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Taxonomy and life history of *Rhodophysema odonthaliae* sp. nov. (Rhodophyta)[1)]

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A new species of *Rhodophysema*, *R. odonthaliae* MASUDA et M. OHTA, sp. nov. was described on the basis of material collected at Erimo, Hokkaido in Japan and its life history was examined in laboratory culture. The alga is distinguished from all the known species of *Rhodophysema* by having the discontinuous perithallus developed only near the sori and by the frequent occurrence of tetrasporangia from the hypothallus cells. The tetraspores derived from field-collected material germinated to repeat the parental tetrasporangial phase and sexual reproductive structures were not observed.

Key Index Words: *crustose red alga*; *life history*; Rhodophysema; *Rhodophyta*; *taxonomy*.

During an investigation of crustose red algae on the coasts of Hokkaido in Japan, a number of small crustose plants growing on *Odonthalia corymbifera* were collected. The plants were tentatively identified as *Rhodophysema* on account of having distinct sori composed of tetrasporangia and paraphyses, and the hypothallus cells lacking rhizoids. However, the morphological features did not correspond with the circumscriptions of the known species of *Rhodophysema*. We conducted laboratory culture experiments in order to obtain information on the variability of the morphological features and on the life history. As a result, the alga is recognized as a new species and described as *Rhodophysema odonthaliae* on the basis of material collected at Erimo, Hokkaido.

Materials and Methods

The materials examined were collected at the following three localities along the Pacific coast of Hokkaido in Japan from 1975 to 1979; Akkeshi (VI-25, 1979, M. MASUDA and T. OGUMA); Hiroo (VII-22, 1975, I. YAMADA and M. OHTA); Erimo (VII-25, 1975, M. KUROGI, T. YOSHIDA, I. YAMADA, M. MASUDA and M. OHTA, including culture material, VIII-3, 1977, M. OHTA).

Most of the materials were preserved in 10% formalin in seawater and used for microscopic observations. A portion of them was dried on herbarium sheets.

Isolated tetraspores were placed in unialgal culture and maintained using methods described in another paper (MASUDA and OHTA, in press). The cultures were placed first at 15°C, 16: $\bar{8}$ (light-dark cycle) and two weeks later a half of them was transferred to 10°C, 16: $\bar{8}$.

Voucher specimens examined are deposited in the Herbarium of Faculty of Science, Hokkaido University, Sapporo (SAP 032145-

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Observations and Discussion

Description

Rhodophysema odonthaliae

MASUDA et M. OHTA, sp. nov.

Plantae epiphyticae, crustosae, noncalcareae, irregulariter vel fere circulares, 500-2500 μm in diametro, 40-65 μm crassae in partibus fertilibus (cum paraphysibus), in colore atrorubrae, pagina inferna omni ad substratum arcte affixae, sine rhizoideis (Fig. 1, E-H); thallus e strato basali monostromatico hypothallo constituenti (Fig. 1, A-D) et filamentis erectis brevibus perithallo constituentibus compositus (Fig. 1, E-H); perithallus solum prope soros evolutus; cellulae hypothalli 5.0-10.0 μm in longitudine et 3.8-5.0 μm in diametro in sectione; filamenta erecta simplicia, cohaerentia et ex 1-3 cellulis compositia (Fig. 1, E-H); cellulae filamentorum erectorum 3.8-7.5 μm in longitudine et 4.5-7.5 μm in diametro in sectione; conjunctiones laterales inter series cellularum hypothalli contiguorum frequenter adsunt (Fig. 1, C-D); tetrasporangia in soro distincto effecta et paraphysibus intructa (Fig. 1, G, H); sori plures in quoque thallo effecti, forma et loco irregularibus; tetrasporangia terminales in filamentis erectis (Fig. 1, H) vel e cellulis hypothalli effectae (Fig. 1, G), late ellipsoideae ad fere globosae, 35.0-47.5 μm in longitudine et 30.0-40.0 μm in diametro; tetrasporae globulares, 22.5-27.5 μm in diametro (Fig. 2, A); paraphyses in colore cellulis vegetativis pallidiores, 27.5-45.0 μm in longitudine et 5.0-7.5 μm in diametro, falcatae, e 4-8 cellulis compositae (Fig. 1, G-H); cellulae paraphysium breves et 4.5-7.5 μm in longitudine; plantae gametangiferae ignotae.

