Age Characteristics in Baleen Plates

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Masaharu Nishiwaki

I. Foreword.

W. Scoresby in 1820 already considered the possibility of a presence of some age factor in the sculptures found on the surface of baleens. Later, E. F. Eschricht, J. Reinhardt and T. Tullberg, studied this matter and showed the structure of baleens as shown in Fig. 1.

Fig. 1. Section of a Baleen Plate
(J. T. Ruud)
a) Cross Section. b) Longitudinal Section.

As can be seen from the photograph, there are a group of horny tubes in the centre, and nail-like tissues in the outer layer that is called blade-pulp.

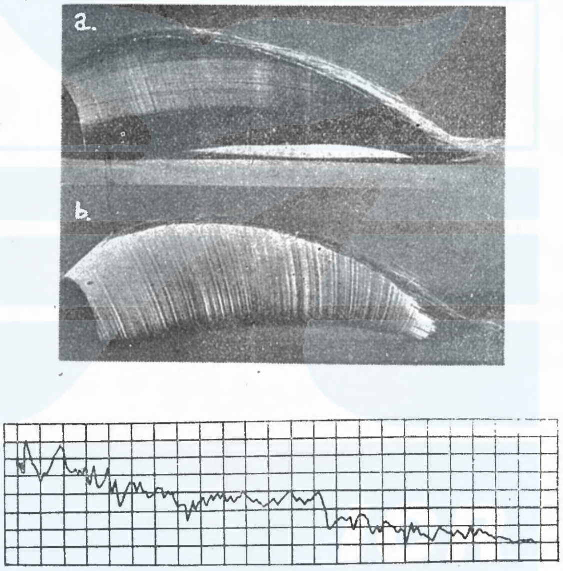
These horny tubes begin at the root of baleen plate, passes through the baleen in parallel lines, and forms what is called the bristle part at the tip of the plate. These tubes form one long tube from the root to tip and contains blood vessels and nerves. These tubular tissues never start from the middle of a baleen plate, one such tube from one end to the other is of fairly uniform size.

On the other hand, the outer layer is formed of pulp-like tissues and contains no blood vessels or nerves. As can be seen from Fig. 1b, this layer varies in thickness.

From these data, it can be seen that the horizontal creases called sculptures on the outer surface of a baleen plate are not due to horny tubular tissues in the centre but to the periodical increases and decreases in the thickness of the outer layer. These periodical changes in thickness are due to the inequality of nutrition by the longitudinal migration of whales. Therefore, this period refers to nutrition period, rather than annual period.

These were the conclusions reached by researchers before J. T. Ruud. J. T. Ruud based on these conclusions, deviced a machine which records the thickness of a baleen plate because he considered that the periodical growth of sculptures could be measured by recording the changes in plate thickness. Such a recording machine is shown in Fig. 2.

Fig. 2. Photograph of a Baleen Plate and a Record of the Baleen (by J. T. Ruud)



In a set of baleens from one whale, the sculptures on their surface are of the same nature, except in the small number of baleens at each end, and a definite number of small sculptures were found to gather together to form one step in growth.

From the results of measurements, three such steps were found in female whales of two years of age (the sexually mature female) as advocated by Mackintosh and Wheeler. Therefore, these females are in the third year, and Ruud claims that his measurements are in agreement with the theory of Mackintosh and Wheeler.

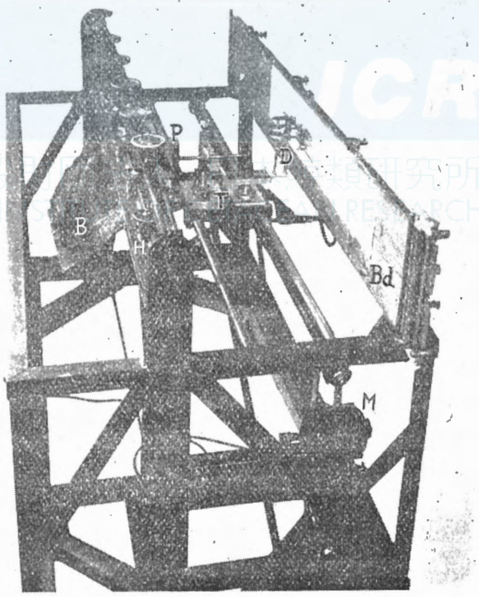
From these facts, it was assumed that each step corresponds to one year. J. T. Ruud made no further reference to it and offered no conclusions but promised further research. (Ruud has published papers on baleens after the war but we have had no chance of seeing the papers.)

Soon after the cessation of the second world war, Japan was again permitted to take part in the Antarctic whaling. We were fortunate in being able to bring back largest baleens on either side for our studies, but those of the first and second expeditions (1946-1947 and 1947-1948 season) were send to the United States and only those of the 1948-1949 season were left in our hands. With these, the sculptures were measured by the methods described later.

II. Measuring Method for Sculptures of Baleen Plates.

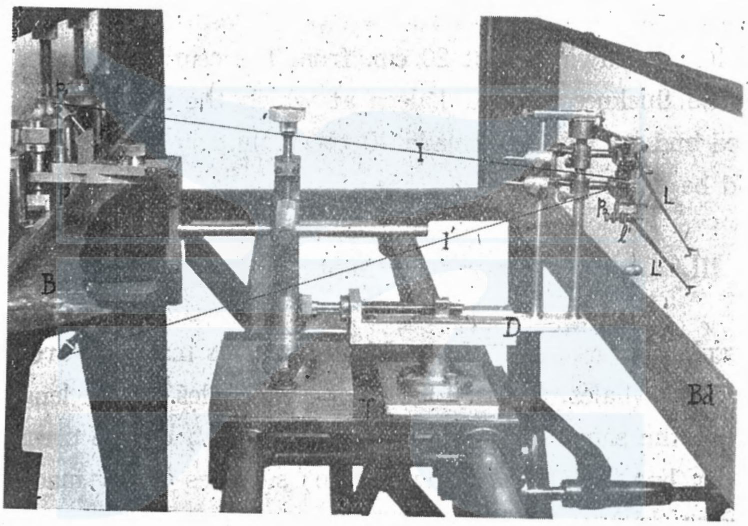
For reasons as described below, plans were made for the measuring of sculptures on baleens obtained from Antarctic whales in the 1948-1949 season, and, with the help of Mr. Hideo Omura of the Marine Products Bureau and Dr. Tsutomu Maruyama, Director of the whale Research Institute, a measuring apparatus as shown in Fig. 3 was manufactured by Mr. Osatake Shibazaki of the University of Tokyo.

