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Seasonal changes in the ovary of the northern fur seal

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Abstract

The 715 individuals of the fur seal were caught in the waters around the Robben Island, USSR, and Hokkaido and off the coast of Sanriku, and the monthly changes in the ovary were examined. Since ovulation occurs alternately between the right and left ovaries, the sexual cycle in the follicle and the corpus luteum consists of two years.

Introduction

In the previous paper the authors histologically examined the formation and degeneration of corpora lutea using ovaries of the northern fur seals collected around the Robben Island during the period from July to October in 1975. Specimens used in the previous report, however, covered only short period from parturition to its following three to four months, i. e., the collection was not done throughout the year. Those specimens in the previous investigation were therefore insufficient to examine the seasonal changes of follicles and corpora lutea in ovaries throughout the year.

The authors recently had a chance to get ovaries of the fur seals collected throughout the year. Using these specimens the diameter of follicles and corpora lutea were examined in order to clarify the monthly process of development and degeneration in follicles and corpora lutea. Observations include those on the corpus luteum without pregnancy and the corpus luteum graviditatis. At the same time histological observations were made.

Materials and methods

The Fur Seal Resource Research Section of the Far Seas Fisheries Research Laboratory, Fisheries Agency of Japan captured fur seals in order to examine their resources based on the Fur Seal Treaty. Fur seal specimens were caught in the waters around the Robben Island, USSR, and Hokkaido and off the coast of Sanriku, Japan. Of all the specimens caught the number of female specimens used in the present investigation is monthly shown in Table 1.

Ovaries are divided into four groups based on their reproductive condition, that is, the immature ovary, the ovary with corpus luteum graviditatis, the ovary without pregnancy and the ovary without ovulation. The number of specimens are not therefore enough except Feb-

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Table 1. The number of female fur seal specimens by month.

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1968	24	110	68	34									236
1973					96	193	3						292
1975							33	30	27	27			117
1977											3	28	31
1978	39												39
Total	63	110	68	34	96	193	36	30	27	27	3	28	715

ruary and June to examine the seasonal changes. In particular the number of specimens in November is only three. The authors have, however, tried to clarify the seasonal changes in the ovary.

After recording their weight, ovaries were cut into slices along the longer side in order to examine the diameter of the largest follicles in both right and left ovaries. Three diameters were measured at each corpus luteum, and the number of corpus albicantia were also recorded simultaenously.

Paraffin sections were made of all the ovaries, and stained with haematoxylin and eosin, or Azan.

Age of fur seals in the present investigation was determined by annual rings formed in canines of upper jaw.

Development of follicle

In the female fur seal mating and ovulation take place soon after parturition, and ovulation occurs alternately between the right and left ovaries every year. A mature oocyte is ovulated from one of ovaries where no ovulation took place last year. The corpus luteum is formed in the ovary soon after ovulation, and follicles developing in the same ovary begin to disintegrate to be absorbed. All of the follicles, which are formed in the early developmental stage, but do not reach maturity, are thus completely absorbed before parturition occurs (i. e., absorption of follicles is already performed before June). In ovaries of this season only small sized follicles are found. Fig. 1 indicates the monthly average of the diameter of the largest follicles in ovaries locating at the uterus which contained pup. This figure reveals a slow increase in the follicle diameter during the period from July to October after parturition. This is due to a great activity of the corpus luteum which is formed in another ovary. As the lutein cells in the corpus luteum in another ovary begin to degenerate from around December, follicles in the ovary start developing. Although, around January, the pregnant female (corpus luteum graviditatis) is distinguishable from the non-pregnant female (corpus luteum without pregnancy) by the implantation of embryos, at the same time size difference in follicles is found between the ovary with the corpus luteum graviditatis and that with the corpus luteum without pregnancy. This trend becomes more clear as the month reaches Feb-

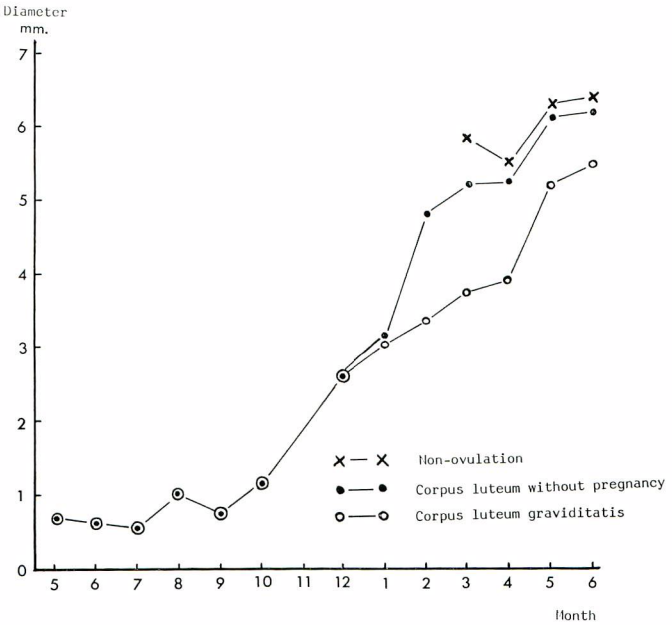

Fig. 1. Development of follicle.

ruary and March. During February and March lutein cells in the corpus luteum graviditatis degenerate, but they still work and restrain the development of follicles. Contrary to this, in the ovary containing the corpus luteum without pregnancy, follicles rapidly develop and grow in size during February, and a great difference in the follicle size is found as compared to the ovary with the corpus luteum graviditatis. This trend continues up to April. During May and June follicles in the ovary containing the corpus luteum graviditatis rapidly grow (this seems to be due to a weak activity in function of the corpus luteum graviditatis). During this period no striking difference in the follicle size is thus found between the ovary containing the corpus luteum graviditatis and that containing the corpus luteum without pregnancy. Fig. 1 suggests that lutein cells completely lose their function by May in the corpus luteum graviditatis, and by February in the corpus luteum without pregnancy.