Holotypus: Specimen tetrasporangiferum (SAP 032145)

Plants epiphytic, crustose, noncalcareous, irregularly or almost circular, 500-2500 μm in diameter, 40-65 μm thick in fertile areas (including paraphyses), dark red in color, closely attached to substrate by whole lower surface, without rhizoids (Fig. 1, E-H): thallus composed of a monostromatic basal layer constituting hypothallus (Fig. 1, A-D) and short erect filaments constituting perithallus (Fig. 1, E-H); perithallus developed only near sori; cells of hypothallus 5.0-10.0 μm in length and 3.8-5.0 μm in diameter in section; erect filaments simple, cohering and composed of 1-3 cells (Fig. 1, E-H); cells of erect filaments 3.8-7.5 μm in length and 4.5-7.5 μm in diameter; lateral fusions between adjacent hypothallus cell-rows frequently present (Fig. 1, C-D); tetrasporangia developed in a distinct sorus provided with paraphyses (Fig. 1, G-H); several sori developed on each thallus, irregular in shape and position; tetrasporangia terminal on erect filaments (Fig. 1, H) or issued from hypothallus cells (Fig. 1, G), broadly ellipsoid to almost globular, 35.0-47.5 μm in length and 30.0-40.0 μm in diameter; tetraspores globular, 22.5-27.5 μm in diameter (Fig. 2, A); paraphyses paler in color than vegetative cells, 27.5-45.0 μm in length and 5.0-7.5 μm in diameter, falcate, composed of 4-8 cells (Fig. 1, G, H); cells of paraphyses short, 4.5-7.5 μm in length; gametangial plants unknown.

Holotype: Tetrasporangial specimen collected at Erimo, Hidaka Prov. Hokkaido in Japan on July 25, 1975 (SAP 032145).

Japanese name: Hime-fuchitoribeni (nom. nov.)

Life history

Isolated tetraspores germinated and grew into encrusting discs (Fig. 1, B; 2, B-D). This process is similar to that reported previously for *Rhodophysema georgii* (FLETCHER 1975, MASUDA and OHTA 1975) and *R. elegans* (GANESAN and WEST 1975, SOUTH and WHITTICK 1976, FLETCHER 1977). The discs reached 120-180 μm in diameter after two weeks. Some plants combined to form a single crust (Fig. 2, E), but no pit-connection between the cells of two the discs was observed. Two-week-old cultures were divided into two groups; one was shifted to 10°C, 16 : $\bar{8}$ and the other was maintained at 15°C, 16 : $\bar{8}$. The discs shifted to 10°C, 16 : $\bar{8}$ grew more slowly.