Fig. 3. Complete Photograph of Measuring Apparatus of Baleen Sculpture.



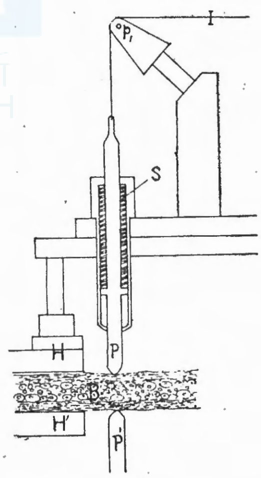
This machine has a holder (H) for a baleen (B) which holds the latter under pressure so as to allow least warping. A measuring needle (P) moves on either side of the baleen. The movable table (T) on which are fixed the measuring needle (P) and a drawing needle (D) moves at a rate of 25 cm. per minute by the motor (M) of 1/3 HP, AC. Details of the movable table (T) and the measuring and drawing needles are shown in Fig. 4.

Fig. 4. Miniature Photograph of Measuring Apparatus of Baleen Sculpture.



The measuring needle (P), Fig. 5, is pressed onto the baleen (B) by a spring (S). The needle transmits the sculpture on the baleen by the up and down movement which is transmitted to leading lever (l) through induction wire (I) and two pulleys (p_1 and p_2). The leading lever for induction wire (I) and drawing lever (L) are completely parallel.

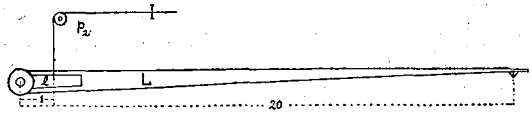
Fig. 5.



The drawing lever (L) writes directly on a piece of paper pinned on a cardboard paper (Bd) the shape and form of the sculptures on a baleen surface.

The magnification, as shown in Fig. 6, is determined by the sculptures, i. e. its height and depth from the ordinary surface, by the drawing lever (L). The length of the baleen itself is as in the original.

Fig. 6.



In the present studies, the magnification were made 20 times on both surfaces. As can be seen from the Fig. 6, the induction wire is fixed at a point one cm. from the central fulcrum of leading lever, and the drawing lever (L) has a drawing point 20 cm. from the central fulcrum. By this means, if the thickness of the baleen at which the measuring needle rests is measured and its thickness made 40 times that amount, the whole thickness would be transmitted as 40 times larger.

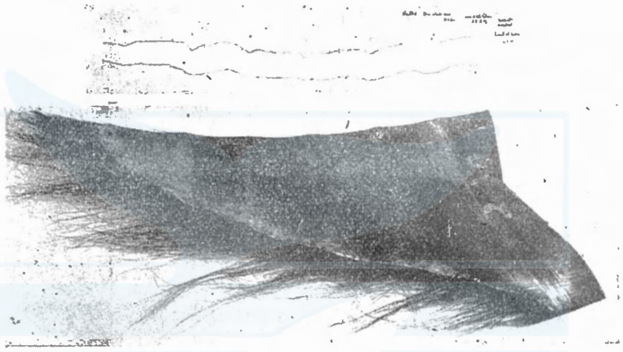
III. The Nature of the Sculptures of Baleen Plates.

The sculptures as depicted graphically by this machine are shown in Fig. 7 for blue whales. and in Fig. 8 for fin whales. The length of the baleens were the same in both cases and the depth of the creases on the upper (upper line) and lower (lower line) surfaces were made 20 times greater. The thickness of the baleen, if made also to 20 times its actual size, would result in too far a space between the upper and lower lines so that the distance has been suitably reduced. This graph is different from that of Ruud, both in the mode of expression and in the method of measurement, but there is not a great difference in showing the tendencies. In short, it shows the periodic cycle of growth well. Disregarding small ups and downs, one cycle was taken as that period from the thin part (malnutritious) to the next thin part through a thick part (nutritious). The spot marked with a round is where the thin part exists. Although not very discernible in the photograph, there were some that had many small holes in this thin place. Measurements were made as to how many of these thin places were present on one baleen.

Studies of a pair of baleens from one animal showed that, not only in the number of cycles but also in the shapes and forms of up and down trends, the pair showed the same tendencies. This seemed to prove the theory that these sculptures show the state of nutrition of the whale and that the periodic cycle is a nutrition cycle. Since there were no evidence of a pair showing different cycles on each baleen out of 100 cases studied, the measurements were then made only with the baleen taken from the right side. Observations were made on its periodic cycle, together with other representative data for age estimation.

Fig. 7. Photographs of Baleen Plates and their Recordings.

a) Blue Whale Male



b) Blue Whale Female

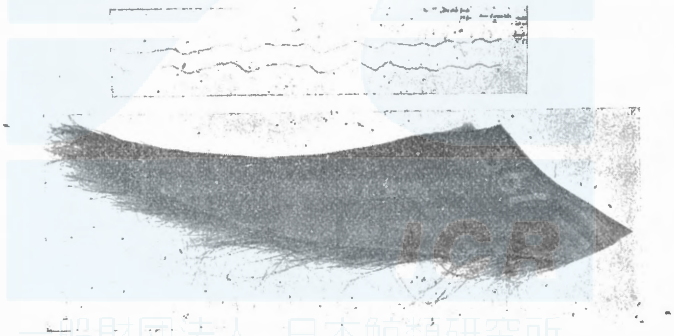
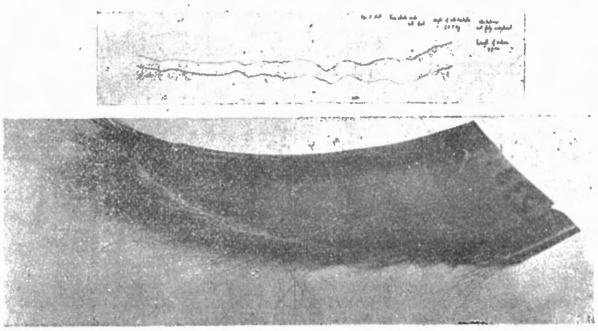
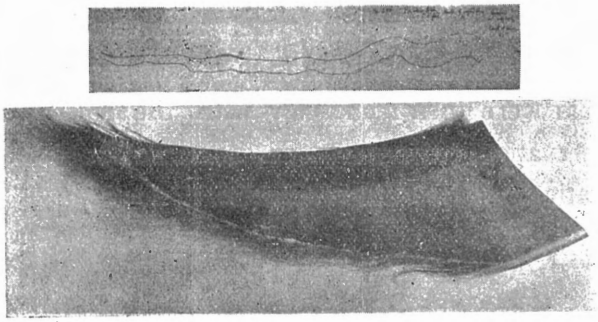


