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Morphometric characteristics of the small and large intestines of *Mus musculus* during postnatal development

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The objective of this study was to investigate the size of the small and large intestine in postnatal development of Mus musculus *mice. The gut was obtained from 2-, 4-, 6-, and 12-week-old animals. The morphometric analysis was performed at microscopic level. Measurements and calculations included dimensions of villi (height, diameter) and their number per 1 mm^2 surface area in the proximal, middle, and distal section of the small intestine, as well as the length and surface area (external and internal) of the small and large intestines.*
To find the allometric relationship between the size of the small and large intestines and body mass, reduced major axis regression was applied. The length and surface area of both intestinal segments gradually increased with age. The increase in the internal surface area of the small intestine was the result of lengthening of the intestine and increasing diameter of the villi in its proximal and middle sections. No increase in villus height during the studied period was detected. A marked increase in the size of the intestinal segments was observed between the 2nd and 4th weeks of life, when the length doubled and the surface area tripled in size. Allometric analysis revealed that the increase in length and internal surface area of the small and large intestines was more rapid than the body mass increase during the weaning period, while it was not different from isometry after the weaning. In conclusion, the greatest changes in the structure and size of the small and large intestines of mice occurred in the weaning period. During this period these two segments of intestine grew faster than the rest of the body and reached adult proportions. (Folia Morphol 2011; 70, 4: 252–259)

Key words: mice intestine, postnatal growth, morphometry, allometry

INTRODUCTION

During postnatal development, the structure of the gastrointestinal tract is affected by several factors including diet, age, genetic determinants, and hormones secreted in the intestine and in the other organs [23]. The mammal growth period between birth and maturity seems to be particularly interesting in the context of the development of intestinal

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mucosa, a tissue that is associated with exchange and absorption processes. At the same time, the form and function of the alimentary tract develop to meet the increased metabolic demands during the growth period. The vast majority of the literature reports quantitative changes in the intestinal mucosa function and structure, such as enzymatic activity, shape of villi, and migration of epithelial cells during ontogenetic development [7, 23, 28]. Although some previous studies have shown data on the height and number of villi at this time [22], information on the postnatal development of the mucosa surface area in the intestine of small mammals is limited [12, 14, 21]. According to the principle of symmorphosis, the structure of organs, on its different levels, is commensurate to functional needs, and formation of structural elements is regulated to satisfy but not exceed the requirements of the functional system [26, 27]. Thus the structure and size of the gut should be adequate to the nutritional and energetic requirements of the organism. This indicates the advantages resulting from morphometric studies that could provide criteria of animal condition.

This morphometric study was aimed at better understanding the quantitative changes in the intestine mucosa in mice from the 2nd to 12th week after birth. The results would allow determination of the character and range of changes that occur at this time in the small and large intestine to meet the increasing metabolic demands during postnatal development. Based on the literature review, it was predicted that the growth in the surface of the mucosa membrane will occur in the small intestine due to the increase in the dimensions of the villi and in the result of the longitudinal growth of the intestine. As the animals in the studied age range represent distinct periods, i.e. weaning and post-weaning, the different growth rate of the intestine of the individuals representing these two different periods was expected. Particularly important changes in the mucosa surface area were predicted to occur in the weaning period when maternal milk is gradually replaced by solid food. As was summarised by Kramer and Bryant [9], an analysis of the intraspecific (ontogenetic) allometry of the structures associated with the intestine could provide the most appreciated index for interspecific comparisons. Thus, the present results describe a normal pattern of intestinal growth and could be used as a reference for experimental animals used as a model for human medicine studies.

MATERIAL AND METHODS

The study subject

The intestines of female and male *Mus musculus* were examined. We selected 8 two-week-old individuals (group I), 8 individuals at the age of 4 weeks (group II), 7 individuals at the age of 6 weeks (group III), and 8 individuals at the age of 12 weeks (group IV). The individuals from the two younger age groups (I and II) were in the weaning period, while those from the two older groups (III and IV) were in the post-weaning period. During weaning, milk is taken together with solid food (mixed-feeding period), whereas in the post-weaning period only solid food is ingested.

The mice were bred in the Department of Animal Physiology of the Nicolaus Copernicus University. They were euthanised by intramuscular injection of 0.2 mL of Ketanest (Pentobarbitan, concentration 50 g/L).