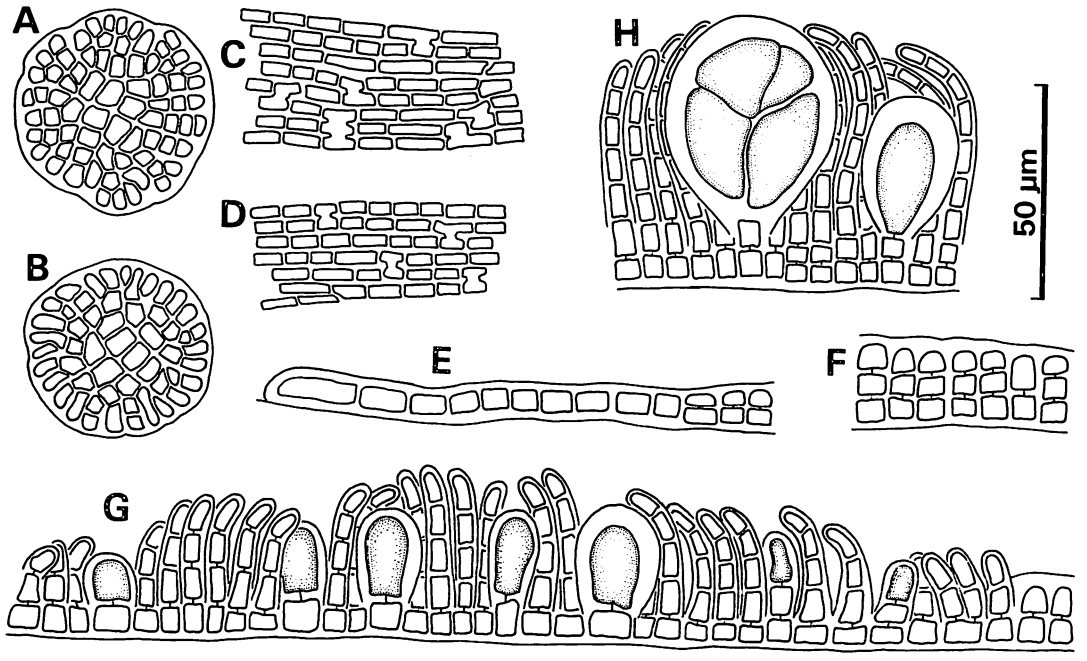

Fig. 1. *Rhodophysema odonthaliae*. A, C and E-H, field-collected plants (type collection); B and D, cultured plants grown at 15°C, 16: $\bar{8}$. A-B. Early developmental stages of hypothallus (B, three-day-old germling). C-D. Marginal portion of hypothallus in surface view, showing lateral fusions between cells of adjacent cell-rows (D, two-month-old plant). E-H. Tangential sections of fertile plants: E, marginal portion; F, vegetative portion near the sorus; G-H, sorus portion.

One month after culture initiation the largest disc measured 700 µm in diameter at 15°C, 16: $\bar{8}$. Some discs reached reproductive maturity and formed a tetrasporangial sorus at this time. The sorus covered the entire surface of the disc (Fig. 2, F). This type of sorus was not observed in field-collected materials. The discs forming this type of sorus are 170–440 µm in diameter and smaller than immature discs. In section, these fertile plants had 4-6 celled erect filaments. Enlarged cells, which occur also in cultured plants of *Rhodophysema georgii* (FLETCHER 1975, MASUDA unpublished), were not observed. The plants attached loosely to the substrate and with the slightest mechanical disturbance they became free from the substrate. In this respect, they resemble the 'sphere' form of the Californian *Rhodophysema elegans* reported by GANESAN and WEST (1975). Many other discs grown at both the culture conditions did not form any reproductive structures at this stage. Two months after culture initiation all the plants grown at both the conditions bore tetrasporangial sori (Fig. 2, G-J). The fertile plants measured 550–1125 µm in diameter. The number and size of the sori varied in different individuals; a large single sorus covering almost the entire surface of the disc except at the margin (Fig. 2, G) or small two to several sori (Fig. 2, H) were observed. The latter soral type like that of field-collected plants predominated. The production of a discontinuous perithallus was observed in plants with plural sori. The size of vegetative cells and number of erect filament cells of these fertile plants are similar to those of the parental plants. However, the tetrasporangium shape was slightly elongated (Fig. 3) and sometimes the paraphyses were