In the non-ovulated ovary where no ovulation occur even in the reproductive season the corpus luteum is not formed. As the lutein cells, which restrain the development of follicles, do not exist, follicles in the non-ovulated ovary are larger in size than those in other ovaries described above (Fig. 1). During May and June, when parturition occurs, follicle in the non-ovulated ovary reach almost the same size as compared to those in two other ovaries.

Change of the size in the corpus luteum

The corpus luteum, which is formed soon after ovulation in July, increases its diameter (Fig. 2). YOSHIDA *et al.* (1977) indicate the monthly changes of the longest and shortest diameters, and highest length of corpora lutea during a period from July to October. After this

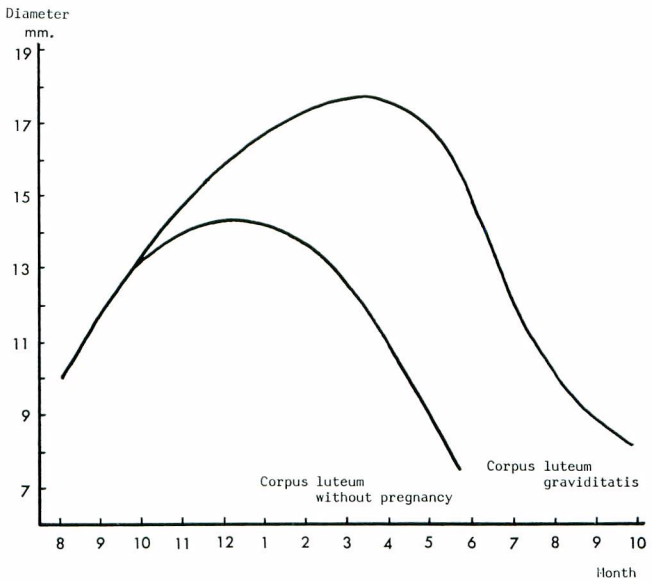

Fig. 2. Change of the size in the corpus luteum.

period the corpus luteum gravitatis continues to develop and it reaches a maximum diameter during March and April. The size of corpus luteum graviditatis rapidly becomes smaller during May through June, and then a rapid contraction is observed in July when parturition takes place. This trend agrees with the development of follicles shown in Fig. 1.

Regarding the corpus luteum without pregancy, it is not clear because only a single specimen was examined in December. It may be, however, said that the corpus luteum without pregnancy is much smaller in diameter than the corpus luteum graviditatis in December. As the month advances, the corpus luteum without pregnancy becomes smaller, and reaches a diameter of about 7 to 8 mm during May through June. This trend in change of the corpus luteum without pregnancy is in accordance with the development of follicles. It is suggested from Fig. 2 that activity of lutein cells in the corpus luteum without pregnancy becomes weak in its function from January and that lutein cells may lose their function during the period from February through March. Moreover, a contracted corpus luteum without pregnancy appears to become a corpus albicans during May through June soon before an ovulation from another ovary.

Monthly average of the corpus luteum diameter shown in Fig. 2 is dealt without considering the age of the fur seal. The value indicated here is the monthly average which is calculated from all of the specimens by month. Fig. 3 indicates wether there is difference in size of the corpus luteum depending on age of the fur seal. In this figure values of the longest diameter of corpora lutea in May and June are protted based on age. This figure thus reveals that there is no correspondence between the size of corpus luteum and age.

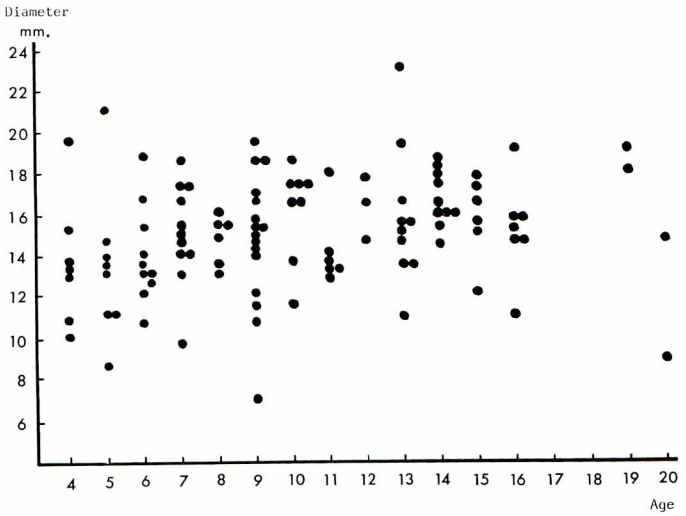

Fig. 3. Size of corpus luteum by age, May-June.

Seasonal changes in the ovary based on the histology

In the previous paper (YOSHIDA *et al.*, 1977) the authors investigated the development of follicles, corpora lutea and corpus albicans using specimens collected during June to October.

The previous work did not contain the observations on the monthly changes throughout the year. It is true that the development and degeneration of follicles and corpora lutea have considerable variations by individual, so that the ovaries collected within the same month do not have the same developmental phase. In addition to this it is impossible to clarify the seasonal change in the ovary using specimens collected during short period such as four months during July to October.

In the present study the authors handled the specimens collected through the year, and seasonal changes in various sexual organs of each life stage of the fur seal are presented. The histological features of ovaries in various reproductive conditions are shown in Plates I–VI.

