

## A Macrometric and Micrometric Description of the Ovary in the European Beaver

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Doboszyńska T., 1977: A macrometric and micrometric description of the ovary in the European beaver. Acta theriol., 22, 18: 261—270 [With 6 Tables, 1 Fig. & Plate XVIII].

Newborn female European beavers (*Castor fiber* Linnaeus, 1758) have on an average about 160,000 primary follicles, half of which atrophy during the first 6 months of life. Primary follicles, ovogonia and their nuclei are characterized by similar dimensions in both newborn and adult females. Crescent follicles occur in the greatest number in females 4—6 months old, and the greater part of them undergo atresia during this period also. The number of crescent follicles decreases with age. The first mature follicles occur as early as in 5-month old females and are also to be found in gravid and lactating females. In all females possessing mature follicles we also observed atresic follicles corresponding in size to the mature follicles. The first *corpora lutea* appear in female beavers during the 6th month of life. They are almost four times smaller than the *corpora lutea* of gravid females. A characteristic feature of the ovaries of older female beavers is the accumulation in them of *corpora atretica*, the number of which increases with age.

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### I. INTRODUCTION

For many years now studies have been carried out on the reproduction of beavers in captivity (Żurowski, 1972; Gienc & Doboszyńska, 1972; Doboszyńska & Żurowski, 1975; Żurowski & Doboszyńska, 1975), and it is therefore important to obtain an exact knowledge of the histomorphological aspects of the reproductive system. No exhaustive treatment of the histological structure of the reproductive organs of the female beaver, a knowledge of which would provide theoretical bases for further studies on its function, was found in the literature available.

The purpose of this study was therefore primarily to prepare a detailed macro- and micrometric description of the ovary, depending on age and different physiological states.

### II. MATERIAL AND METHODS

The animals used for the studies were obtained from the Popielno Experimental

Station of the Polish Academy of Sciences and the State Fur Farm at Wiartel. Ovaries were taken from 19 females, which were divided into the following age groups: newborn—3 individuals, 4—6 months old—5, 1—3 years old—5 and over 3 years old—6. The last of these groups included 3 gravid, and 2 permanently sterile females and 1 lactating female. Healthy animals which had died accidentally due to mechanical injuries, lethal bites, suffocation etc. were chosen for the studies.

Before excising the ovaries macroscopic observations and also the following macrometric measurements were made for both ovaries: length, breadth and thickness (in mm) and weight (in g). In addition the animals were weighed, as were also the organs of the reproductive system excised whole (in g). The left ovary of each female, fixed in AFA fluid and embedded in paraffin, was used for micrometric measurements. Serial sections (5—10  $\mu\text{m}$ ) were made for each left hand ovary and stained by Mallory's method.

#### Micrometric Measurements

1. Planimetric measurements of the cross-section area of the ovary consisted of: the whole cross-section area, area of the vascular and follicular layers. Measurements were made using a polar planimeter of the PL-1/PZO Warszawa type on microphotographs, according to a scale in agreement with the linear magnification of the micrometer model. When calculating area the following equation was used:

$$\chi = Z/M^2$$

when

$\chi$  — true area of the object (in  $\text{mm}^2$ ),

$Z$  — area obtained by planimetric measurement on an enlarged positive print (microphotogram),

$M^2$  — positive are (total final area of the object) with square magnification.

Fifteen sections of each left ovary taken on three sites (5 on each), separated from each other by  $1/4$  of the cross-section of the whole ovary, were used for the measurements. The results obtained were compared, giving the arithmetical means of measurements (calculated per  $\text{mm}^2$ ) and the participation of the different layers in the ovary (in %).