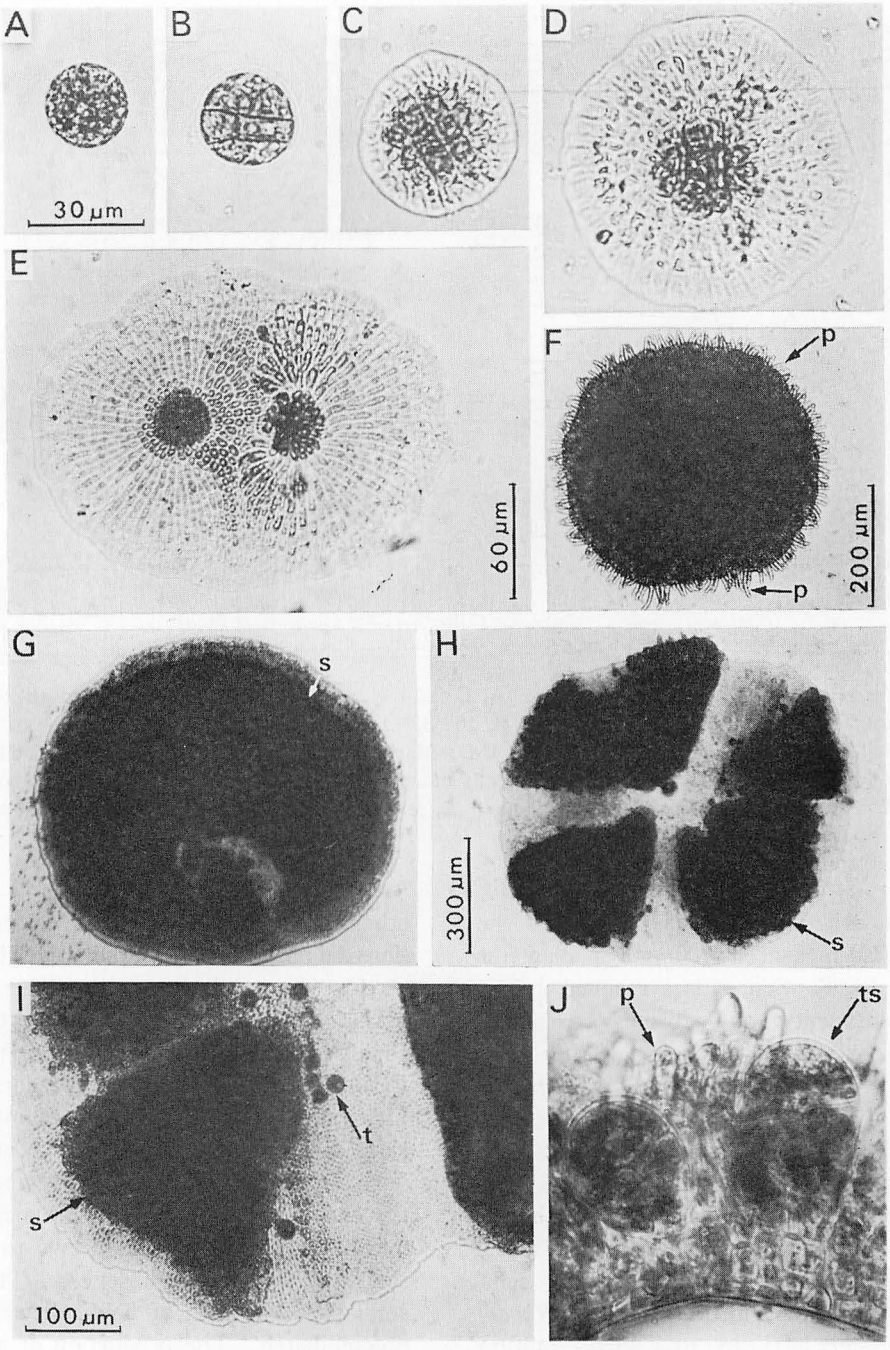

Fig. 2. Tetraspore and its development at 15°C, 16: $\overline{8}$. A. Tetraspore. B-E. Young tetraspore germlings: B, one-day old; C, three-day old; D, seven-day old; E, fourteen-day old, note two germlings coalescing. F. One-month-old crust forming a tetrasporangial sorus covering the entire surface of the thallus (p, paraphysis). G-H. Two-month-old fertile crusts forming tetrasporangial sori (s). I. Portion of a two-month-old plant, showing a tetrasporangial sorus (s) and tetraspores (t). J. Tangential section through the tetrasporangial sorus, showing a mature tetrasporangium (ts) and paraphysis (p).

Scale in A applies also to B-D and J; scale in H applies also to G.

longer and up to 10 cells (68.8 μm in length). Liberated tetraspores were 21.3-27.5 μm in diameter, germinated and formed discs similar to the parental plants producing tetrasporangial sori within two months in both the conditions.

Taxonomic remarks

At present six species are ascribed to the genus *Rhodophysema*: *R. georgii* BATTERS (1900), *R. elegans* (CROUAN et CROUAN ex J. AG.) DIXON (1964), *R. minus* HOLLENBERG et ABBOTT (1965), *R. africana* JOHN et LAWSON (1974), *R. feldmannii* CABIOCH (1975), and *R. nagaii* MASUDA (1978). *Rhodophysema odonthaliae* is added to this list in our present paper. The possible taxonomic relationships among the species are discussed below.