1) Monthly changes of the ovary in pups and youngs less than one year old

In pups collected during August there are already many follicles in the ovary, a small number of which develops into small-sized vesicular follicles. Some of vesicular follicles have, however, already started degenerating. In pups of October the number of follicles increases more than that in August, but at this stage most follicles are still smaller than 0.2 mm in diameter. Most follicles at this stage are already in the process of degenerating. Many of these follicles are found to be as corpus albicantia in the ovary. Histological view of ovaries in pups in December and January shows almost the same as that in October. In ovaries of pups in May and June the ovarian medulla increases in thickness, and most follicles in the medulla disappear. Follicles in the process of degenerating are not found, and the number of corpus albicantia is small. In the cortex near ovarian epithelium oogonia and oocytes which sank from the epithelium are found. Right and left ovaries of pups less than one

year old have the same histological characteristics.

2) Seasonal changes of the immature ovary

Female fur seal reaches maturity at the age between three and five years old. Most female fur seals first ovulate and mate around early June of their five years old. In the ovary of one-year old fur seal in July and August a few follicles are observed to be developing into vesicular follicles. In ovaries of females including two and three year-old ones collected during September and October relatively developed follicles are found. In November and December follicles begin to be absorbed by phagocytes which appear within the follicles. In the normal mature ovaries ovulation occurs during early July, and many interstitial cells and blood capillaries are found around this season. In the immature ovaries the interstitial cells and capillaries reach a maximum in number around October, i. e., three months later than the mature ovaries. In the specimens of January and February the immature ovaries have follicles, most of which become corpora albicans or contract into very small in size. This means that this season is a resting period for the ovary, and no follicles develop any more. During March and April in ovaries of the immature specimens of three and four year-old fur seals which are expected to be ovulated in July relatively large follicles are found. In April much more large-sized follicles are observed in the ovary, but ovaries are still in the resting period in the immature specimens less than two years old. In the immature specimens of three and four year-old of May both ovaries have large follicles which are developing. In specimens of one and two years old ovaries are still in the resting, but small sized-follicles appear from late May. In June both ovaries of three and four year-old specimens have large-sized follicles, some of which seem to be ovulated at once. In one and two year-old specimens ovaries contain relatively many follicles.

3) Seasonal changes in the ovary without ovulation

The ovaries where no ovulation occur in the reproductive season are in the same developmental stage as that found in ovaries of the three and four-year old specimens which are expected to be ovulated in the next reproductive season, that is, follicles start developing from March (ovaries are in the resting period up to February), and they grow as the month advances. In May the nucleus as well as the cytoplasm in each of interstitial cells, which are arranged around a large follicle, grow to become large in size. Many blood capillaries scatter among the interstitial cells. These suggest that the ovarian activity becomes great. In June follicles in both ovaries become the largest in size and ovulation appears to occur imminently.

4) Seasonal changes in the mature ovary

In females which are now reaching maturity both right and left ovaries have large-sized follicles, and in the ovulating season, ovulation occurs from the two ovaries. In the ovary where no ovulation occur a large-sized follicle still exists and it takes a long time for the follicle to be absorbed. In some cases a corpus luteum is formed near a large-sized follicle to absorb it.

In females which had been pregnant the development of follicles is different in both ovaries. This is due to that an ovulation occurs alternately between the right and left ovaries every year. In the mature specimens collected during early June there are many post-ovula-

ted ovaries with scars by ovulation. In these ovaries the stratum granulosum having been surrounded the antrum folliculi grows and increases its layer in thickness. At the same time both nucleus and cytoplasm of a granular cell grow to become large in size, and the stratum granulosum becomes great in activity. Enlarged granular cells develop into lutein cells. After this the corpus luteum develop to become large in size. The process of development in the corpus luteum has been described in the previous paper. The corpus luteum continues to develop up to the stage when the implantation of a fertilized egg takes place in November. In the ovary where an ovulation has occurred many large-sized follicles are still found, and it takes a relatively long time for these large-sized follicles to be absorbed after formation of the corpus luteum, i. e., pagocytes begin to appear in the stratum granulosum around December. Absorption and contraction of these follicles occur actively after January. In specimens of January follicles remained are surrounded by the connective tissue. As the month advances (February and March), follicles disintegrate rapidly, and they are completely absorbed during April. Even reaching early July no follicles can develop in the ovary due to an influence of the corpus luteum which is formed in another ovary after ovulation. The resting period for the ovary (where no ovulation occur in July) continues up to around December. Development and disintegration of follicles, which is described here, agrees with that in the ovary without pregnancy.

Implantation of a fertilized egg takes place during November, and vacuolation in the lutein cell commences from around December. In most corpora lutea graviditatis of specimens of January vacuolation has occurred in the lutein cells. In corpora lutea of February many interstitial cells scatter among lutein cells where vacuolation has occurred. CRAIG (1966), working with ovaries in the fur seals occurring in the waters around Pribilof Islands, described that the corpus luteum graviditatis starts degenerating from around March. In the present specimens, however, the corpus luteum graviditatis seems to start degenerating from January, when the vacuolation commences in the lutein cells. In the present specimens of March the connective tissue, containing blood capillaries as well as interstitial cells, invade the corpus luteum at many places. In April the vacuole in the lutein cell increases its area, and the connective tissue in the corpus luteum also expands its area. In specimens of May the corpus luteum is almostly occupied by the connective tissue where vacuolated lutein cells scatter. In many places of the corpus luteum the cells forming the cortex concentrate like a mass. Moreover, the boundry between the corpus luteum and the ovarian cortex is not clear. In June no lutein cells are observed, and a large vacuole is formed at the place where lutein cells occupied. The connective tissue actively invades and many blood capillaries scatter there. The corpus luteum seems to completely lose its function as a real corpus luteum.

