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ECONOMICALLY IMPORTANT SEAWEEDS

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The plants in the sea other than seagrasses—what we call seaweeds—belong to the simplest group of plants; the marine algae. With few exceptions, these plants are so simple that they have no distinguishable roots, stems or leaves. The algae vary in size from microscopic single-celled forms (eg. diatoms) to the giant macrophytes of temperate waters (*Macrocystis*, *Nereocystis*, etc).

Seaweeds are chlorophyll-bearing plants with a plant body showing no differentiation into true tissues. It never forms true roots, stems and leaves and so is called a thallus or frond. The thallus has no elements for the transport of fluids (nonvascular). Seaweeds exhibit a great diversity in organisation of their body. The filamentous forms are usually multicellular and the filament may be simple (eg. *Chaetomorpha*) or branched (eg. *Cladophora*). There are coenocytic forms or siphonaceous forms in which the cells are multinucleate without cross walls so that the entire plant consists of a variously ramified hollow tube (eg. *Caulerpa* and *Codium*). Other filamentous thalli, known as parenchymatous forms, are one or more layers of cells in thickness (eg. *Enteromorpha*, *Dictyota* and *Padina*). Complex parenchymatous thalli of the Rhodophyta are formed by the aggregation of filaments (eg. *Centroceras* and *Spyridia*). The most highly evolved marine algae exhibit external differentiation and considerable size. Some of them possess a plant body consisting of parts that bear superficial resemblance to the roots, leaves and stems of higher plants (eg. *Sargassum*). Apart from the external structure, the vegetative thalli of Phaeophyta and

Rhodophyta are internally differentiated into a few-layered photosynthetic cortex, below which occur hyaline storage cells called medulla.

The seaweed attaches itself to the substratum by means of a holdfast. The manner of attachment differs widely from a holdfast consisting of a single modified basal cell (eg. *Chaetomorpha*) to various kinds of penetrating or entangling rhizoids (eg. *Turbinaria*), multicellular adherent discs, creeping stolons (eg. *Gelidium*) and massive clasping hapteras. In some multicellular forms the same cells perform both vegetative and reproductive functions, whereas in others special reproductive cells or organs such as tetrasporangia, zoosporangia, male and female gametangia, antheridia, oogonia, receptacles, stichidia and cystocarps are developed. Illustrations of all the important algae are given in the chapter for easy identification of the different seaweeds (Figs. 1-14 and plates I to IV).

Taxonomical Work in India

Studies made on Indian algae have been reviewed from time to time by various authors, Agharkar (1923), Biswas (1932 and 1934), Joshi (1949), Iyengar (1957), Randhawa (1960) and Srinivasan (1965). Based on the collections of M. O. P. Iyengar and on his own collections, Boergesen has published a series of papers on the green, brown and red algae of the northern parts of the west coast (Boergesen, 1930, 1931, 1932 a, b, 1933 a, b, 1934 a, b and

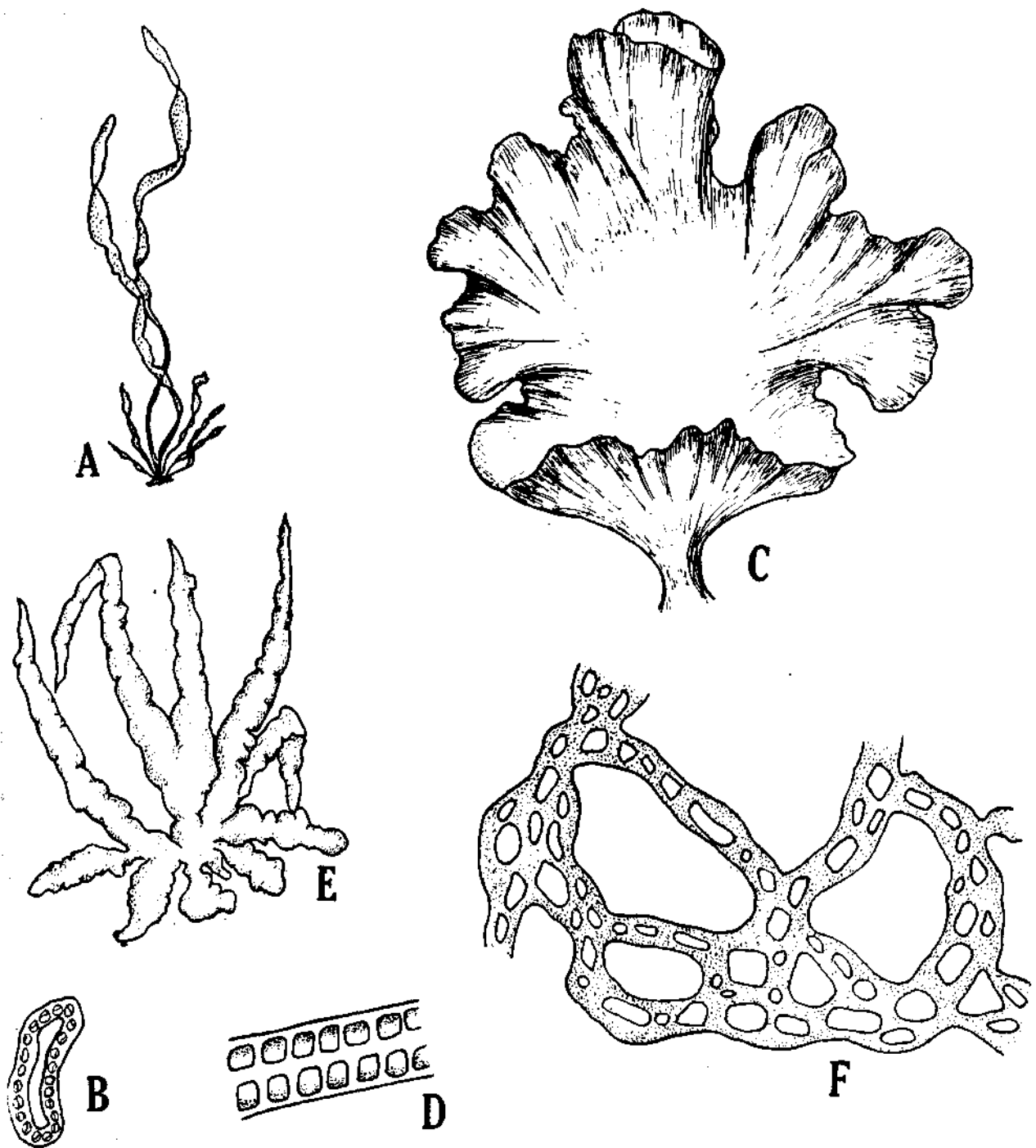


Fig. 1. Common green seaweeds of the Indian coast. A. *Enteromorpha compressa* (X 1)
 B. *Enteromorpha compressa* - transverse section of the thallus (X 100) C. *Ulva lactuca* (X 1)
 D. *Ulva lactuca* - transverse section of the thallus (X 260) E. *Ulva fasciate* (X 0.5)
 F. *Ulva reticulata* - part of a plant (X 2)