The species of *Rhodophysema* are simply organized in thallus structure. Each thallus consists of a monostromatic hypothallus composed of radiating filaments closely adhered to each other and a polystromatic perithallus composed of tightly packed erect filaments, which are arranged at right angles to the hypothallus filaments except those of *R. minus* and *R. feldmannii*. The latter two species lack a distinct perithallus (HOLLENBERG and ABBOTT 1965, CABIOCH 1975). *R. georgii* is unique among the species in the formation of globular thalli. This species had various forms of thalli, globular to crustose (BATTERS 1900, KYLIN 1907, ROSENVINGE 1917). The globular thalli are formed by enlargement of erect filament cells or sometimes hypothallus cells and repeated occurrence of cellular fusion between adjacent erect filament cell-rows (ROSENVINGE 1917, MASUDA unpublished). This seems to represent a reduced multiaxial construction of the upright thallus (FLETCHER 1975). However, the crustose thalli of *R. georgii* is similar to those of *R. elegans*. Thus, as to the thallus structure three distinct grades can be recognized in this genus. From the ontogenetic point of view, *R. minus* and *R. feldmannii* with the monostromatic thalli may be the simplest. *R. georgii* may represent the most complex condition. *R. elegans*, *R. africana* and *R. nagaii* may be intermediate representatives. *R. odonthaliae* is characterized by having the discontinuous perithallus developed only near the sori. This species may be simpler than the *R. elegans* group as to the thallus structure.

All the species possess definite tetrasporangial sori composed of numerous tetrasporangia and paraphyses. In addition, spermatangial plants have been reported for *R. georgii* (MASUDA and OHTA 1975) and for *R. elegans* (ROSENVINGE 1910, TAYLOR 1957, MASUDA 1978, MASUDA and OHTA, in press), although no female gametangial plants have been detected. Tetrasporangial pedicels and paraphyses have important taxonomic significance. *R. africana*, *R. feldmannii* and *R. nagaii* are characterized by having long tetrasporangial pedicels and long paraphyses (JOHN and LAWSON 1974, CABIOCH 1975, MASUDA 1978). *R. minus* has also somewhat longer pedicels than the other species which have one celled pedicels or are devoid of them (HOLLENBERG and ABBOTT 1965). *R. odonthaliae* is characterized by the frequent occurrence of sessile tetrasporangia from the hypothallus cells. This may represent the simplest condition.

Furthermore, tetrasporangium shape and dimension, and cell length of paraphyses are taxonomically important. *R. minus* and *R. feldmannii*, which are distinguished from each other by the paraphysis length, can be also distinguished by the tetrasporangium shape and dimension. The former has ellipsoid sporangia measuring 15-20 μm in length and 14-16 μm in diameter (HOLLENBERG and ABBOTT 1965) and the latter has subspherical sporangia measuring 20-30 μm in diameter (CABIOCH 1975). *R. africana* and *R. nagaii* are similar to each other in paraphysis length (JOHN and LAWSON 1974, MASUDA 1978). However, the former's paraphyses are 12-20 celled, whereas the latter's ones are 5-8 celled. This suggests that the cell length of paraphyses of *R. africana* (not given by JOHN and LAWSON) is shorter than that of *R.*