In July when an ovulation occurs from another ovary. The same process which is observed in the previous months continues to be found, and the corpus luteum transforms into the typical corpus albicans. After this the corpus albicans continues to contract and then disappear within the next two years. That whether the corpus luteum accompanies pregnancy or not becomes clear during November. Neither histological observation nor measurement on the corpus luteum, however, do clarify the difference between the corpus luteum with and

without pregnancy. The corpus luteum, which does not accompany the pregnancy, is not distinguishable histologically from the corpus luteum garviditatis from December through February. During the period after this, degeneration in the corpus luteum without pregnancy occurs faster than that in the corpus luteum graviditatis. In May any lutein cells are not found in the corpus luteum without pregnancy, which completely changes into the corpus luteum albicans in June. PEARSON and ENDERS (1951) described that the corpus luteum, not accompanying the pregnancy is histologically the same as the corpus luteum graviditatis even in late March. The present histological observations and the value by measurement (Fig. 2) are different from the result by PEARSON and ENDERS. YOSHIDA *et al.* (1977) also indicated that the process of degeneration in the corpus luteum, not accompanying pregnancy, is the same as that in the corpus luteum graviditatis. The present observations, however, do not agree with those by YOSHIDA *et al.*

Summary

1. The 715 individuals of the fur seal were caught in the waters around the Robben Island, USSR, and Hokkaido and off the coast of Sanriku, and the monthly changes in the ovary were examined.
2. Follicles in the ovary containing the corpus luteum reach minimum in diameter during May through June, but they increase diameter after ovulation. In February, however, the size difference of follicles between the ovaries with and without pregnancy becomes more clear, and this trend continues to be observed up to parturition season. After parturition follicles in the ovary where no ovulation occur degenerate gradually.
3. The corpus luteum, which is formed soon after ovulation, rapidly increases its diameter. From December the size difference in diameter occurs between the corpus luteum graviditatis and the corpus luteum not accompanying the pregnancy (corpus luteum without pregnancy). The corpus luteum without pregnancy rapidly decreases its diameter after this. The corpus luteum graviditatis, however, continues to increase and reach a maximum in diameter during March and April and a rapid increase occurs after this.
4. In the immature specimens follicles in the ovary develop and reach maturity before reproductive season. Follicles developing in both ovaries degenerate at the same time after ovulation. In December since phagocytes begin to appear in the stratum granulosum, degenration of follicles is rapidly taken place, and follicles are changed into corpus albicans during April. After this any follicles do not develop, and the resting period continues up to the next December. The same process of development and degeneration is also observed in follicles of the ovary without pregnancy.
5. After ovulation cells forming the stratum granulosum develop into lutein cells. Lutein cells proliferate and grow by November, but vacuolation commences from December and lutein cells start degenerating. Vacuolation starts with an invasion of the connective tissue with many blood capillaries into the corpus luteum, which becomes the corpus albicans during the parturition season. The corpus albicans completely disappear within the next

two years. The corpus luteum without pregnancy shows the same histological character as that of the corpus luteum graviditatis before February, but it rapidly degenerates after this. The corpus luteum without pregnancy becomes the corpus albicans two months earlier.

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オットセイ卵巣の季節的変化

吉田主基・馬場徳寿・大矢真知子・水江一弘

要　　約

ロベン系群オットセイの卵巣標本715個体を用いて，卵胞，排卵黄体及び妊娠黄体の形成と退化の過程を肉眼的並びに組織学的に一年間を通して検討し，次の結果を得た。

1. 肉眼的観察

(1) 出産側卵巣での卵胞は7月～10月頃まで成長を示さず，12月頃から次等に発達し始める。しかし，反対側の卵巣に排卵黄体を持つ個体と妊娠黄体を持つ個体とでは12月以降その発達の過程が異なる。

(2) 反対側卵巣に排卵黄体を持つ個体の卵胞の発達は妊娠黄体を持つ個体をしのぎ2月～4月頃に急速に発達するが，妊娠黄体を持つ個体の卵胞は5月頃から急速に発達してその差異をちぢめる。

(3) 妊娠黄体の発達は3月～4月に最大となり，5月頃から急速に収縮し，特に7月には収縮度がいちぢるしい。排卵黄体の発達は12月に最大となり，その後は急速に収縮する。

(4) 年令と黄体の大きさには全く相関がない。

2. 組織学的観察

(1) 成熟獣の卵巣は卵胞の発達過程及び間細胞での毛細血管の出現から見て，7月初旬頃最も充実するが，未成熟獣の卵巣は約3ケ月おくれた10月頃に最も充実する。

(2) 無排卵獣（すでに成熟に達しているが，前期の繁殖期に何らかの理由で排卵しなかったもの）の卵巣は次期の繁殖期に初めて排卵すると思われる若令獣の卵巣と同じ発達過程をたどる。その発達過程は2月まで休止の状態であるが，3月頃から卵胞の発達が見られ，5月～6月には極めて活動的な様相を示す。

(3) 排卵側卵巣で排卵されなかった大型の胞状卵胞の吸収・収縮は黄体が形成された後相当経過してからおこなわれる。12月頃に卵胞の顆粒細胞層に食細胞が出現し，1月頃から本格的に吸収・収縮が始まり，2月～3月と急速になり，4月にはほとんど吸収しつくされる。

(4) 妊娠黄体の退化はルテイン細胞が空胞化する1月から始まる。その後，結合組織が黄体組織中に侵入し，8月には典型的な白体の型態となり，その後2年以内に消失する。

(5) 排卵黄体の退化は組織像上12月～2月までは妊娠黄体と区別することが出来ないが，その後退化は早く，6月には完全に白体化する。

EXPLANATION OF PLATE I

Fig. 1. X 20. Histological section of fur seal ovary after 6 months from birth. Caught 13 January, 1978.

Fig. 2. X 10. Histological section of immature fur seal ovary, 2 years old. Caught 13 October, 1975.

