# The Determination of a Lifespan

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## *A 400-Year-Old Shark and a 40,000-Year-Old Plant*

By

Yasumi Ohshima

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A 400-Year-Old Shark and a 40,000-Year-Old Plant

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# PREFACE

Recent developments in our understanding of the lifespans of organisms have been really outstanding. About a decade ago, the longest recorded lifespan of an animal was said to be less than 200 years, but now it is known that the longest records for vertebrates and invertebrates are about 400 years and 4,000 years, respectively. Likewise, in the plant kingdom, the longest recorded lifespan was extended from about 5,000 years to more than 40,000 years. Elsewhere, molecular and statistical studies on lifespans, mainly in humans and animals, have been developing extensively, and will help us to live longer. This book describes the present states of actual lifespans of animals, plants and humans; important factors for their lifespans, especially for humans; and surprising facts and secrets of centenarians, based on many scientific papers and books.

This book is basically an English version of the book "４００年生きるサメ、４万年生きる植物　生物の寿命はどのように決まるのか", published in 2020 by Kagaku-Dojin. However, Chapter 9, "Biological significance of a lifespan", which was lacking in the Japanese book but is important, has been newly written and added for this English book.

The author knows of no other similar comprehensive book on lifespans like this. He wishes that this book will be read by scientists and students in the field of biology as a textbook, and by many general readers for their interests and for the further extension of their lifespans.

Yasumi Ohshima
March 8, 2022

# PROFILE OF THE AUTHOR

Professor Emeritus from Kyushu University, Japan, Yasumi Ohshima obtained his PhD from the Graduate School of Science, University of Tokyo in 1969, and since then has studied molecular biology in Japanese universities and at the Carnegie Institution in the USA. His main study areas are the biology of the nematode *C. elegans*, and the molecular biology of RNA. He has published several books in Japan, the most recent one translated here, and another recent one on the body sizes of organisms (published in 2013).

# CHAPTER 1

# A 400 YEAR OLD SHARK, 4,000 YEAR OLD CORALS: THE LIFESPAN OF AN ANIMAL

## 1-1 Lifespan ranking of vertebrates

### 1st: Greenland shark

The longest lifespans of some animals of each of the vertebrate classes are presented in **Table 1-1**. For each group, the lifespans are listed in order from shortest to longest. Among all the animals listed, the one with the longest lifespan is a shark known as the **Greenland shark** (*Somniosus microcephalus*) (**Fig.1-1**), the long lifespan of which was reported quite recently in 2016. This shark lives widely in the North Atlantic Ocean and the Arctic Ocean. The females are larger than the males, and they are said to grow up to 4~5m long (Nielsen et al. 2016, 702-704).

Its longest lifespan was reported to be 392+/-120 years as shown in the table. This lifespan belonged to the biggest (~5m long) of the 28 female sharks studied, and is a value estimated from the **radioactivity of the carbons** in the eye lens (+/-120 years represents 95% confidence interval or 2σ). This suggests that their longest lifespan may be up to about 500 years, or even longer in bigger specimens. The Greenland shark is thought to have the

longest lifespan among all vertebrates. This record is twice or three times as long as the longest lifespan of the Galapagos or Aldabra giant tortoise which was previously thought to be the longest, and therefore is an epoch-making discovery.

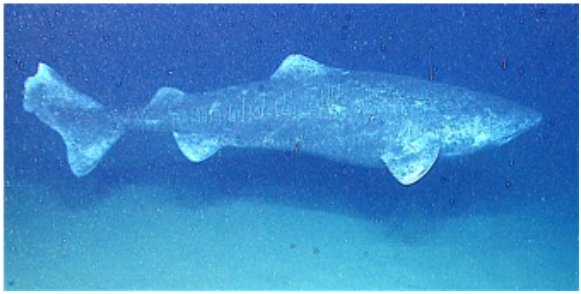

**Fig.1-1: Greenland shark** (https 8).

**Table 1-1: The longest lifespans of animals in each class of vertebrates.**

| Class | Species | Longest lifespan (years) |
|---|---|---|
| Fish | guppy | 5 |
| | salmon | 13 |
| | whale shark | 70 |
| | carp | 70~100 |
| | eel | 88 |
| | sturgeon | 152 |
| | Greenland shark | 392+/-120 (Nielsen et al. 2016,702) |
| Amphibian | toad | 40 |
| | giant salamander | 55 |
| Reptile | boa | 40 |