Preparation of histological samples

Specimens were weighed to the nearest 0.1 g and their body length (from nares to anus) was measured to the nearest 0.1 mm. The intestine was then dissected and fixed in a 10:1 mixture of 10% formaldehyde solution and 75% ethanol proportion. After three days, the samples were moved to 4% formalin for 1 month and surplus fixative was removed with running water. The samples were weighed (OHAUSE®) and stored in 75% ethanol.

To prepare histological slides, the intestine was divided into small intestine and large intestine. The measurements for the small intestine were made in its proximal, middle, and distal section whereas those for the large intestine were made at the level of the caecum, colon, and rectum.

To measure the length of the intestine parts, their image was projected onto a piece of paper from a stereoscopic microscope, using a specialised eyepiece (PZO, Poland), which allowed the intestine and the drawing paper to be viewed simultaneously. The lengths of the given parts of the intestine were drawn along their long axis and measured with an electronic curvature measuring device (Scalex Corporation, Carlsbad CA) to the nearest 0.01 mm.

Serial histological sections of the intestine were prepared. For all sections of small and large intestine, 5 to 6 pieces, 0.5 cm long and located 2 cm apart, were selected. To prepare the histological specimens, the paraffin method was used. The paraffin sections, 5–8 μm thick, were stained with Delafield's haematoxylin and counterstained with eosin.

Measurements and calculations

To calculate the digestive-absorptive area of the small and large intestine, their internal and external circumferences were determined. The circumferences were measured, like the intestine length, from the images of the cross sections projected on a vertical screen (1 mm accuracy).

Because the intestine is roughly cylindrical in form, the external (Ex_{area}) and internal surfaces (IN_{area}) of the sections were calculated using the formula for the area of a cylinder. In both intestines, external circumference was measured along the serous membrane. The internal circumference of the large intestine was measured at the luminal edge of the epithelial layer of the mucosa. For the proximal, middle, and distal regions of the small intestine, the circumference at the base of the villi was used to calculate the internal surface area. This area is referred to as the smooth internal area (SIN_{area}). The surface area of a villus (SA_v) was calculated using the formula for the area of a cylinder. The diameter and height of villi and the distance between villi were measured using a calibrated measuring eyepiece (PZO, Poland) (with an accuracy of 3.70 μm and linear magnification of 128×). The diameter of a villus was calculated as the arithmetic mean of measurements taken at two levels: at the base of the villus and at 3/4 of its height. The height of 20–30 villi was measured from their base to the top. To calculate the number of villi along 1 mm^2 of the mesenteric intestinal circumference, the following formula was used: V = = 1000 μm/(D_v+B_v), where D_v is the diameter of the villus at its base and B_v is the distance between villi, measured between the bases of two neighbouring villi.

The result was squared to calculate the number of villi per 1 mm^2 of the mucous membrane of the particular sections of the small intestine (V^2). The above values were used in the formula: $TIN_{area} = SIN_{area}+[(SA_v \times V^2) \times SIN_{area}]$, to get the total internal area (TIN_{area}) of the proximal, middle, and distal section of the small intestine.

These values were used to calculate the ratio of the internal area of the large intestine to its external area (IN_{area}/EX_{area}). For the small intestine, the ratio of the total internal area of sections of the small intestine to their external area (TIN_{area}/EX_{area}) and length (TIN_{area}/length of segment) were calculated. The ratios of the internal areas of the consecutive regions of the intestine to the body mass of mice (large intestine: IN_{area}/body mass; small intestine: TIN_{area}/body mass) were also calculated. All measurements and calculations were carried out separately for each section of the small and large intestines.

Data analyses

The results are presented as mean values ± standard deviations. The differences among age groups in the body mass, body length and morphometric parameters of the sections of the small and large intestine (height and diameter of villi, number of villi per 1 mm^2 of the mucous membrane, and size of external and internal areas) were checked using a one-way analyses of variance (ANOVA). When the ANOVA results were significant, mean values of particular groups were compared by the multiple range Tukey's test. A sequential Bonferroni correction was applied to the ANOVA results to control for multiple comparisons.

To find the allometric relationships between the analysed variables (the body mass *vs* body length, intestine length, and internal surface area of small and large intestines), reduced major axis regression was applied to the log transformed data. The slope of such regression is equivalent to the exponent (b) of the allometric equation $y = ax^b$. The regression lines were calculated separately for the growth during the weaning period (groups I–II) and during the post-weaning period (groups III–IV). The exponents of the allometric equations were compared with the values corresponding to the isometric growth (i.e. 0.33 for the relationship between the mass and a linear dimension and 0.67 for the relationship between the mass and a surface area). The slopes calculated for the two growth periods were also compared with each other for each pair of regression lines. Significance tests for RMA regression parameters were carried out following McArdle [13].