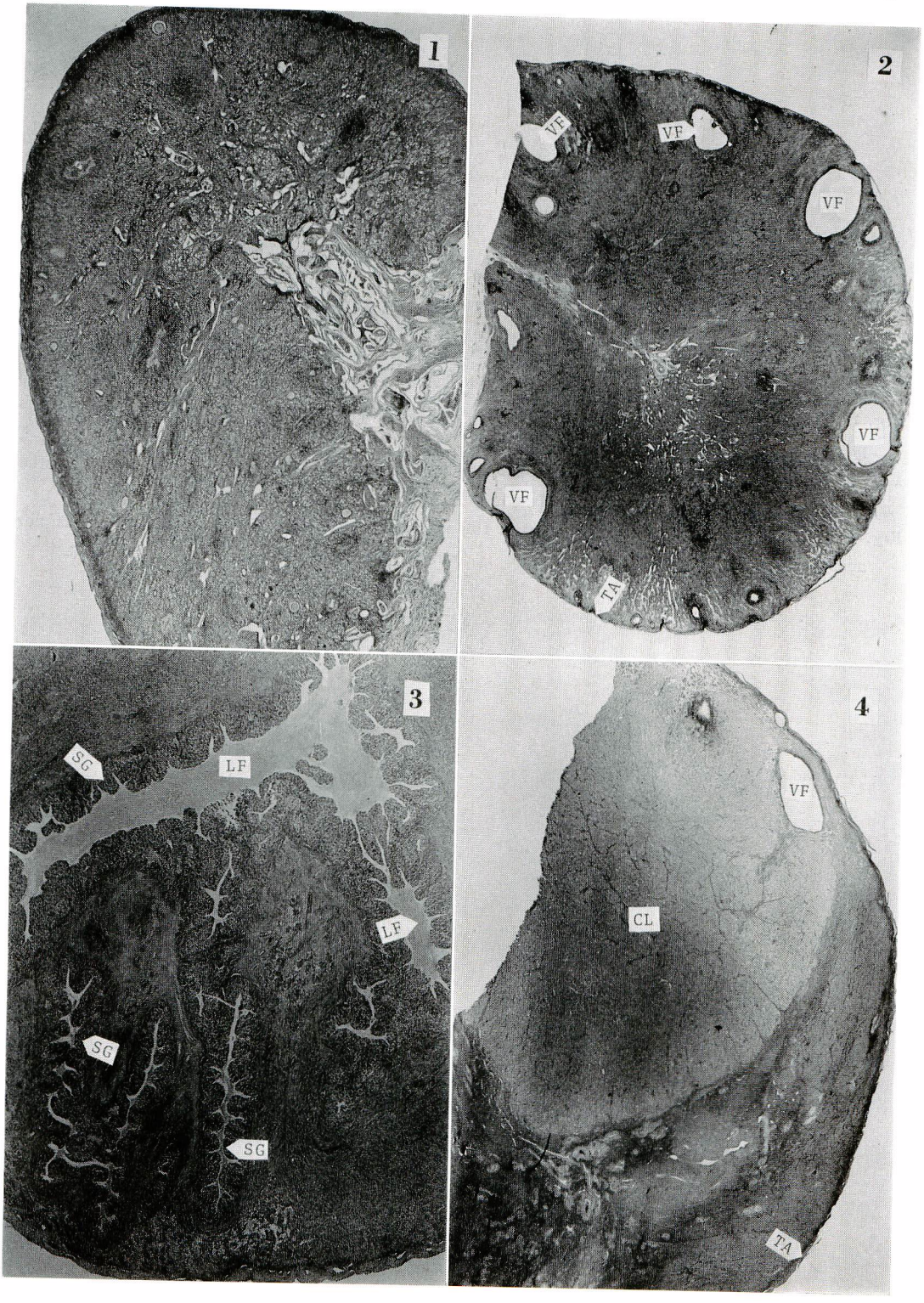
Fig. 3. X 20. Ovulated follicle, 14 years old. Caught 3 July, 1975.

Fig. 4. X 10. Histological section of mature fur seal ovary, 14 years old. Corpus luteum is resulted from this ovulation. Caught 11 October, 1975.

EXPLANATION OF SYMBOLS IN PLATES

VE	Vesicular follicle	C	Cortex
TA	Tunica albuginea	LC	Lutein cell
SG	Stratum granulosum	N	Nucleus
LF	Liquor folliculi	P	Protoplasm
CL	Corpus luteum	S	Secretion
CLG	Corpus luteum graviditatis	IC	Interstitial cell
CLWP	Corpus luteum without pregnancy	CFC	Cell forming cortex
CAT	Corpus atreticum	CT	Connective tissue
CA	Corpus albicans	BC	Blood capillaries