| | | |
|---|---|---|
| | American alligator | 66 |
| | sphenodon | 100 |
| | Galapagos giant tortoise | 177 (大島 2013, 27) |
| | Aldabra giant tortoise | 183 (Nat. Geo. News 2016) |
| Bird | hummingbird | 8 |
| | chicken | 30 |
| | crane | 62 |
| | ostrich | 62 |
| | owl | 60~70 |
| | stork | 70~100 |
| | cockatoo | 100 |
| | griffon vulture | 118 |
| Mammal | shrew | 1.5 |
| | mouse | 4 |
| | pig | 27 |
| | dog | 34 (under breeding) |
| | cat | 35 |
| | chimpanzee | 59 (鈴木 2002, 22) |
| | horse | 61 (under breeding) |
| | Indian elephant | 69 (鈴木 2002, 22) |
| | donkey | 100 |
| | finback whale | 116 (鈴木 2002, 22) |
| | human | 122 (https 6) |
| | Arctic whale | 211+/-35 (George et al. 1999, 574) |

Abstracted from Table 1.1.2 of Flindt et al. 2007, 7-9, if not indicated otherwise.

## Estimation of a lifespan is a difficult task

In the case of the Greenland shark, its lifespan is an estimation and has a wide range of confidence. Likewise, as for other data in Table 1-1, there are a wide range of confidence intervals such as 70~100 years for carp and stork. The cases in which precise lifespan data were obtained are those of animals under breeding such as dogs and horses (as shown in the table). The lifespans of the guppy, chicken and cat in the table are probably those obtained under breeding, and so they are thought to be exact, too (the longest lifespan of a cat is shown to be 34 years in the Guinness Book of World Records). Many of the data in Table 1-1 may not be exact but are estimated values.

It is easy to imagine that the exact determination of the lifespan of an animal may be difficult especially for a long lifespan, except when there is a precise record under breeding. The methods used to measure or estimate an animal lifespan will be described in Chapter 10. Table 1-1 is an important one in this book, but readers should be cautious with its findings as stated above.

## 2nd: Arctic whale

The second longest lifespan in Table 1-1 is that of the **Arctic whale** (also called the **Greenland whale**, *Balaena mysticetus*), at 211+/-35 years (George et al. 1999, 574). The Arctic whale (**Fig. 1-2**) is a kind of giant whale belonging to the suborder Mysticeti, lives in the cold Arctic Ocean (likely with the Greenland shark), and grows up to 20m long (https 9). The longest lifespan of the Arctic whale shown in the table is the longest one

among the 48 individuals studied. It is based on the racemization rate of amino acid aspartic acid in the nuclei of cells in the eye lens (as described in Chapter 10).

By the way, a carp named Hanako bred in the Japanese village of Higashishirakawa was said to be 226 years old based on annual rings of the scales. This lifespan record is included in the Guinness Book of World Records, but its reliability is said to be in question, and so it is not listed in Table 1-1.

**Fig. 1-2: Arctic whale** (https 9).

## 3rd and 4th: Tortoises

The third and the fourth places in the longest lifespan records in Table 1-1 both belong to reptiles. The **Aldabra giant tortoise** (also called as the Seychelle giant tortoise) has been known to live for 183 years while the **Galapagos giant tortoise** has reached 177. Both are terrestrial big tortoises, and the Aldabra giant tortoise named Johnathan (**Fig.1-3**) was 183 years old and fine in 2016 (大島 2013, 27) and therefore now, in 2022, is 189. Based

on another reference (http: 11), Johnathan was 182 years old in 2014, and was the oldest among the living individuals of the same or similar species. It is said that the Aldabra giant tortoise Adoweicha, raised in a zoo in India, lived for 255 years, but the veracity of this is questionable (http 11).