RESULTS

Body mass and length

The body mass of the mice in group IV (12 weeks) was 4.1 times greater than in group I (2 weeks), 2.5 times greater than in group II (4 weeks), and 1.7 times than in group III (6 weeks). All the groups differed significantly from one another with respect to body mass ($F_{3, 27} = 292.0$, $p < 0.001$). The same pattern is held for the differences in body length among groups ($F_{3, 27} = 77.7$, $p < 0.001$; Table 1). The relationship between these two variables did not depart from the isometric pattern (the slope did not differ significantly from the isometric value of 0.33) both before and after weaning ($t_{(16)} = 0.5$, $p = 0.655$ and $t_{(15)} = 0.8$, $p = 0.426$, respectively; Table 2). In both cases, Pearson correlations were about 0.8, indicating a high correlation between body length and body mass.

Table 1. Body mass, length, and morphometric parameters of the small and large intestines of studied individuals of *Mus musculus*

		Age group				ANOVA	
		I (n = 8)	II (n = 8)	III (n = 7)	IV (n = 8)	$F_{3,27}$	P
Body	Body mass [g]	5.6 ± 0.39^{a}	9.4 ± 1.38^{b}	13.8 ± 0.89^{c}	23.2 ± 1.82^{d}	292.0	***
	Body length [mm]	48.8 ± 2.36^{a}	54.1 ± 4.73^{b}	65.1 ± 4.29^{c}	73.8 ± 2.36^{d}	77.7	***
Small intestine	Length [mm]	147.2 ± 15.84^{a}	260.9 ± 35.95^{b}	304.2 ± 42.19^{bc}	348.9 ± 57.37^{c}	36.0	***
	External area [mm^2]	656.4 ± 109.86^{a}	1943.4 ± 392.44^{b}	2222.3 ± 524.59^{b}	3197.5 ± 850.21^{c}	30.0	***
	Total internal area [mm^2]	4366.8 ± 1518.12^{a}	11356.6 ± 4447.09^{b}	14218.2 ± 3269.11^{b}	20754.7 ± 4231.69^{c}	28.9	***
	TIN area/length [mm]	29.9 ± 10.67^{a}	43.4 ± 16.61^{ab}	46.9 ± 10.53^{ab}	60.1 ± 11.44^{b}	7.7	**
	TIN area/EX area	6.6	5.7	6.5	6.6		
	TIN area/body mass [mm^2/g]	790.8 ± 316.17^{a}	1206.1 ± 436.40^{a}	1040.7 ± 275.62^{a}	907.2 ± 241.57^{a}	2.4	NS
	Height of villi in proximal section (μm)	347.5 ± 56.04^{a}	372.7 ± 32.93^{a}	377.9 ± 41.76^{a}	371.3 ± 44.99^{a}	0.7	NS
	Height of villi in middle section [μm]	328.5 ± 59.67^{a}	365.7 ± 48.19^{a}	356.2 ± 51.13^{a}	355.0 ± 45.82^{a}	0.8	NS
	Height of villi in distal section [μm]	282.1 ± 69.03^{a}	208.1 ± 38.02^{a}	258.0 ± 73.57^{a}	244.4 ± 22.61^{a}	2.6	NS
	Diameter of villi in proximal section [μm]	84.4 ± 16.64^{a}	109.6 ± 9.47^{b}	111.1 ± 23.64^{b}	107.4 ± 10.04^{b}	5.1	*
	Diameter of villi in middle section [μm]	62.9 ± 14.39^{a}	79.0 ± 14.47^{ab}	93.9 ± 17.37^{b}	94.2 ± 9.92^{b}	8.6	**
	Diameter of villi in distal section [μm]	56.6 ± 13.17^{a}	69.9 ± 18.57^{a}	75.1 ± 20.15^{a}	81.4 ± 14.28^{a}	3.2	NS
	Number of villi in proximal section per mm^2	80.3 ± 8.6^{a}	66.5 ± 18.80^{a}	55.1 ± 11.20^{a}	56.1 ± 21.20^{a}	4.2	NS
	Number of villi in middle section per mm^2	94.9 ± 14.70^{a}	74.9 ± 17.50^{ab}	63.1 ± 11.20^{b}	66.5 ± 16.60^{b}	6.7	*
	Number of villi in distal section per mm^2	151.9 ± 64.50^{a}	96.5 ± 52.40^{ab}	73.0 ± 22.80^{b}	72.4 ± 11.30^{b}	5.6	*
Large intestine	Length [mm]	40.3 ± 6.41^{a}	77.4 ± 10.44^{b}	93.6 ± 12.28^{c}	111.3 ± 13.88^{d}	59.3	***
	External area [mm^2]	182.1 ± 59.39^{a}	581.5 ± 136.00^{b}	763.3 ± 119.89^{b}	1118.0 ± 173.06^{c}	72.6	***
	Internal area [mm^2]	181.2 ± 53.56^{a}	558.1 ± 121.62^{b}	745.9 ± 112.74^{c}	1178.7 ± 117.18^{d}	125.3	***
	IN area/EX area	1.0	1.0	1.0	1.1		
	IN area/body mass [mm^2/g]	32.3 ± 9.05^{a}	59.0 ± 8.66^{b}	54.2 ± 7.96^{b}	51.1 ± 6.51^{b}	16.6	***