2. Absolute number of elements of the follicular layer: primary follicles, crescent follicles and their atretic forms — A (follicles becoming atretic in the early phases of their development, similar in size to crescent follicles), mature follicles and their atretic forms — B (becoming atretic in the later phases of development, similar in size to mature follicles), either periodic or pregnancy *corpora lutea*, atretic bodies and *corpora albicantia*. At the same time calculation was made of the ratio of atretic follicles to those developing normally, in accordance with the equation:

$$X = \frac{b \times 100\%}{(a+b)}$$

when

$X$  — percentage of atretic follicles,

$b$  — absolute number of atretic follicles,

$a$  — absolute number of normally developing follicles,

$(a+b)$  — sum total of absolute numbers of atretic and normally developing follicles.



Table 1  
Description of animals used for studies and macroscopic measurements of ovaries (linear measurements in mm, weight in g).

No. of female	Age*	Body wt.	Sexual organ wt.	Left ovary			Right ovary				
				Wt.	Length	Breadth	Thickness	Wt.	Length	Breadth	Thickness
1	2 D	490	4.8	0.009	5	2	1	0.013	5	2	1
2	1 D	527	4.7	0.022	9	3	1	0.027	10	3	1
3	1 D	570	5.2	0.033	8	3	1	0.031	9	3	1
					Newborn						
4	4 M	3250	9.5	0.075	12	3	2	0.078	12	3	2
5	5 M	6200	7.5	0.065	9	3	2	0.066	9	3	2
6	5 M	6850	9.3	0.063	11	6	3	0.059	11	6	3
7	6 M	6540	8.4	0.160	12	6	3	0.167	14	6	3
8	6 M	6620	10.3	0.125	15	5	3	0.130	13	6	3
					4-6 months						
					1-3 years						
9	16 M	13540	32.5	0.467	19	5	5	0.455	18	3	3
10	22 M	17500	73.5	0.493	23	12	6	0.490	25	11	6
11	22 M	16500	67.5	0.550	19	5	5	0.476	17	8	6
12	31 M	23400	78.0	0.540	22	15	8	0.528	22	14	9
13	33 M	21300	85.9	0.790	26	13	7	0.780	24	14	6
					Over 3 years						
14	58 M, g	28300	132.0	1.730	28	14	8	1.780	26	15	8
15	69 M, g	27500	125.0	1.190	21	14	5	1.250	24	9	6
16	108 M, g	31200	197.0	1.850	29	17	7	1.890	27	16	8
17	65 M, l	27000	92.5	0.780	21	11	7	0.700	22	12	7
18	72 M, s	18000	85.0	0.700	21	9	7	0.621	20	8	8
19	79 M, s	27000	79.0	0.670	19	10	9	0.654	19	10	9

\* D — days, M — months, g — gravid, l — lactating, s — sterile

Calculation of the absolute numbers of ovarian elements was made on serial sections of the whole ovary, under an MB-30 (PZO — Warszawa) microscope, with  $50\times$  magnification of large objects, i.e. large follicles or *corpora lutea* and  $200\text{--}400\times$  magnification in the case of primary and crescent follicles. Graphic reconstructions were simultaneously made for the various sections and of each ovary.

3. Measurements of elements of the follicular layer of left ovaries, as follows: length and breadth in the median cross-section and in lines perpendicular to each other, for the following objects:

(a) primary follicles, ovocyte and its nucleus — 100 objects measured for each ovary,

(b) crescent follicles, ovocyte and its nucleus and atretic follicles — A — 50 successive objects measured,

(c) mature follicles, ovocyte and its nucleus and atretic follicles — B, all follicles in left ovaries were measured,

(d) periodic and pregnancy *corpora lutea* — all objects were measured and atretic bodies — all or on an average 50 were measured, depending on the number which occurred.

Measurements were made using a drum measuring eyepiece with  $600\times$  magnification.

The criteria used for evaluating the various development stages and atresia of follicles and *corpora lutea*, connected with the morpho-histological descriptions, will be described in a subsequent paper.