Plate I



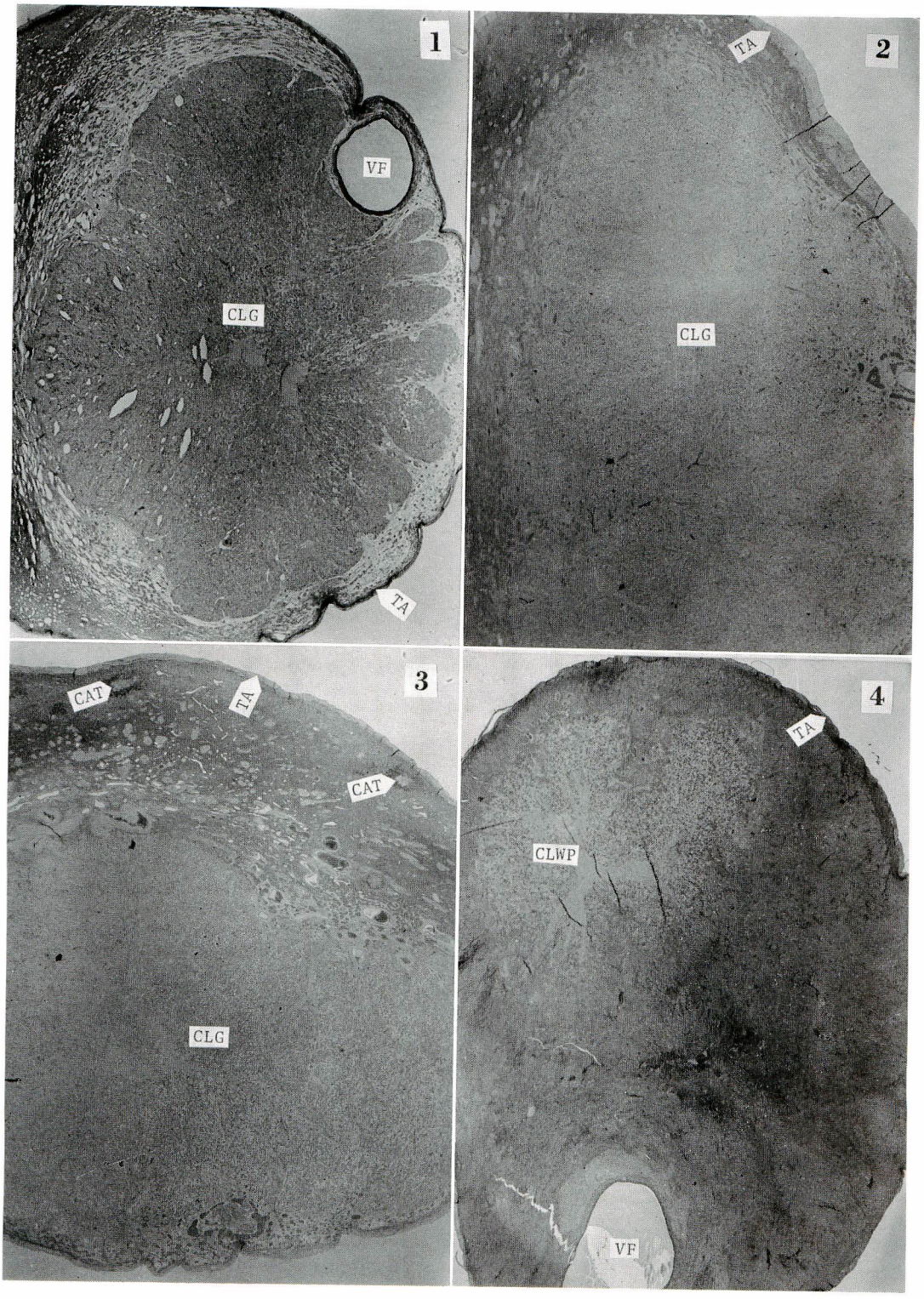
EXPLANATION OF PLATE II

Fig. 1. X 10. Histological section of pregnant fur seal ovary, 3 years old. Caught 5 December, 1977.

Fig. 2. X 10. Histological figure of corpus luteum graviditatis, 12 years old. About seven months passed after ovulation. Caught 29 February, 1968.

Fig. 3. X 10. Histological figure of corpus luteum graviditatis, 6 years old. About 8 months passed after ovulation. Caught 11 March, 1968.

Fig. 4. X 10. Histological section of mature fur seal ovary, 11 years old. Corpus luteum is not accompanied by pregnancy passed about 11 months after ovulation. Caught 3 June, 1973.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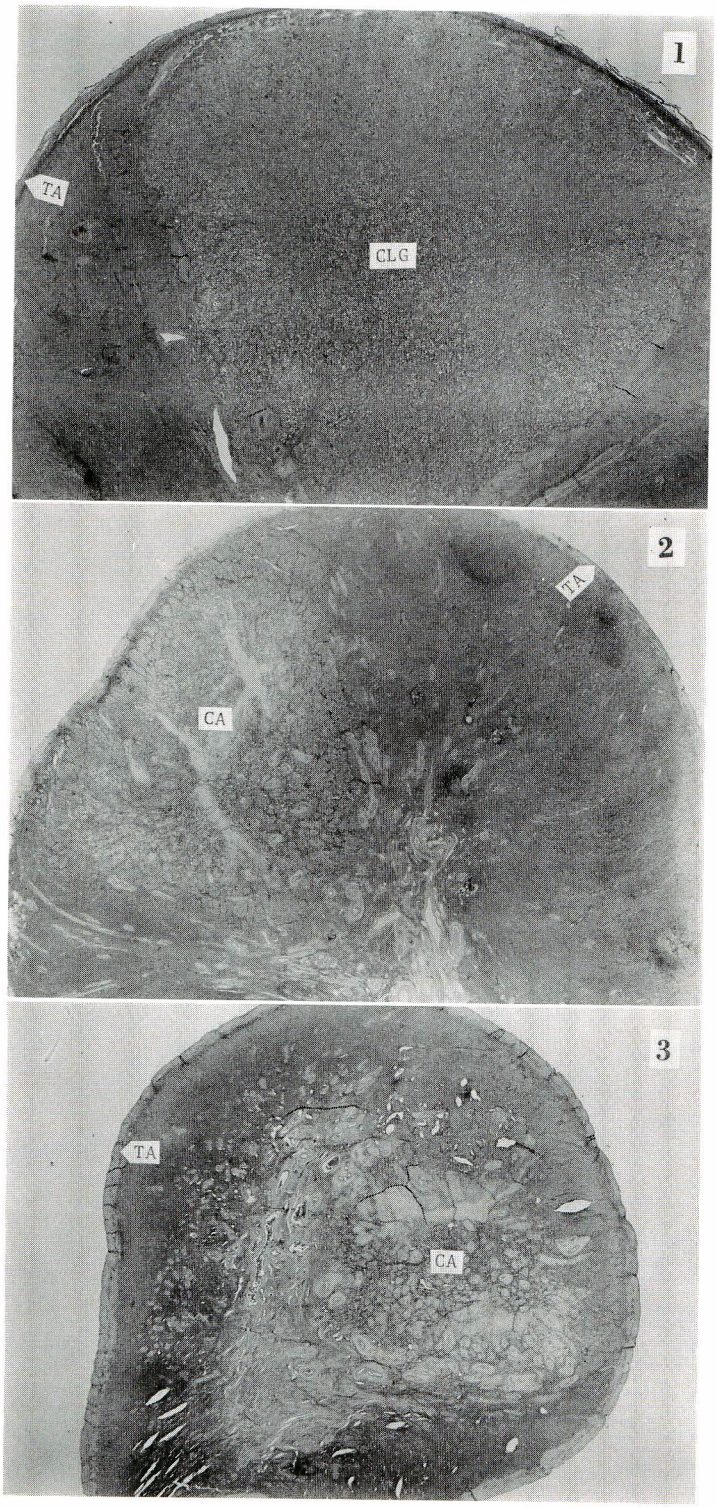
EXPLANATION OF PLATE III

