# Study for reproductive mechanism of fur seal (*Callorhinus ursinus*) of Asian origin

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**Abstract**

Using the data of the Robben Island fur seal origin collecting in Western Pacific Ocean from November to June and also those in Sea of Okhotsk from June to October during 1959 to 1980, we analyzed a trend of their reproductive condition, and observed their ovaries visually and microscopically.

The purpose of the present study is to analyze the correlation between changes of the resource and those reproductive mechanism and to reflect the result to the control of resources by finding out exactly the sexual cycle of an individual and analysing the reproductive condition from a new aspect.

## Introduction

The report forms on the reproductive condition presented by Japan, USA, Canada and USSR from 1958 to 1970 under the Interim Convention on Conservation of North Pacific Fur Seals show only the pregnant records and the apparent pregnancy rates, but are not so useful for the study of reproductive mechanism contributing to the resource assessment.

Therefore, YOSHIDA and ICHIHARA (1974) analyzed how the reproductive condition was correlative to changes of the fur seal resource and also proposed a new method of classification in order to reflect the result of analysis to the control of this resource. The data collected in the past were analyzed with the proposed method.

Also in the biological research of fur seals, more precise data have been required in recent years. However, the maturity of each individual as the basis of the resource assessment is determined only with gross observation of the ovary, which was not sufficient to determine exactly the sexual cycle of an individual.

The microscopical observation on these genital organs were reported only on the American fur seal origin by ENDERS (1946), PEARSON (1951) and CRAIG (1964), but it may be fairly said that nothing was reported on the Asian fur seal origin.

Therefore, the microanatomical study on the genital gland is required to clarify the reproductive mechanism of the Asian fur seal origin. The present study was made in order to clarify histologically the micromechanisms on the process of growth, contraction and ab-

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sorption in the follicle, the fates of the corpus luteum and corpus albicans, annual changes of the ovary, and the mechanism and change of the lutein cell.

## Materials and methods

The materials and specimens used in the present study were collected from January to June in the offshore of Sanriku by the Japanese Fisheries Agency and Tokai Regional Fisheries Research Laboratory (1959~1967), and also from January to June/November to December in the offshore of Sanriku, from July to October in Sea of Okhotsk by the Japanese Fisheries Agency and the Far Seas Fisheries Research Laboratory (1968~1980).

Table 1 shows the number of materials on the genital glands of female fur seals by month and year which were used in the present study. The materials of 5, 195 individuals collected in the offshore of Sanriku during 5 years from 1959 to 1963 could not be used for researching the subject by the new classification method, but were used only for the review of apparent pregnancy rates.

The materials of 2, 883 individuals collected in the offshore of Sanriku during 4 years from

**Table 1.** Volume of data used in the research of genital glands. Nov.-Jun. Research in water off Sanriku, Jul.-Oct. Research in Sea of Okhotsk

| Year \ Month | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1959 | | 106 | 363 | 840 | 276 | 42 | | | | | | | 1, 627 |
| 1960 | | | 24 | 473 | 332 | 50 | | | | | | | 879 |
| 1961 | | | 41 | 394 | 410 | 15 | | | | | | | 860 |
| 1962 | | 5 | 83 | 528 | 218 | 62 | | | | | | | 896 |
| 1963 | | | 48 | 200 | 393 | 266 | 26 | | | | | | 933 |
| 1964 | | | 219 | 203 | 347 | 78 | | | | | | | 847 |
| 1965 | | | 120 | 62 | 299 | 263 | 9 | | | | | | 753 |
| 1966 | | | 114 | 145 | 209 | 70 | | | | | | | 538 |
| 1967 | 82 | 226 | 132 | 145 | 160 | | | | | | | | 745 |
| 1968 | 24 | 110 | 67 | 34 | | | | | | | | | 235 |
| 1969 | 18 | 98 | 123 | 24 | | | | | | | | | 263 |
| 1970 | 61 | 214 | 260 | 3 | 3 | | | | | | | | 541 |
| 1971 | | 128 | 173 | 19 | 55 | 11 | | | | | | | 386 |
| 1972 | | 23 | 260 | 98 | 13 | 8 | 109 | 189 | | | | | 700 |
| 1973 | | | | | 96 | 193 | 122 | | | | | | 411 |
| 1974 | | | | | | | 222 | 284 | 208 | | | | 714 |
| 1975 | | | | | | | 313 | 321 | 252 | 78 | | | 964 |
| 1976 | | | | | | | | 302 | 158 | 20 | 31 | | 511 |
| 1977 | | | | | | | | | | | 3 | 28 | 31 |
| 1978 | 40 | | | | 29 | 155 | 303 | 195 | | | | | 722 |
| 1979 | | | | | | | | | | | | 51 | 51 |
| 1980 | 26 | 95 | 73 | 24 | 154 | 15 | 294 | 344 | | | | | 1, 025 |
| Total | 251 | 1, 005 | 2, 100 | 3, 192 | 2, 994 | 1, 228 | 1, 398 | 1, 635 | 618 | 98 | 34 | 79 | 14, 632 |

**Table 2.** Volume of data used in the histological observation. Nov.-Jun. Research in water off Sanriku, Jul.-Oct. Research in Sea of Okhotsk

| 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 |

1964 to 1967 were not so sufficient to research the subject by the new classification method, but some of them were used for observing changes during years.

All the specimens of 6,554 individuals collected in the offshore of Sanriku and Sea of Okhotsk during 13 years from 1968 to 1980 were used for visual determination of the genital gland (immaturity, maturity-non-ovulation, maturity-ovulation-non-pregnancy, maturity-ovulation-pregnancy, the observation of abortion or a dead fetus) as well as for determination of the ovary, the corpus luteum and the follicle.

The specimens of 715 individuals out of 2,363 individuals collected in 1968, 1973, 1975, 1977 and 1978 were used to prepare the paraffin sections (by haematoxylin-eosin stain and Azan stain) and the carbowax section (by fat stain) for the purpose of annual histological observation, and trace annual changes of the corpus luteum and the luteinic function. Table 2 shows the number of specimens on the genital glands of female fur seals by month and year which were used for the histological observation.

## Results

### The trend and contents of reproductive condition

As mentioned above, the pregnant records and the apparent pregnancy rates were only obtained from the report forms presented by the said countries (the Japanese Fisheries Agency and Tokai Regional Fisheries Research Laboratory; 1959～1967, the Japanese Fisheries Agency and the Far Seas Fisheries Research Laboratory; 1968～1980, All-Union Institute Marine Fisheries and Oceanography; 1959～1970, the Fisheries Research Board of Canada; 1958～1971, Marine Mammal Biological Laboratory; 1958～1970) from 1958 to 1970, and were arranged into 5 forms as follows:

(1) $\frac{\text{Nonpregnant}}{\text{N. P. M.}}$ , $\frac{\text{Pregnant}}{\text{P. M.}}$

(2) Immature , $\dfrac{\text{Mature}}{\text{Pregnant, Nonpregnant}}$

(3) $\dfrac{\text{N.}}{\text{Immature, Mature}}$ , $\dfrac{\text{P.}}{\text{Pregnant, Missed pregnant, Aborted}}$ ,

$\dfrac{\text{M.}}{\text{Pregnant, Missed pregnant, Aborted}}$

(4) Immature , $\dfrac{\text{Mature}}{\dfrac{\text{Nonpregnant}}{\text{N. P. M.}} \quad \dfrac{\text{Pregnant}}{\text{P. M.}}}$

(5) $\dfrac{\text{N.}}{\dfrac{\text{Ovulated}}{\text{Yes} \quad \text{No}}}$ , $\dfrac{\text{P.}}{\dfrac{\text{Nonpregnant}}{\dfrac{\text{Ovulated}}{\text{Yes} \quad \text{No}}} \quad \text{Pregnant}}$ , $\dfrac{\text{M.}}{\dfrac{\text{Nonpregnant}}{\dfrac{\text{Ovulated}}{\text{Yes} \quad \text{No}}} \quad \text{Pregnant}}$

The definitions of terms used herein were quoted from the United States Department of Interior (1963) as explained as follows:

N: (Nulliparous)…A matured individual without experience of birth and embryo after implantation.

P: (Primiparous)…An individual with an experience of birth, during the period of the first pregnancy or after abortion of an embryo.

M: (Multiparous)…An individual with two or more experiences of birth, with experiences of one birth and one abortion or with an experience of birth and during the period of pregnancy,

The classification of above (1) to (5) seems complicated, and shows unclear expressions on the reproductive condition; for example, P. and M. of Nonpregnant are not distinguishable whether it has not ovulated or has ovulated but missed pregnancy.

As mentioned above, the previous research on the genital gland of fur seal depended mainly upon anatomical findings in the vertical folds of the external uterine peries or the uterine membrane with anatomical findings in the ovary. The result could be used for determination of the delivery but not for researches on the reproductive mechanism and its change according to changes of the fur seal resource.

Since the author found out the point, they proposed a new method of classification as mentioned below in order to improve the previous method of research, and analyzed the pergnancy rates by age (apparent and true pregnancy rates), the maturity rate, the missed pregnancy rate and the aged change of the non-ovulation rate.

Undermentioned are the new proposed form of classification on the reproductive condition, the calculating expressions of those rates and definitions of terms.

The new form of classification

Immature, $\dfrac{\text{Mature}}{\text{Non-ovulation, False yellow body (ovulated but not pregnant), True yellow body (pregnant).}}$

Calculating expression of rates:

$$\text{Apparent pregnancy rate} = \frac{\text{Number of pregnant fur seals (include abortion, dead foetus)}}{\text{Number of caught fur seals (immature+mature)}} \times 100$$

$$\text{True pregnancy rate} = \frac{\text{Number of pregnant fur seals}}{\text{Number of mature fur seals}} \times 100$$

$$\text{Maturity rate} = \frac{\text{Number of mature fur seals}}{\text{Number of caught fur seals (immature+mature)}} \times 100$$

Definitions:

Immature animal…an individual without experience of ovulation.

Non-ovulated animal…a mature individual that did not ovulate in the previous breeding season.

Animal with corpus luteum menstruationis (animal of missed pregnancy)…an individual that ovulated but did not conceived.

Animal with corpus luteum graviditatis…an individual that ovulated and became pregnant (including the cases of abortion, absorption and dead foetus).

The fur seals that appear in the offshore of Sanriku are not of a completly single origin but consist of the American origin (Pribilof origin) and the Asian origin (Robben origin, Commander origin and Kuril origin) in the variety of mixture. Therefore, the rate of mixture should be considered to study these problems.

Calculation of the rate of mixture is based on the number of marked infants, the rates of marked infants and these reciprocals in breeding islands as well as the collection number of marked infants and the collection rate of marked infants in the sea. The rates of mixture in the offshore of Sanriku published by the North Pacific Fur Seal Commission (1958~1961, 1962~1963 and 1964~1966) show that the rate of mixture in females of Robben origin decreases slightly against increase of the age, both sexes of Commander origin are approximately same in the number, and females of Pribilof origin relatively increase against increase of the age. However, the rates of mixture in the case of 4 to 5 year group are about 52% in Robben origin, 36% in Commander origin and 12% in Pribilof origin. Consequently it is not considered that the rate of mixture in 4 to 5 year females of Pribilof origin has increased drastically since 1967. Accordingly, the trend of the reproductive condition regarding the females caught in the offshore of Sanriku may appear to be caused by changes of Asian origins (particularly Robben origin).

Robben origin also mix by 96% in Sea of Okhotsk at the breeding period, and the data collected there can be considered as the material on the single group of Robben.

The pregnancy rates are slightly different depending upon the collecting times of specimens and the collecting areas: For example, the highest pregnancy rate in the offshore of Sanriku is found from January to February, and then the rate shows a trend of declining thereafter. However, the result in the offshore of Sanriku from March to April is almost same as that in Sea of Okhotsk from July to August. Resultedly, it is considered that the data plentifully available from March to April and from July to August may be used together to study a trend from year to year, although it is the other problem when the exact pregnancy rate of Asian origins (mainly Robben origin) should be collected.

1. The age of sexual maturity

Fig. 1 shows a trend of the sexual maturity by the age during 17 years from 1964 to 1980.

The female criterion of sexual maturity is based on occurrence of ovulation. The data of marine researches show a remarkable change in the sexual maturity of 4-year group (3-year group at the breeding period) during 17 years from 1964 to 1980: i.e. the rate of 78% level in 1964 sharply decreased by about 64% during 6 years, and then it recovered from 14% level in 1970 to 71% level in 1980 during 11 years.

The sexual maturity rate of 5-year group (4-year group at the breeding period) scarcely changed during 6 years from 1964 to 1969, but the rate began to decline from 1970 and showed the decrease of 17% as 81% in 1974 compared with the rate in 1971. Thereafter the rate indicated a trend of increase, and recovered in 1978 to the same level as that in 1971. The lowest level of 5-year group was found 4 years later after the year with the lowest level of 4-year group, but no change was observed in the sexual maturity rate of 6-year group.

The above result may show that changes of the sexual maturity rates are observed mainly in 4 or 5 year group-remarkably in 4-year group of the first reproductive group in particular, and changes in 5-year group slightly appear several years later.

Changes of the rates in 4 and 5 year group suggest the increase of immature individuals in this age group, and show that the age of sexual maturity at the breeding period moved temporarily from 3 years to 4 years during 9 years from 1968 to 1976 in view of the criterion of 50% maturity rate.

In order to elucidate why the age of sexual maturity changes, the relationship among the growth, the food volume and the number of harem bull was studied.

The author reviewed the data of 1964 and 1980 showing the highest maturity rate and those of 1970 indicating the lowest rate at the research off Sanriku from March to April, and also the data of 1974 and 1980 at the research in Sea of Okhotsk from July to August.

The average body lengths of 4-year immature group during March and April were 113.4 cm (23 specimens) in 1964, 113.0 cm (23 specimens) in 1970 and 114.0 cm (3 specimens) in 1980, while average body lengths of 4-year mature group were 115.4 cm (35 specimens) in 1964, 114.7 cm (5 specimens) in 1970 and 120.4 cm (3 specimens) in 1980. The average body length of 4-year immature group during July and August were 112.0 cm (18 specimens) in 1974 and 114.5 cm (6 specimens) in 1980. The average body lengths of mature group after delivery were 114.3 cm (4 specimens) in 1974 and 119.3 cm (11 specimens) in 1980.