1935) and brown and red algae of south India (Boergesen, 1937 a, b and 1938).

After the valuable contribution of Boergesen, much work has been done on the morphology and taxonomy of Indian marine algae during the last four decades. A general

review of the marine algae of the west coast was published by Biswas (1945). Srinivasan (1946) studied the marine algal flora of Mahabalipuram. Parija and Parija (1946) studied the vegetation of Chilka Lake. Chacko *et al.* (1955) have listed the algal flora of the Krusadai Island and Varma (1960) studied

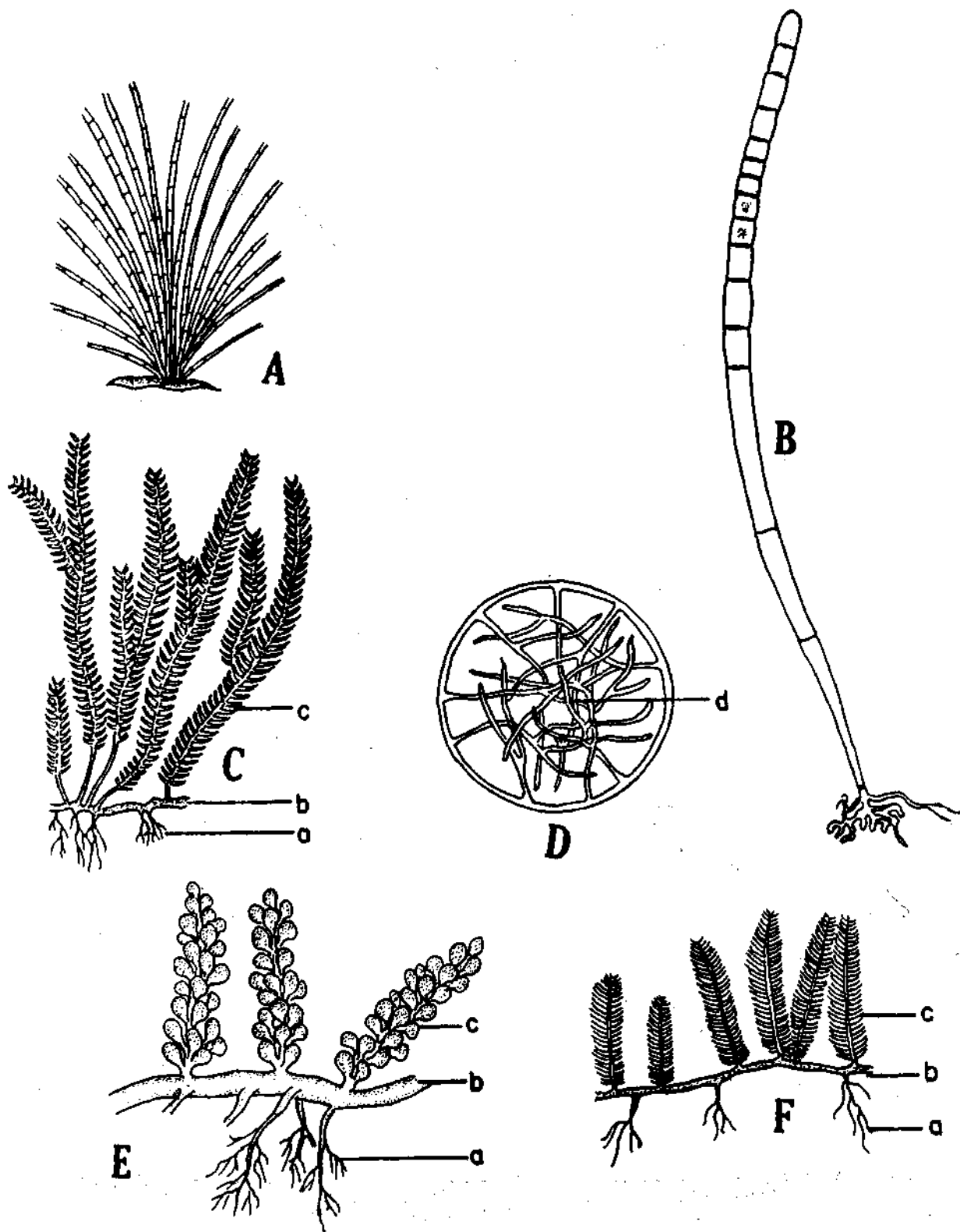


Fig. 2. Common green seaweeds of the Indian coast (contd.) A. *Chaetomorpha antennina* (X 1)
 B. *Chaetomorpha antennina* - a single filament enlarged (X 50) C. *Caulerpa taxifolia* (X 1)
 D. *Caulerpa* - transverse section (X 12.5) E. *Caulerpa racemosa* (X 1) F. *Caulerpa sertularioides*
 (X 1) a - rhizoid; b - rhizome; c - erect frond; d - trabeculae