Results are expressed as mean ± SD. Within a row, means with different superscript letters (a, b, c, d) are significantly different ($p < 0.05$); *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; NS — not significant ($p > 0.05$)

Table 2. Allometric relationship between body mass and body length, intestine, and internal surface area of small and large intestine of studied individuals of *Mus musculus*

	Age group	Pearson correlation		Coefficients of RMA regression log Y = b log (body mass) + log a			Tests of isometric growth				Comparisons of slopes between the age groups		
		r	P	b	SE (b)	log (a)	Isometric b	t	df	P	t	df	P
Body length	I–II	0.77	**	0.31	0.05	3.33	0.33	0.46	16	NS	0.20	18	NS
	III–IV	0.85	***	0.30	0.04	3.38	0.33	0.82	15	NS			
Length of small intestine	I–II	0.86	***	1.11	0.15	3.08	0.33	8.65	16	***			
	III–IV	0.38	NS										
Length of large intestine	I–II	0.90	***	1.29	0.15	1.47	0.33	11.67	16	***	3.66	17	**
	III–IV	0.64	*	0.56	0.12	2.99	0.33	2.45	15	NS			
Total internal area of small intestine	I–II	0.76	**	2.14	0.37	4.56	0.67	6.68	16	***	2.70	17	*
	III–IV	0.58	*	1.04	0.24	6.72	0.67	1.99	15	NS			
Internal area of large intestine	I–II	0.94	***	2.20	0.20	1.38	0.67	13.21	16	***	5.23	16	***
	III–IV	0.87	***	0.98	0.14	4.00	0.67	2.81	15	NS			

*p < 0.05; **p < 0.01; ***p < 0.001; NS — not significant (p > 0.05)

Height, diameter, and number of villi in the small intestine

The height of villi was similar in all the studied groups of mice in the case of proximal ($F_{3, 27} = 0.7$, $p = 0.554$), middle ($F_{3, 27} = 0.8$, $p = 0.522$), and distal parts of the small intestine ($F_{3, 27} = 2.6$, $p = 0.073$; Table 1).

The diameter of the villi was smallest in group I in the proximal, middle, and distal section of the intestine. In the proximal section, the diameter of the villi increased from 84.4 μm in group I up to about 110 μm (30%) in groups II, III, and IV. The differences in the diameter of the villi between group I and the other groups were statistically significant ($F_{3, 27} = 5.1$, $p = 0.006$; Table 2). In the middle section of the small intestine the diameter of villi in group I was smaller than in group II by 26%, and smaller than in groups III and IV by 49%. The differences between groups I and III, and I and IV were statistically significant ($F_{3, 27} = 8.6$, $p < 0.001$; Table 1). In the distal section of the small intestine the diameter of the villi in group II increased by 23%, in group III by 33%, and in group IV by 44%, compared to group I. However, the differences between these groups were not statistically significant ($F_{3, 27} = 3.2$, $p = 0.040$, insignificant with a Bonferroni correction; Table 2).