### III. RESULTS

The ovaries of the beaver, both in newborn and adult females, are similarly situated. The mesovarium suspends them in the vicinity of the posterior poles of the kidneys (about 10 mm from the pole of the left kidney and 30 mm from that of the right kidney). In relation to the spine both ovaries are situated symmetrically, at the level of the 3—4 lumbar vertebra, in the lateral sagittal plane, at a distance of 30—35 mm in newborn and 40—60 mm in adult females.

Table 2

Changes in ovarium weight of the European beaver depending on the age of animals.

Age	Avg. wt, g	Ovarium weight in percentage of:	
		reproductive organs	body wt.
Newborn	0.022	0.45	0.004
4—6 months	0.099	1.10	0.002
1—3 years	0.556	0.83	0.003
Over 3 years	1.150	0.97	0.004

The ovary is oval in shape, and its dimensions vary in different individuals (Table 1), depending on age and physiological state. In adult females the linear measurements increase disproportionately in relation to newborn animals, causing increase particularly in thickness and breadth. The average weights of one ovary are given in Table 2.

Two main layers were distinguished, as in other mammals, in the internal structure of the beaver's ovary: a medullary or vascular layer situated internally (*medulla ovarii*) and external cortical or follicular layer (*cortex ovarii*). As shown by planimetric measurements of the area of these layers, their ratio undergoes change over the course of the animal's life (Table 3). In newborn females the area of the whole cross-section of an ovary is on an average 1.808 mm<sup>2</sup>, and in females

Table 3  
Planimetric measurements of ovary (in mm<sup>2</sup>).

No.	Ovary cross-section	Area of vascular layer	Follicular layer	Percentage formed by the different layers in ovary	
				Vascular	Follicular
Newborn					
1	1.718	0.216	1.502	12.6	87.4
2	2.054	0.480	1.574	23.4	76.6
3	1.654	0.340	1.314	20.5	79.5
$\bar{x}$	1.808	0.345	1.463	18.8	81.2
4-6 months					
4	2.697	0.438	2.259	16.2	83.8
5	2.977	0.505	2.472	17.1	82.9
6	3.128	0.625	2.505	19.9	80.1
7	9.189	1.305	7.884	14.3	85.7
8	8.367	1.356	7.012	16.3	83.7
$\bar{x}$	5.271	0.846	4.426	16.8	83.2
1-3 years					
9	8.303	1.343	6.960	16.1	83.9
10	24.526	4.442	20.084	18.1	81.9
11	7.803	2.618	5.185	35.5	64.5
12	17.327	5.220	12.107	30.1	69.9
13	18.511	5.972	12.539	32.2	67.8
$\bar{x}$	15.294	3.921	11.373	26.4	73.6
Over 3 years					
14	21.273	3.941	17.332	18.5	81.5
15	36.075	8.399	27.676	23.3	76.7
16	51.928	12.394	39.534	23.9	76.1
17	29.474	7.796	21.678	26.5	73.5
18	27.513	6.500	21.013	23.6	76.4
19	37.352	9.134	28.218	24.4	75.6
$\bar{x}$	33.936	8.027	25.909	23.4	76.6

4-6 months old this increases to 5.271 mm<sup>2</sup>, its abrupt growth taking place in females 6 months old. In 1-3 year old females it reaches 15.314 mm<sup>2</sup> in area, but in this group of animals fairly considerable divergences occurred in the participation of these layers in different individuals. In adult females over 3 years old the area of the cross-section is even greater (33.936 mm<sup>2</sup>) and consists of a vascular layer forming 23.4% and follicular layer — 76.6%. This group included gravid



females in which the percentages formed by the layers did not alter greatly, although the total mass of the ovary increased at this time, as is plainly shown in the increase in the area of the whole cross-section, particularly in female no. 16, which had died during the final period of gestation.

The occurrence of the number of follicles and *corpora lutea* and the degree of their development exerted a decisive influence on increase in the cross-section of the ovarian area, and in the case of older individuals, also the occurrence of follicles and *corpora atretica*.

Only primary follicles were present in the ovaries of newborn beavers,

Table 4

Numbers of the different structural elements of the beaver ovary depending on age and physiological state (n, %).