The average body weight of 4-year mature group during March and April is heavier than that of immature group, of course, because of pregnancy, and cannot be used for the

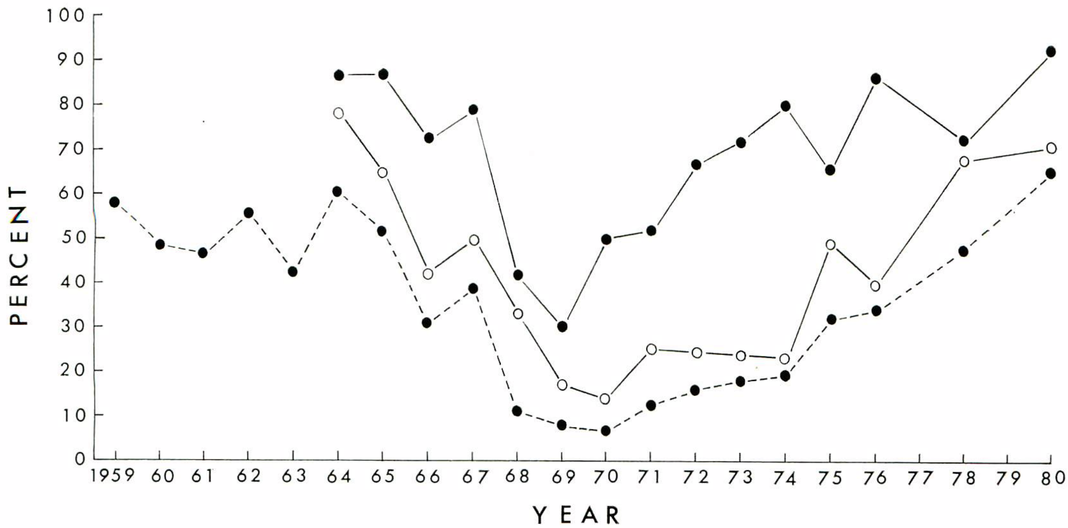


**Fig. 1** Rate of maturity by age group, rate of true pregnancy and rate of apparent pregnancy
For the 1959~1971 period, data collected off Sanriku in March and April
For the 1972~1980 period, data collected in the Sea of Okhotsk in July and August
●—● True pregnancy rate ○—○ Maturity rate ●‥● Apparent pregnancy rate

**Fig. 1-1** 4 year old

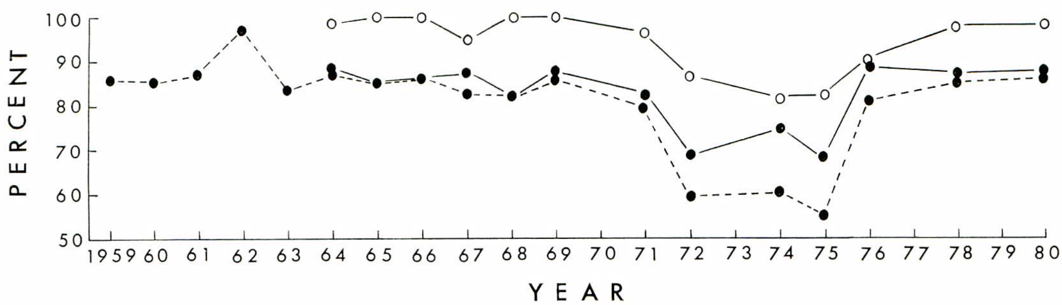


**Fig. 1-2** 5 year old

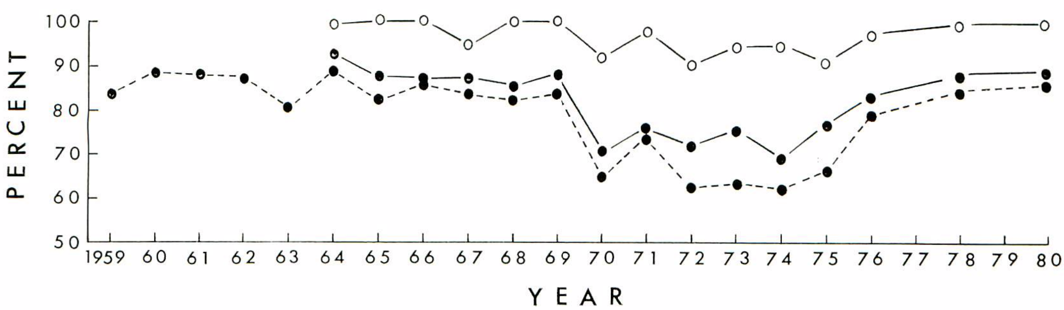


**Fig. 1-3** 5-7 year old

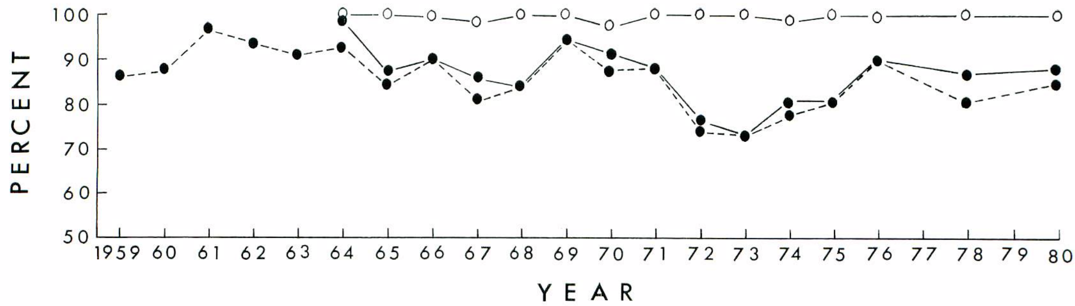


**Fig. 1-4** 8-10 year old

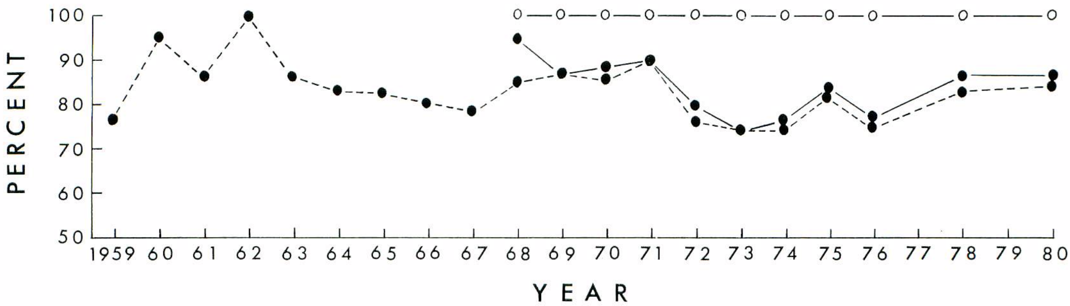


**Fig. 1-5** 11-15 year old

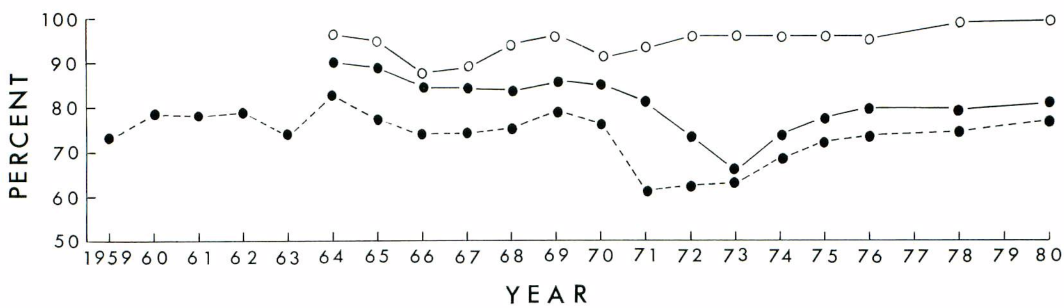


**Fig. 1-6** 4 year or older

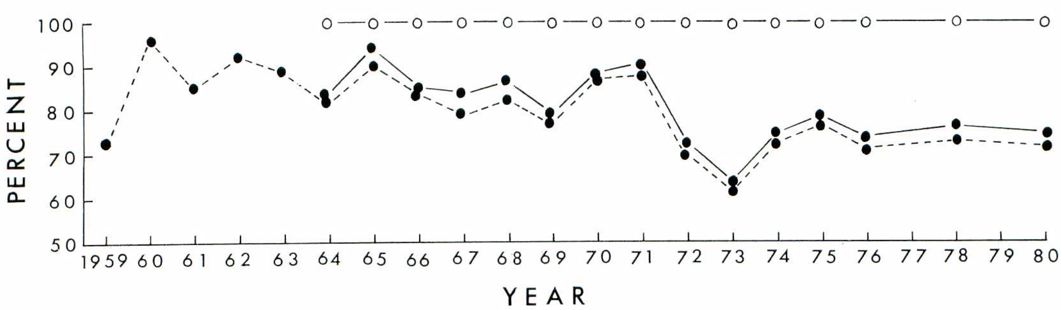


**Fig. 1-7** 10 year or older

present study. The average body weights of 4-year immature group during July and August were 28.3 kg in 1974 and 29.4 kg in 1980. The average body weights of mature group after delivery were 30.8 kg in 1974 and 32.9 kg in 1980.

The above result, in spite of limited specimens, shows that both weights and lengths of immature group in any month were inferior to those of the same age mature group, and those in the year of low maturity indicated smaller figures than those in the year of high maturity.

In the next stage, in order to study the feed intake which appears to be most relative to the growth, the contents in the stomach and the bile colors were pigeonholed as shown in Figs. 2-1 and 2-2. Fur seals usually take food from night to early morning. They are omnivorous and do not take selectively a specific fish. They take any fish plentifully available in their floating sea. For example, contents in the stomach of fur seals at the research of Sanriku were almost Lanternfishes during 1961 to 1964 when plenty of these fishes came to the area, and the majority of their stomach contents were Pacific mackerels during 1968 to 1972 when a lot of Pacific mackerels were found there.

The graph in the upper side of Fig. 2-1 shows the occurrence rate of individuals with food in the stomach among the fur seals caught from 05 : 00 to 12:00 am. The graph in the lower side indicates the average stomach contents per individual with food in the stomach.

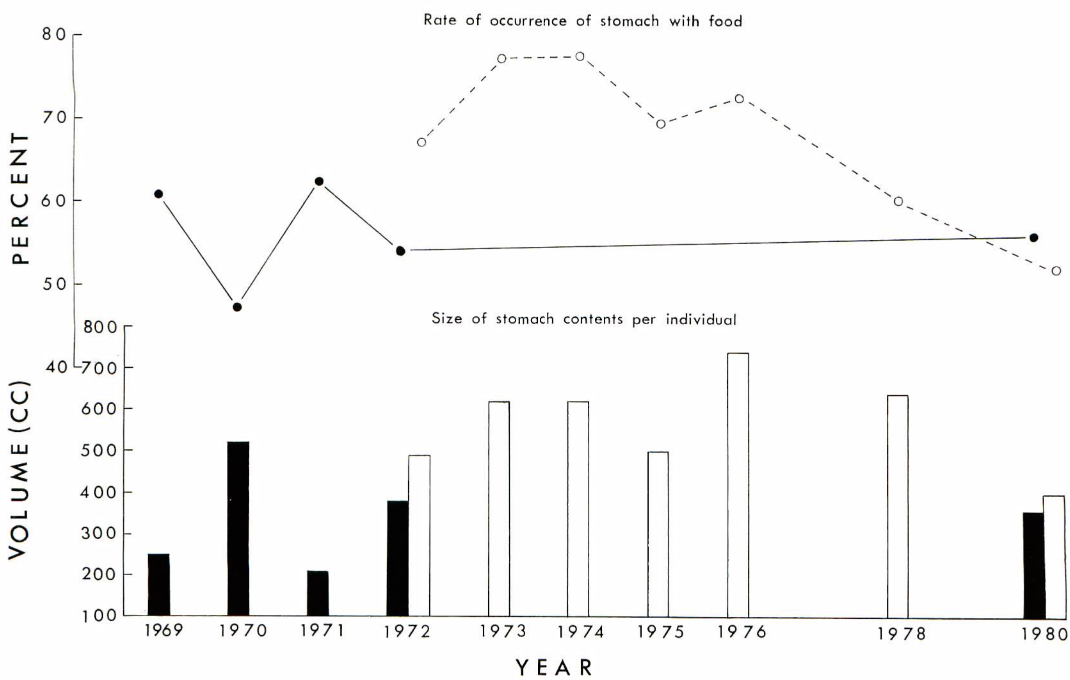


**Fig. 2-1** Volume of feed consumption. Data off Sanriku in Feb.-Apr. are shown with black column and circle. Data from the Sea of Okhotsk in July-Sept. are shown with white ones.

The result shows that a wide variation was found from year to year at the research in the offshore of Sanriku but both data during 1969 to 1980 were unchanged. The occurrence rate of individuals with food in the stomach was decreasing in recent years at the research in the Sea of Okhotsk.

In addition to the conventional method as mentioned above, the author took notice of the fact that more feeding volume takes a longer time to make the bile color dark, and analyzed the result of the research at Sea of Okhotsk as shown in Fig. 2-2.

As the result, most of the fur seals caught in the morning had food in their stomachs with the light color bile, while much less individuals caught in the afternoon showed remained food in their stomachs with the light color bile, and more individuals of the empty stomach with the dark color bile were caught in the afternoon in recent years. The result conforms to the result on stomach contents by the conventional method, and suggests that the absolute quantity of fishes as feed of the fur seal resource is insufficient and fur seals are unable to feed as they want.

In recent years, however, the maturity rate of 4-year animals became better as compared with the previous years, but the occurrence rate of individuals with food in the stomach became lower and the volume of feed consumption per head also declined. The fact is inconsistent with the above result though.

Regarding the comparison between a trend of the sexual maturity age in 4-year animals and the aged change of harem bull number in Robben Island (Fig. 3), the sexual maturity age changed from 3 years old to 4 years old about 4 years before the number of harem bulls

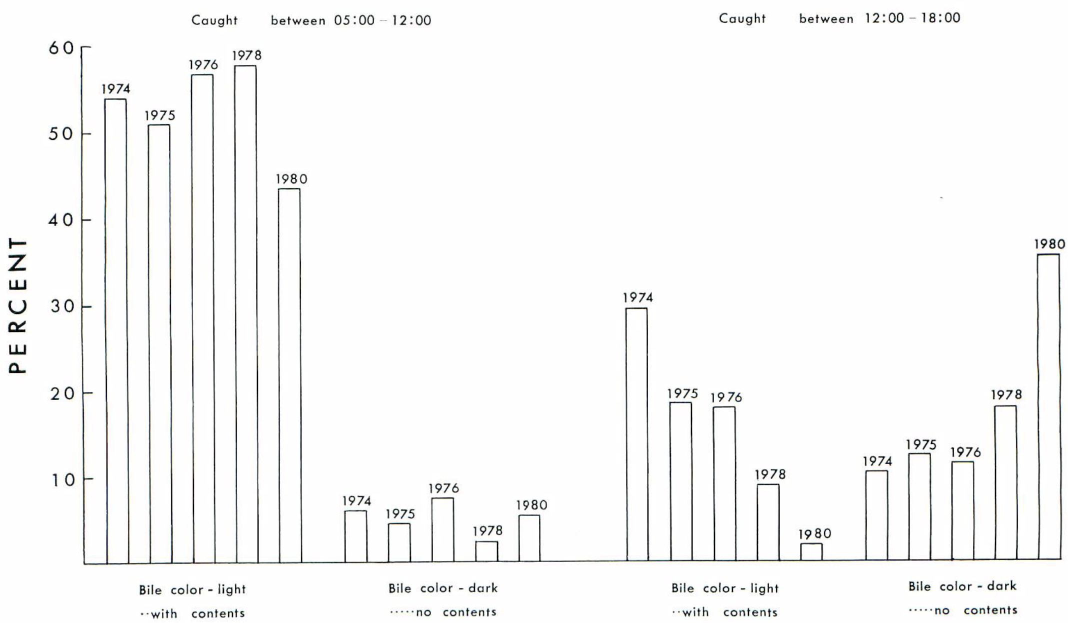


**Fig. 2-2** Relation of the color of bile with stomach contents

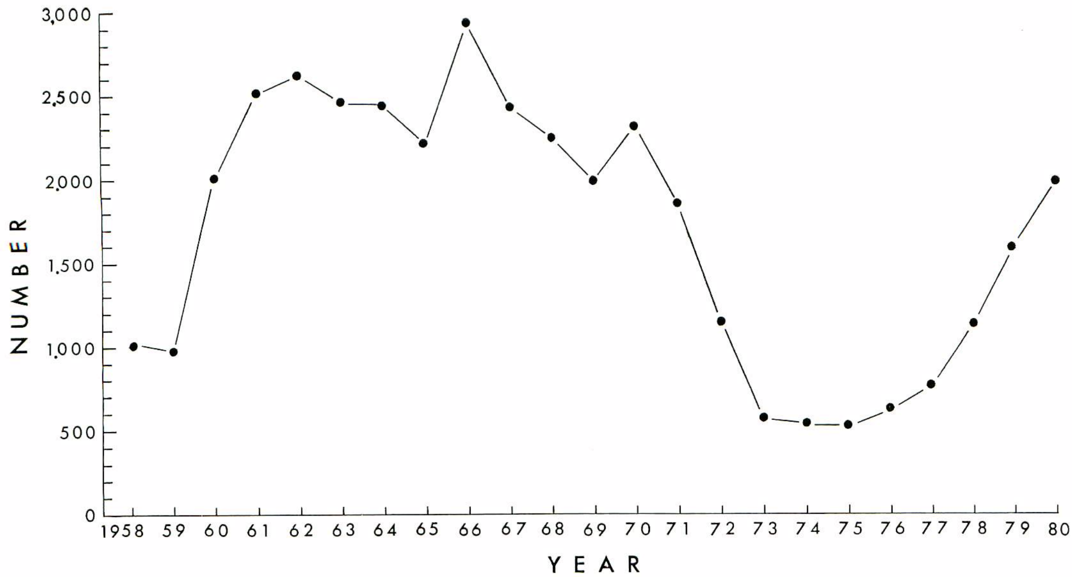


**Fig. 3** Number of harem bull on the Robben Island (Maximum number at the end of June)

began to decrease sharply. Then, the sexual maturity age returned again to 3 years old nearly in 1977 when the number of harem bulls showed a trend of recovery. A relationship between both factors is presumed, but the problem cannot be clarified with the knowledge from the present research on fur seals, and its result depends upon future studies.