Among all the studied groups, the largest number of villi, calculated per 1 mm^2 of mucosa surface area in three sections of the small intestine, was found in group I. On average there were about 21, 26, and 70 villi per 1 mm^2 more in group I than in the remaining groups, respectively, in the consecutive intestine sections. These values differed significantly from one another in the middle ($F_{3, 27} = 6.7$, $p = 0.002$) and distal sections ($F_{3, 27} = 5.6$, $p = 0.004$) of the small intestine, but not in the proximal section ($F_{3, 27} = 4.2$, $p = 0.015$, insignificant with a Bonferroni correction; Table 1).

Length of the intestine sections

The length of the small intestine gradually increased with age, from week 2 to 12. Therefore, in group IV the small intestine was 2.4 times longer than in group I ($F_{3, 27} = 36.0$, $p < 0.001$; Table 1). The maximum rate of lengthening was observed between 2 and 4 weeks of postnatal life, coinciding with the weaning period.

The length of the small intestine was positively correlated with the body mass only during the weaning period (groups I–II; $r = 0.9$, $p < 0.001$). The slope describing the association between these two parameters was significantly greater than 0.33, which

was expected for isometry ($t_{(16)}$ = 8.6, $p < 0.001$; Table 1). The correlation between these variables after the weaning period was insignificant ($r = 0.38$, $p = 0.167$).

The length of the large intestine was tripled during the entire experimental period, with an approximately two-fold increase, which occurred between weeks 2 and 4 and one-half after week 4 of postnatal development. However, the differences among all groups were statistically significant ($F_{3, 27} = 59.3$, $p < 0.001$; Table 1).

The allometric relationship between the length of the large intestine and body mass of mice showed diphasic growth during the examined postnatal period. During the weaning period (groups I–II, i.e. from the 2nd to 4th week of age) the slope value was significantly higher than that predicted by isometry ($t_{(16)}$ =11.7, $p < 0.001$; Table 2). Conversely, in the post-weaning period (groups II–IV i.e. 6–12 weeks) the relationship did not differ significantly from the isometric model ($t_{(15)}$ =2.5, $p = 0.030$, insignificant with a Bonferroni correction; Table 2).

Size of external and internal surfaces

The surface area of the small intestine clearly increased during the postnatal growth of mice. In group II (4 weeks), the external surface area of this section was 1287 mm^2 greater (three-fold) than in group I (2 weeks). A further increase of 279 mm^2 was found in group III (6 weeks) and an increase of 975 mm^2 in group IV (12 weeks). Groups I and IV differed significantly from each other as well as from the other groups ($F_{3, 27} = 30.0$, $p < 0.001$; Table 1).

The total internal surface of the mucous membrane of the small intestine in group IV was greater than in groups I, II, and III by 375%, 83%, and 46%, respectively ($F_{3, 27} = 28.9$, $p < 0.001$). The ratio of the total internal to external surface areas of the small intestine was similar in all age groups. No differences were found among the groups of mice with respect to the ratio of the total internal surface area to body mass ($F_{3, 27} = 2.4$, $p = 0.927$) (Table 1).

The smallest value of the ratio of total internal surface area of the small intestine to its length was found in group I, while the largest value occurred in group IV. These values differed significantly from each other ($F_{3, 27} = 7.7$, $p < 0.001$, Table 1).

The slope calculated for the total surface area of the small intestine changed during the postnatal period. During the weaning period, the slope was steeper than the isometric value of 0.67 ($t_{(16)}$ = 6.7, $p < 0.001$, Table 2), whereas it did not depart from isometry in older mice (Table 2).

The area of the external and internal surfaces of the large intestine increased in size from the 2 to 12 postnatal weeks and significantly differed among groups (EX_{area}: $F_{3, 27} = 72.6$, $p < 0.001$; IN_{area}: $F_{3, 27}$ = = 125.3, $p < 0.001$). The greatest, three-fold increase was observed between weeks 2 and 4 of life. Much slower growth (about 1.5-fold) was found in the later period (4–12 weeks). The ratio of the internal to external surface areas of the large intestine was similar in all age groups (Table 1). The relative internal surface of the large intestine (mm^2/g body mass) was smaller in group I than in the remaining groups by 71% on average, and this difference was statistically significant ($F_{3, 27} = 16.6$, $p < 0.001$; Table 1).

The slope value calculated for the total surface area of the large intestine was clearly greater than the isometric value for mice in the weaning period ($t_{(16)}$ = 13.2, $p < 0.001$), but not in the post-weaning period (Table 2).