Fig. 8. Photographs of Baleen Plates and their Recordings.

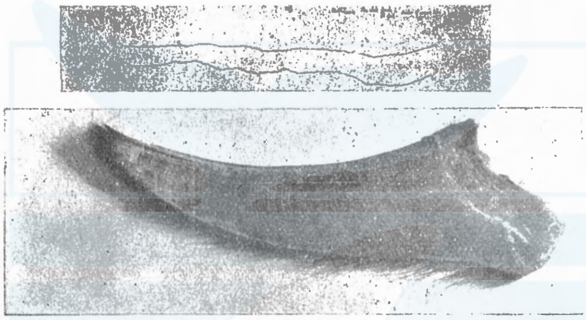
a) Fin Whale Male



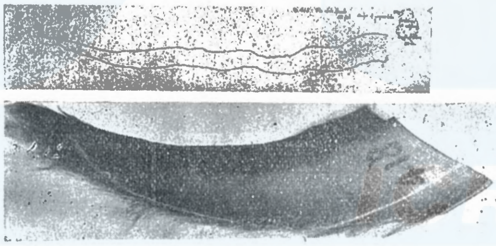
b) Fin Whale Female



c) Fin Whale Female



d) Fin Whale Female



IV. Relationship between Periodic Cycles on Baleen Plates and Number of Corpora Lutea.

The number of corpora lutea in the ovary has been studied by many investigators and are considered the most reliable data on estimation of age in female whales. The maturity or immaturity of a female whale can be judged very simply by the presence or absence of corpus luteum. Both blue and fin whales are known to become mature two years after the birth.

The sculpture of baleens were measured of whales having no corpus luteum, i. e. on sexually immature whales. Of 24 heads of blue whales measured, 1 was found to be in its fourth cycle, 10 in fifth cycle, and 13 in sixth cycle. Of 33 heads of fin whales examined, 27 were in the fourth cycle and 6 in the fifth cycle.

If sexually immature whales are taken as those under two years since birth, then the cycle we have been considering does not mean one year.

It was also considered that the cycle we have been using and that of Ruud's are the same, but, if the cycle does mean one year, then the period necessary for sexual maturity is between five and six years in blue whales and four years in fin whales. This is contrary to the conventional theory that female whales become sexually mature two years after their birth.

At any rate, period necessary to attain sexual maturity seems to be different in blue and fin whales. This is an important point on which our investigation rests. However, we shall let these points rest a while and arrange the results of measurements made on all of the female whales.

In Fig. 9, the black dots (physically mature whales) and white circles (physically immature whales) represent individual data, and the solid line is the average cycle curve according to the number of corpora lutea. The broken line is the average number of corpora lutea according to the number of cycles.

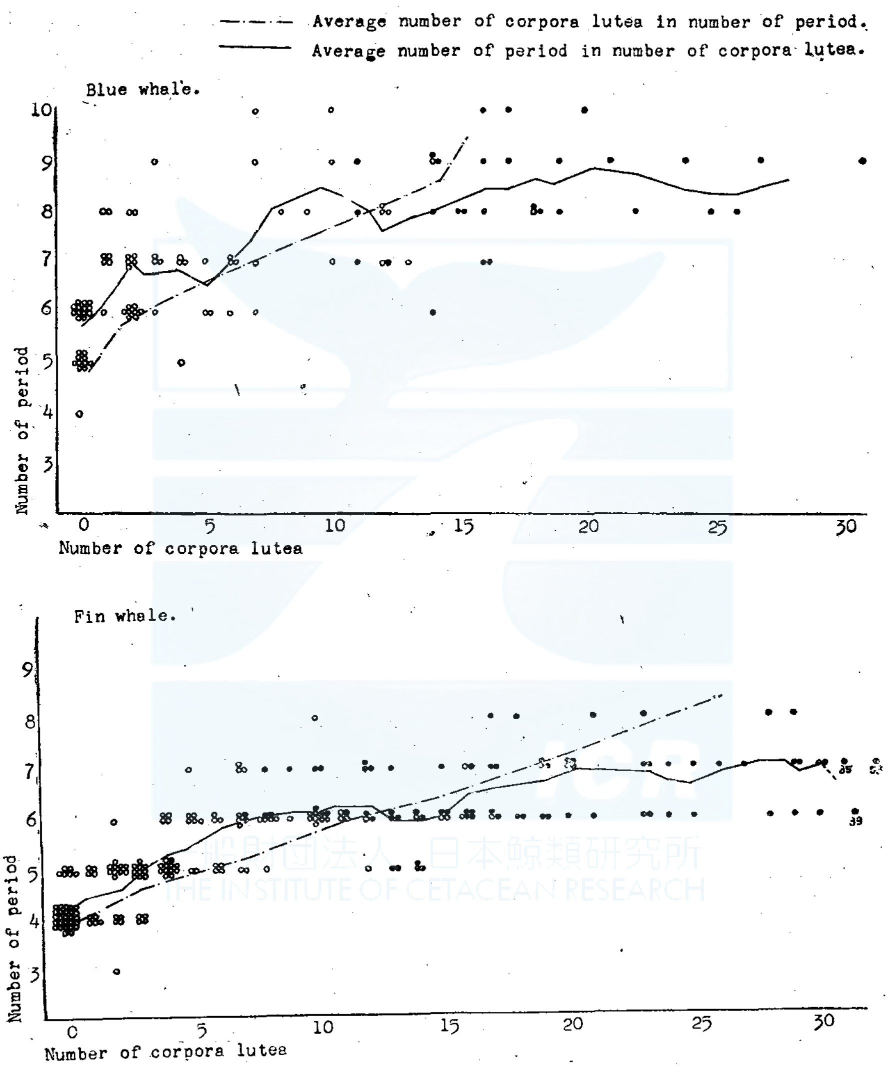
If baleens are not replaced since birth, the growth rate must differ at the tip and at the root. The number of cycle must also change at a certain proportion, and an increaes in the number of corpora lutea must have the same increase in the number of cycles. Also, the aforementioned two curves must show approximately the same results. However, the curve showing average mumber of cycles according to the number of corpora lutea levels off after a certain number of cycles, i. e. eight to nine cycles in blue whales, seven cycles in fin whales.