Items	Newborn	4—6 month	1—3 years	Over 3 years		
				Gravid	Lactating	Sterile
Primary follicles, n	161088	78396	27950	9291	8519	6403
Crescent follicles, n	—	3371	589	309	345	144
Atretic follicles, A, n	—	1742	401	159	171	275
%	—	34.1	40.5	34.0	33.1	65.6
Mature follicles, n	—	7.4	9.8	10.0	3.0	3.5
Atretic follicles, B, n	—	9.8	22.0	18.3	17.0	20.5
%	—	57.0	69.2	64.7	85.0	85.4
<i>Corpora lutea</i> , n	—	2.5	4.7	2(6.5) *	—	—
<i>Corpora atretica</i> , n	—	21.0	463.6	1039.0	1157.0	1972.0
<i>Corpora albicantia</i> , n	—	—	3.4	2.5	3.0	2.0

\* Average number of two kinds of *corpora lutea gravida* given.

numbering on an average 161,100 per ovary. The number of these elements was far lower in 4—6 months old females and markedly decreased with each month of life (4 months — 88,000, 5 months — 77,000, and 6 months — 69,000). It may therefore be assumed that during the first 6 months of life half of the primary follicles disappear. A further decrease in the number of primary follicles was observed in older females (Table 4). In consequence, only from 6—9,000 of these follicles occur in adult females. The measurements made permit of establishing that in all the females examined none of the primary follicles differed greatly in size (Table 5), were oval in shape and their average length was 18—19  $\mu\text{m}$ , and breadth 14—15  $\mu\text{m}$ . The average dimensions of the

ovogonium contained in them were as follows: length 12—14  $\mu\text{m}$ , breadth — 10—12  $\mu\text{m}$ . The nucleus of the ovogonium was spherical, with a diameter of approx. 6  $\mu\text{m}$ .

The greatest number of crescent and atretic follicles were present in the ovaries of 4—6 month old females (Table 4). In the remaining females crescent follicles occurred in far smaller numbers and a proportionately smaller number of them became atretic. The highest percentage of atretic follicles occurred in sterile females (65.6%) (Table 4). The ovocytes

Table 5

Dimensions of follicles: primary (I), crescent (II), and mature (III), their reproductive cells and nuclei of reproductive cells in different age group ( $\mu\text{m}$ ). A mean and minimum-maximum values are given

Follicle	Follicles		Reproductive cells		Nucleus	
	Length	Breadth	Length	Breadth	Length	Breadth
Newborn						
I	18.2	15.9	14.2	12.4	6.8	6.3
	13.1—23.0	10.0—20.7	9.8—19.8	7.2—18.0	5.2—9.0	4.8—8.6
4—6 months						
I	19.5	15.2	13.7	11.1	6.7	6.3
	13.1—23.0	10.0—23.0	8.7—18.6	7.0—16.2	5.5—9.2	4.8—7.8
II	84.9	73.3	36.3	31.8	16.1	13.5
	27.0—278.3	19.8—247.8	15.6—68.2	14.5—59.1	7.9—32.1	7.8—23.0
III	400.2	358.5	48.8	41.9	20.0	17.8
	275.3—543.6	257.8—526.2	32.5—54.8	25.2—58.4	13.1—28.4	10.7—21.6
1—3 years						
I	19.0	15.2	13.5	11.2	6.9	6.2
	15.3—26.0	11.5—23.0	9.5—18.0	7.8—16.0	7.8—16.0	5.5—10.1
II	104.6	92.6	37.5	32.5	15.6	12.9
	28.7—234.0	24.6—210.7	19.3—62.0	13.9—64.8	9.8—28.5	7.9—26.1
III	358.8	328.4	50.1	43.1	17.2	14.7
	231.1—496.1	189.5—397.6	27.5—67.2	27.0—64.1	11.2—21.5	9.6—21.2
Over 3 years						
I	18.3	14.6	12.5	10.4	6.3	6.3
	14.0—24.6	9.1—20.5	6.2—18.0	5.0—16.2	5.0—12.5	4.0—9.6
II	98.2	81.9	37.3	33.2	16.0	13.6
	29.6—240.0	22.7—217.8	13.7—59.6	12.3—57.4	8.9—31.8	6.8—29.7
III	502.5	448.6	49.2	44.6	22.4	17.9
	240.0—697.6	217.8—693.5	37.1—62.5	33.0—54.7	13.5—29.3	12.0—26.5