DISCUSSION

The results of this study support our hypothesis on the increase in the length and internal surface area of the small and large intestine in mice between the 2nd and 12th week of their postnatal development. It has been proven that the increase of the internal surface area of the small intestine is the result of the lengthening of this segment and increasing diameter of the villi. However, the increase in the villus height was not described. Allometric analysis revealed that in the case of the length and internal surface area of the small and large intestines the increase was more rapid than the body mass growth during the weaning period, while it was not different from isometry after the weaning. In contrast, the increase in body length was isometric in relation to the body mass during the entire analysed period.

The presented results describing the increase of the digestive-absorptive area of the intestine are comparable with the results obtained for other mammalian species, such as the rat, pig, and dog [5, 15, 21]. However, there is diversity in the data dealing with the changes in the intestinal mucosa membrane in mammals, especially during the weaning period. The current study demonstrates that no significant changes in the height of villi in three sections of the small intestine have occurred in the examined period, apart from some modifications in the distal section. This was unexpected because the majority of researchers have described changes of the villus height around

weaning. Yu and Chiou [28] reported an increase in villus height in the duodenum, jejunum, and ileum of the rabbit during the 2nd to 8th postnatal weeks and very small changes in their height after that time. In the beagle dog, the height of villi decreases between the 21st and 42nd days of life, and no further changes in this parameter were stated since then [15]. For rats the data are contradictory. It was described that the villous height could change during the early postnatal period, increasing or decreasing depending on the study [2, 16, 20, 22, 24].

Numerous studies have shown that not only the length of villi but also their diameter and/or number can change during postnatal development [2, 3, 6, 8, 14, 22]. In mice, the most intensive increase in villus diameter was observed in the proximal and middle sections of the small intestine between the 2nd and 6th weeks of life. In the same period, villus density decreases. A similar phenomenon was observed in rats between the 3rd and 8th weeks of life [6]. These significant changes in the mucosa architecture during the weaning period and shortly after it are probably related to dietary changes, viz. the transition from milk to solid food. The structural modifications indicate intestine maturation and the adaptation of mucosa to the intake of a new type of food different from the previous diet, both in terms of nutritional value and energy.

Quantitative and qualitative changes of diet during the weaning period significantly influence the length and diameter of the intestine, and thus the size of the external and internal surfaces. A substantial increase in the size of the intestine during this period was observed in rats [2, 21], pigs [5], and horses [10, 19]. In mice, the weaning period was related to an almost twofold increase in the length and threefold increase in the external and internal surface areas of the small and large intestines. Moreover, the growth rates of both segments of the gastrointestinal tract were similar and significantly exceeded the increase in body mass, as shown by the allometric analysis. It should be emphasised that such a fast growth rate of digestive organs does not occur later in the life of mice. Although the length and surface area of both intestine segments of mice increased gradually until the 12th week of life, the growth rate declined significantly after weaning. The allometric relationship between these parameters and body mass showed that the gut in the post-weaning mice grew proportionately to the increase in body mass. A similar model of postnatal growth of both intestinal parameters was also observed in rats [17, 18, 21]. Conversely, in cats only the small intestine showed disproportionately rapid growth during weaning, while the large intestine grew isometrically [1]. In humans, small intestine growth exceeds body length growth during the prenatal life [25]. Lentle et al. [11] stated that positively allometric growth of the intestine with respect to body mass reflected a pursuit of the intestine to obtain its adult shape and showed area to volume compensation. Therefore, it can be said that the small and large intestines of the 2-week-old mice were disproportionately short and reached adult proportions during the weaning period. This fact underlines the importance of this period for the development of the alimentary canal of mice.

The changes observed in the mucosal surface area, regardless of their nature, contribute significantly to satisfying the functional requirements of an animal during its development [14]. The mucosa is influenced by this development, which could be finished at the moment when dry food becomes the main component of the diet [4]. It seems that in mice this phenomenon takes place in the 6th week after birth when no further increase in the villus diameter nor decrease in its number per unit area of mucous membrane is observed in comparison to the 12th week of postnatal development. However, the most significant developmental changes occur in the weaning period, i.e. between 2 and 4 weeks after birth. In this period the gut develops faster than the rest of the body. This dynamic growth of digestive organs might be an adaptive reaction to changes in a pup's diet. Thus it can be concluded that the presented results agree with the general prediction of symmorphosis, namely that all gut components develop in a coordinated manner in response to the demand of digestion and absorption.

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