As can be seen from Figs. 7 and 8, the space between each cycle, though differring slightly between whales, is almost the same in each individual.

These facts seem to point out that baleens, like human hair or nails, grow from their roots all the time and, after a lapes of certain time (the length of this time being different in each individual) bigin to chip off from the tips.

The curves for number of cycles according to the number of corpora lutea stabilizes already at seventh cycle in blue whales and at sixth cycle in fin whales. Even with varieties of ups and downs, curves finally level off at the above period which give the impression that, even at that early period, chipping off starts in some individuals.

Fig. 9. Number of Periodic Cycles on Baleen Plates and Number of Corpora Lutea.

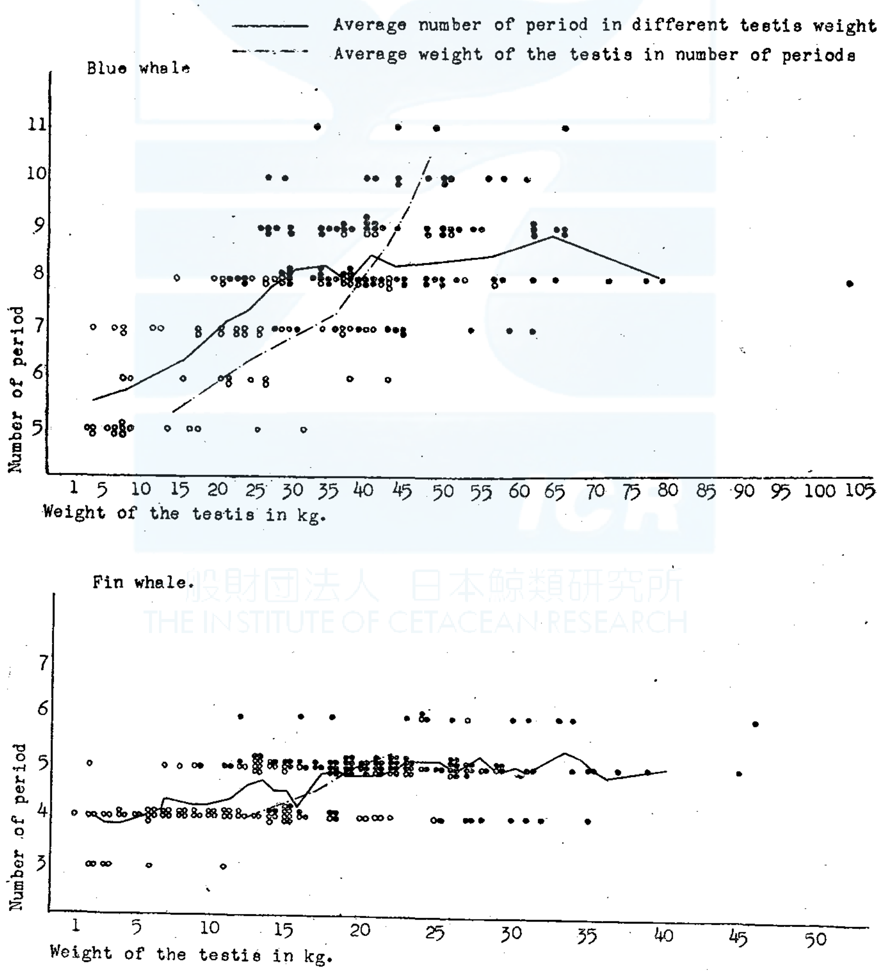


V. Relationship between the Periodic Cycles on Baleens and the Weight of Testes.

Combination of the periodic cycles appearing on baleens and age data in male whales, i. e. weight of testes, is given in Fig. 10. Black dots show individual data for physically mature whales, and white circles, those for physically immature whales. The solid lines represent average number of periodic cycles according to weights of testes. Where only a few heads of whales were available, an average of that group has been taken up. The broken lines show the average weight curve of testes according to the number of cycles.

In this case also, the same idea applies as to the female whales. The chipping of baleen seems to start at seventh to eighth period in blue whales, and at fourth to fifth period in fin whales.