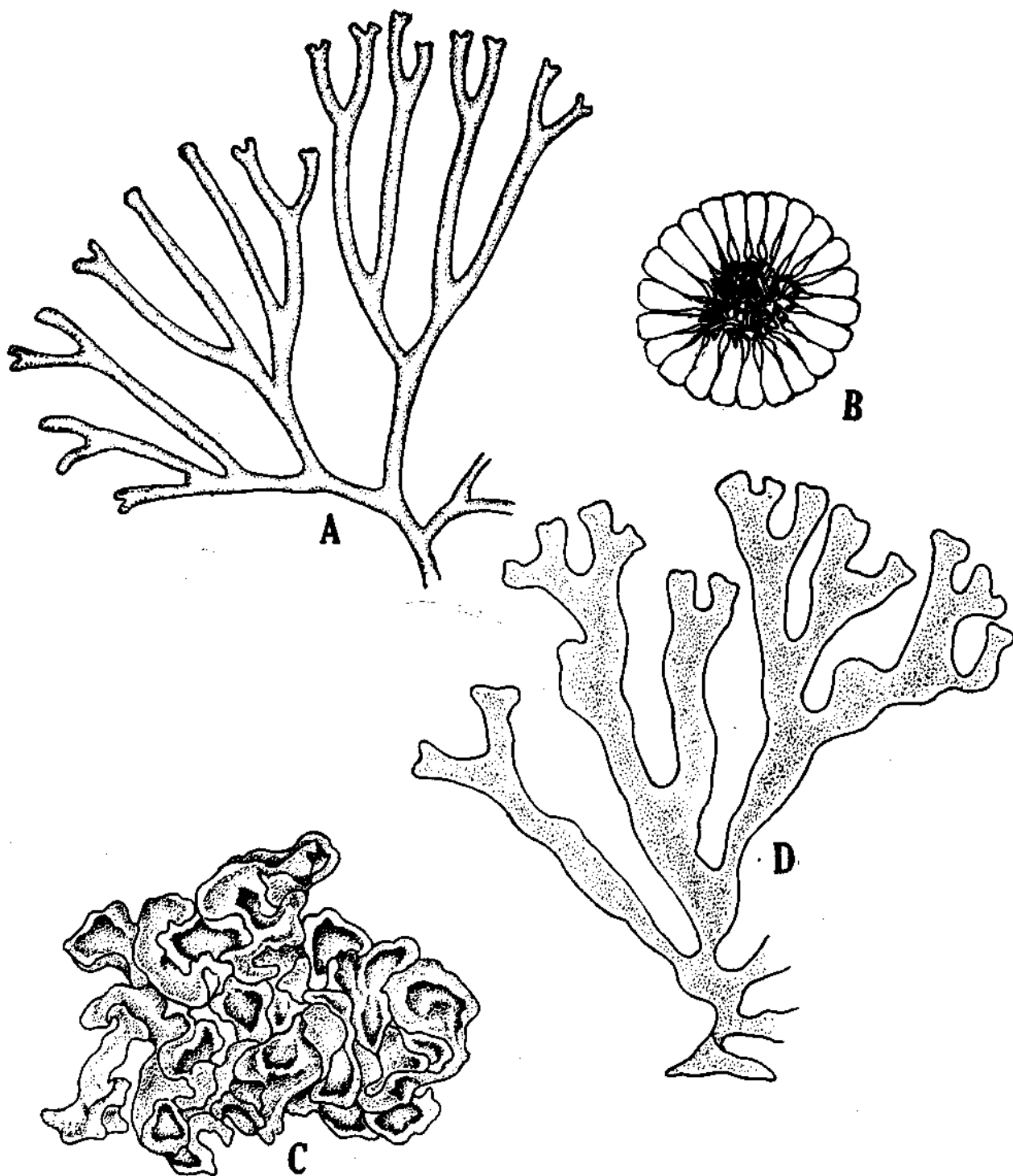


Fig. 3. Common green seaweeds of the Indian coast (contd.) A. *Codium tomentosum* - part of a plant (X 1)
 B. *Codium* - transverse section of the thallus (X 20) C. *Codium adherens* (X 1)
 D. *Codium decorticatum* - part of a plant (X 1)

the seaweeds growing on the pearl and chank beds off Tuticorin. Srinivasan (1960) has given a detailed account of marine algae of the east and west coasts of India based on the then available reports. According to

the estimates given by him, 162 genera and 413 species of marine algae were known from the Indian waters. Taylor (1964) has described the Indian species of *Turbinaria*. The checklists of Indian algae have been