2. The pregnancy rate (apparent and true pregnancy rates)

Fig. 1 shows the aged changes on the apparent pregnancy rates during 21 years from 1959 to 1980 and the true pregnancy rates during 17 years from 1964 to 1980.

The aged change of the apparent pregnancy rate in 4-year group fluctuated every year from 1959 to 1965, but was unchangeable in the average, except sharp decrease of the rate during 5 years from 1966 to 1970. It was 45% decrease from 52% level of 1965 to only 7% level of 1970. The rate recovered thereafter gradually until 1974, and then the rate sharply increased during 10 years as a higher level than that of 1965.

The aged change of the apparent pregnancy rate in 5-year group was almost stable without fluctuation during 11 years from 1959 to 1969. However, about 30% declined during 6 years from 1970 to 1975, but a sharp increase has been shown since 1976, and the rate in 1980 returned completely to the level of 1969 before the declining trend.

The aged change of the apparent pregnancy rate in 5 to 7-year group showed the same trend as that in 5-year group, but its decrease was smaller as approximately 20% than that in 5-year group. Consequently, the rate in 5-year group fluctuates more than that in 5 to 7-year group.

As shown in Figs. 1-4 and 1-5, the aged changes of the apparent pregnancy rates in

8 to 10-year group and 11 to 15-year group are almost similar in the trend: i. e., the rates began to decrease nearly from 1972 and about 15% declined during a few years, but the rates were increasing nearly from 1974 to the level of 1971 before the decrease in 1980. In the case of the older group than 10-years old as shown in Fig 1-7, the rate sharply decreased by 25% during 2 years from 1972 to 1973, and about 10% recovered in 1974, but it has been stable at the 10% lower level since 1975 as compared with the rates from 1964 to 1971. The result shows that the older group than 16-years old has a higher sterility rate again.

As the result, a lower apparent pregnancy rate as well as a lower maturity rate appears more remarkably in younger groups, and the period of lower rate is also longer in such groups, while old age groups show decreases in both of the low apparent pregnancy rate and its period. However, the older group than 16-years old has a trend of increasing slightly the low apparent pregnancy rate. In the case of declining the apparent pregnancy rate, such a sign appears firstly in young age groups and then extend to old age groups several years later.

The difference of decrease or increase between the apparent pregnancy rate and the true pregnancy rate is smaller in old age groups but particularly large only in 4-year group. The difference between both rates means the occurrence rate of immature individuals as mentioned in the subject of sexual maturity, the result proves that a high occurrence rate of immature individuals appears in 4-year group (3-year group at the breeding period). Especially as shown in Fig. 1-1, the occurrence rate of immature individuals were high during 9 years from 1968 to 1976. The period completely conforms to the period in which the number of harem bulls decreased in Robben Island, some relationship between both periods is presumed.

3. Correlation among the true pregnancy rate, the missed pregnancy rate and the non-ovulation rate

The true situation of the propagation rate which works as a compensation activity depending upon decrease or increase of the resource and the relation in numbers of sexually mature females vs. males, is understood only as changes of such numbers with the apparent pregnancy rates as mentioned above, and its actual condition cannot be revealed.

However, the new method of classification proposed by the author divided all the mature females into 3 types as the non-ovulation group, the ovulation without pregnancy group and the pregnancy group, each of which are classified as different groups. Therefore, it is easy to clarify whether changes in the occurrence rate of the non-ovulation group by age and the occurrence rate of the ovulation without pregnancy group are caused by increase of the female resource or otherwise decrease of mature males.

Fig. 4 shows the result of determination on conditions of the genital glands according to the new method of classification (maturity-non-ovulation, maturity-ovulation-nonpregnancy and maturity-ovulation-pregnancy).

If all the sexually mature females ovulate and become pregnant, the true pregnancy rate

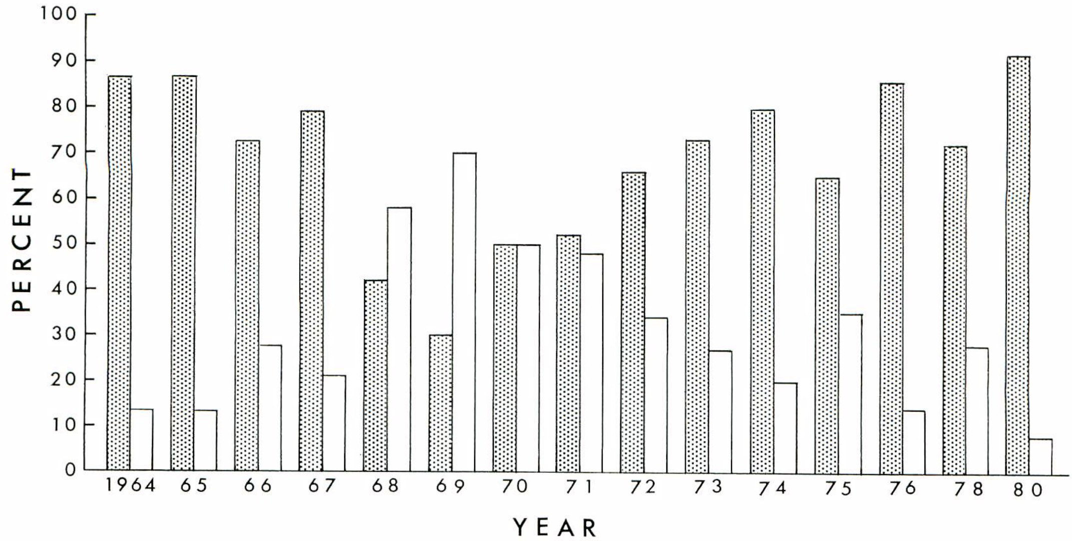


**Fig. 4** Rate of occurrence of non-ovulation fur seals, of fur seals with true yellow body, and of fur seals with false yellow body, by age group

For the 1964～1971 period, data collected in waters off Sanriku, March-April
For the 1972～1980 period, data collected in the Sea of Okhotsk, July-August

Non-ovulation　True yellow body　False yellow body

**Fig. 4-1** 4 year old

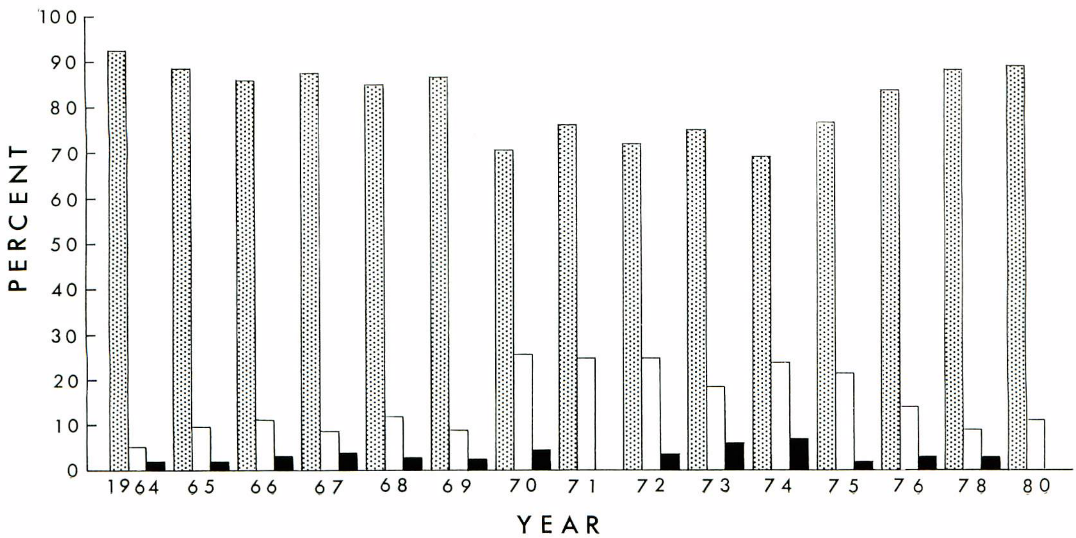


**Fig. 4-2** 5-7 year old

(corpus luteum graviditatis) is 100%. The true pregnancy rate of each age group is actually lower than 100%, because some individuals ovulate but miss pregnancy (corpus luteum menstruationis) and some do not ovulate (non-ovulation). Such a correlation was studied by age from year to year.

(1) The non-ovulation rate

Non-ovulation did not appear in any of 4-year group (3-years old at the breeding period), but was found in older groups than 5-years old, because 4-years females of non-ovulation

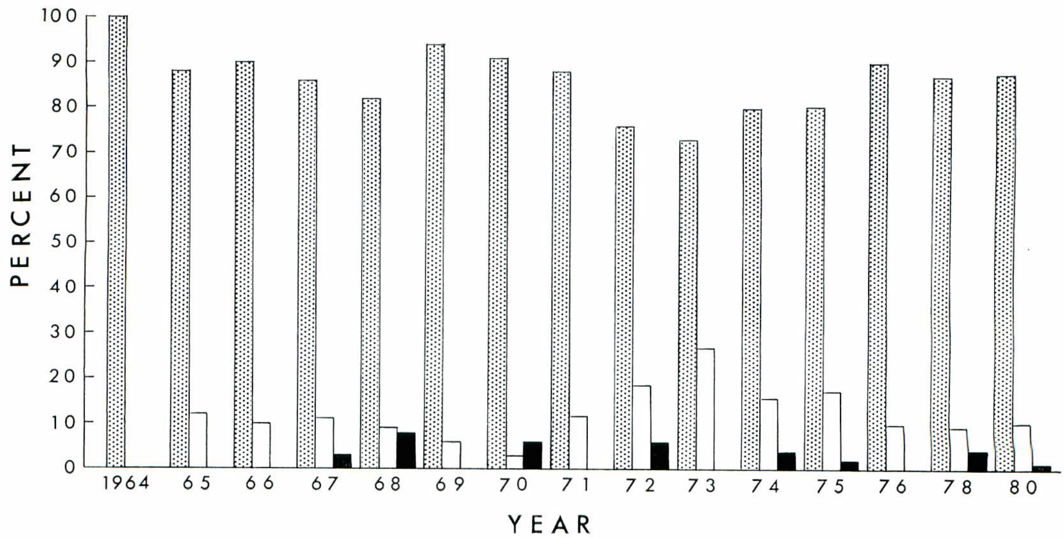


**Fig. 4-3** 8-10 year old

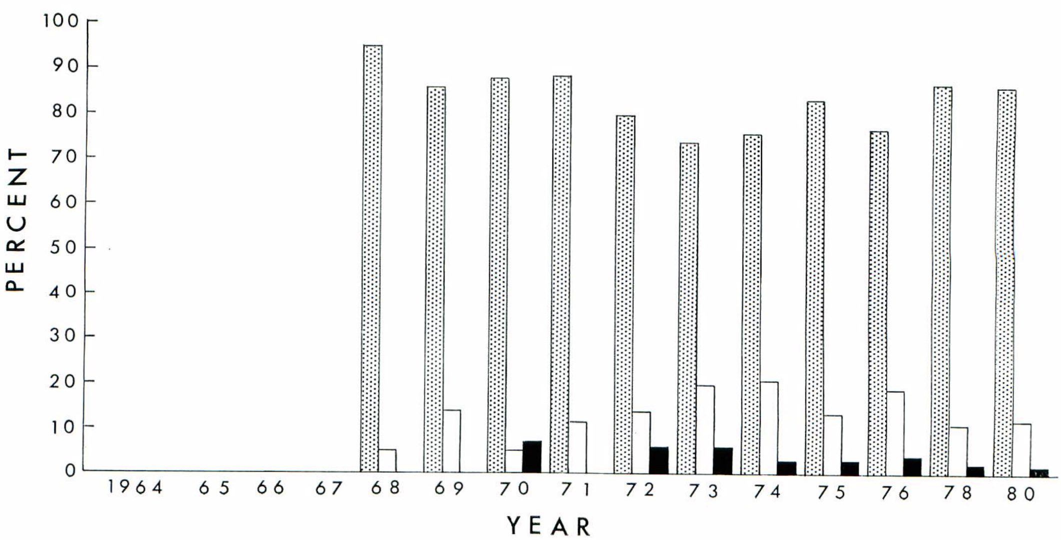


**Fig. 4-4** 11-15 year old

joining to the reproductive group at the first time are classified in the immature group.

As shown in Fig. 4-5, the occurrence rates of non-ovulation among older mature females than 4-years slightly fluctuated yearly, but the scope of occurrence was mostly constant as 0.0% to 8.8% (average 4.5%), and such a trend is considered as the original characteristic of this species.

The occurrence rates of non-ovulation by age are 0.0% to 6.8% (average 2.4%) in 5 to 7-year group, 0.0% to 8.7% (average 2.4%) in 8 to 10-year group, 0.0% to 7.4% (average 3.4%) in 11 to 15-year group, 0.0% to 18.2% (average 10.9%) in 16 to 20-year group

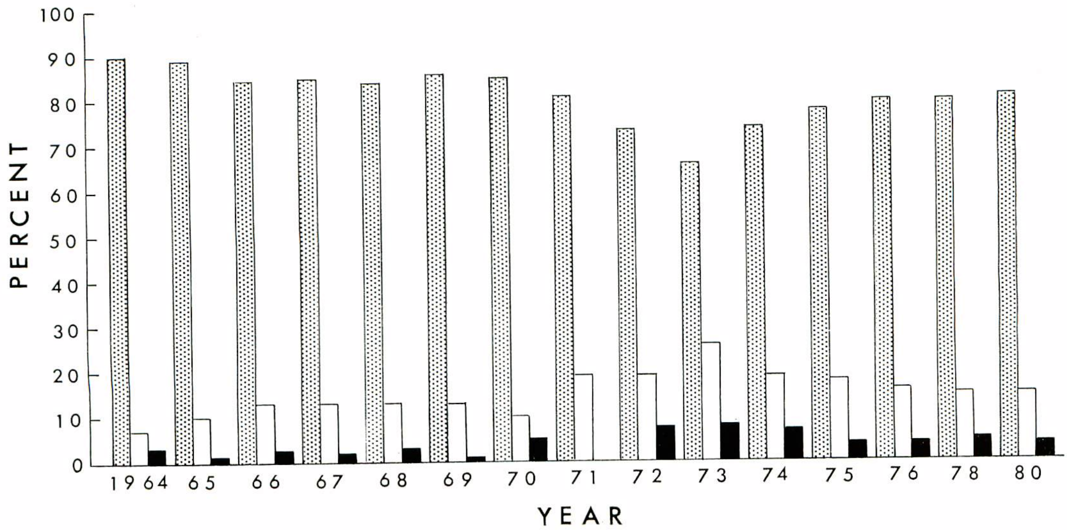


**Fig. 4-5** 4 year or older

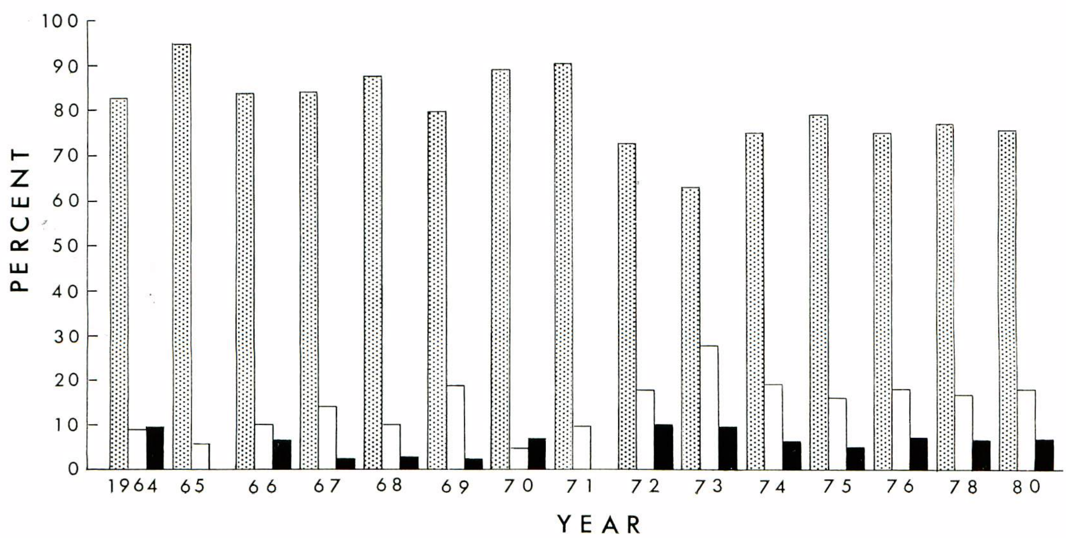


**Fig. 4-6** 10 year or older

and 0.0% to 50.0% (average 23.9%) in older group than 20 years: i.e., the occurrence rate is higher in older females, and particularly the older group than 20 years shows the highest as 23.9%. Such phenomenon is probably caused by the disturbance of the ovarian function depending upon increase of the age. In the gross observation of the ovaries is the older group than 20 years, the ovary of an individual with normal propagative function is large in diameter and normal in the ovarian condition, while an individual of non-ovulation shows small diameter of the ovary and its inside has been sponge-like. These fact may prove the above-mentioned problem.