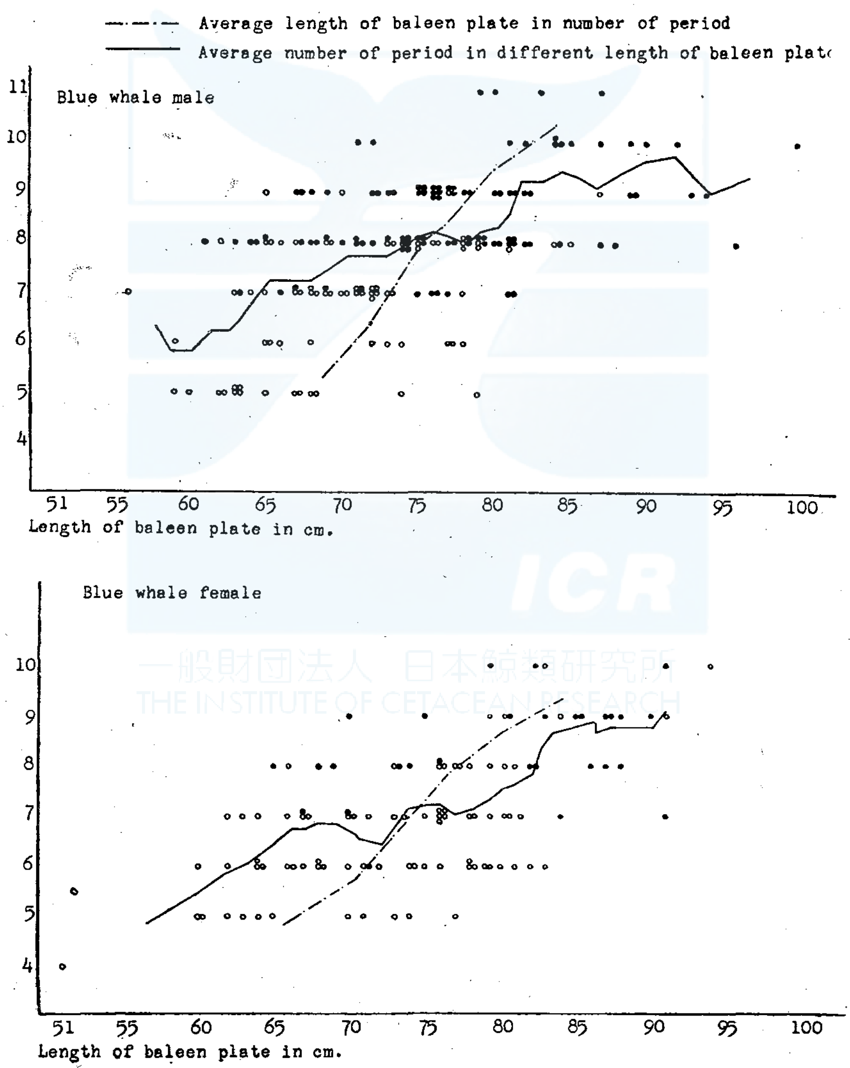
Fig. 10. Number of Periodic Cycles on Baleen Plates and Weight of Testes.



VI. Relationship between Periodic Cycle on Baleens and Baleen Length.

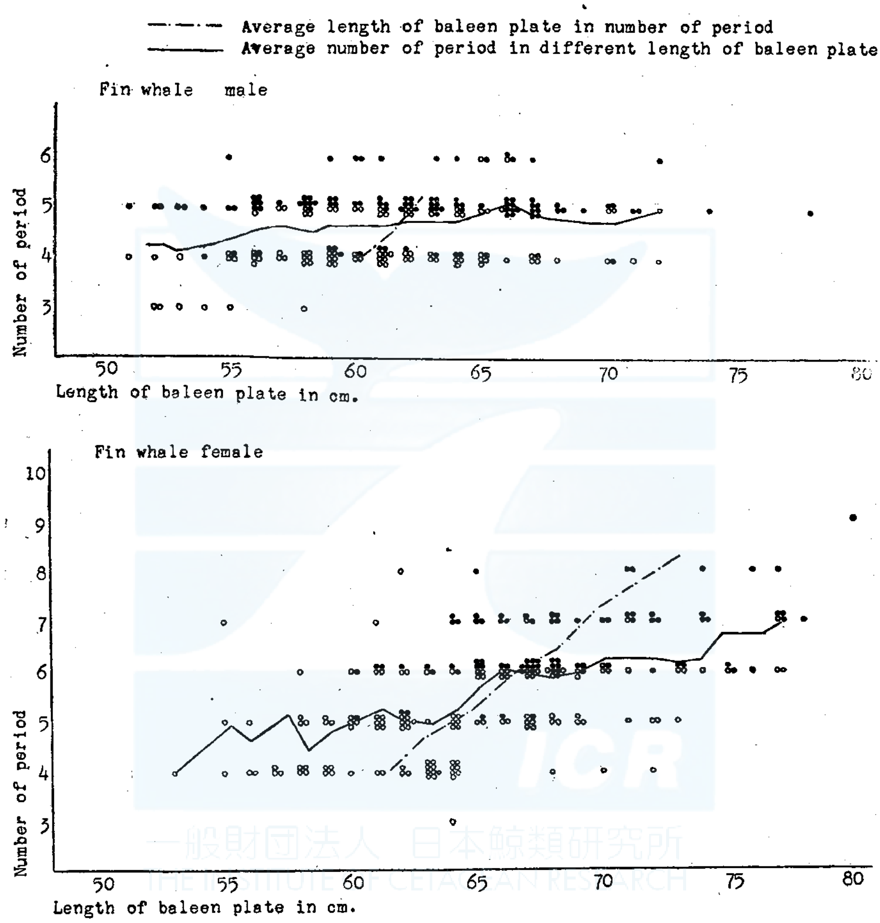
In accordance with the ideas formulated in the foregoing chapters, long baleens should have larger number of periodic cycles, although a slight difference may exist between individuals. In other words, in two whales of similar nature, one possessing less chipped baleens would possess

Fig. 11. Number of Periodic Cycles on Baleen Plates and Length of Baleen Plate in Blue Whales.



longer baleens. Figs. 11 and 12 show the combination of baleen length and the periodic cycles appearing on the baleens for blue and fin whales, respectively.

Fig. 12. Number of Periodic Cycles on Baleen Plates and Length of Baleen Plate in Fin Whales.



Black dots show individual data for physically mature, and white circles, those for physically immature whales. The solid lines represent average curve for number of periods according to baleen length, and the broken lines, average curve for baleen length according to the number of periods.

In both graphs, the positions of individual data, i. e. black dots and white circles, are different from foregoing data. Although there are various small movements, the curves as a whole have no relationship to the number of corpora lutea or to the weight of testicles, and short baleens have fewer number of cycles, the longer ones, more. This proves authenticity of the hypothesis that baleens begin chipping off at the tips.

The curves for fin whale males are all without much variation which seem to show that no great difference in periodic cycles exists between individuals, the majority showing four to five cycles. Hewever, variation between these two periods are not small, compared to others.