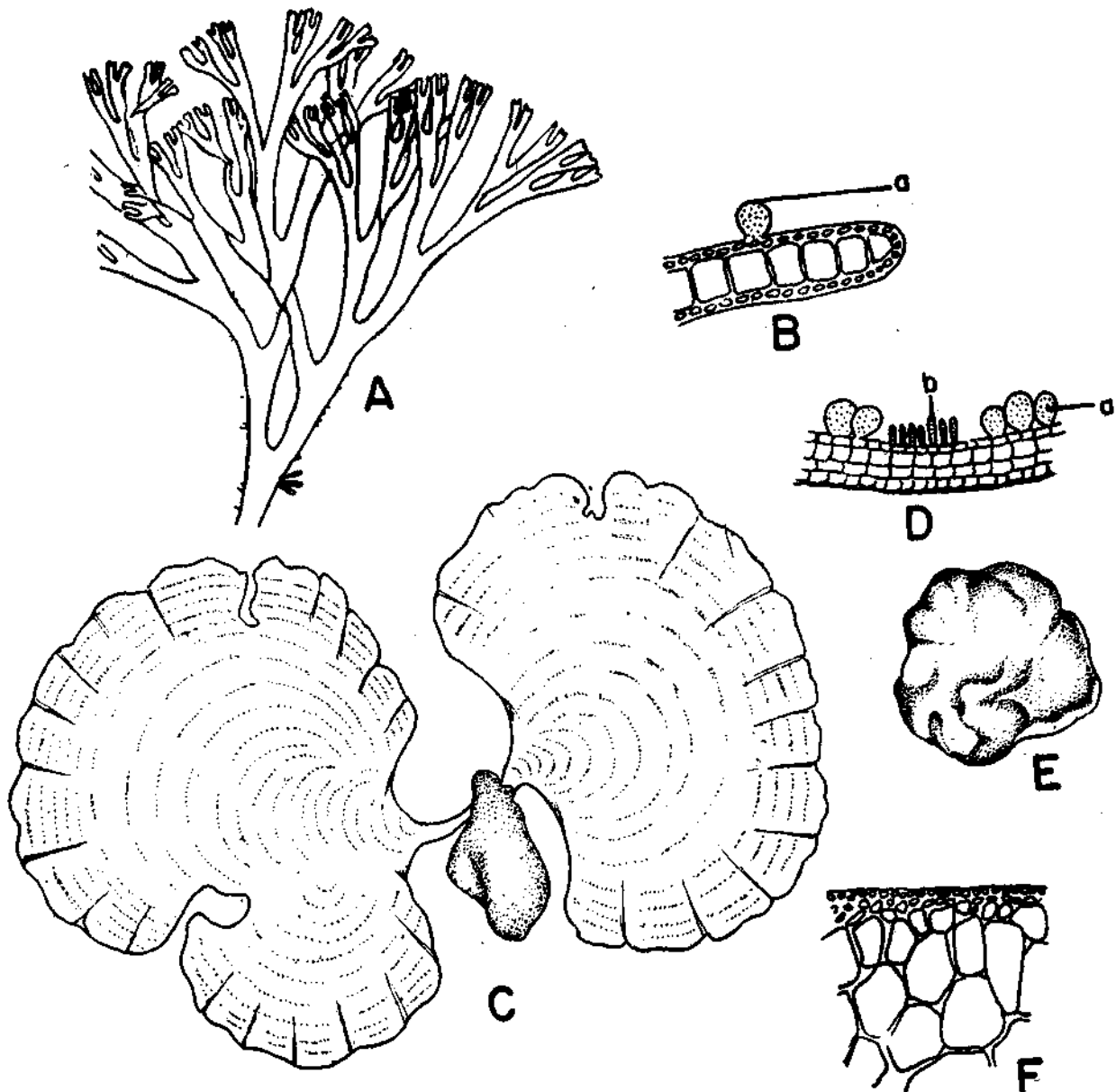


Fig. 4. Common brown seaweeds of Indian coast A. *Dictyota dichotoma* - part of a plant (X 1) B. *Dictyota dichotoma* - transverse section of the thallus (X 95) C. *Padina gymnospora* (X 1) D. *Padina tetrastromatica* - transverse section of the thallus (X 75) E. *Colpomenia sinuosa* (X 1) F. *Colpomenia sinuosa* - sectional view of the thallus (X 70). a - tetrasporangium; b - hair

published by Dixit (1964 and 1968) and Srinivasan (1965). The list published by Dixit consists of 411 species, which also include records from Pakistan and Sri Lanka. Misra (1966) has prepared a monograph of the brown algae occurring along the Indian coast. Srinivasan (1966) has published an account of the Indian species of *Sargassum*. A list of 1980 algae collected from Mandapam area has been published by Umamaheswara Rao (1969 a). The composition of marine algae off Gopnath has been studied by Sreenivasa Rao and Kale (1969) and that of

Gulf of Kutch by Gopalakrishnan (1969). The species of *Ulva* from Indian waters is published by Krishnamurthy and Joshi (1969). An annotated list of 80 algae growing along the Visakhapatnam coast has been given by Umamaheswara Rao and Sreeramulu (1970). Gopalakrishnan (1980) has reported 64 species of algae from the collection grounds of Dwarka, Okha, Adatra, Hanumandandi and Balapur from Okha coast. A systematic account of 10 taxa of Indian Gelidiales has been given by Sreenivasa Rao (1970). A checklist of 520 species of Indian

marine algae has been published by Krishnamurthy and Joshi (1970).

Joshi and Krishnamurthy (1971) have listed 13 species of *Enteromorpha* from India. Umamaheswara Rao (1972 a) has published the

coralreef flora of the Gulf of Mannar and Palk Bay. The description of 17 species and 2 varieties of *Gracilaria* and 2 species of *Gracilariopsis* and also their habitats and distribution in India are given in detail by Umamaheswara Rao (1972 b). Agadi and Untawale (1978)