As mentioned before, the aged change of the non-ovulation is scarcely found in the groups of 4-years or older, though its occurrence rate increases in older groups. Consequently the occurrence rates by month were reviewed with the data collected from 1964 to 1980.

The occurrence rate by month in 5-year or older group increases in progress such as 0.5% in January, 0.9% in February, 2.7% in March, 2.6% in April, 4.0% in May and 7.3% as the highest in June and thereafter decreased.

The distribution characteristic in sea by sex and age according to the present data shows that the feeding area of the American origin floating mainly in Eastern Pacific Ocean locates at area around the upwelling, and the distribution is defined by sex and age. However, the distribution in Western Pacific Ocean is undistinguishable because of singularity that the feeding area locates in the confluence of the warm and cold current masses. According to the result of analysis on the previous data, however, the floating distribution of female fur seals in the offshore of Sanriku is concluded as follows:

1) Generally in the down south excursion (feeding excursion), females come earlier than males and stay longer.
2) The pregnant females arrive earlier at the wintering area than the non-pregnant females, come along the coast to the south end of distribution, and return to the island through the offshore.
3) Most of the females coming down to the offshore of Sanriku are 4 to 10 years old, and correspond to about 57% of all the caught fur seals.
4) The old females of 10 years or older constantly decrease from January to June. It probably means that older females return to the island earlier than younger ones.
5) The numbers of pregnant females and nonpregnant females are equivalent in mid-April.

It was concluded that the feeding excursion of nonovulation females was similar to that of immature or non-pregnant young females due to the above result of distribution and excursion patterns, and also because the occurrence rate of non-ovulation females increased in progress to June and thereafter decreased as mentioned before.

(2) The true pregnancy rate and the missed pregnancy rate

As mentioned before, all the mature females are classified into 3 types as the non-ovulation group, the ovulation without pregnancy group and the pregnancy group. If the occurrence rate of non-ovulation is fixed, the occurrences of the true pregnancy rate (corpus luteum graviditatis) and the missed pregnancy rate (corpus luteum menstruationis) are reversely correlative.

As shown in Fig. 4, the missed pregnancy rate by age remarkably fluctuates in 4-year group. The missed pregnancy rate nearly in 1964 to 1965 was about 14%, but then the rate sharply increased to about 70% during 4 years until 1969. However, the rate drastically decreased thereafter during 7 years, and it came to the same level as that of 1964 to 1965 before the increase.

The rate of 5 to 7-year group showed about 10% every year during 6 years from 1964 to 1969, and increased about by 25% during 6 years from 1970 to 1975, but gradually decreased from 1976 to 1978 or 1980 to the level of 1964 to 1969 before the increase.

The rate of 8 to 10-year group showed a decreasing trend during 6 years from 1965 to 1970, but increased again during 3 years from 1971 to 1973. It gradually decreased, and became equivalent to the level of 1965 to 1968 in 1976 to 1980.

The rate of 11 to 15-year group slightly increased during 2 years from 1973 to 1974 compared with the other years, insufficient data with wide fluctuation was not enough to determine a trend. However, in the comparison between 11 to 15-year group and 10-year and older group shown in Fig. 3-6, the rate of 10-year and older group was higher. The result suggests that the older females than 16 years show a higher rate of individuals that ovulate by miss pregnancy.

The average rates of non-pregnant females with ovulation by age are 31.2% in 4-year group, 15.4% in 5 to 7-year group and 11.5% in 8 to 10-year group from 1964 to 1980, while those from 1968 to 1980 are 13.0% in 11 to 15-year group and 23.7% in older group than 16 years. This result suggests that the true pregnancy rate of 8 to 10-year group is the highest, and does not fluctuate against any change of the reproductive environment as the key group of reproduction. Meanwhile, the wide fluctuation in the true pregnancy rate of 4-year group may prove that the group is in the most influenced age joining to the reproductive group at the first time.

Regarding the peaks of the missed pregnancy rates by age, 4-year group peaked in 1969, 5 to 7-year group nearly in 1971 and 8-year and older group in 1973 respectively. The peaks of older groups appear later in the interval of several years. The result corresponds to the result of the pregnancy rates (the apparent pregnancy rate and the true pregnancy rate) that such a phenomenon firstly appears in younger groups and then extends to older groups several years later.

As mentioned before, the missed pregnancy rate is higher in 16-year and older females. It is considered that their reproductive cycle became irregular, and when they ovulated but were not pregnant, their feeding excursion in sea was same as that of young groups of non-ovulation and non-pregnancy, and returned to the propagating island out of the best propagation season. Eventually they lost chances of mating although their reproductive capacity was remained, and repeated a wrong condition of non-pregnancy in spite of ovulation.

Now, we study why the highest rate of missed pregnancy appears in 4-year group joining to the reproductive group at the first time.

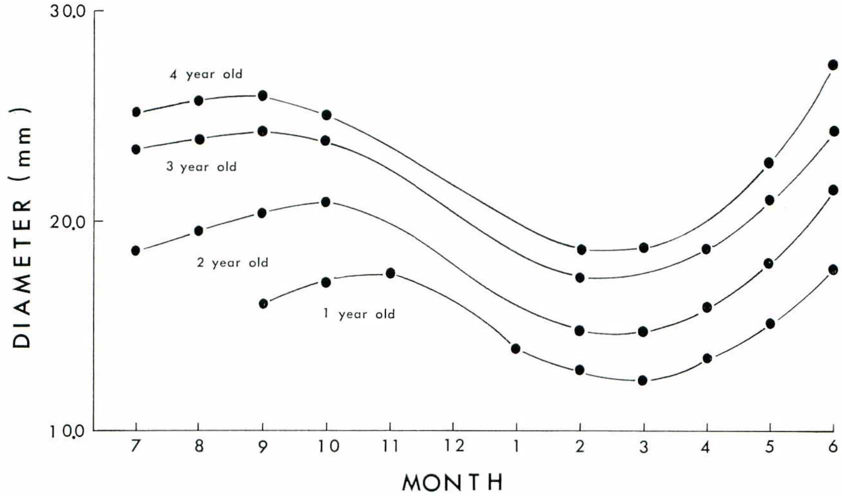


**Fig. 5-1.** Annual change in major axis of ovary (immature fur seal)

The failure of pregnancy has two reasons: chances of mating were lost, or a female fails impregnation after mating. The disturbance of the ovarian function is probably potential, but such a transiently physical variation as concentrated occurrence of the ovarian disturbance cannot be expected. Therefore it is reasonable that the rate is peculiar to this species.

Fig. 5-1 shows the annual changes on the ovarian diameters of immature females between propagating seasons. The graphs suggest that the ovarian function of 4-year group joining to the reproductive group at the first time becomes most active nearly in September when the first ovulation occurs.

The male reproductive capacity in the off-season of propagation in unknown but not inactive probably. The true pregnancy rate of the first ovulated females caught in the offshore of Sanriku in 1964, wa so high as 86%, but decreased year by year, and again increased to about 90% in 1980. Therefore, it is impossible to understand the male reproductive capacity weakened or many females failed impregnation only in the year of the low true pregnancy rate.

In the cases of wild animals, it may be reasonable to understand that decrease of mating chances declined the true pregnancy rate. Decrease of mating chances is caused by decrease of mature males or increase of mature females. Mating chances decrease particularly when there are many young females in the estrus condition after the harem has been dissolved out of the best propagating season as mentioned above.

As shown in Fig. 4-1, the time when the true pregnancy rate of 4-year group began to decline, was consistent with the time when the number of harem bulls in Robben Island began to decrease. It is considered that the balance of mature females and males reflects decrease of mating chances, which results in decline of the true pregnancy rate in 4-year group.

## Gross Observation of the Ovary

The author measured annually long-diameters on pairs of the ovaries, and the follicle and the corpus luteum formed in the ovary to study annual changes by age and reproductive condition. The ages used herein are full years.

**1. Annual changes of the ovarian long-diameters**

The ovary of a fur seal is oval, and its longest diameter was measured. Both diameters of the right and left ovaries in an immature female are almost same, but the longer ovary was traced for a year, and its annual changes were illustrated in Fig. 5-1. A fur seal female has the biangle uterus, and a pair of the mature ovaries ovulate alternately once a year. Therefore, long-diameters of the ovaries in mature females are not so uniform as those of immature females, and classified into 4 types depending upon the reproductive condition: i. e., the ovary of ovulated side were divided in two groups of conception and non-conception in this uterus, while the ovary of delivered side were divided in two groups of conception and non-conception in uterus of ovulated side in order to measure long diameters of the ovaries, of which annual changes were illustrated in Fig. 5-2.

As illustrated in Fig. 5-1, the ovarian long diameters of older immature females show longer proportionally, but their annual changes are almost same as a trend. The season of the longest ovary, i. e., the season of the most repletion ovary is dependent on age, but younger females show later maturity in the season such as November in 1-year group, October in 2-year group and September in 3 to 4-year group. The ovary reduces gradually to the smallest size in February of the rest season, but again starts to increase nearly from March to September-November of the repletion season.

The ovarian long diameters of 4-year and older mature females were classified into 4 types by month, age and aforementioned reproductive condition to study the difference in the ovarian sizes, but no difference was noted. Annual changes of the ovarian long-diameters were same without any relation with the age. However, it may said that the ovarian long-diameters of non-ovulation females with disturbance of the ovarian function possibly occurred by increase of the age is smaller than those of the same age individuals with the normal reproductive function.

As shown in Fig. 5-2, the long-diameters of both mature ovaries of ovulation and delivery become longest in July as the ovulation and delivery season, but are smaller in any other month, and the annual average long-diameters are in the scope of 18 to 28 mm.

The long-diameter of the ovulating ovary rapidly reduces in a short period untill end-August after the ovulation in July, and then is slightly reducing from month to month. Since the zygot of a fur seal is late implanted in the womb, it is difficult to determine whether the ovulation has succeeded in pregnancy or not before the pregnancy period nearly in November. Even after pregnancy by the implanted zygot has been determined, its diameter continues to reduce until end-March, and then begins to increase after April.

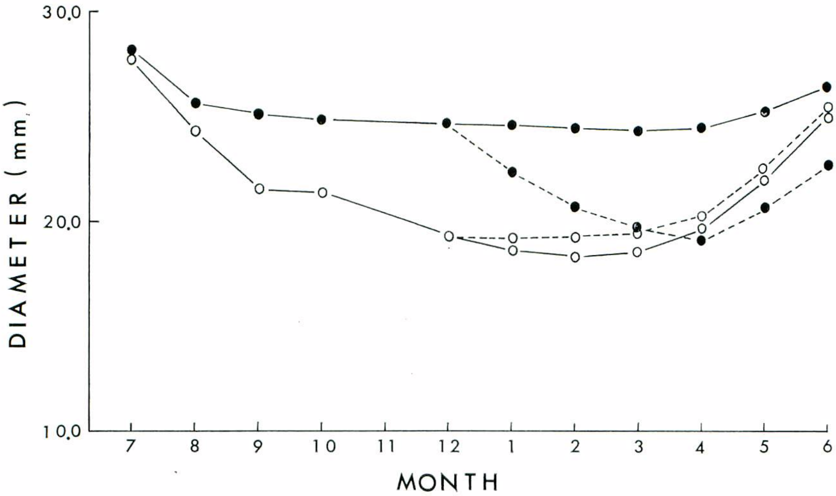


**Fig. 5-2** Annual change in major axis of ovary (4 year or older, mature)
Black circle; Ovulation side Line; Ovulation-Pregnancy
Open circle; Parturition side Chain; Ovulation-Non pregnancy

In the failure of pregnancy, the diameter begins to reduce rapidly from January and such a trend continues until end-April, but it starts to increase immediately from May although the diameter is still smaller than that of the ovary with pregnancy or delivery.

The long-diameter of the ovary with delivery rapidly begins to reduce nearly from September. Even after October, it continues to reduce though not so much as the case in July to September, and the diameter is longer than that of the ovulating ovary. In the case of ovulation and missed pregnancy, its ovarian diameter begins to increase slightly from January and rapidly from May to be similar in the size compared with that of pregnancy. Also in the case of ovulation and pregnancy, its ovarian long-diameter slightly becomes smaller until February, but begins to increase nearly from March showing the same trend as the case of ovulation and missed pregnancy.

The long-diameters of ovaries with delivery show some difference in sizes depending upon the productive condition at the time of ovulation (pregnancy or missed pregnancy) but indicating a similar trend, and the difference in diameters is not also significant. The long-diameter of the ovary with delivery exceeds that of the ovary with ovulation and missed pregnancy in April, and then the difference increases to ovulate at the next breeding season.

According to the above results, the pregnant ovary is larger than the non-pregnant ovary of the same individual in any time without any exception.

**2. Annual changes of follicular long-diameter**

The shape of the follicle is oval, and the longest diameter is longer than 10.0 mm, but the annual average long-diameters are in the scope of 0.5 to 6.3 mm.

The follicular sizes were studied by age, month and reproductive condition to find out the possible difference in their sizes depending upon the age. As the result, mature females showed a significant difference in their follicular sizes depending upon the reproductive condition, but no difference by age was noted. Accordingly, regarding all the mature females as a group without the factor of age, the longest follicular diameters in the ovaries of females with delivery classified by the reproductive condition were traced for one year as shown in Fig. 6. However, before the delivery in May and June, the follicles in the ovaries of pregnant side were measured.

As illustrated in Fig. 6, May and June are in the period just before delivery, when females hold foetues and large follicles are not found in the ovaries but very small ones. The delivery is found from late June to early July, but thereafter the follicles scarcely grow until September. It appears to show that the function of the corpus luteum formed in the ovulating ovary is active. Its growth starts thereafter nearly from October. About in November, pregnant individuals (corpus luteum graviditatis) are distinguished from individuals of missed pregnancy by nidation of zygots in the wombs. The follicles grow in remarkably different progress nearly from February depending upon whether the corpus luteum graviditatis or the corpus luteum menstruationis has been formed in the ovulating ovary.