The longest lifespan on record for a Galapagos giant tortoise is 177 years, written in the book *On Size and Life* (MacMahon and Bonner 2000, 12), but the evidence for it is missing. Another data suggests that a Galapagos giant tortoise in an Australian zoo was 176 years old.

**Fig. 1-3: The Aldabra giant tortoise Johnathan** (http 11).

## 5th and 6th: Sturgeon and human

In fifth place of the longest lifespans in Table 1-1 is 152 years for a **sturgeon**, after which in sixth comes a human at 122 years. This human record of 122 years is based on the lifespan of a French woman, Jeanne-Louise Calment (**Fig. 1-4**). There are records indicating that she was born on February 21, 1875, and died on August 4, 1997, and she is believed to have the longest human lifespan on record for which the evidence is certain (https 6; https

13). Meanwhile, **the longest lifespan recorded among Japanese** has recently increased. Mrs Kane Tanaka living in Fukuoka prefecture has been assigned as the oldest person in the Guinness Book of World Records, and it was recently reported in the newspaper *The Mainichi* that she became 117 years old and was fine (as of January 6, 2020). This news is exciting for us Japanese as a symbol of Japanese longevity.

**Fig. 1-4: Jeanne L. Calment** (https 6).

In seventh place among the longest lifespans in Table 1-1 is the **griffon vulture** (**Fig. 1-5**), a bird which has been recorded to live up to 118 years. It is one of the birds of prey of the order Falconiformes, and is big enough that its wings are 2.6m wide when open (https: 14). In eighth place is a lifespan of 116 years for a finback whale.

**Fig. 1-5: Griffon vulture** (https 14).

## Animals with a short lifespan

On the other hand, the shortest lifespans shown in Table 1-1 are 1.5 years for a shrew, 4 years for a mouse, 5 years for a guppy, 8 years for a hummingbird, and so on. All these animals are very small in terms of bodily size, and their body weights are several grams or less, except for the mouse (~20 g). In contrast, all the long-lived animals are big, and lifespan seems to be proportional to body weight for vertebrates in general (see Chapter 7).

The average lifespan of dogs in Japan is 14.36 years, based on "The studies of dogs and cats under breeding in Japan in 2016" (https 15). This represents about 40% of the longest lifespan of 34 years for dogs.

If you're interested in finding out more information on animal lifespans, there is a list of lifespans for more than 50 birds and one for about 200 fish freely available on the web (https 16; https 17).

## 1-2 The average lifespan of the human being

While the longest human lifespan is around 120 years, as stated above, how long is the average lifespan? Based on a report by the WHO (World Health Organization) from 2018, the worldwide average was 72.0 years for men and women together, 69.8 years for men and 74.2 years for women in 2016. This indicates that women live more than 4 years longer than men.

### The average lifespan in each country

Average lifespans differ among the countries of the world. **Table 1-2** shows the data for the top 10 countries and the bottom 10 countries abstracted from the WHO report. The table shows that the highest is 84.2 years for Japan and the lowest is 52.9 years for Lesotho, with the difference between them more than 30 years. The countries showing very long lifespans are in Europe or Asia, but those showing very short lifespans are all located in Africa, which is telling. For us Japanese, it is fortunate that our country belongs to the top long-living countries. On the other side, the main reason for the very short average lifespans in the African countries may be their poverty due to their history of being colonies of the European countries. The races, climates and environments in Africa may also be related. Swaziland in the table changed its name to Eswatini in 2018. This country and Lesotho are kingdoms while all the other African countries in the table are republics.