The rate of growth of baleen plates in one periodic cycle, calculated from Figs. 11 and 12, give the values of 7 to 10 cm. in blue whales, and 9 to 15 cm. in fin whales. These values coincide well with actual measurements.

VII. Relationship between Periodic Cycles on Baleen Plates and Body Length.

Combination of the body length and number of periodic cycles in blue and fin whales are shown in Figs. 13 and 14, respectively.

Black dots signify data for physically mature whales and white circles, those of the physically immature. The solid lines represent average curve of the number of periods according to body length, and the broken lines, that of body length according to the number of periods. In these graphs, as in the others, the curves level off after eight to nine cycles in blue whales, and five to six cycles in fin whales, showing that baleen plates start chipping off after these periods. This period seems to be late in fin whale males but, compared with curve for baleen plates, it shows that they have strong tendency to chip off.

Figs. 15 and 16 show the combination of body length and baleen length in blue and fin whales, respectively. They both show similarity to the curve for periodic cycle and body length. As a whole, the increase in body length is accompanied by increase in the length of baleen plates. This shows that the baleen plates increase, not only in proportion to passage of time but also with the increase in body length, i. e. increase in the size of the mouth. The change in the length of baleen plates differ greatly in individuals of the same body length and not so much between whales of similar body length, which makes this factor unsuitable as age determination datum. However, this fact also proves the explanations given regarding relationships between the body length and the number of periodic cycles, or that between the length of baleen plates and the number of periods.

Fig. 13. Number of Periodic Cycles on Baleen Plates and Body Length in Blue Whales.

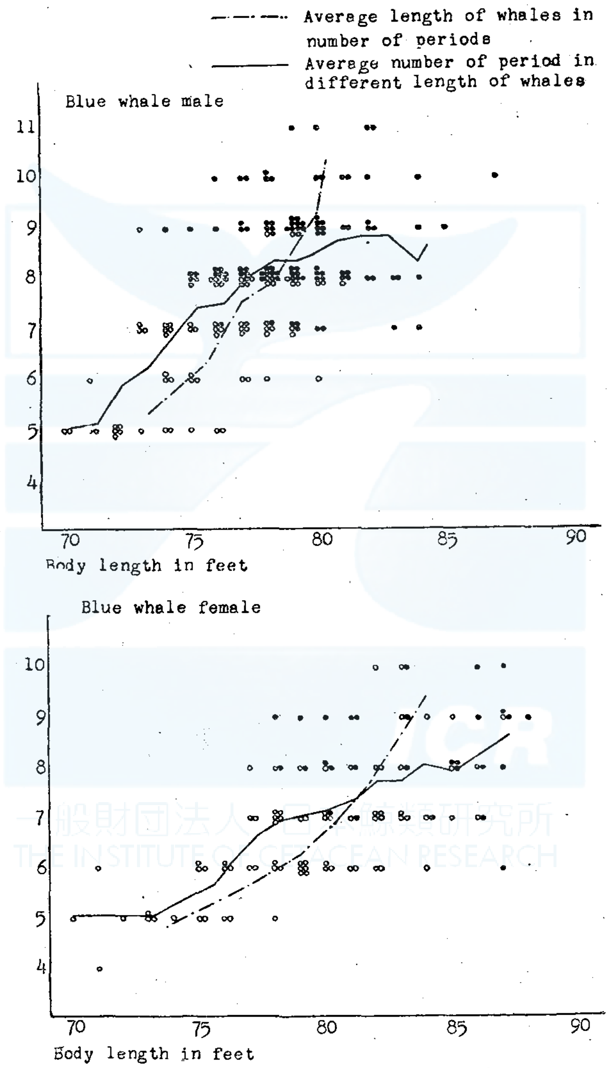


Fig. 14. Number of Periodic Cycles on Baleen Plates and Body Length in Fin Whales.

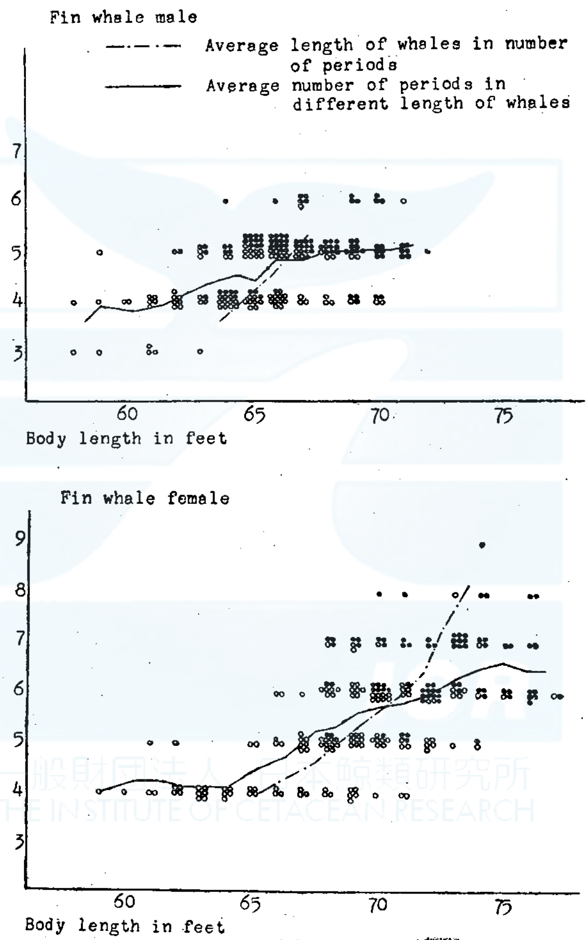


Fig. 15. Length of Baleen Plates at different Body Lengths in Blue Whales.