occurring in crescent follicles (Table 5) were oval cells and did not differ greatly in average size in the different groups. The same applies to their nuclei, the average dimension of which were: 15—16  $\mu\text{m}$  in length and 12—13  $\mu\text{m}$  in breadth.

Normally developed mature follicles were not observed earlier than in 5-month old females (2—6 in an ovary) and 6-month old females (13—16). In older females the number varied (3—26 in an ovary). They



also occurred in the ovaries of gravid females (7—14), in a lactating female (3) and in one of the sterile females (7) (Table 4). These follicles differed slightly in size in the different age groups (Table 5). It may be assumed that the average mature follicle is oval in shape with dimensions of 420.5 and 387.5  $\mu\text{m}$ . The ovocyte and its nucleus contained in them are also oval and their average dimensions are: 49.4 and 43.2  $\mu\text{m}$  and 19.8 and 16.8  $\mu\text{m}$  (Table 5).

During the same time as normally developed mature follicles occurred in ovaries large follicles undergoing atresia were observed in all females. There were always more atretic than normally developing follicles (Table 4). The highest percentage of these elements was observed in sterile females (85.4%) and the lactating female (85.0%). They did not differ greatly in size from mature follicles (Table 6).

It must be assumed that the first *corpora lutea* appear in the female beaver at the age of 6 months. In both the females examined at this

Table 6

Variation in size (mean and min.—max.) of atretic follicles in different age group ( $\mu\text{m}$ ).

Group	Atretic follicles — A		Atretic follicles — B	
	Length	Breadth	Length	Breadth
4—6 month	61.4	50.4	421.1	361.9
	21.0—183.0	14.9—27.6	215.5—596.1	165.4—567.0
1—3 years	105.9	91.5	486.0	423.0
	23.9—202.1	21.8—196.0	215.6—932.0	172.5—826.4
Over 3 years	94.5	67.6	591.6	485.3
	26.8—214.0	23.6—192.0	286.4—1346.0	162.4—1289.0

age there were from 2—3 in the ovary, but they were relatively small and as in the case of older non-gravid females attained a length of 471.6—511.6  $\mu\text{m}$  and breadth of 415.9—423.8  $\mu\text{m}$ . They differed greatly in size from the *corpora lutea* of gravid individuals (Table 7), for which the corresponding dimensions were respectively: 2050.2 and 1698.4  $\mu\text{m}$ . *Corpora lutea* varied very considerably in dimensions in the various gravid females. In females no. 14 and 15 two kinds of *corpora lutea* occurred, one kind being almost twice bigger than the other.

*Corpora atretica* accumulate in the ovaries of beavers with age (Table 4). In 4—6 month old females there are as yet only a few of them (21 in an ovary), but in adult females it was found that there may be about 1000 or even 2000 in sterile females. They are most often fusiform and attain average dimensions of 254.5—399.1  $\mu\text{m}$  in length and 113.6—203.0  $\mu\text{m}$  in breadth (Table 7).

*Corpora albicantia* occurred in some of the females from 1—3 years



old and in the lactating female, and also in sterile females. The dense connective tissue enveloping them made it impossible to determine their dimensions.

## IV. DISCUSSION

The macroscopic observations made of ovaries and the macrometric dimensions obtained, taking into account their weights, are similar to data obtained by Gienc & Doboszyńska (1972), but the present paper deals with a greater amount of material and also into consideration the group of newborn females and females from 4–6 months old.