**Table 1-2: The top ten and bottom ten countries of the world in terms of average lifespan**

| The top ten countries | | | The bottom ten countries | | |
|---|---|---|---|---|---|
| Order | Country | Average lifespan (years) | Order | Country | Average lifespan(years) |
| 1 | Japan | 84.2 | 183 | Lesotho | 52.9 |
| 2 | Switzerland | 83.3 | 182 | Central African Rep. | 53.0 |
| 3 | Spain | 83.1 | 181 | Sierra Leone | 53.1 |
| 4 | Australia | 82.9 | 180 | Chad | 54.3 |
| 4 | France | 82.9 | 179 | Côte d'Ivoire | 54.6 |
| 4 | Singapore | 82.9 | 178 | Nigeria | 55.2 |
| 7 | Canada | 82.8 | 177 | Somalia | 55.4 |
| 7 | Italy | 82.8 | 176 | Swaziland | 57.7 |
| 9 | Korea | 82.7 | 175 | Mali | 58.0 |
| 10 | Norway | 82.5 | 174 | Cameroon | 58.1 |

Abstracted from the report in The WHO World Health Statistics, 2018

As for the average lifespan of males in each country, Switzerland came first (81.2 years), Japan second (81.1 years), and Australia third (81.0 years). As for that of females, Japan was first (87.1 years), and joint second were France and Spain (85.7 years).

In the WHO statistics, in addition to the 183 countries for which average lifespan values are shown, the names of 12 countries or districts were listed without any lifespan data. Hong Kong is not included in these 12 countries/districts, the reason for which may be that Hong Kong is a part of China and not a member of the WHO. However, in the statistics by The World Bank, Hong Kong was top in terms of the average lifespans for both men and women. *The Mainichi* (July 21, 2018) reported that the Japanese average lifespans were 87.26 years for women and 81.09 years for men. Both numbers had increased since the previous year, with the female value ranking second globally (as it had done the year before) and the male value ranking third. In first for both men and women was Hong Kong, and in second place for men was Switzerland. Even at present, Japan may have the longest average lifespan for men and women combined across the globe.

## Extension of the average human lifespan

**The average human lifespan** is a great deal longer today than for most of human history. *A Concise History of World Population* (Fifth Edition) by M. Livi-Bacci states that the estimated average human lifespan was 20 years in 10,000 BC, 22 years in 1 BC/1 AD, 27 years in 1750 (in the middle of Edo era in Japan), 35 years in 1950 and 56 years in 2,000. In recent years the elongation of the average has become especially remarkable, and is now more than twice what it was in 1950. This situation is likely to be due to the recent development of medicine, food, economic state etc., in the world. Clearly, the average human lifespan has extended significantly based on the advances of civilization. The recent value of 72 years in the world is about

60% of the longest human lifespan of about 120 years, and thus is a higher percentage than the one for dogs mentioned above (about 40%).

The extension of the average human lifespan has been continuing in both Japan and the world at large. In Japan in 2017 it was 0.1 year longer than it was in 2016. The extension in Japan may continue for the time being, but it is difficult to say when it will stop.

## 1-3 Factors for the long lifespan of a vertebrate

In general, the mechanisms determining the lifespan of an animal are very complex, and the related factors are various. The mechanisms including those at the molecular level will be explained in Chapter 7. Here, I would like to pick up the probable factors that are supposed from the contents described above.

The factors for a long lifespan can be classified into environmental factors and those inherent to the animal. Table 1-1 shows that very long-lived animals are all considerably large. Namely, **big body size** is likely a factor for a long lifespan. This seems true for both homoiotherms (mammals and birds) and poikilotherms (such as fish and reptiles), whether they live on land or in water.

The reason that big body size is a factor for a long lifespan may be that big size is favorable to bear an environmental change, such as that in temperature or food, and an unfavorable environment. For example, both the Greenland Shark and Arctic whale, the first and the second in the

lifespan ranking, live in the cold seas. However, the temperatures in their body's centers are high enough due to their big body sizes, and therefore they can hold a fairly active metabolic activity to support their lives and growth.

As for environmental factors, both the Greenland shark and Arctic whale stated above live in cold seas, which suggests that the **cold temperature of the environment** is thought to be a factor for their long lives. In low temperatures, growth is slow and a long time is needed to grow to an adult, from which we can understand their long lifespans. The low temperature of an environment leads to the slow growth of an animal, which is a characteristic of that animal, and a big body size leads to a very long lifespan.