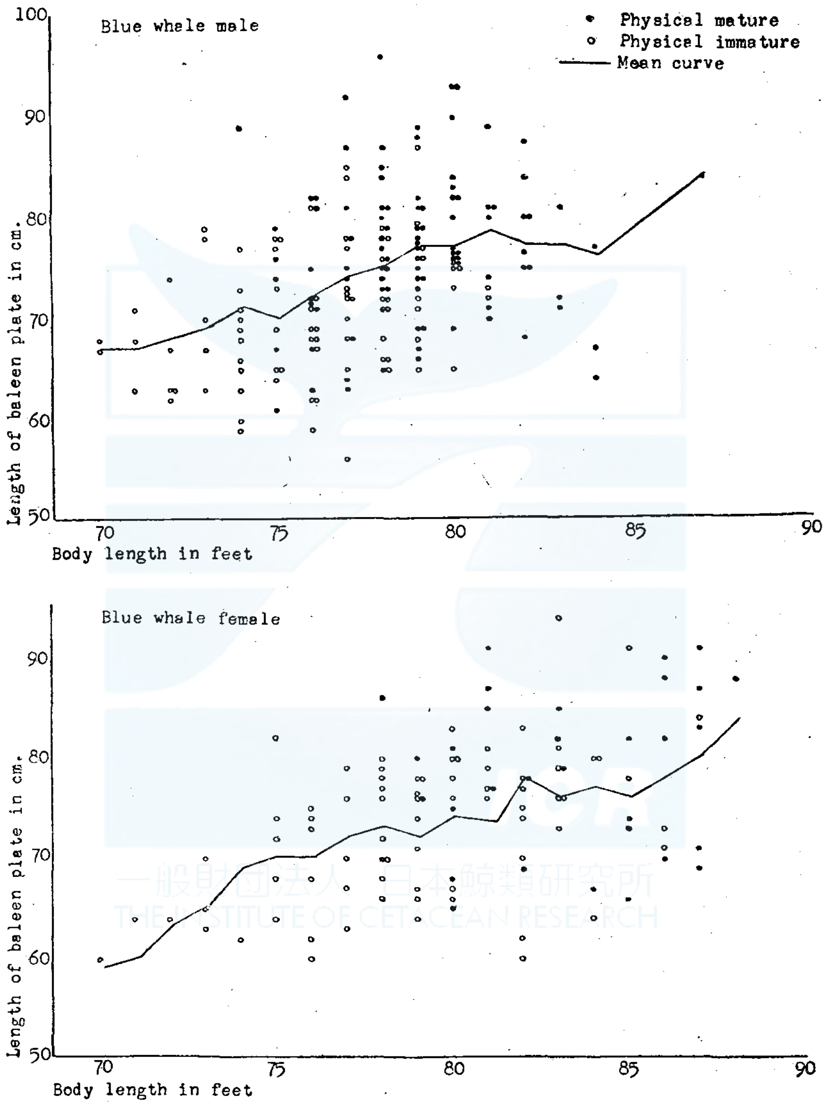
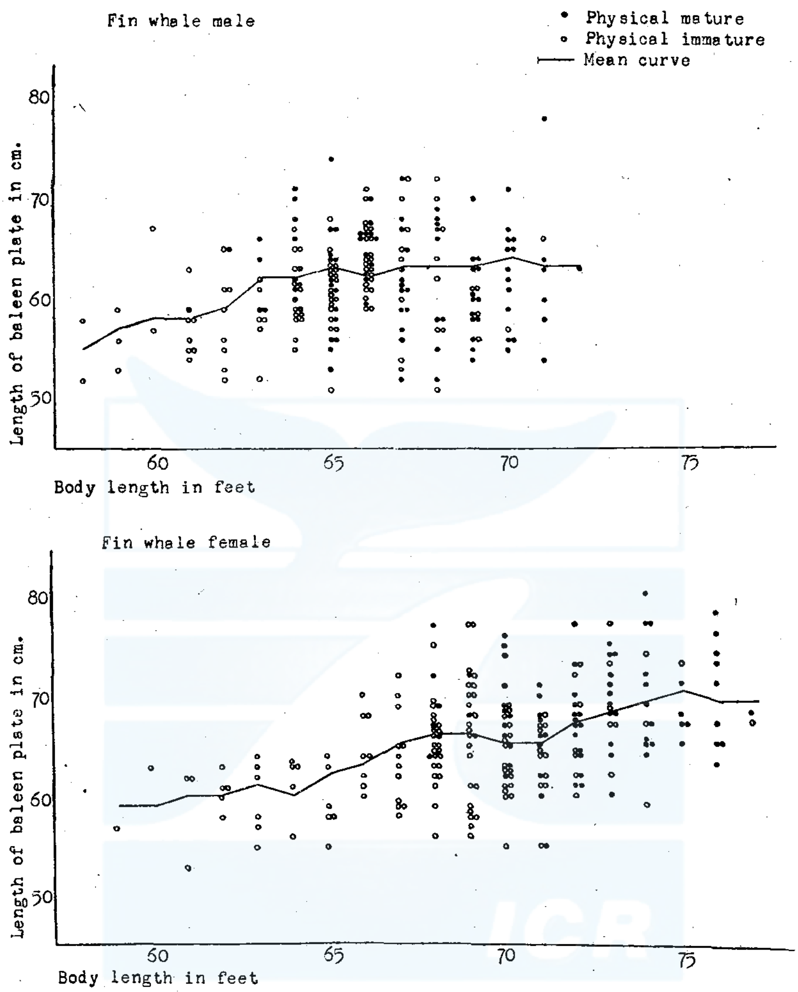


Fig. 16. Length of Baleen Plates at different Body Length in Fin Whales.



VIII. Relationship between Periodic Cycles on Baleen Plates and Sexual Maturity.

Judging from the various curves obtained in the foregoing chapters, following conclusions may be drawn, although in some instances where two curves show coincidence or approximate coincidence such conclusion would be dangerous.

The number of corpora lutea according to periodic cycles seems to be about four corpora per cycle.

Number of corpora lutea	Blue whales	Fin whales
0—2	up to 6th cycle	up to 4th cycle
3—6	6—7 〃	4—5 〃
7—10	7—8 〃	5—6 〃
11—14	8—9 〃	6—7 〃

According to Wheeler's theory, the whales are divided into groups having five corpora lutea each, from the curve of the number of corpora lutea.

The sexual maturity of female whales, i. e. those having one corpus luteum, is at the seventh period in blue whales, and at the fourth to fifth period in fin whales, according to Fig. 9. The body length at that period, from Figs. 13 and 14, is 78 feet for blue whales and 66 feet for fin whales. These values coincide well with other theoretic data.