Fig. 1. X 10. Histological section of corpus luteum graviditatis of about a month before delivery, 6 years old. Caught 2 June, 1973.

Fig. 2. X 10. Histological section of post-partum in this breeding season, 6 years old. Caught 26 October, 1975.

Fig. 3. X 10. Corpus albicans originated from copus luteum graviditatis passed about 5 months from parturition. Caught 13 December, 1977.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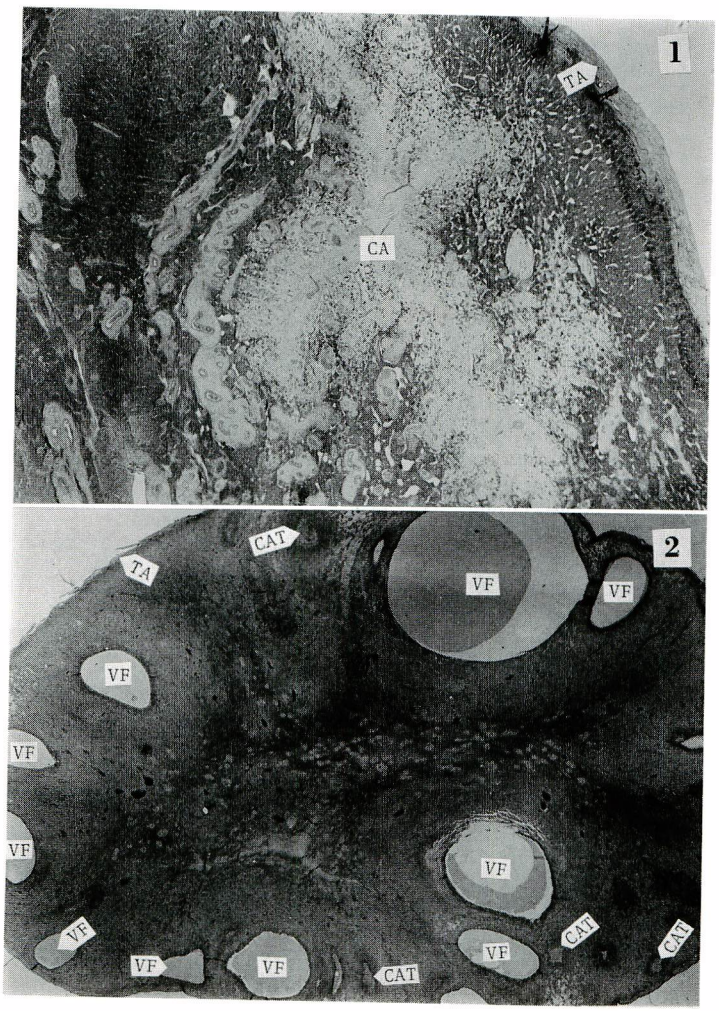
EXPLANATION OF PLATE IV

Fig. 1. X 20. Histological figure of corpus albicans of about 20 months after ovulation, 10 years old. Caught 29 March, 1968.