Living in a cold sea is an ability which likely derives from the characteristics of the organism that are basically determined by its genes. Therefore, the reason for a long lifespan of an animal resides ultimately within the body of the animal. The **average lifespans** for human beings and dogs, for example, depend greatly on their living environments. This is clear from the large differences in human lifespans among countries or across history.

## 1-4 Lifespan ranking of invertebrates

As in the case of vertebrates, **Table 1-3** shows the longest lifespans of invertebrates classified into groups. In this table, the groups are phyla, such as Porifera, Cnidaria and Mollusca, which are the largest units in biological classification. Studies on lifespan have greatly developed for invertebrates too, and several lifespans of more than 1,000 years have been reported.

**Table 1-3: Longest lifespans of invertebrates**

| Phylum | Species | Longest lifespan (y=years) |
|---|---|---|
| Porifera | glass sponge | 9000 y? (Kenny 2019, 50) |
| Cnidaria | beadlet anemone<br>hard coral<br>*Octocorallia* coral (*Geradia* sp.)<br>black coral (*Leiopathes* sp.)<br>Yamato hydra (*H. magnipapillata*)<br>immortal jellyfish | 15 y<br>＞28 y<br>2740+/-15 y (Roark et al. 2009, 5204)<br>4265+/-44 y (Roark et al. 2009, 5205)<br>＞3572 y (Schaible et al. 2015, 15702)<br>eternal? (Piraino et al. 1996, 302-312) |
| Platyhelminthes | tapeworm | 35 y |
| Rotifera | saline rotifer (*B. plicatillis sp.*) | 14 days |
| Nematoda | *C. elegans*<br>roundworm | 36 days (Kenyon et al. 1993, 462)<br>5 y |
| Annelida | earthworm | 10 y |
| Mollusca | golden cuttlefish<br>oyster<br>winkle (*L. littorea*)<br>nautilus (Nautilidae)<br>*Hyriopsis schlegelii*<br>ocean quahog (*A. islandica*) | 5 y<br>12 y<br>20 y<br>60~100 y<br>100 y<br>507 y (https 26; Nat.Geo. News 2013) |

| | | |
|---|---|---|
| Arthropoda | fruit fly (*D. melanogaster*) | 46 days |
| | bed bug (*C. lectularius*) | 6 months |
| | stone centipede | 5~6 y |
| | mantis | 8 y |
| | crayfish | 20~30 y |
| | lobster | 45 y |
| | termite queen (*N. triodae*) | 100 y (https 28; http 29) |
| Chordata | nudibranchi | 7 months |

y = years. Abstracted from Table 1.1.2 of R. Flindt (2007), 7-9, except for the cases stated otherwise.

## 1st and 3rd: Corals

Among the lifespan values in Table 1-3 that are likely to be relatively reliable, the first and the third ranks are both for corals in Cnidaria. **Figure 1-6** shows a community of a few kinds of corals. The Cnidaria phylum is a group of animals to which jellyfish, corals, sea anemones and hydras belong, and it was previously called as Coelenterate. A cnida or nematocyst is an organ used for injection of a toxin or for catching food, and is a common characteristic among Cnidaria animals.

**Fig. 1-6: A community of a few kinds of corals** (https 30).

As for the two corals, *Octocorallia* coral and black coral, the ages were estimated based on the carbon radioactivity of living corals from the sea near Hawaii (Roark et al. 2009, 5204). The black coral ranking 1st with the age 4,265 +/-44 years is a member of the order Antipatharia in the subclass Hexacorallia. The coral in third place with the age 2,740+/-15 years belongs to the subclass Octocorallia, and therefore differs much from black coral in its classification. In the slices of a semi-fossilized or calcified branch of each of these corals, the radioactivity of the carbon was measured at various depths, which indicated that the examined parts were essentially not metabolized. Therefore, the time of formation of each part of the coral branch was estimated. For example, the $^{14}C$ level of the deepest part of the coral ranked 1st was about 40% lower than that of the surface. Since the half-life of $^{14}C$ radioactivity is 5,730 years, we can understand that the age of the coral is 4~5,000 years near the half-life of $^{14}C$.