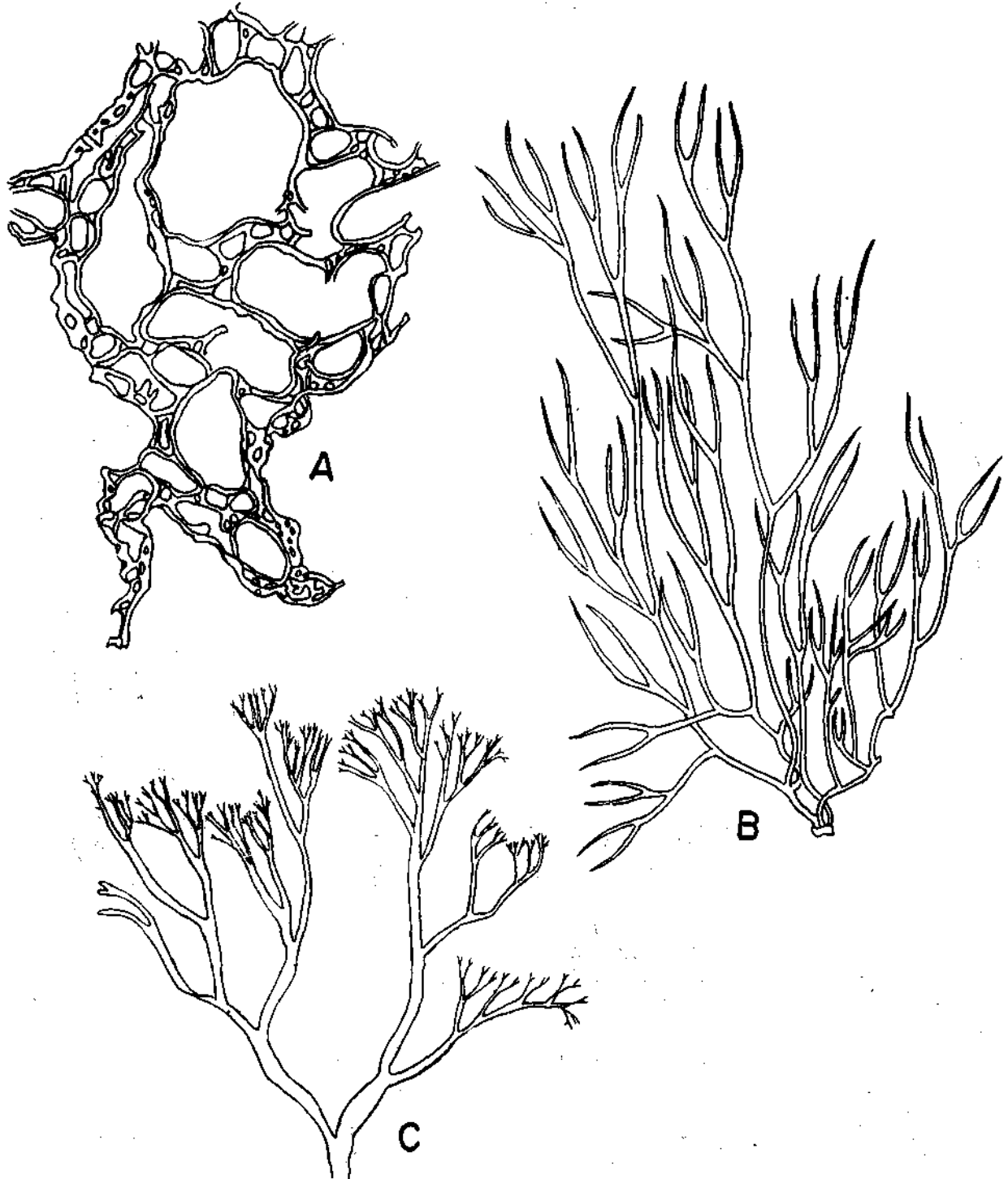


Fig. 5. common brown seaweeds of the Indian coast (contd.) A. *Hydroclathrus* - a portion of the plant (X 1) B. *Chnoospora minima* (X 1) C. *Rosenvingea intricata* - part of the plant (X 1)

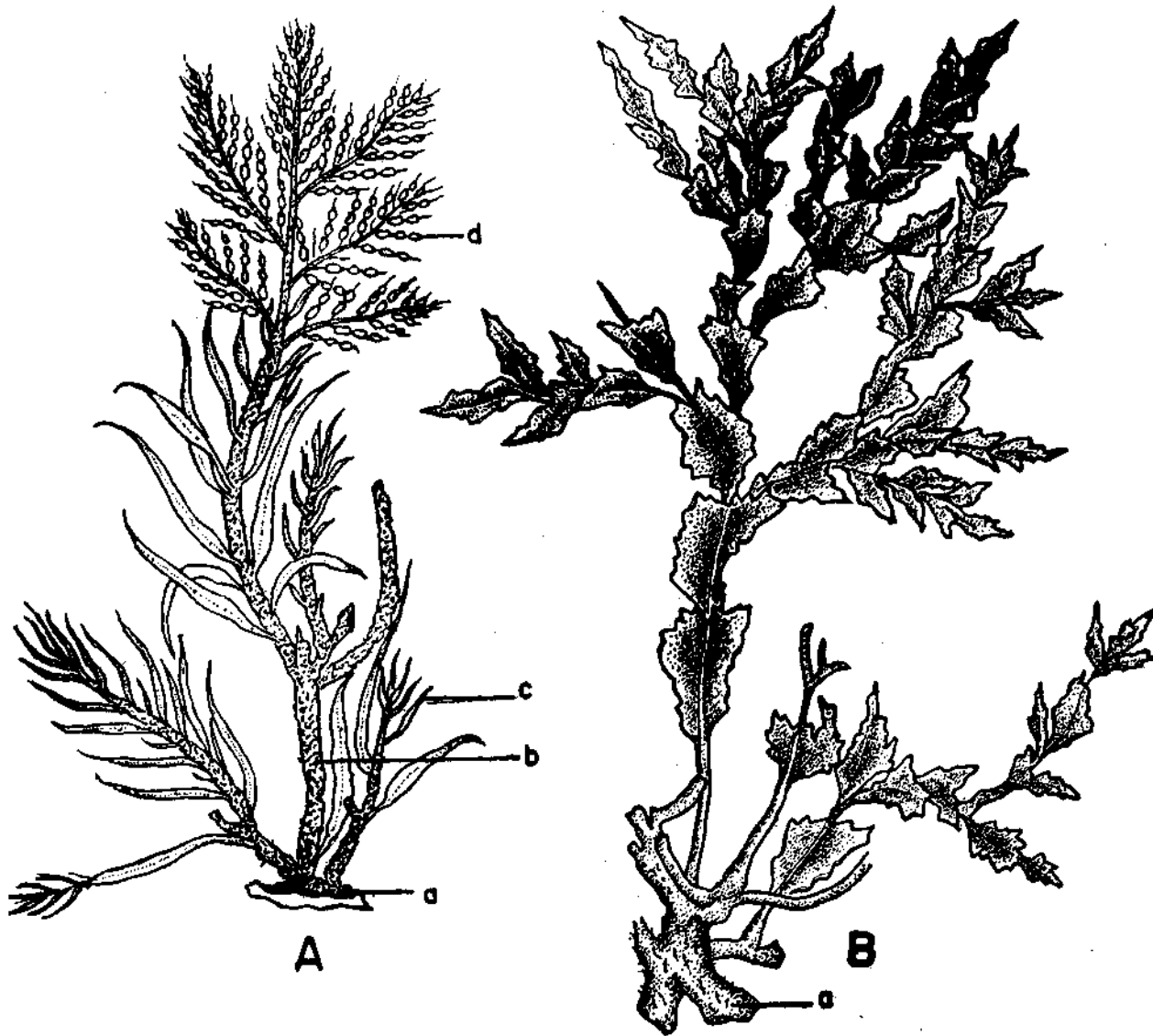


Fig. 6. common brown seaweeds of the Indian coast (contd.) A. *Cystoseira trinodis*
 B. *Hormophysa triquetra* (X 1) a - holdfast; b - stem; c - leaf; d - vesicles

have reported 50 algal species from the intertidal areas along the Goa coast. Qasim and Wafar (1979) have recorded in total 72 seaweeds from Ratnagiri, Malwan and Redi along the west coast. An account of 46 species of marine algae occurring at Tiruchendur on the Tamil Nadu coast has been given by Krishnamurthy (1980). Sarma and Khan (1980) have published a checklist of Indian fresh water and marine algae. A taxonomic account of Indian Ectocarpales and Rhodiales has been given by Balakrishnan and Kinkar (1981). An annotated systematic list of 44 species of algae collected from 10 localities along the southern Kerala coast (including

Asthamudi Lake and Kanyakumari) was published by Balakrishnan Nair *et. al.* (1982). Chennubhotla *et. al.* (1987) reported 35 species of seaweeds occurring along Kerala Coast. Stray marine algal collections have also been reported by various workers from different localities of Indian coast. Untawale *et. al.* (1983) enumerated 624 species of marine algae and their distribution along the maritime states of India. After 1983 some additions to the list are also made so as the number could be put around 680.