In any case of the corpus luteum menstruationis or the corpus luteum graviditatis in the ovulating ovary, the follicle begins to grow gradually from December. It is considered to be caused by regression of the lutein cells in the corpus luteum formed in the ovulating ovary.

The follicle of an individual with the corpus luteum menstruationis in its ovulating ovary grows rapidly in February showing a significant difference from the follicle of an individual with the corpus luteum graviditatis, and such a trend is observed until April.

Even the follicle of an individual with the corpus luteum graviditatis in the ovulating ovary continues to grow gradually from December to April, because growth of the follicle

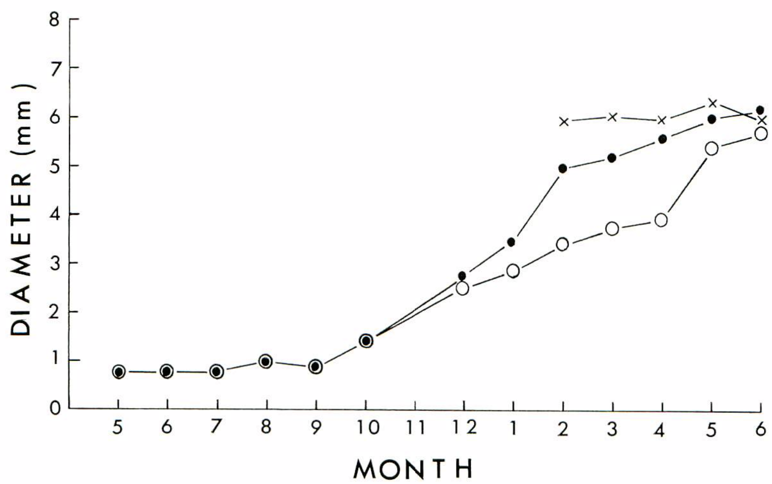


**Fig. 6** Annual change in major axis of follicle of mature

Open circle; True yellow body, Black circle; False yellow body, Cross; Non ovulation appears to be still controlled by the degenerating lutein cells in the corpus luteum gravisitatis even after December. Thereafter, the follicle rapidly grows in May and June, and the difference from that of an individual with the corpus luteum menstruationis becomes smaller. In view of the difference in the growing period of the follicle, the lutein cells in the corpus luteum menstruationis formed in the ovulating ovary seems to lose its function completely nearly in February, while the lutein cells in the corpus luteum graviditatis does so about in May.

The growing condition of the follicle in the ovary of an individual (non-ovulation female) that has not ovulated due to some reason during the breeding period in July, is definitely better in the follicular diameter as compared with that of an individual with the corpus luteum graviditatis or the corpus luteum menstruationis. It may be reasonable, because the individual did not ovulate in the last breeding period and has no lutein cells controlling growth of the follicle without formation of the corpus luteum. However, in May and June when the ovulation season is coming, the growth is almost same as the others.

**3. Annual changes of the luteinic long-diameters**

The luteinic shapes of both the corpus luteum graviditatis and the corpus luteum menstruationis are about globular. The measurement is easy since the luteinic tissue is definitely distinguished from the other surrounding tissues by gross observation.

Considering a possible difference in sizes of the corpus luteums by age, sizes of the corpus luteums were compared by age and month. The long-diameters of the corpus luteums by age and month were plotted in graphes from nidation to delivery regarding the

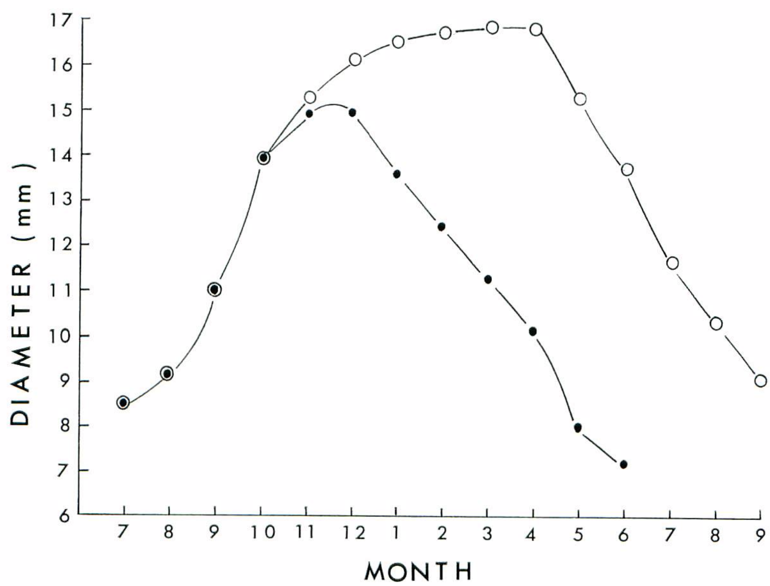


**Fig. 7** Annual change in major axis of yellow body
Open circle; True yellow body, Black circle; False yellow body

corpus luteum graviditatis and from January to June regarding the corpus luteum menstruationis, but no corration as the average data was observed in the age and size of the corpus luteum, although some variation was noted in each year. Consequently, regarding individuals of ovulation as a group without the factor of age, the luteinic long-diameters were traced from July to September of the next year, and the average diameters by months were illustrated in Fig. 7.

As shown in Fig. 7, the corpus luteum formed after the ovulation in July increases rapidly its diameter at the pre-nidation period regardless of forming the corpus luteum graviditatis or the corpus luteum menstruationis after the nidation period.

After the nidation period, the corpus luteum graviditatis of a pregnant individual continues to grow and reaches to the largest size in next March or April. Thereafter, the size rapidly decreases in May and then continues to contract. It is interest that this pattern conforms closely to the rapid growing trend from April to July in annual changes of the follicle in a pregnant individual shown in Fig. 6. According to the above result, the corpus luteum graviditatis seems to have lost its function in May.

The diameter of the corpus luteum menstruationis reaches to the longest in November or December, but is smaller than that of the corpus luteum graviditatis in the same month. After the nidation period, the diameter begins to contract rapidly from January, and the corpus luteum menstruationis becomes so small as undistinguishable as the corpus luteum.

Comparing the corpus luteum menstruationis and the corpus luteum graviditatis in January, the former is definitely smaller than the latter. This trend expands further, and the difference increases during February to May. This phenomenon is reasonable because of non-pregancy.

Comparing this trend with annual changes of the follicle in a female of missed pregnancy (that ovulated but missed pregnancy), both trends are similar although about a time lag of one month is observed, because the growing period of the follicle is February and the contracting period of the corpus luteum menstruationis is January.

As the above result, the lutein cells in the corpus luteum menstruationis probably begins to reduce its function from January, and scarcely functions in February and March. Furthermore, the corpus luteum menstruationis may have lost the lutein cells and been already the corpus albicans nearly in June just before the other ovary ovulates.

## Microscopic Observation of the Ovary

### 1. Growth and degeneration of the follicle

(1) The follicle of a pup or a younger female than one full year

The histological picture of a pup in October is shown in Plate I-Fig. I. In October, follicles in every progressive stage of absorption and contraction are observed, and many of them have been in the form of the corpus albicans. The histological pictures of a pup in December and January are almost same as that of October in comparison.

Plate I–Fig. 2 shows the histological picture of 1-year female in May. In those of May and June, the medullary substance of the ovary has increased and the ovary itself is large, but most follicles inside have disappeared, while few follicles are absorbed or contracting and few corpus albicans are observed. Only the primary follicles and the oocytes embedded from the ovarian surface are observed in the cortex around the ovarian surface.

(2) The follicles of an immature female

Even in a full one-year female, 2 or 3 follicles grow to some extent in the ovary in July and August, and some have developed to the vesicular follicles. Plate I–Fig. 3 shows the ovary of an immature female of 2 years old in October. In the figure, further developed vesicular follicles including those of 2 and 3 year females are observed in September and October, when the number and diameters of those follicles become largest and the ovary is in the most ripe condition. Thereafter, the follicle without ovulation enters into the regression period.

Plate II–Fig. 1 shows the follicles of an immature 3-year female in the regression period. As illustrated in the picture, the phagocytes appear in those follicles to start absorption and contraction in November or December.

Plate II–Fig. 2 shows the corpus albicans of an immature of 4-year female. As illustrated in the specimen of January or February, most of the follicles become the corpus albicans, but in most of 3-year or 4-year immature individuals with further contraction of the follicles show the resting pattern, although some big follicles still contracting are observed in the histological picture. The resting condition continues until late May, and then growing follicles are observed again. They are growing until the ripening period in September or October. However, the immature females that will ovulate in coming July of the breeding period are in the resting condition until February, and the follicles in both ovaries start to develop in March or April, and some big vesicular follicles are also found. The follicles develop favorably thereafter, and some large follicles just before ovulation are observed in June as shown in Plate II–Fig. 3.

(3) The follicles of a non-ovulation female

The ovary of an individual that was mature in the ovulating period of early July but did not ovulate due to some reason develops in the same process as the case of an immature individual that will ovulate firstly in the next ovulating period: In the ovary resting until February, the follicles begin to develop from March, some large follicles are observed in April, and the cell group forming the deep layer cortex around such large follicles increase their nucleus and cytoplasm. Also many blood capillaries appear between those cells, and a very active condition occurs. In June, the follicles both ovaries grow so lage as those just before ovulation.

(4) The follicles of a mature female

In the ovaries of an individual coming to the first sexual maturity, large follicles are found in both of the right and left ovaries. When one of both ovaries ovulates in the ovulating period, large vesicular follicles remain in the other ovary of non-ovulation, and a long time is required to contract these follicles. In some cases, the corpus luteum appears around such a follicle as shown in Plate III–Fig. I, although such a case is very rare in fur seals.

On the other hand, the right and left ovaries of a mature individual with the experience of pregnancy are different completely in the inside condition, because the ovulate alternately from one of both ovaries once a year at the breeding period.

Plate III–Fig. 2 shows a pregnant ovary about one month before delivery. In the figure, no large follicle is found in the pregnant ovary in May or June, but only minute follicles are observed. The growing process of follicles in the delivered ovary after delivery is as mentioned in the chapter of "Annual changes of the follicular sizes by gross observation".

As shown in Plate III–Fig. 3, many large vesicular follicles are found in the ovary which ovulated in early July, but the other follicles enter into the regression period by forming the corpus luteum. In the case that these large follicles contract, firstly the phagocytes appear in the stratum granulosum to help the degeneration as shown in Plate IV–Fig. 1. In the next, the oocytes are degenerated, and both of the stratum granulosum and the oocytes disappear completely to be a curved and swelled glassy membrane. This is the oocyte-dependent corpus albicans (Plate IV–Fig. 2.). In April, almost all the follicles in this side ovary have been already absorbed.

In early July, the other side ovary ovulates and form the corpus luteum, by which no follicle in the ovary is developed and the resting condition continues until December. The process of the follicles mentioned herein is same as the case of non-pregnancy. This is the typical pattern at degeneration of the vesicular follicles in a fur seal. However, as shown in Plate IV–Fig. 3, the oocyte-dependent corpus albicans is distinguishable from the lutein cell-dependent corpus albicans in shapes and sizes.

**2. Development and degeneration of the corpus luteum**

(1) Histological observation

There are two kinds of the corpus luteum formed in the ovary of a fur seal as shown in Plate III–Fig. 1 such as one formed by discharge of the oocytes and the other formed around the outside of the follicle. The latter is a very rare case in fur seals, and the corpus luteum in this case seems to occur from the oolemma. This corpus luteum probably plays a role of not only controlling directly the development of inside follicles but also functioning as the normal corpus luteum.

Plate V–Fig. 1 shows the tissue just after the oocytes have excreted from the ripe vesicular follicles. It indicates that the follicular fluid and blood still remain in the cavity of follicle. The stratum granulosum along the internal paries of follicle has swelled, and its magnified picture shows that the membrana granulosa cells have been already changing to the lutein cells. Then the stratum granulosum surrounding the cavity of follicle develops abnormally resulting in increase of its swell as well as increases of the nucleus and cytoplasm of the stratum granulosum to be extremely active, and immediately followed by further change into the lutein cells. Therefore, the corpus luteum of a fur seal resulted from the membrana granulosa cells.

Plate V–Fig. 2 is a magnified picture of the lutein cell 3 months after ovulation, and shows a good active condition of the lutein cell. Many secretions are found around a cellular protoplasm and a cell, the nucleus increases with the most active function. Also in the corpus luteum which appears around the follicle, the lutein cell shows the same histological pattern.

Thereafter, the lutein cells proliferate and swell until nearly November, when the corpus luteum graviditatis and the corpus luteum menstruationis become distinguisable by nidation of a zygot. In the case of the corpus luteum graviditatis, the connective tissue enters into the corpus luteum nearly in December. Plate V-Fig. 3 shows the tissue of the corpus luteum graviditatis in January, when the connective tissue has much more blood capillaries, and the vacuolar degeneration of the corpus luteum is found in some individuals. Regression of the corpus luteum appears to start in this time. Annual changes of the luteinic long-diameters develop until nearly April according to the gross observation as mentioned before, and are not always consistent with the function by histological observation. This point must be reviewed in a further study.

In the specimen of February, there are many interestitial cells among the vacuolated lutein cells. In the luteinic specimen of March, not only the interstitial cells but also the connective tissue including many blood capillaries are complicated in the corpus luteum. In April, vacuolation of the corpus luteum further probresses, and the connective tissue increases much more. In the specimen of May, almost all the inside of the corpus luteum has been occupied with the connective tissue, while some vacuolated lutein cells remain in some places, and clots of the cell forming cortex are found throughout the corpus luteum. The boundary between the corpus luteum and the cortex of ovary becomes also undistinguishable.

Plate VI-Fig. 1 shows the corpus luteum graviditatis in June. There is no lutein cell but the places where the lutein cells existed have been vacuolated during June to July, and it cannot be called as the corpus luteum at the time.

Ovulation from the other side ovary is observed in July, when regression of the lutein cells further progresses, and finally they become the typical forms of the corpus albicans in August to September as shown in Plate VI-Fig. 2.

Plate VI-Fig. 3 shows the corpus albicans one year after the post-delivery corpus luteum started to contract. As progresses further, its outside is torn off and disappears, and it becomes gradually smaller. Many individuals hold the corpus albicans one year after delivery in their ovaries, but the corpus albicans has disappeared in 20% of the individuals at this time. These individuals are often found in young females.

Plate VII-Fig. 1 shows the corpus albicans of an individual two years after delivery. The corpus albicans in the ovary of a fur seal seems to disappear within 2 or 3 years after delivery, although some variation is dependent upon individuals.

As mentioned before, the corpus luteum is distinguished as the corpus luteum graviditatis or the corpus luteum menstruationis by observing whether a zygot has been implanted in the womb or not nearly in November. However, both long-diameters are not different visually nor distinguishable histologically. It means that the tissue of the corpus luteum menstrationis is distinguished from the corpus luteum graviditatis during December to February.

Therefore the corpus luteum menstruationis shows earlier regresson than the corpus luteum graviditatis, and no lutein cell is observed in the former of May. It turns completely to the corpus albicans in June.

(2) Histo-chemical observation

When the luteinic function of the ovary is studied, the existing stain method is able to reveal only the general structure, but not to be used for observation of secretions such as the corpus luteum hormon.

Since the corpus luteum hormon is a steroid hormon, the fatty stain is important. Cholesterol as a original substance of steroid hormon is stored in a lipid droplet, and the annual observation of the corpus luteum hormon was performed by the fatty stain.

We stained the neutral fat with three methods of Nile red sulfate stain, Nile blue sulfate stain and Sudan black B stain, phosphatide with acid haematein method and cholesterol with Schultz test, but all methods resulted in the same data.