## 2nd: Hydra?

The second rank of the estimated longest lifespans, which are thought to be relatively reliable in Table 1-3, is 3,572 years (or longer) of a kind of Yamato hydra (*Hydra magnipapillata*) (Schaible et al. 2015, 15702). **Figure 1-7** shows a similar hydra in the same genus. Hydras belong to Cnidaria like corals, but live in fresh water, have unique forms, and are small (less than 2.5 cm). *H. vulgaris*, the hydra shown in Fig. 1-7, is also well studied, and the age of the oldest among the studied individuals is estimated to be 1,893 years. These hydras showed little ageing in breeding experiments for several years and have a very low mortality rate. Their lifespans were estimated from these mortality rates, and there is no solid evidence for them (Schaible et al. 2015, 15701-706).

**Fig. 1-7:** ***Hydra vulgaris*** (https 31).

## Is the jellyfish immortal?

The immortal jellyfish in Table 1-3 also belongs to Cnidaria, but to the order Anthomedusae in the class Hydrozoa, and is a kind of jellyfish (**Fig. 1-8**). This jellyfish is said to be possibly immortal (Piraino et al. 1996, 302-12).

This possibility is based on the observations of the abilities of its adult body for repeated rejuvenation by contraction of the tentacles, followed by turning over its umbrella-shaped bell, reduction of its body size, settling on a rock and becoming a polyp. This was first discovered for the Mediterranean immortal jellyfish (*Turitopsis dohrnii*) in 1991, which led to a sensation, and was then confirmed for another jellyfish (*T. nutricula*) (Piraino et al. 1996, 302-312). Examples of rejuvenation of an adult animal capable of sexual reproduction are quite rare among multicellular organisms, and have been reported otherwise only for another kind of jellyfish. In Japan, M. Kubota, an associate professor in the Marine Experimental Station of Kyoto University, succeeded up to 10 times in rejuvenation of an immortal jellyfish picked from the Kagoshima Bay (https 23). These results indicate that an immortal jellyfish can really be immortal. However, its solid record for a long lifespan seems to be much shorter than those for corals, and so I have written “eternal?” in the table.

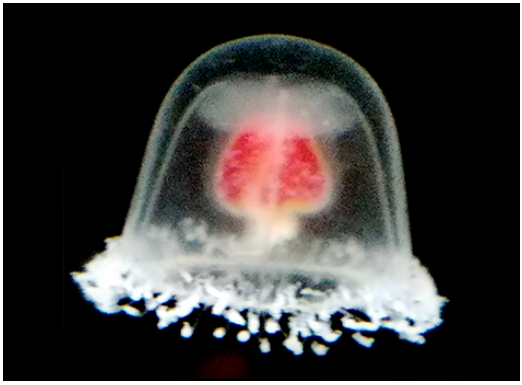

**Fig. 1-8: A kind of immortal jellyfish, *Turitopsis. sp*** (https 32).

## Colony

Many members of Cnidaria such as corals described above live in a characteristic form called a "**colony**". A colony is defined as "an assembly of individuals which is produced by uniting individuals newly born by division or budding using a body part or a structure secreted outside such as a shell, and there are many examples among organisms, from the protozoan to the sea squirt (八杉 et al. 1996, 376)". Also for plants, most of the very long-lived species living for 10,000 years or longer are the examples of this colony. The very long lifespans of the corals are probably due to the formation of colonies. A colony is formed based on the production of new individuals by cell division or budding, as presumed by the above definition, and therefore the lifespan of the colony as a whole is elongated even if the lifespan of an individual is not long. In principle, a colony could be as immortal as the immortal jellyfish. An adult of a jellyfish such as the immortal jellyfish is not a colony, however a polyp, as a developing form, is a colony, and this may be related to the long lifespan of the immortal jellyfish.