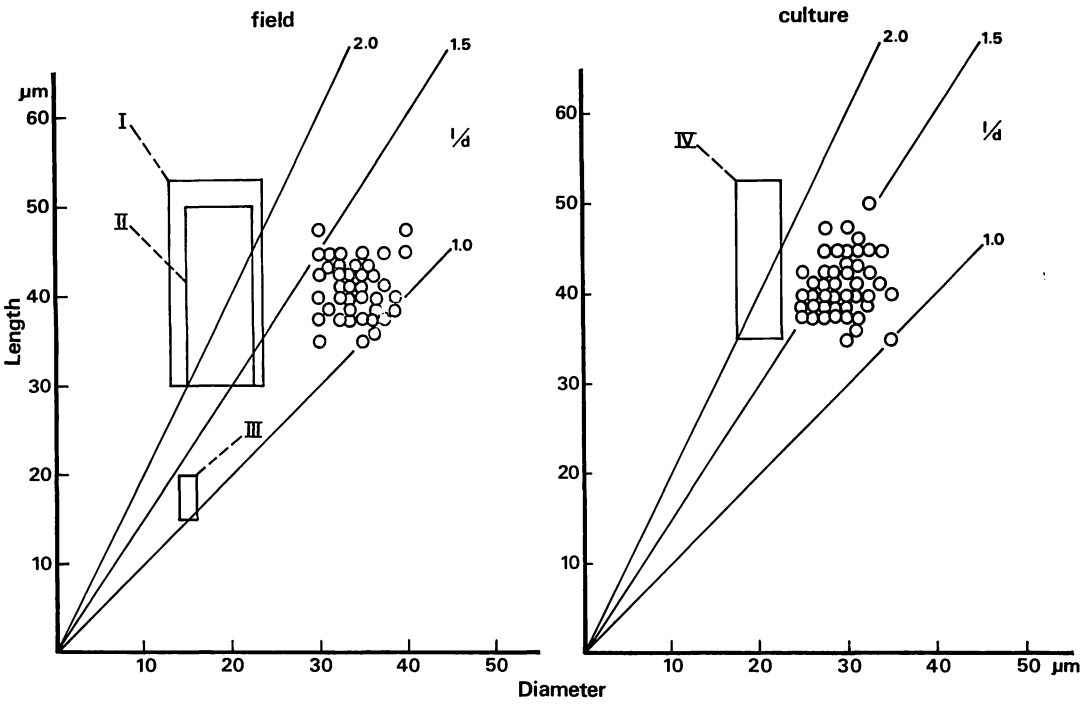

Fig. 3. Scatter diagram showing variations of tetrasporangium dimensions for *R. odonthaliae*. Rectangle I showing the range of tetrasporangium dimension for the British *R. elegans* reported by FLETCHER (1977) ; II showing that for the Japanese *R. elegans* given by MASUDA and OHTA (in press) ; III showing that for *R. minus* given by HOLLENBERG and ABBOTT (1965) ; IV showing that for the Erimo isolate of *R. elegans* reported by MASUDA and OHTA (in press).

nagaii. *R. odonthaliae* possesses globular to broadly ellipsoid tetrasporangia. The length/diameter ratio is 1.0-1.5, measuring 35.0-47.5 μm in length and 30.0-40.0 μm in diameter, by which also it can be distinguished from related species, *R. elegans* and *R. minus* (Fig. 3). Furthermore, dimensions of thalli and of vegetative cells have some taxonomic significance.

The following synoptical key is given for the seven species of *Rhodophysema*, according to the criteria mentioned above.

1. Plants forming monostromatic thalli .. .. 2.
1. Plants forming di- to polystromatic thalli .....3.
2. Paraphyses short (4-5 celled)..... ..... *R. minus*
2. Paraphyses long (14-20 celled) ..... *R. feldmannii*
3. Perithallus developed discontinuously near sori.....*R. odonthaliae*
3. Perithallus developed continuously toward growing margins .....4.
4. Thalli crustose, without inflated cells ..... 5.
4. Thalli crustose to globular, with inflated cells.....*R. georgii*
5. Tetrasporangial pedicels short (one celled) or lacking..... *R. elegans*
5. Tetrasporangial pedicels long (2-14 celled) .....6.
6. Paraphyses 5-8 celled, tetrasporangial pedicels 2-6 celled..... *R. nagaii*
6. Paraphyses 12-20 celled, tetrasporangial pedicels 5-14 celled..... *R. africana*

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増田道夫・太田雅隆：紅藻の1新種ヒメフチトリベニ（*Rhodophysema odonthaliae* MASUDA et M. OHTA, sp. nov.）の分類と生活史

北海道襟裳岬の近くで採集されたハケサキノコギリヒバ（*Odonthalia corymbifera*）に着生していたフチトリベニ属（*Rhodophysema*）の1種を新種ヒメフチトリベニ（*R. odonthaliae*）として記載し，その生活史を培養実験によって調べた。本種は perithallus が四分胞子嚢群の近くにだけ発達すること，および hypothallus の細胞から直接四分胞子嚢がごく普通に形成される特徴を持つことで，現在までに報告されているフチトリベニ属のいずれの種とも区別される。四分胞子は発芽して2カ月後に，再び四分胞子嚢を生じる個体に生長し，有性生殖器官の形成はみられなかった。（060 札幌市北区北10条西8丁目　北海道大学理学部植物学教室）