinderianus*—Temminck, 1827) during Foetal and Postnatal Development. *Veterinarski arhiv*, **89**, 559-577. https://doi.org/10.24099/vet.arhiv.0269

[17] Byanet, O., Nzalak, J.O., Salami, S.O., Umosen, A.D., Ojo, S.A., Obadiah, H.I., Bosha, B.A. and Onoja, B.O. (2008) Morphometric Observations of the Brain of the African Grasscutter (*Thryonomys swinderianus*) in Nigeria.

[18] Schoenemann, P.T. (2003) Brain Size Scaling and Body Composition in Mammals. *Brain, Behavior and Evolution*, **63**, 47-60. https://doi.org/10.1159/000073759

[19] van Praag, H., Kempermann, G. and Gage, F.H. (2000) Neural Consequences of Enviromental Enrichment. *Nature Reviews Neuroscience*, **1**, 191-198. https://doi.org/10.1038/35044558

[20] Mohammed, A.H., Zhu, S.W., Darmopil, S., Hjerling-Leffler, J., Ernfors, P., Winblad, B., *et al.* (2002) Environmental Enrichment and the Brain. *Progress in Brain Research*, **138**, 109-133. https://doi.org/10.1016/s0079-6123(02)38074-9

[21] Rosenzweig, M.R. and Bennett, E.L. (1969) Effects of Differential Environments on Brain Weights and Enzyme Activities in Gerbils, Rats, and Mice. *Developmental Psychobiology*, **2**, 87-95. https://doi.org/10.1002/dev.420020208

[22] Burns, J.G., Saravanan, A. and Helen Rodd, F. (2009) Rearing Environment Affects the Brain Size of Guppies: Lab-Reared Guppies Have Smaller Brains than Wild-Caught Guppies. *Ethology*, **115**, 122-133. https://doi.org/10.1111/j.1439-0310.2008.01585.x

[23] Kihslinger, R.L., Lema, S.C. and Nevitt, G.A. (2006) Environmental Rearing Conditions Produce Forebrain Differences in Wild Chinook Salmon Oncorhynchus Tshawytscha. *Comparative Biochemistry and Physiology Part A*: *Molecular & Integrative Physiology*, **145**, 145-151. https://doi.org/10.1016/j.cbpa.2006.06.041

[24] Burns, J.G. and Rodd, F.H. (2008) Hastiness, Brain Size and Predation Regime Affect

the Performance of Wild Guppies in a Spatial Memory Task. *Animal Behaviour*, **76**, 911-922. https://doi.org/10.1016/j.anbehav.2008.02.017

[25] Gonda, A., Välimäki, K., Herczeg, G. and Merilä, J. (2011) Brain Development and Predation: Plastic Responses Depend on Evolutionary History. *Biology Letters*, **8**, 249-252. https://doi.org/10.1098/rsbl.2011.0837

[26] McNab, B.K. and Eisenberg, J.F. (1989) Brain Size and Its Relation to the Rate of Metabolism in Mammals. *The American Naturalist*, **133**, 157-167. https://doi.org/10.1086/284907

[27] Mace, G.M., Harvey, P.H. and Clutton-Brock, T.H. (1981) Brain Size and Ecology in Small Mammals. *Journal of Zoology*, **193**, 333-354. https://doi.org/10.1111/j.1469-7998.1981.tb03449.x

[28] Ibe, C., Ikpegbu, E. and Nlebedum, U. (2018) Structure of the Main Olfactory Bulb and Immunolocalisation of Brain-Derived Neurotrophic Factor in the Olfactory Layers of the African Grasscutter (*Thryonomys swinderianus*—Temminck, 1827). *Alexandria Journal of Veterinary Sciences*, **56**, 1-10. https://doi.org/10.5455/ajvs.278580

[29] Olude, M.A., Mustapha, O.A. and Olopade, J.O. (2016) Morphological Characterization of the African Giant Rat (Cricetomys Gambianus, Waterhouse) Brain across Age Groups: Gross Features of Cortices. *Nigerian Journal of Physiological Sciences*, **31**, 133-138.