By making serial sections of the different ovaries and detailed measurements of the different elements of the ovary it proved possible to prepare a graphic reconstruction of each left ovary. The diagram made

Table 7

Variations in size (mean and min.—max.) of gravid and periodic *corpora lutea* and *corpora atretica* in different age groups ( $\mu\text{m}$ ).

<i>Corpora lutea gravida</i>		Periodic <i>corpora lutea</i>		<i>Corpora atretica</i>	
Length	Breadth	Length	Breadth	Length	Breadth
4–6 months					
—	—	511.6	423.8	254.5	138.7
—	—	379.1–642.5	307.1–562.5	63.5–493.0	39.5–284.2
1–3 years					
—	—	471.6	415.9	306.9	113.6
—	—	265.0–939.5	143.0–808.3	37.8–465.4	28.3–186.4
Over 3 years					
2050.2	1698.4	—	—	399.1	203.0
1487.6–2537.2	1224.0–2124.5	—	—	42.—647.2	39.6–430.8

on this basis (Fig. 1) illustrates the ovary in an adult gravid female and shows that *corpora lutea gravida*, mature follicles, atretic follicles and *corpora atretica* may occur simultaneously in the ovary of a female beaver. The last of these maintain their distinctly separate character and persist the whole time as clearly visible structures often corresponding in size to mature or atretic follicles. It was found at the same time that two kinds of *corpora lutea gravida* may occur in the ovary of the same female, corresponding in number to the two kinds, differently advanced in development, of young beavers born, which points to the existence of superfoetation (Żurowski & Doboszyńska, 1975).

The numerical details of the ovary showed that primary follicles, of which there are about 160,000 in newborn females, disappear to a great extent during the first 6 months of life, that is, during the period when some of them attain complete development, providing the »first« mature follicles and periodic *corpora lutea*. They differ, however, from the *corpora lutea gravida* of adult females.

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Accepted, November 22, 1976.

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MAKROMETRYCZNA I MIKROMETRYCZNA CHARAKTERYSTYKA  
JAJNIKA BOBRA EUROPEJSKIEGO

Streszczenie

Do badań wykorzystano jajniki 19 samic w różnym wieku (noworodki, 4—6 miesięcy, 1—3 lat oraz powyżej 3 roku życia) i różnych stanach fizjologicznych (ciążarne, karmiące i bezpłodne). Pomiary makrometryczne wykonano na obydwu jajnikach, mikrometryczne zaś, dotyczyły lewego jajnika, który po wykonaniu seryjnych skrawków posłużył do określenia liczby poszczególnych stadiów pęcherzyków, ciałek żółtych, białawych i elementów atretycznych oraz wykonania pomiarów: długość i szerokość tych elementów oraz poszczególnych stadiów komórki rozrodczej i jej jądra. Jednocześnie wykonano pomiary planimetryczne przekrojów jajnika oraz warstwy naczyniowej i rdzennej.