Fig. 2. X 10. Mature ovary, 6 years old. This ovary will ovulate in this breeding season. Caught 3 June, 1973.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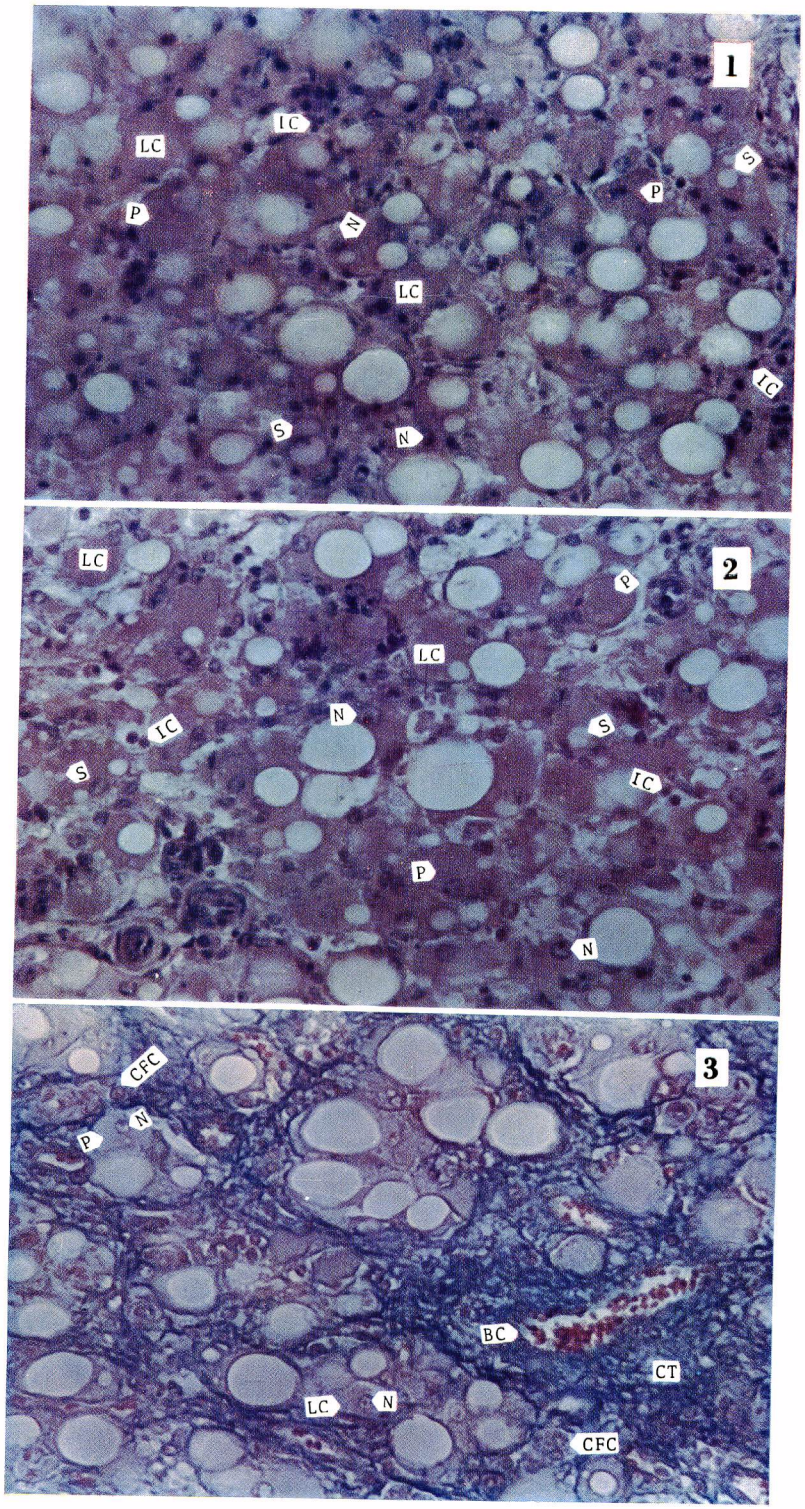
EXPLANATION OF PLATE V

Fig. 1. X 150. Histological figure of corpus luteum graviditatis, 15 years old. Caught 22 February, 1968. (H. E. Stain)

Fig. 2. X 150. Histological figure of corpus luteum graviditatis, 10 years old. Caught 29 March, 1968. (H. E. Stain)

Fig. 3. X 150. Histological figure of corpus luteum graviditatis about a month before delivery, 6 years old. Caught 26 May, 1973. (Azan Stain)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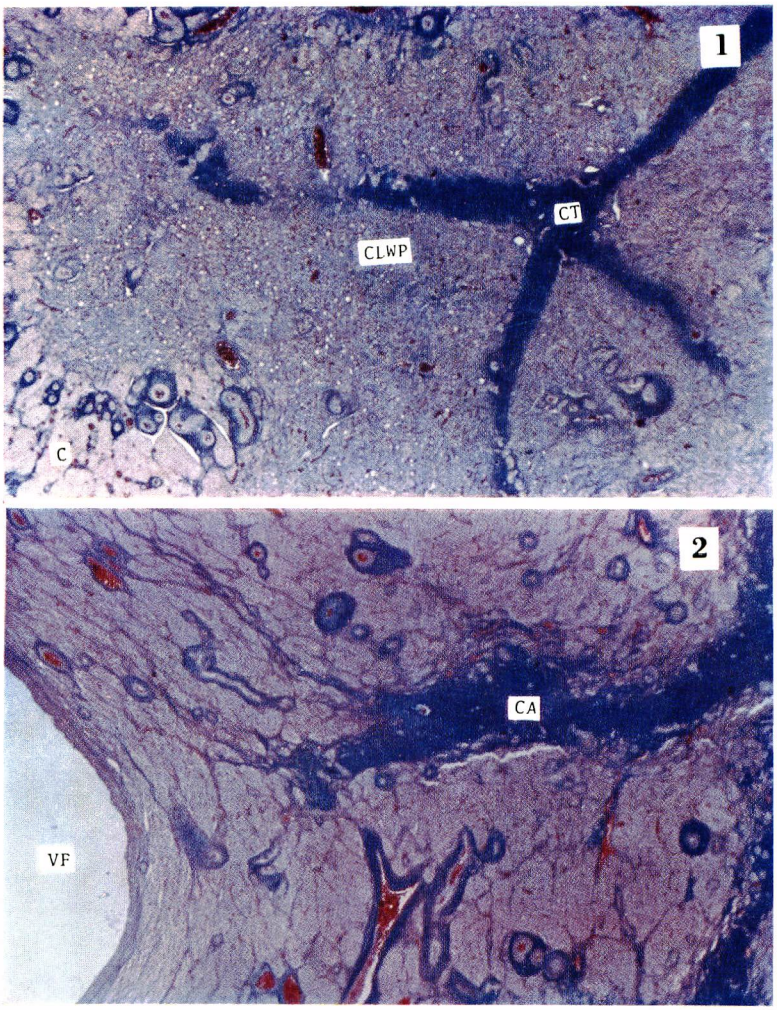
EXPLANATION OF PLATE VI

Fig. 1. X 20. Corpus luteum not accompanied by pregnancy passed about 10 months after ovulation, 11 years old. Caught 25 May, 1973. (Azan Stain)

Fig. 2. X 20. Corpus albicans of 23 months after ovulation, 11 years old. This ovary will ovulate in this breeding season. Caught 18 June, 1973. (Azan Stain)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