[30] George, I.O., Fawehinmi, H.B., Oyakhire, M.O., Musa, S.A. and Akintola, O.M. (2020) Comparative Studies on the Brains of Local Breeds of Pig (Landrace Breed) and Dog (Mongrel Breed). *European Journal of Biomedical*, **7**, 324-330.

[31] Kavoi, B.M. and Jameela, H. (2011) Comparative Morphometry of the Olfactory Bulb, Tract and Stria in the Human, Dog and Goat. *International Journal of Morphology*, **29**, 939-946. https://doi.org/10.4067/s0717-95022011000300047

[32] Lee, Y.H., Bak, Y., Park, C., Chung, S.J., Yoo, H.S., Baik, K., *et al.* (2020) Patterns of Olfactory Functional Networks in Parkinson's Disease Dementia and Alzheimer's Dementia. *Neurobiology of Aging*, **89**, 63-70. https://doi.org/10.1016/j.neurobiolaging.2019.12.021

[33] Ship, J.A., Pearson, J.D., Cruise, L.J., Brant, L.J. and Metter, E.J. (1996) Longitudinal Changes in Smell Identification. *The Journals of Gerontology Series A*: *Biological Sciences and Medical Sciences*, **51**, M86-M91. https://doi.org/10.1093/gerona/51a.2.m86

[34] Murphy, C. (2002) Prevalence of Olfactory Impairment in Older Adults. *JAMA*, **288**, 2307-2312. https://doi.org/10.1001/jama.288.18.2307

[35] Turetsky, B.I., Moberg, P.J., Yousem, D.M., Doty, R.L., Arnold, S.E. and Gur, R.E. (2000) Reduced Olfactory Bulb Volume in Patients with Schizophrenia. *American Journal of Psychiatry*, **157**, 828-830. https://doi.org/10.1176/appi.ajp.157.5.828

[36] Kavoi, B., Makanya, A., Hassanali, J., Carlsson, H. and Kiama, S. (2010) Comparative Functional Structure of the Olfactory Mucosa in the Domestic Dog and Sheep. *Annals of Anatomy—Anatomischer Anzeiger*, **192**, 329-337. https://doi.org/10.1016/j.aanat.2010.07.004

[37] Veyseller, B., Ozucer, B., Aksoy, F., Yildirim, Y.S., Gürbüz, D., Balikçi, H.H., *et al.* (2012) Reduced Olfactory Bulb Volume and Diminished Olfactory Function in Total Laryngectomy Patients: A Prospective Longitudinal Study. *American Journal of Rhinology & Allergy*, **26**, 191-193. https://doi.org/10.2500/ajra.2012.26.3768

[38] Opara, M.N. (2010) The Grasscutter I: A Livestock of Tomorrow. *Research Journal of Forestry*, **4**, 119-135. https://doi.org/10.3923/rjf.2010.119.135

[39] Obadiah, B., Dzenda, T. and Wanmi, N. (2018) Lobulation Pattern of the of the

Cerebellum of African Grasscutter (*Thryonomys swinderianus*). *Nigerian Veterinary Journal*, **39**, 66-74. https://doi.org/10.4314/nvj.v39i1.8

[40] Byanet, O., Onyeanusi, B.I. and Ojo, S.A. (2012) Sex Differences in the Cerebellum and Its Correlates with Some Body Traits in the African Grasscutter (*Thryonomys swinderianus*-Temminck, 1827): Morphometric Study. *Basic and Clinical Neuroscience*, **3**, 15-21.