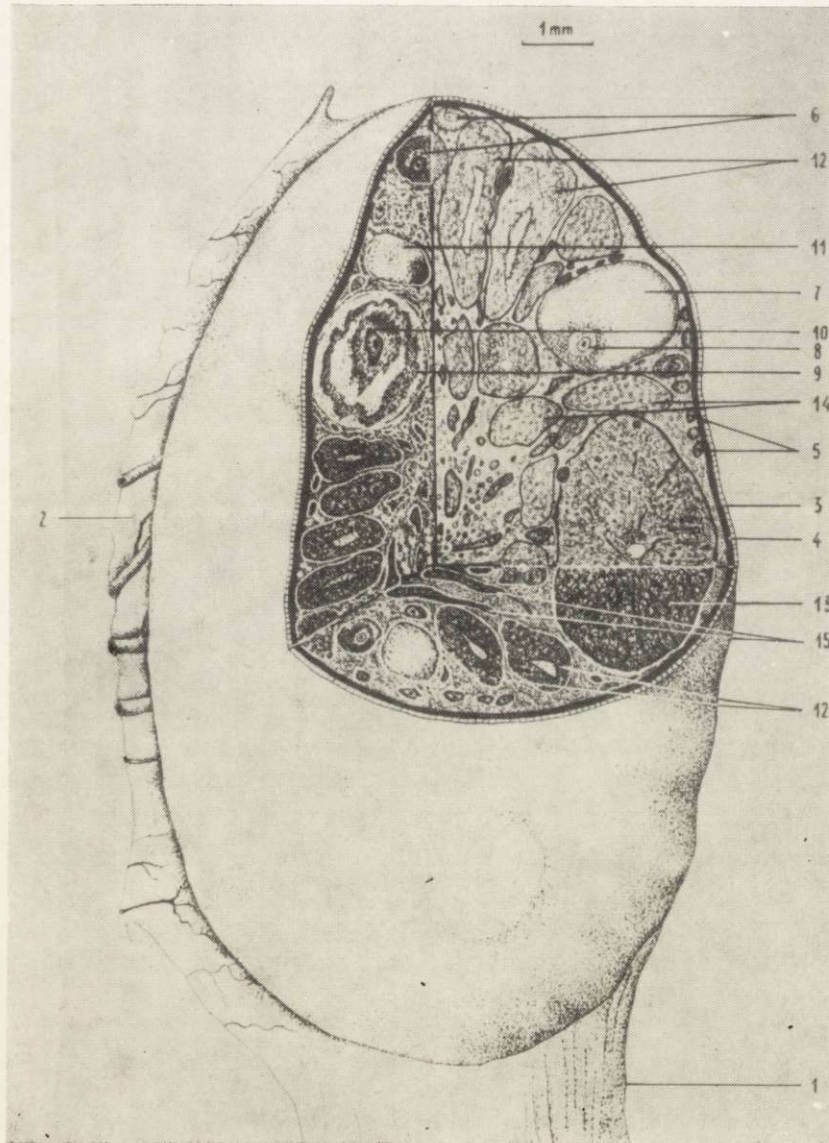
Na podstawie przeprowadzonych badań ustalono, że noworodki bobra posiadają ok. 160 tys. pęcherzyków pierwotnych w jajniku, z których połowa ulega zanikowi do 6 miesiąca życia. Najwięcej pęcherzyków wzrastających pojawia się w okresie 4—6 mies. życia, jak również w tym czasie najczęściej ich ulega atrezji. Liczba pęcherzyków wzrastających obniża się wraz z wiekiem, z czym równocześnie wiąże się spadek liczby pęcherzyków atretycznych. Pierwsze pęcherzyki dojrzałe występują u bobra już w 5 miesiącu życia. Można je spotkać oprócz follikularnej fazy jajnika u samic ciężarnych i karmiących. Pierwsze ciała żółte obserwowano w 6 miesiącu, lecz były one 4-krotnie mniejsze od ciałek żółtych ciążowych. Cechą charakterystyczną jajnika bobra jest gromadzenie ciałek atretycznych, których liczba rośnie wraz z wiekiem.

EXPLANATION OF PLATE XVIII

Fig. 1. Diagram illustrating the occurrence of different ovarian elements of a gravid female beaver, made from a graphic reconstruction.

1. *lig. ovarii proprium*, 2 — *mesovarium*, 3 — *epithelium superficiale*, 4 — *tunica albuginea*, 5 — *folliculus ovaricus primarius*, 6 — *folliculus ovaricus crescens*, 7 — *folliculus ovaricus vesiculosus*, 8 — *ovum*, 9 — atretic follicle — B, 10 — degenerated reproductive cell in atretic follicle, 11 — atretic follicles — A, 12 — *corpus atreticum*, 13 — *corpus luteum*, 14 — *corpus albicans*, 15 — *medulla ovarii*.





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