Although all the seaweeds are beneficial to man in one way or the other, only 49 species

which are presently found useful either as directly edible materials or as industrial raw materials are being dealt with in the classification given in this chapter following that of Fritsch (1935). The distribution of these economically important algae along the Indian coast are given along with a few other species commonly occurring in India in the Appendix III.

Classification

Following the classification of Fritsch (1935), a systematic list of the important and common Indian seaweeds is given below:

I CLASS : CHLOROPHYCEAE

Order : Ulotrichales

- a. Family : Ulvaceae
 1. *Ulva fasciata*
 2. *U. lactuca*
 3. *U. rigida*
 4. *U. reticulata*
 5. *Enteromorpha compressa*

Order : Cladophorales

- b. Family : Cladophoraceae
 6. *Chaetomorpha antennina*

Order : Siphonales

- c. Family : Caulerpaceae
 7. *Caulerpa racemosa*
 8. *C. sertularioides*
 9. *C. taxifolia*
- d. Family : Codiaceae
 10. *Codium adharens*
 11. *C. decortcatum*
 12. *C. tomentosum*

II CLASS : PHAEOPHYCEAE

Order : Dictyotales

- a. Family : Dictyotaceae
 13. *Dictyota dichotoma*
 14. *Padina commersoni*
 15. *P. gymnospora*
 16. *P. tetrastromatica*

Order : Punctariales

- b. Family : Punctariaceae
 17. *Colpomenia sinuosa*
 18. *Hydroclathrus clathratus*
 19. *Rosenvingea intricata*
 20. *Chnoospora minima*

Order : Fucales

- c. Family : Sargassaceae
 21. *Cystoseira trinodis*
 22. *Hormophysa triquetra*
 23. *Sargassum johnstonii*
 24. *S. myriocystum*
 25. *S. swartzii*
 26. *S. tenerrimum*
 27. *S. wightii*
 28. *Turbinaria conoides*
 29. *T. ornata*

III CLASS : RHODOPHYCEAE

Sub-Class : Bangioideae

Order : Bangiales

- a. Family : Bangiaceae
 30. *Porphyra vietnamensis*

Order : Gelidiales

- b. Family : Gelidiaceae
 31. *Gelidiella acerosa*

Order : Cryptonemiales

- c. Family : Grateloupiaceae
 32. *Halymenia floresia*
 33. *Grateloupia filicina*
 34. *G. lithophila*

Order : Gigartinales

- d. Family : Gracilariaceae
 35. *Gracillaria corticata*
 36. *G. crassa*
 37. *G. foliifera*
 38. *G. edulis*
 39. *G. verrucosa*
- e. Family : Solieriaceae
 40. *Sarconema furcellatum*
- f. Family : Hypneaceae
 41. *Hypnea musciformis*
- g. Family : Gigartinaceae
 42. *Gigartina acicularis*

Order : Rhodymeniales

- h. Family : Rhodymeniaceae
 43. *Rhodymenia dissecta*

Order : Ceramiales

- i. Family : Ceramiaceae
 44. *Centroceras clavulatum*
 45. *Spyridia filamentosa*
 46. *S. fusiformis*
- j. Family : Rhodomelaceae
 47. *Acanthophora spicifera*
 48. *Laurencia papillosa*
 49. *L. obtusa*