[41] Braitenberg, V. (1993) The Cerebellar Network: Attempt at a Formalization of Its Structure. *Network*: *Computation in Neural Systems*, **4**, 11-17. https://doi.org/10.1088/0954-898x_4_1_002

[42] Kalinichenko, M. and Stepanenko, O. (2023) Shape and Surface Structure of the Human Cerebellum: Variant Anatomy. *Acta Morphologica et Anthropologica*, **30**, 78-86. https://doi.org/10.7546/ama.30.3-4.2023.10

[43] Bernard, J.A. and Seidler, R.D. (2014) Moving Forward: Age Effects on the Cerebellum Underlie Cognitive and Motor Declines. *Neuroscience & Biobehavioral Reviews*, **42**, 193-207. https://doi.org/10.1016/j.neubiorev.2014.02.011

[44] Koziol, L.F., Budding, D., Andreasen, N., D'Arrigo, S., Bulgheroni, S., Imamizu, H., *et al.* (2013) Consensus Paper: The Cerebellum's Role in Movement and Cognition. *The Cerebellum*, **13**, 151-177. https://doi.org/10.1007/s12311-013-0511-x

[45] King, M., Hernandez-Castillo, C.R., Poldrack, R.A., Ivry, R.B. and Diedrichsen, J. (2019) Functional Boundaries in the Human Cerebellum Revealed by a Multi-Domain Task Battery. *Nature Neuroscience*, **22**, 1371-1378. https://doi.org/10.1038/s41593-019-0436-x

[46] Schmahmann, J.D., Guell, X., Stoodley, C.J. and Halko, M.A. (2019) The Theory and Neuroscience of Cerebellar Cognition. *Annual Review of Neuroscience*, **42**, 337-364. https://doi.org/10.1146/annurev-neuro-070918-050258

[47] Allen, G. and Courchesne, E. (2003) Differential Effects of Developmental Cerebellar Abnormality on Cognitive and Motor Functions in the Cerebellum: An fMRI Study of Autism. *American Journal of Psychiatry*, **160**, 262-273. https://doi.org/10.1176/appi.ajp.160.2.262

[48] Seidler, R.D., Bernard, J.A., Burutolu, T.B., Fling, B.W., Gordon, M.T., Gwin, J.T., *et al.* (2010) Motor Control and Aging: Links to Age-Related Brain Structural, Functional, and Biochemical Effects. *Neuroscience & Biobehavioral Reviews*, **34**, 721-733. https://doi.org/10.1016/j.neubiorev.2009.10.005

[49] Holviala, J., Kraemer, W.J., Sillanpää, E., Karppinen, H., Avela, J., Kauhanen, A., *et al.* (2011) Effects of Strength, Endurance and Combined Training on Muscle Strength, Walking Speed and Dynamic Balance in Aging Men. *European Journal of Applied Physiology*, **112**, 1335-1347. https://doi.org/10.1007/s00421-011-2089-7

[50] Anguera, J.A., Reuter-Lorenz, P.A., Willingham, D.T. and Seidler, R.D. (2011) Failure to Engage Spatial Working Memory Contributes to Age-Related Declines in Visuomotor Learning. *Journal of Cognitive Neuroscience*, **23**, 11-25. https://doi.org/10.1162/jocn.2010.21451

[51] Bo, J., Peltier, S.J., Noll, D.C. and Seidler, R.D. (2011) Age Differences in Symbolic Representations of Motor Sequence Learning. *Neuroscience Letters*, **504**, 68-72. https://doi.org/10.1016/j.neulet.2011.08.060

[52] Shevelkin, A.V., Ihenatu, C. and Pletnikov, M.V. (2014) Pre-Clinical Models of Neurodevelopmental Disorders: Focus on the Cerebellum. *Reviews in the Neurosciences*, **25**, 177-194. https://doi.org/10.1515/revneuro-2013-0049

Abbreviations

AGC	African Grasscutter
BRL	Brain Length
OB	Olfactory Bulb
OBL	Olfactory Bulb Length
CBL	Cerebellum Length
BRW	Brain Width
OBW	Olfactory Bulb Width
CBW	Cerebellum Width
BRH	Brain Height
OBH	Olfactory Bulb Height
CBH	Cerebellum Height