In male whales, there is no state in which the two curves in Fig. 10 show the same tendencies. This shows that not only the chipping of baleen plates but also the relationship between growth rate (e. g. body length) and testicular weight must be very irregular. However, the average curve for testicular weight according to the number of periodic cycle stabilizes at about the seventh period showing that there is no remarkable increase in weight after that period. This period is about fourth to fifth in fin whales. The testicular weight at these periods is 35 kg. in blue whales and 17. 5 kg. in fin whales. From the curve of testicular weight according to body length, no great change occurs after blue whales reach the length of 75 feet with 32 kg. testicular weight, and at 65 feet with 32 kg. testicular weight in fin whales.

The increase in testicular weight during one periodic cycle at sexual maturity is about 10 kg. in blue whales and about 7. 5 kg. in fin whales.

The rate of body growth during one periodic cycle, as calculated from Figs. 13 and 14, is about 2. 5 feet in blue whale males at fifth to seventh period, and 3. 5 feet in blue whale females at the same period. In fin whale males, this is 6 feet at fourth to fifth period, and in females, 4 feet at fourth to sixth period. From these data, it seems that fin whales gain more in body length than blue whales during one periodic cycle. The growth rate is especially high in fin whale males. This may offer somewhat baffling idea but multiplication of these rate of body length increase by the number of periods give values equal to the increase in body length from infancy to the sexually mature stage.

The increase in body length during the young stage should be much greater than at or near the sexual maturity. Although not among my own data (J. T. Ruud's data), one young fin whale caught during its suckling period possessed a baleen plate 42 cm. long, yet it could not be even one year old.

If the increase in the length of baleen plate during one periodic cycle is taken as 12 cm., and the increase in body length during the same period as 4 feet, then 42 cm. would mean the increase in body length of 14 feet. Based upon these assumptions, values obtained are coincidental with the actual measurement of body length from birth to sexual maturity.

From foregoing ideas, it seems that one periodic cycle on baleen plates mean one solar year. According to this assumption, several years elapse between birth until attainment of sexual maturity, and the length of time differs between blue and fin whales. However, according to existing theories, both blue and fin whales reach sexual maturity in about two years, and there have been no data to disprove this theory.

IX. Relationship between the Periodic Cycle on Baleen Plates and Physical Maturity.

In all the graphs shown in the foregoing chapters, black dots denote physically mature whales, i. e. those in which the vertebrae are fully ankylosed, both in thoracic and lumbar series, and white circles, the immature.

In female whales, as shown in Fig. 9, the physical maturity is related to the number of corpora lutea but the relationship between the number of corpora lutea and the number of periodic cycles on baleen plates is very obscure. The number of heads examined, as a whole, is very small but no physically mature whales were found in blue whales of less than the fifth period, and fin whales of less than the fourth period. The number of mature whales increases as the number of periodic cycles increase, but in both species of whales, physically immature whales can be found in those having the maximum number of periodic cycles.

In male whales, as shown in Fig. 10, the physical maturity is not related either to testicular weight or to the number of periodic cycles on baleen plates.

Its relation to the lengths of baleens is also doubtful since, from Figs.

11 and 12, the longer the baleen plates does not always mean a mature whale, or vice versa.

Figs. 13 and 14 show that physical maturity is not at all related to body length or to the number of periodic cycles found on baleen plates. Of course, the ratio of maturity is greater in whales of larger body length, or in those having larger number of cycles on baleen plates since the latter means a longer time passed from birth.

However, no clear line can be drawn as was possible with the number of corpora lutea between the physically mature and immature whales.

These facts seem to indicate that baleen plates, when it has reached a certain length (differing in each individual), begins to chip off irrespective of physical maturity, i. e. the age.

X. Conclusion.

As can be seen from the foregoing, baleen plates begin to chip off after reaching a certain period. This period is at a stage when the rate of increase in the mouth volume becomes smaller than the rate of increase in length of baleen plates and seems to differ by the growth rate of each individual.

In other words, the inner volume of the mouth becomes larger as whales grow, similar to body length, but the growth rate becomes smaller after a certain period of time. However, baleen plates go on growing as before without any regard for growth rate, so that, at one time or another, it begins to get in the way. This is the period referred to above, which naturally differs in each individual. Some whales show chipping at the fourth period, while some show no chipping even at the seventh period.

J. T. Ruud gives a graph for a young fin whale (still in suckling stage) of 42 feet of body length, among his data. He sites the fact that the sculptures on the baleen plate from this whale is remarkable smooth compared to those of mature whales, and explains the phenomena by saying that the young whale does not receive any nutritional effect other than periodic drinking of milk.

In examing many baleen plates, several were found to have these phenomena towards the tips. These must be plates in which the chipping had not started. Generally, the surface towards the tip is more smoother than at the root of a plate, but this must be a different phenomenon. These baleen plates, as shown in Fig. 17, show more sharper point than the one that has began chipping.

Fig. 17. Baleen Plates with Chipped and Unchipped points.
a) Unchipped plate b) Chipped plate

a b

During measurements, it was found that some blue whales showed chipped plates as early as the fifth period but generally, this chipping seem to take place from the seventh period. In fin whales, this phenomenon was found from the fourth to fifth period in males, and from fifth to sixth period in females.

This poses a question of whether these results are entirely negative and that the chipping of plates would give no data as to the total number of periodic cycles since birth and consequently no determination as to the age of whales.

It is true that whales with whole plates offer enough data for age estimation but in those having chipped baleen plates, only the life history during the recent several periods can be learned and there is nothing to tell the passage of time since birth.

The investigations were made more difficult by the fact that it was very hard to determine whether the tip of baleen plate was chipped or not. It was generally easy enough to tell whether a certain baleen had began to chipped off, but it was very difficult to say that a plate was not chipped off at all.

In short, further investigations are necessary to determine whether these sculptures on the surface of baleen plates represent one solar year per one periodic cycle, or whether several periods constitute a one solar year. However, there is no doubt that a certain relationship does exist between baleen plates and age determination data.

(October 20, 1949)

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