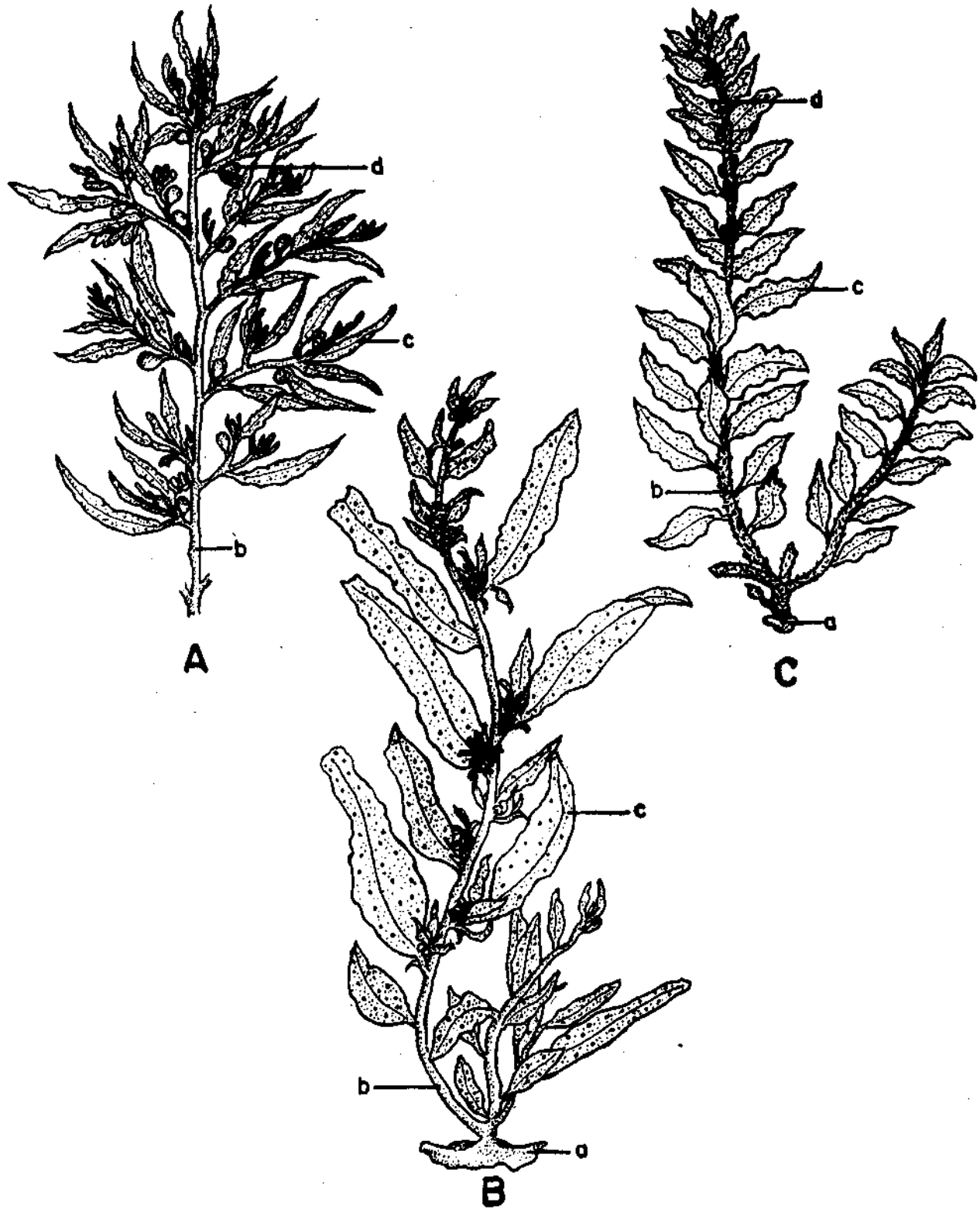
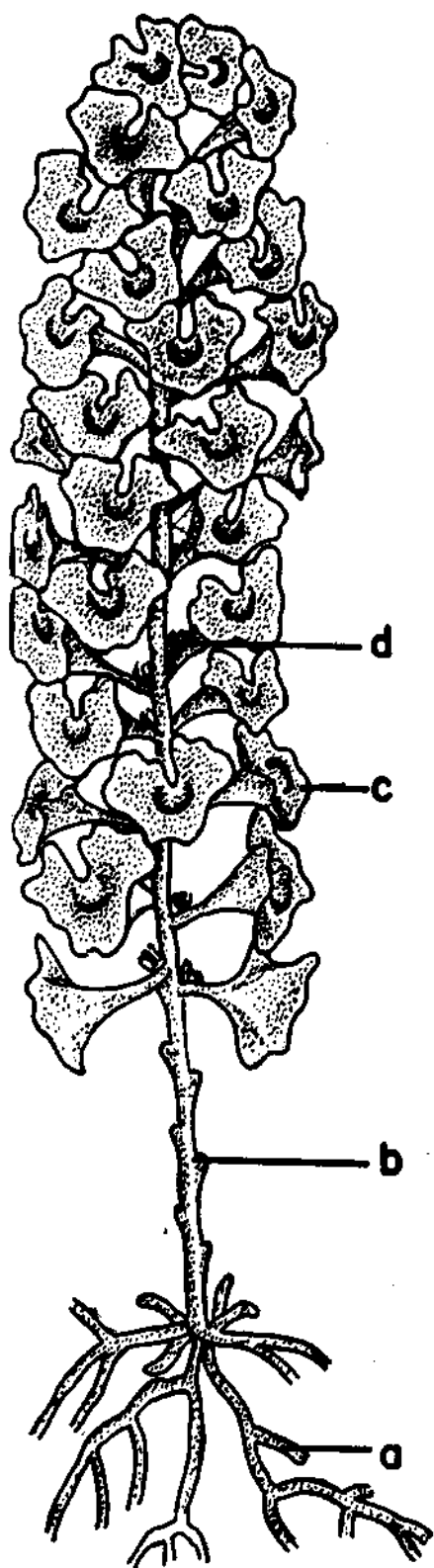
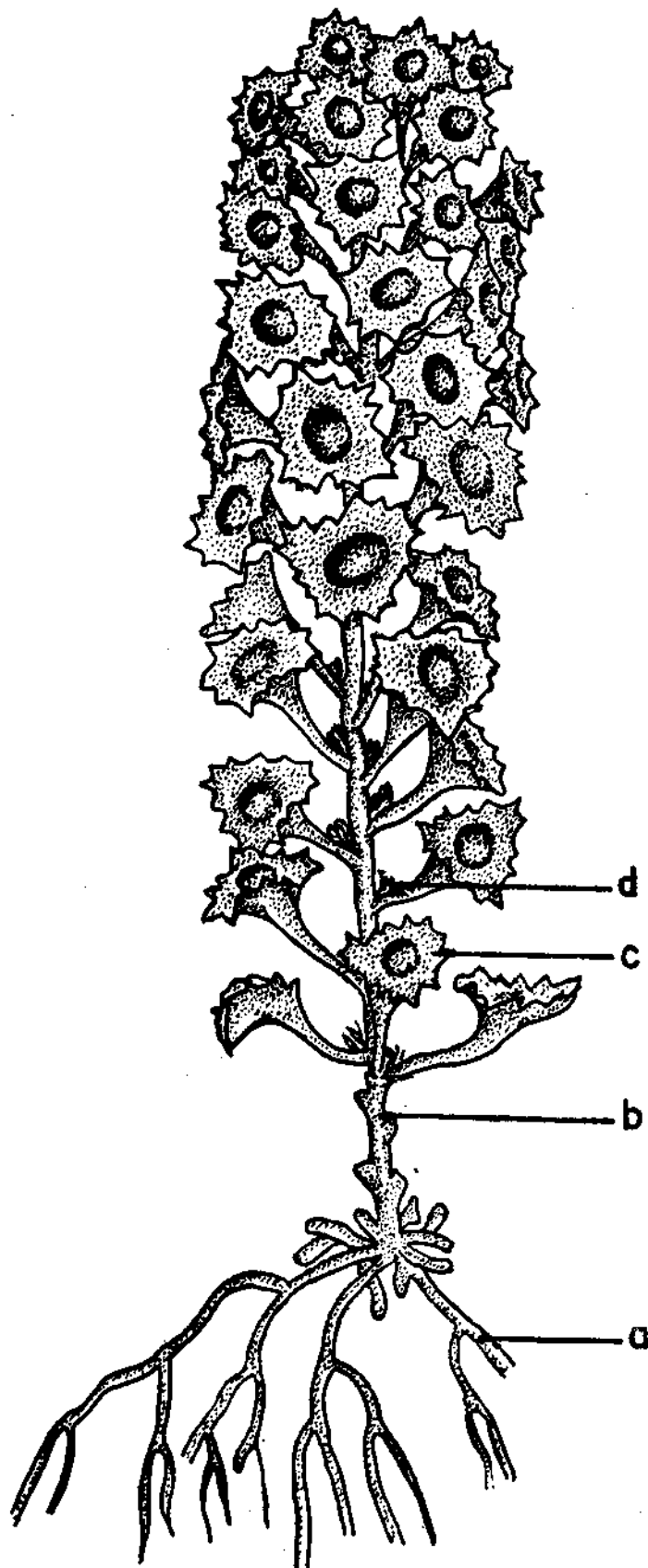