No fat reaction is observed just after formation of the post-ovulative corpus luteum. However as shown in Plate Ⅶ-Fig. 2, a trace of the reaction is observed from late July to late August, and then the reaction increases a little by little, but it is found mainly around the corpus luteum as shown in Plate VII-Fig. 3.

As shown in Plate Ⅷ-Fig. 1, when pregnancy is determined, the reaction sharply increases, and lipid droplets become more minute with more active function. It leads to the presumption that the corpus luteum plays an important role of implanting a zygot in the womb.

Plate Ⅷ-Fig. 2 is a high magnified picture of Plate Ⅷ-Fig. 1 showing that many lipid droplets are secreted in a lutein cytoplasm. Such a condition continues until January.

As shown in Plate Ⅷ-Fig. 3, the connective tissue penetrates into the corpus luteum nearly in January as before-mentioned, and many lipid droplets are still observed in the other parts than the connective tissue in the center, although some individuals show regression of the lutein cells. Then in May to June, lipid droplets decrease with regression of the lutein cells and penetration of the connective tissue, and the granules become larger. Plate Ⅸ-Fig. 1 shows such a condition.

As shown in Plate Ⅸ-Fig. 2, lipid droplets increase again after delivery in early July, and this condition continues until late August. Lipid droplets sharply decrease in September, and finally no lipid droplet is found in December. The corpus luteum menstruationis shows almost the same trend as that of the corpus luteum graviditatis, but lipid droplets are quantitatively limited.

## Discusstion

According to the ovary size, the ovarian function of a 3-year female is most active nearly in September. CRAIG (1964) presumed that the first ovulation would be in September. Young females that return to the breeding island latter than the main breeding period and become estrogenic, have less opportunity of mating because the harem has already broken up.

This trend increases, when the number of harem bulls decreases.

CRAIG (1964) reported that the failure of pregnancy is probably caused by the failure of mating or disturbance of the ovarian function. However, it is impossible to consider that disturbance of the ovarian function appears transiently only in specific young females. Therefore, it seems to be caused by losing the opportunity of mating due to unbalance of young mature males and young mature females.

The ovarian long-diameter of an immature female becomes longer with increase of the age, and its annual changes show the same trend, but the time when the long-diameter becomes longest depends upon the age such as November in 1-year females, October in 2-year females and September in 3-year and 4-year females. The result is consistent with the report of CRAIG (1964) mentioning that the first ovulation probably occurs in September.

CRAIG (1964), ENDERS *et al.* (1946) and PEARSON & ENDERS (1951) reported that the zygote of a fur seal is not implanted about 4 months after fertilization, and RAND (1955) mentioned the same face on a Cape fur seal. These reports are consistent with our finding. The late nidation of a zygote seems to be not only a phenomenon on fur seals but also a common feature of pinniped.

In annual changes of the corpus luteum graviditatis by the gross observation, its diameter increases until April, while it begins to regress in nearly from December according to the histological observation. Therefore, the size does not exactly conform to the function by the histological observation. This point must be reviewed in the future study.

CRAIG (1964) reported that the follicle begins to develop in March, but the author's finding shows that the corpus luteum menstruationis gradually grows nearly from December and rapidly develops in February. Also the corpus luteum graviditatis gradually grows during December to April, the rapidly develops from May to June. Either cases are different from his results. He also reported that the corpus luteum graviditatis of a fur seal in Eastern Pacific Ocean is active until February and begins to regress from March. According to the author's observation, regression of the corpus luteum graviditatis started in January, and this result is also different from his.

PEARSON and ENDERS (1951) reported that the corpus luteum without pregnancy (the corpus luteum menstruationis) is similar to the corpus luteum graviditatis even in late March. The result of the author's observation is different instrumentally and histologically from their result. They also reported that the corpus albicans disappears before the next ovulation starts from the same ovary. In the other words, no corpus albicans one year after delivery exists. According to the author's observation, it disappears within 2 to 3 years after delivery, and the result is different from theirs.

In most mammals, the corpus albicans disappears in a short period, but it is said that the corpus albicans remains for life in the case of whales out of the aquatic mammalians. It is probably because their ovaries are very large and have enough space to keep the remaining corpus albicans. However, the ovary of a fur seal is quite small, and the tissue of corpus albicans has no nucleus not like that of a whale. Therefore, in the case of a fur seal, the period for disappearance of the corpus albicans is not so short compared with the other mammals, but does not remain for life. Regarding the whales, there is a controversary on the difference between the corpus albicans changed from the corpus luteum graviditatis and the corpus albicans changed simply from the corpus luteum menstruationis: LAWS (1958, 1961). However, it cannot be said that there is a difference between both corpus albicans in the case of a fur seal.

In May to June, decrease of lipid droplets and enlargement of granules were observed as well as regression of the lutein cells and penetration of the connective tissue. The reason why lipid droplets exist in spite of its decrease, is probably to make ovulation easy at the next breeding period and promote growth of the mammary gland for the lactation. CRAIG (1964) reported that secretion of the placental hormon with regression of the corpus luteum substitutes for the ovarian hormon to keep the pregnant condition. The placental hormon will be a subject of the future study.

After delivery in early July, lipid droplets increase again until late August. In September, lipid droplets rapidly decrease, and most of them disappear in December. The reason why lipid droplets increase from early July to late August is unclear. Generally mammals do not ovulate during the lactation, but a fur seal ovulates, copulates and lactates immediately after delivery. This behavior may be relative to the above question. As mentioned above, the corpus luteum hormon is scarcely secreted until late Augsut even after formation of the corpus luteum. Therefore, secretion of the hormon from the ovary of delivery side seems to inhibit the second ovulation.

## Summary

The revision of classification for the reproductive condition was proposed in 1972 in order to review the contents of the reproductive condition from a new aspect, study how the reproductive condition changes with variation of the fur seal resource, and reflect the result on the resource control. Referring to the research materials in the offshore of Sanriku during November to June and the research materials in Sea of Okhotsk during July to October from 1959 to 1980, changes of the reproductive condition in the Asian groups (mainly Robben group) was studied according to the proposed method. The genital gland was also studied microanatomically to make the reproductive mechanism more clear, and the following result was obtained.

I. Trends of the reproductive condition

(1) In younger females, the pregnancy rates as well as the maturity rate decline remarkably and the period of a low rate is also longer, while the reduction is smaller and the period of a low rate is shorter in older females. When the pregnancy rates decline, the sign appears in young females at the first, and then extends to older females several years later.

(2) Changes of the maturity rate appear mainly in 4-year and 5-year females-in particular remarkably in 4-year females (3-year at the breeding period) that enter firstly in the reproductive group, and slight changes appear several years later in 5-year females.

However, no change was observed in 6-year or older females.

(3) Judging from the basis of 50% maturity rate, the sex-mature age at the breeding period changed transiently from 3 years to 4 years for 9 years from 1968 to 1976.

(4) In 4-year females (3 years at the breeding period), the occurrence rate of immature individuals became higher for 9 years from 1968 to 1976. This period is consistent with the years when the number of harem bulls sharply increased, and some correlation between both factors is presumed.

(5) The occurrence rate of non-ovulating females became higher in older females and particularly so high as 23.9% in 20-year or older females. This phenomenon seems to be caused by disturbance of the ovarian function with increase of the age.

II. Gross observation on the ovary

(1) The ovarian long-diameter of an immature female becomes longer as her age increases, and its annual changes show the same trend. The seasons of the longest ovarian diameter are November in 1-year females, October in 2-year females and September in 3-year to 4-year females. The ripeness season of the ovary is later in younger females.

(2) The ovarian long-diameters of mature females are same without any relation to the age, but a significant difference is observed depending upon the reproductive condition. The ovarian long-diameters of both ovaries become longest in July, but are shorter in any other months. The pregnant ovary is larger than the non-pregnant ovary of the same individual at any time without any exception.

(3) The ovarian long-diameter of ovulation side in an individual of missed pregnancy becomes sharply shorter nearly from the nidation time to late April, and then rapidly increases again from May.

(4) The ovarian long-diameter of delivery side becomes rapidly shorter to September after delivery, and continues to be shorter after October at a slower pace than that during July to September. It begins to be larger from February or March, and exceeds the diameter of ovulation side in the individual of missed pregnancy, so that the difference becomes wider.

(5) The vesicular follicles are observed in immature females of full 1 to 3 years, and the largest number of them is found in September and October when their diameters are also large. Thereafter, the follicular cells begin to be absorbed and contracted, then most of them have regressed in January or February of the next year, and the whole ovary is in the rest condition until May. The follicles grow again until the ripe season of September and October. Immature females that seem to ovulate firstly at the breeding period of July are in the rest condition nearly until February, but growth of their follicles is observed in March and April, and large follicles probably just before ovulation are observed in June.

(6) The large follicles in the ovary of a mature female (holding a fetus because of pre-delivery) are not observed in May and June, but minute follicles are found. Even after delivery, follicles scarcely grow until September, but start to grow nearly from October. About in November, pregnancy or failure of pregnancy is determined with nidation of

a zygot in the womb. If the corpus luteum formed in the other ovary is the corpus luteum menstruationis, the follicle begin to develop rapidly from February to be widely different from that of an individual with the corpus luteum graviditatis in the other ovary. Such a trend continues until April. Even in the individual with the corpus luteum graviditatis in the other ovary, the follicle gradually grows from December to nearly April, and then rapidly develops in May and June, so that the difference from the individual with the corpus luteum menstruationis becomes smaller.

(7) The diameter of the corpus luteum formed immeidately after ovulation in July rapidly increases. Nearly in November, the corpus luteum graviditatis is distinguished from the corpus luteum menstruationis with nidation of a zygot in the womb. The corpus luteum graviditatis grows further, and its diameter becomes longest in March or April, but the size becomes sharply smaller, and then continues to contract.

(8) In the case of the corpus luteum menstruationis, its diameter becomes longest in November or December, but smaller than that of the corpus luteum graviditatis in the same month. The diameter begins to contract rapidly from January, and the corpus luteum menstruationis becomes so small as non-corpus luteum in May or June. Comparing the corpus luteum menstruationis with the corpus luteum graviditatis in January, the former is definitely smaller than the latter. This trend increases furthermore from month to month.

III. Microscopic observation on the ovary

(1) After ovulation and formation of the corpus luteum during late June to early July, the other vesicular follicles enter in the regression period. In contraction of these large follicles, phagocytes appear in the stratum granulosa cells to help the regression. In the next, the oocytes regress, and both of the stratum granulosum and the oocytes completely disappear to focus into the glassy membrane.

(2) After ovulation, the stratum granulosum which formed the cavity of follicle, develops and swells, while the stratum granulosa cells also increase to change to the lutein cells. The lutein cells proliferate and swell until November. Thereafter, the connective tissue penetrates into the cells nearly from December, and then blood capillaries appear in the cells in January. Also vacuolation of the lutein cells starts in some individuals. Regression of the corpus luteum seems to begin at the same period. In June just before delivery, it is almost out of the condition of corpus luteum, and then becomes a form of the typical corpus albicans in August after delivery. Thereafter, the corpus albicans continues to contract, and disappears within 2 to 3 years.

(3) The histological pattern of the corpus luteum menstruationis is not distinguishable from the corpus luteum graviditatis nearly until February, but thereafter it regresses more rapidly than the corpus luteum graviditatis, and becomes almost a form of the corpus albicans in June.

(4) The fatty reaction is not available just after formation of the corpus luteum, but a trace of the reaction is observed from late July to late August. The reaction increases a little by a little thereafter, but is limited around the corpus luteum.

(5) If pregnancy is determined nearly in November, the reaction sharply increases, the granules become minute, and the function is activated. Such a condition suggests that the corpus luteum hormon plays an important role of implanting a zygot in the womb. It continues until January.

(6) The lipid droplets transiently increase until late August after delivery, but sharply decrease in September, and few are observed in December.

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# アジア系オットセイ *Callorhinus ursinus* の再生産機構に関する研究

吉　田　主　基

## 摘　　要

1959年-1980年迄の11月-6月の間に西部太平洋及び7月-10月の間にオホーツク海で収集した資料を用い，ロベン系群の生殖状態の動向の解析，卵巣の肉眼的並びに顕微鏡的観察を行ない，下記の知見が得られた。

I.　生殖状態の動向

1.　妊娠が低下する場合は，高令獣にくらべ若令獣ほど顕著に低下し，その低下期間も長い。又，その兆候はまず若令獣に現われ，数年遅れて高令獣に波及する。

2.　成熟率の変動は，初めて生殖群に加入する4才獣（繁殖期には3才）に最も顕著に現われる。繁殖期における性成熟年令は，1968年頃から1976年頃迄の9年間，一時的に3才から4才に移行した。この時期とハーレム・ブル数の急激な減少時期がほぼ一致しており，両者の間に何らかの関係があるものと推察される。

3.　若年の性成熟雌獣に不妊の率が一時高まった。この時期とハーレム・ブル数の急激な減少時期とがほぼ同じであり，両者の間に何らかの関係があるものと推察される。

4.　無排卵獣の出現率は，高令獣になるにしたがって高くなる。特に20才以上では23.9%の高率を示す。この現象は，年令の増加に伴う卵巣機能の障害によるものと推測される。これらの索餌回遊は，未成熟獣もしくは妊娠をしていない獣と同じである。

II.　卵巣の肉眼的観察

1.　未成熟獣の卵巣長径は，年令が増すにつれて大きくなり，周年変化は同傾向を示す。卵巣長径が最大になる時期は，1才獣では11月，2才獣では10月，3～4才獣では9月であり，若令獣ほど卵巣の充実時期が遅れる。

2.　成熟獣の卵巣長径は，生殖状態によってかなりの差異があるが，排卵側・出産側をとわず，7月に最大となる。又，同一個体における妊娠側の卵巣は，いずれの時期においても例外なく，非妊娠側より大きい。

3.　未成熟獣では，9～10月頃に最も多くの胞状卵胞が観察されるが，翌年の1～2月頃にはほとんど退化する。6月頃から再び発達し始め，9～10月の充実期へと向う。

4.　成熟獣の卵胞は，9月頃までは極小であるが，10月頃から次第に成長し始める。反対側の卵巣に形成される黄体が排卵黄体ならば2月頃から急速に発達し，妊娠黄体ならば5～6月に急速に発達する。

5.　7月の排卵後，直ちに形成される黄体は，その径を急速に増大させる。妊娠黄体の場合は更に発達を続け，3～4月にその径が最大となる。その後，5月には急速にその値を減じる。排卵黄体の場合は11～12月頃にその径が最大となるが，1月から急速に縮少し始める。

III.　卵巣の顕微鏡的観察

1.　胞状卵胞が退化する過程は，まず顆粒細胞中に食細胞が出現し，その退化を助ける。次に，卵母細胞が退化をし，顆粒層・卵母細胞共に全く姿を消し，硝子様塊の像となる。

2.　排卵後，卵胞腔を形成していた顆粒層が発達し，黄体細胞へと変化する。その後，11月まで増殖・膨大するが，12月頃より結合組織の侵入が始まり，1月頃には更に毛細血管を伴うようになる。又，個体によっては，黄体細胞の空胞化も始まり，退化期に入る。分娩後の8月頃には典型的な白体の形態となり，2～3年の間に消失する。

3.　黄体の組織化学的観察では，黄体形成直後に脂肪の反応はないが，7月下旬から8月下旬にかけては微量の反応が認められる。11月に妊娠が確定すると，反応は非常に増加し，この状態が1月頃まで続く。その後，黄体細胞の退化が始まるが，いまだ脂肪滴が多く観察出来る。5～6月頃には，脂肪滴は減少するが，分娩後から8月下旬頃までの間は，一時的に増加し，9月になると急に減少し，12月頃には殆ど認められなくなる。