## Porifera

The animals belonging to Porifera are the animals of the most primitive group. They live in the sea, as corals and jellyfish do, and form colonies. The glass sponge, which is able to live for 9,000 years, is a giant assembly formed by three kinds of sponges *Aphrocallistes vastus*, *Farrea occa* and *Heterochone calyx* near the Pacific coast of Canada (Kenny, 2019, 50). The above lifespan of 9,000 years, if true, would mean it ranked first. But solid

evidence for it has not been found, so a question mark was added in the table. The glass sponge is also a kind of colony, and a long-lived individual in the colony is estimated to have a lifespan of 200~250 years.

## 4th: Clam

The 4th longest lifespan in Table 1-3 is 507 years for the ocean quahog (*Arctica islandica*, **Fig. 1-9**). This is an edible bivalve shell and a kind of general food in the coastal areas of the North Atlantic Ocean. It also goes by the name ocean hard clam. Its shell size is larger than 5cm at its biggest. It is believed that the clam has a striped pattern like that of a tree on the surface of the shell and therefore its age can be estimated by counting the number of stripes.

In 2007, the researchers Scourse and Butler of Bangor University in Wales collected 200 individuals of this clam and examined their ages in order to study changes in climate. Then, the age of the individual supposed to be the oldest was estimated to be 405~410 years old, and this clam was named Ming. However, the age of this clam was re-estimated to be 507 years by the second examination including $^{14}C$ radioactivity measurement in 2012. It is said that the growth of this clam is slowed when it grows to a certain age, therefore many individuals show similar sizes and their age cannot be supposed by size alone (Nat. Geo. News, 2013).

As to this clam, the reason for its longevity was studied, and its increased resistance to oxidative stress was reported (Munro and Blier 2012, 845-855; Ungvari et al. 2011, 741-750). In one of these studies (Munro and

Blier 2012, 854), the paper on the estimation of the age of the clam, 507 years (Butler et al. 2012) was cited.

**Fig. 1-9: Shells of an ocean quahog** (https 26).

*Arctica islandica* belongs to the phylum Mollusca that includes many shells, cuttlefish and octopuses. Mollusca is a considerably advanced group of animals among invertebrates, and the members do not form a colony like that of a coral. *Arctica islandica* lives longer than any vertebrate listed in Table 1-1, and is believed to have the longest lifespan record among non-colony forming animals. It is interesting that *Arctica islandica* is much smaller than the Greenland shark and Arctic whale which carry long lifespan records of vertebrates and are very big in terms of bodily size.

Nautilus and *Hyriopsis schlegelii* listed in Table 1-3 live up to about 100 years old. Therefore, shells or clams may live long in general, which suggests the possibility of finding a shell or clam with a longer lifespan than that of *Arctica islandica*. *Arctica islandica* lives in a rather cold sea and

grows slowly like the long-lived shark and whale, which may be a reason for its long lifespan.

## Short-lived invertebrates

The shortest lifespan in Table 1-3 is 14 days for the saline rotifer (*Brachionus plicatillis sp.*). It is a member of rotifers belonging to the phylum Rotifera. Rotifers are actively moving animal planktons, abundant in fresh water, and more than 1,500 species are known in the world (椎野, 1969, 95-97). Most of us are not familiar with this group of animals. However, saline rotifer (**Fig. 1-10**) is a plankton living in brackish water, and is raised in large amounts for feeding salt water fish. Fig. 1-10 shows a female of about 0.2 mm in size. It has a fairly complex body system, whereas the male is lacking a digestive organ and is smaller.

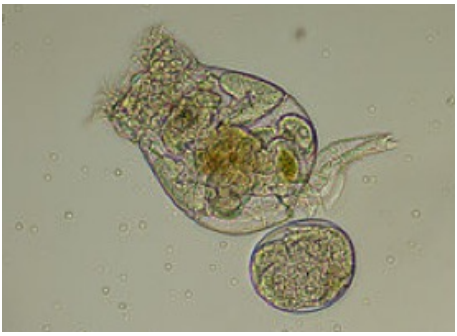

**Fig. 1-10: Saline rotifer** (https 24).

The second shortest span in Table 1-3 is 36 days for the nematode *C. elegans*. *C. elegans* is a small and liny worm of about 1mm in length. This worm is said to be abundant in the soil and on fallen leaves in nature. It has been