## EXPLANATION OF SYMBOLS IN PLATES

| | |
|---|---|
| BC | Blood capillaries |
| C | Cortex |
| CA | Corpus albicans |
| CAT | Corpus atreticum |
| CFC | Cell forming cortex |
| CL | Corpus luteum |
| CLG | Corpus luteum grabiditatis |
| CT | Connective tissue |
| GM | Glassy membrane |
| L | Lipid droplet |
| LC | Lutein cell |
| LF | Liquor folliculi |
| N | Nucleus |
| O | Oocyte |
| PH | Phagocyte |
| S | Secretion |
| SG | Stratum granulosum |
| TA | Tunica albuginea |
| VF | Vesicular follicle |
| ZP | Zona pellucida |

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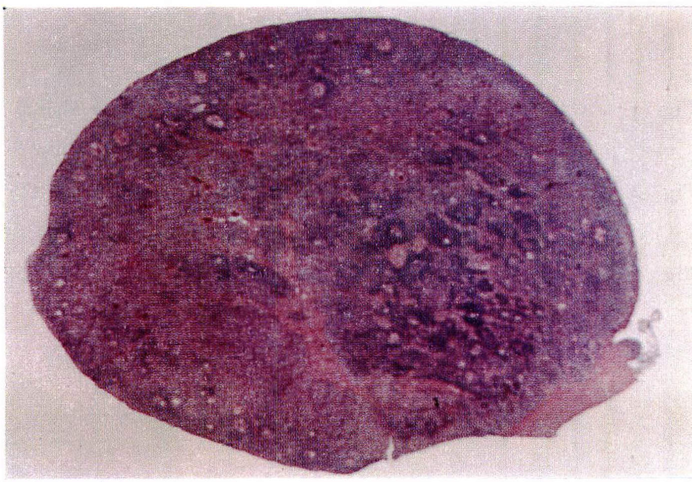
## EXPLANATION OF PLATE I

**Fig. 1.** ×7 A 3-month pup caught on October 11, 1975.
The whole image of the ovary. H. E. stain.

**Fig. 2.** ×6 A 1-year immature female caught on May 13, 1973.
The whole image of the ovary. H. E. stain.

**Fig. 3.** ×5 A 2-year immature female caught on October 13, 1975.
The whole image of the ovary. H. E. stain.

1



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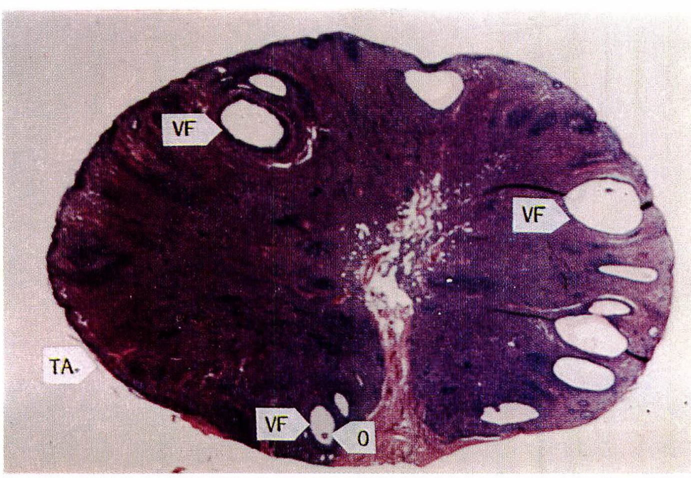


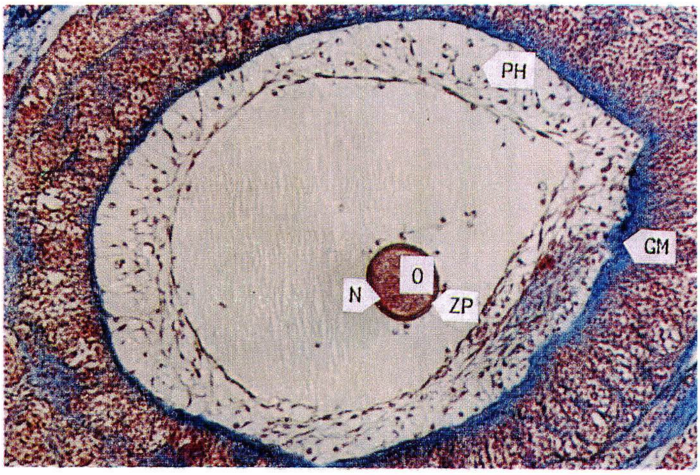

3

## EXPLANATION OF PLATE II

Fig. 1. ×30 A 3-year immature female caught on November 5, 1977. The follicle during regression period. Azan atain.

Fig. 2. ×10 A 4-year immature female caught on January 18, 1978. The closed follicle. H. E. stain.

Fig. 3. ×5 A 4-year immature female caught on June 24, 1973. The ovary with the follicle which seems to ovulate at the breeding period. Azan stain.

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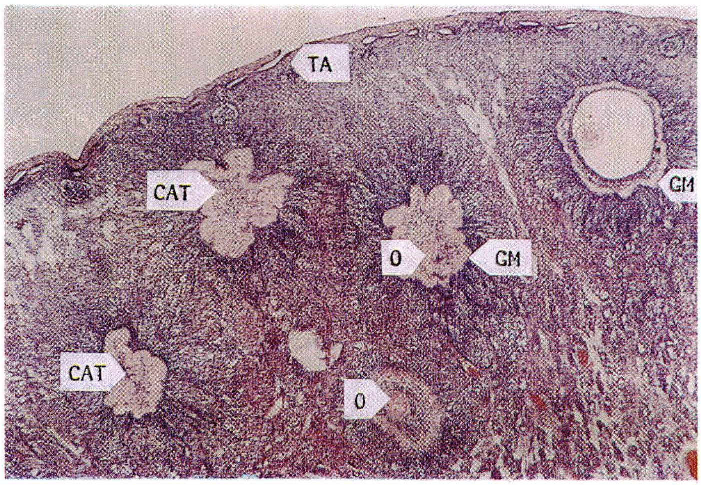


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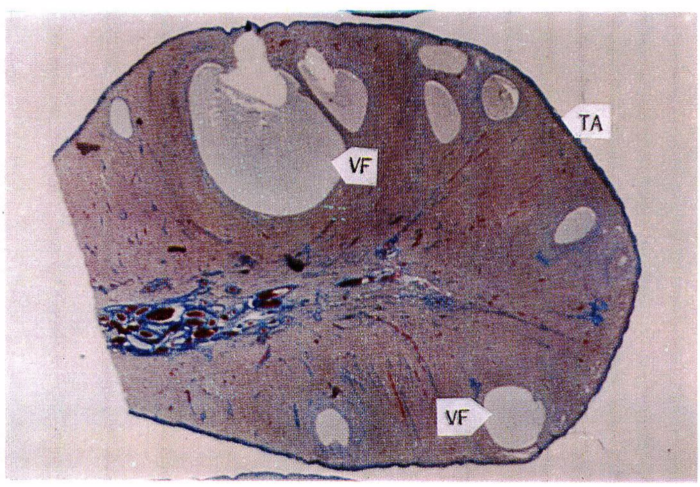


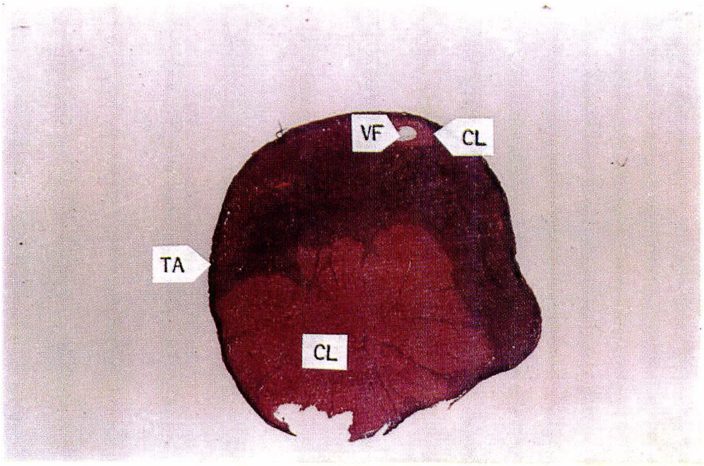

3

## EXPLANATION OF PLATE III

**Fig. 1.** ×4 A 20-year female caught on September 14, 1975. The lutein cells originated from the stratum granulosa cells and those from the membrane granulosa cells. H. E. stain.

**Fig. 2.** ×6 A 6-year female caught on June 4, 1973. The corpus luteum graviditatis about one month before delivery. Azan stain.

**Fig. 3.** ×25 A 10-year female caught on July 31, 1975. The vesicular follicle which has just entered in the regression period after ovulation, and the corpus luteum after ovulation. H. E. stain.



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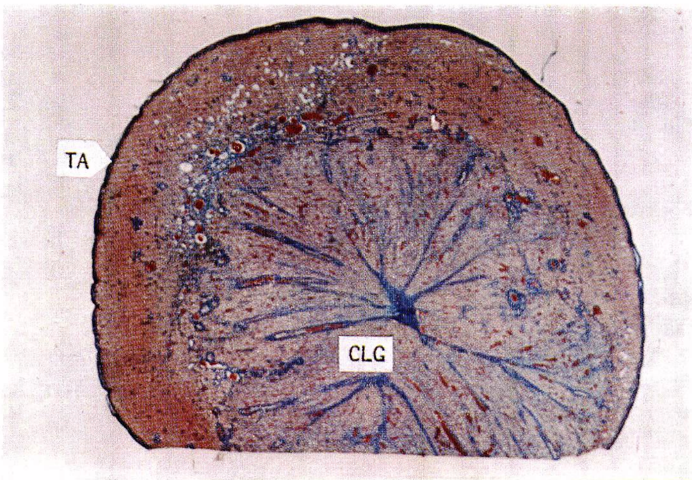

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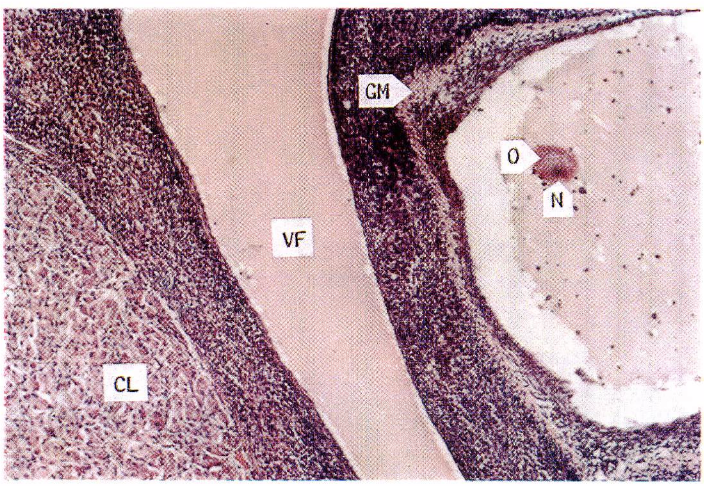

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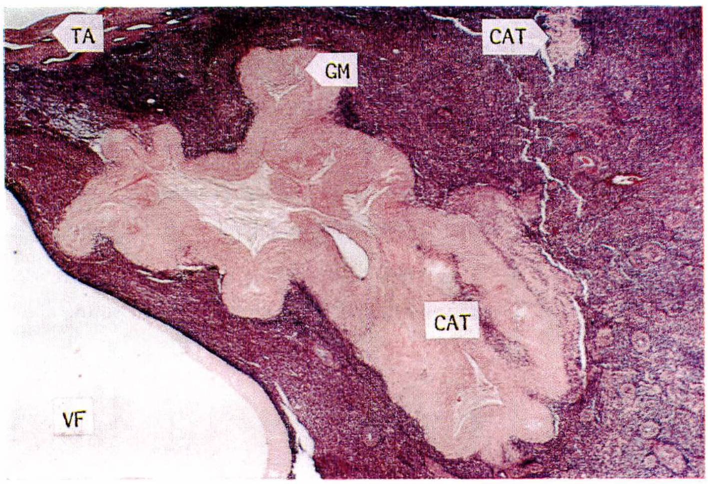
## EXPLANATION OF PLATE IV

**Fig. 1.** ×50 A 5-year female caught on July 15, 1975.
The follicle during the regression period. H. E. stain.

**Fig. 2.** ×10 A 18-year female caught on August 6, 1975.
The closed form occurred by contraction of the vesicular follicle. H. E. stain.

**Fig. 3.** ×10 A 10-year female caught on July 11, 1975.
The corpus albicans originated from the corpus luteum, and the corpus albicans from the follicle. H. E. stain.


1

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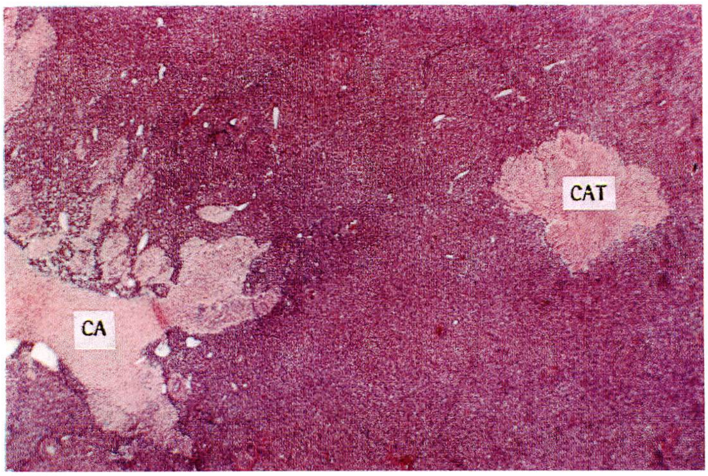


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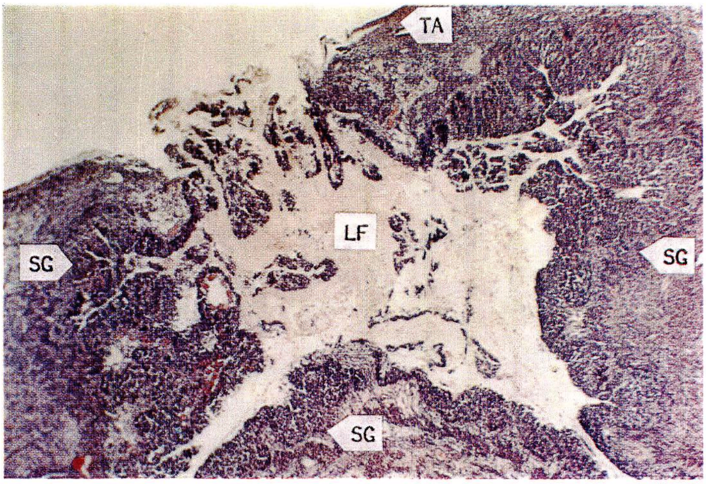
## EXPLANATION OF PLATE V

| | | |
|---|---|---|
| **Fig. 1.** | ×10 | A 4-year female caught on July 29, 1975.<br>The follicle just after ovulation. H. E. stain. |
| **Fig. 2.** | ×75 | A 14-year female caught on October 11, 1975.<br>The functioning corpus luteum. H. E. stain. |
| **Fig. 3.** | ×10 | A 12-year female caught on January 18, 1978.<br>The corpus luteum graviditatis. Azan stain. |

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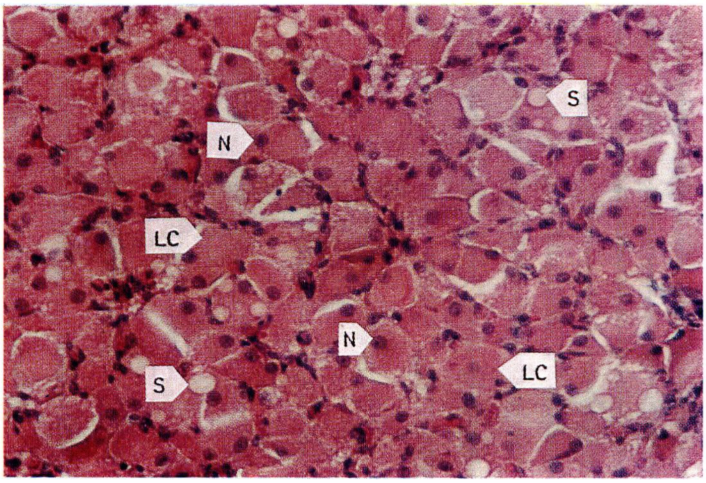


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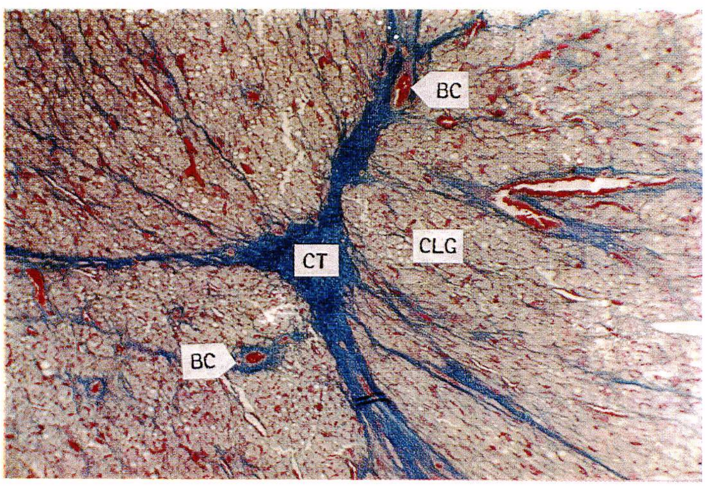


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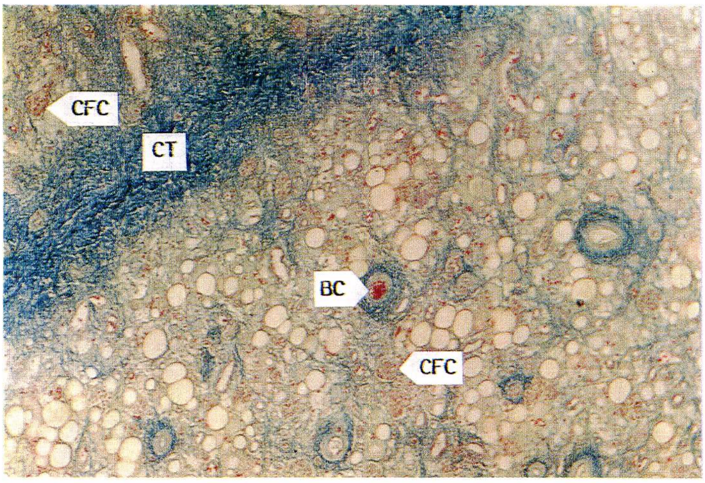
## EXPLANATION OF PLATE VI

**Fig. 1.** ×25 A 5-year female caught on June 24, 1973.
The corpus luteum graviditatis. Azan stain.

**Fig. 2.** ×10 A 7-year female caught on September 13, 1975.
The corpus albicans of delivery in this year.
H. E. stain.

**Fig. 3.** ×10 A 14-year female caught on July 3, 1975.
The corpus albicans about one year after delivery.
H. E. stain.



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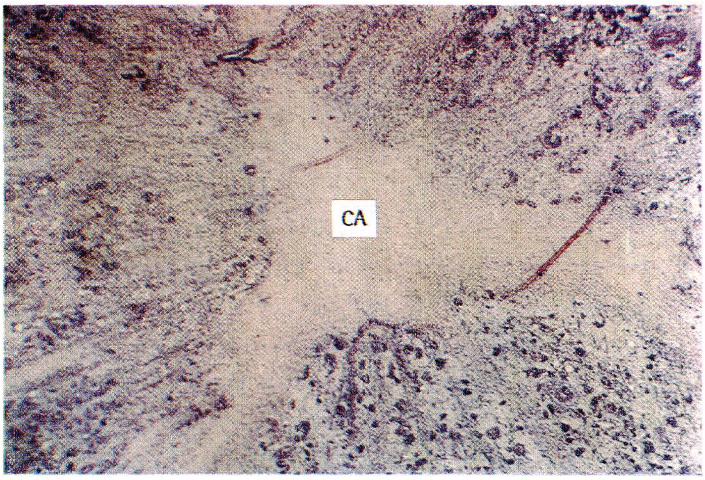

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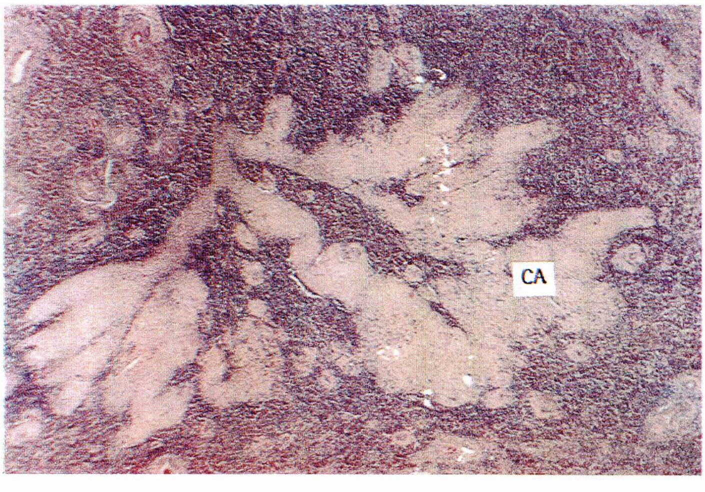

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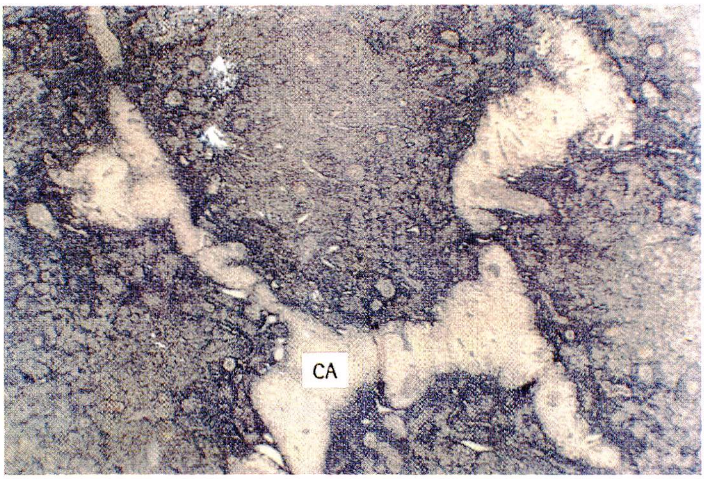
## EXPLANATION OF PLATE VII

| | | |
|---|---|---|
| **Fig. 1.** | ×10 | A 15-year female caught on July 3, 1975. The corpus albicans about two years after delivery. H. E. stain. |
| **Fig. 2.** | ×75 | A 15-year female caught on August 25, 1975. The corpus luteum-showing a trace of lipid droplets. Sudan black stain. |
| **Fig. 3.** | ×50 | A 4-year female caught on September 20, 1975. The corpus luteum-with increase of lipid droplets around the corpus luteum. Sudan black stain. |

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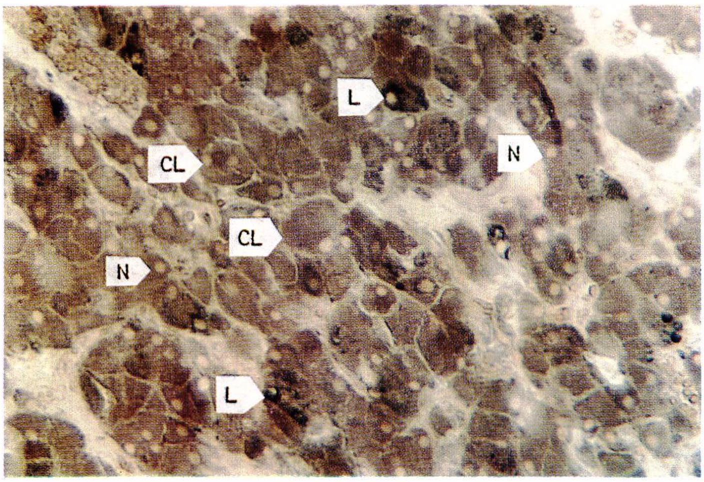


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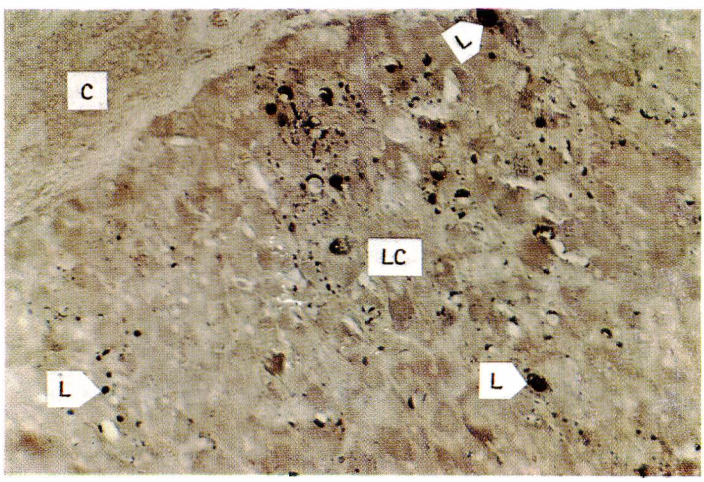


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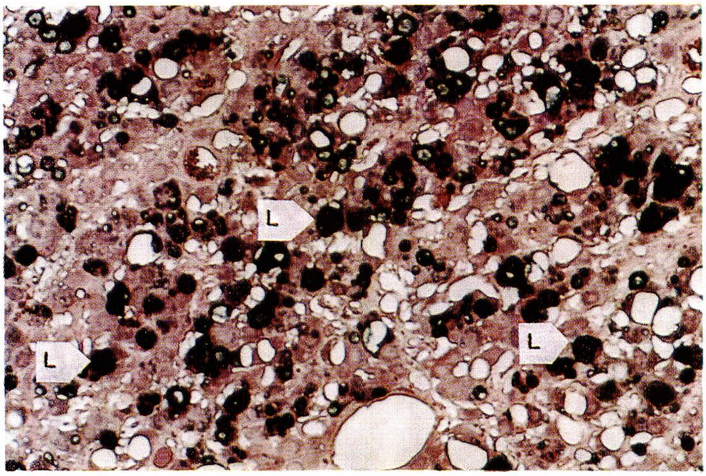
## EXPLANATION OF PLATE VIII

**Fig. 1.** ×30 A 14-year female caught on December 4, 1977.
The corpus luteum graviditatis-showing a lot of lipid droplets. Sudan black stain.

**Fig. 2.** ×150 The high-magnified image of Plate VIII-Fig. 1.
Sudan black stain.

**Fig. 3.** ×10 A 12-year female caught on January 18, 1978.
The corpus luteum graviditatis-showing penetration of the connective tissue into the corpus luteum and regression of the corpus luteum, but a lot of lipid droplets are still observed. Sudan black stain.



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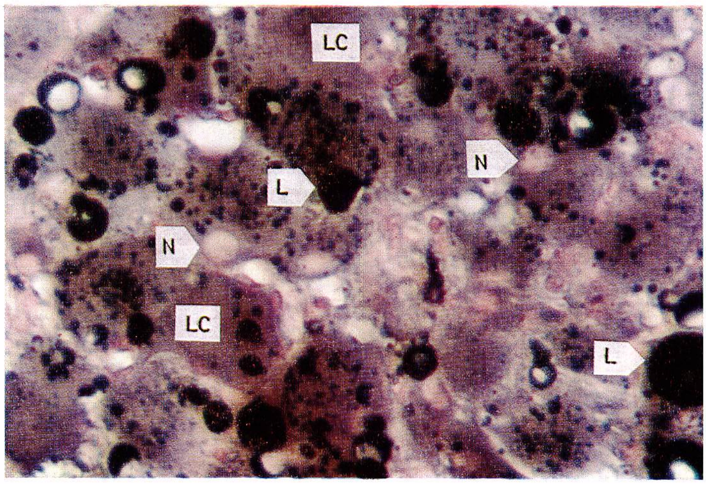

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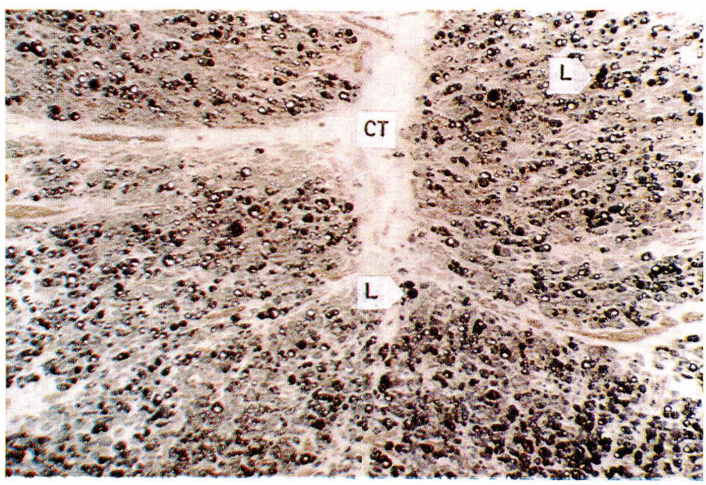

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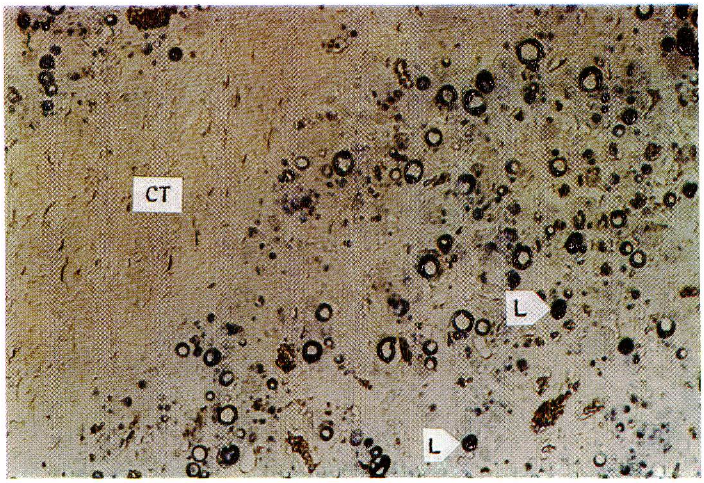
## EXPLANATION OF PLATE IX

**Fig. 1.** ×10 A 9-year female caught on May 26, 1973.
The corpus luteum graviditatis-regression of the corpus luteum has considerably progressed. Nile blue stain.

**Fig. 2.** ×10 A 4-year female caught on August 4, 1975.
Re-increase of the lipid droplets. Sudan black stain.

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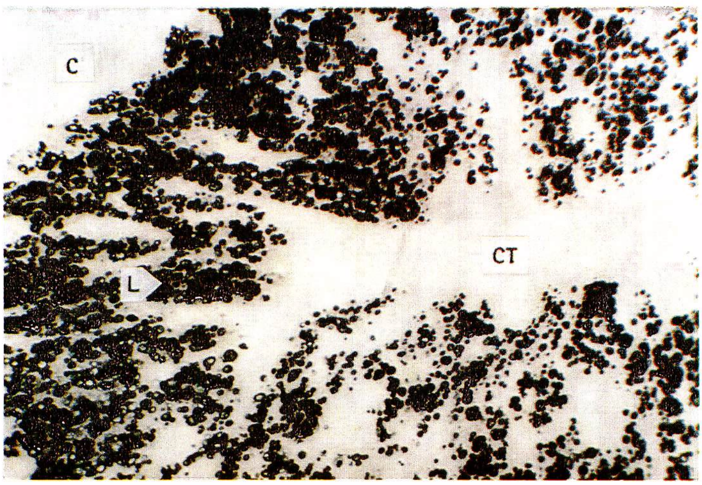


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