Fig. 7. common brown seaweeds of the Indian coast (contd.) A. *Sargassum tenerrimum*—part of the plant (X 1) B. *Sargassum wightii* (X 1) C. *Sargassum myriocystum* (X 1)
 a - holdfast; b - stem; c - leaf; d - vesicle



A



B

Fig. 8. common brown seaweeds of Indian coast (contd.) A. *Turbinaria conoides* (X 1)
 B. *Turbinaria ornata* (X 1) a - heteron; b - stem; c - leaf; d - receptacle

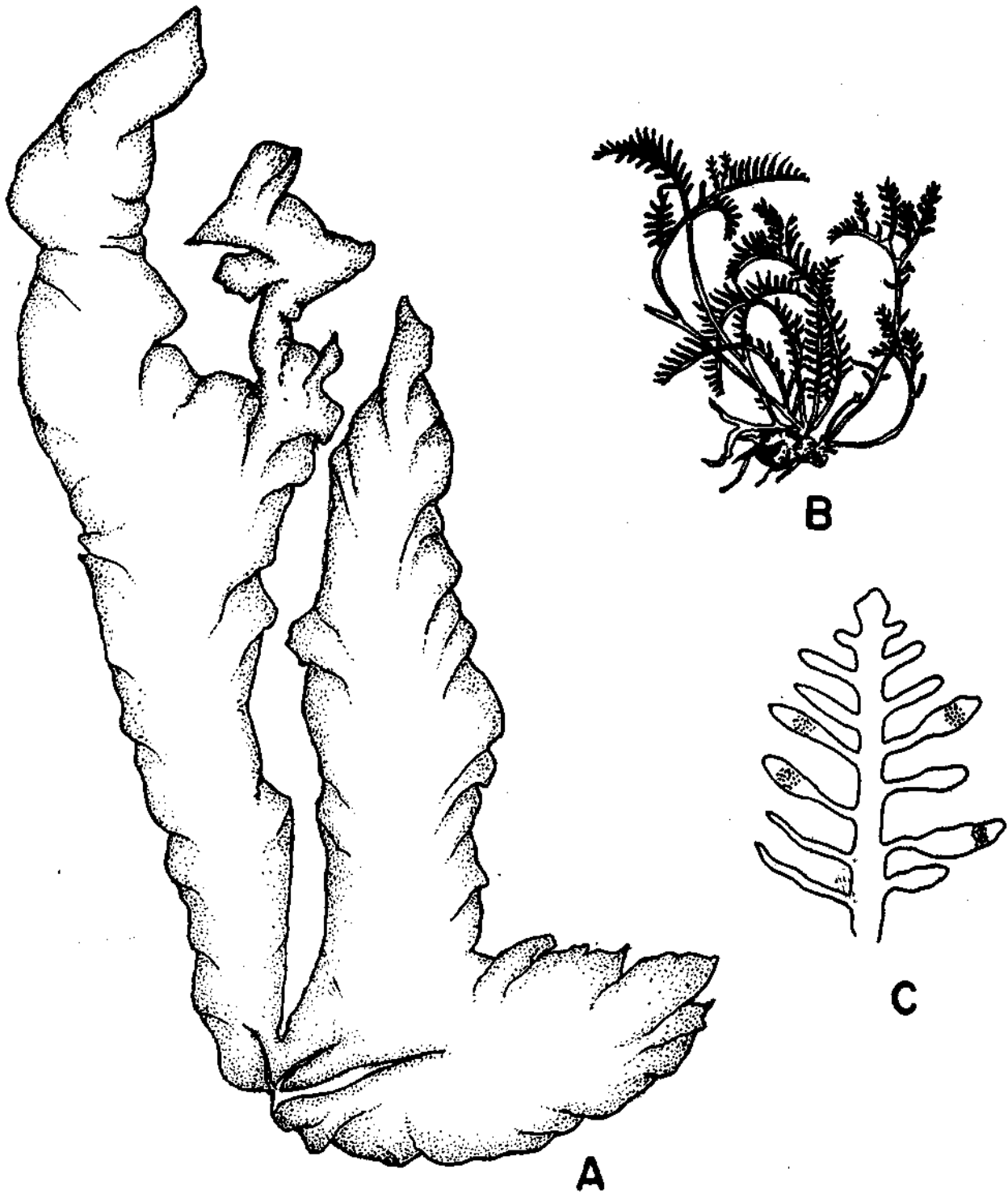


Fig. 9. Some common red seaweeds of Indian coast A. *Porphyra vietnamensis* (X 1)
 B. *Gelidiella acerosa* (X 1) C. *Gelidiella acerosa* - axis showing swollen branchlets (X 50)

At present *Gelidiella acerosa* and *Gracilaria edulis* are used as raw material for the production of agar-agar in India. Species of *Hypnea*, *Gigartina*, *Spyridia*, *Sarconema*, *Acanthophora* and *Laurencia* give gell-like

extracts known as agaroids. Species of *Sargassum*, *Turbinaria*, *Cystoseira*, *Hormophysa*, *Dictyota* and *Padina* yield alginic acid and iodine. In India, sodium alginate is manufactured by the seaweed industries from

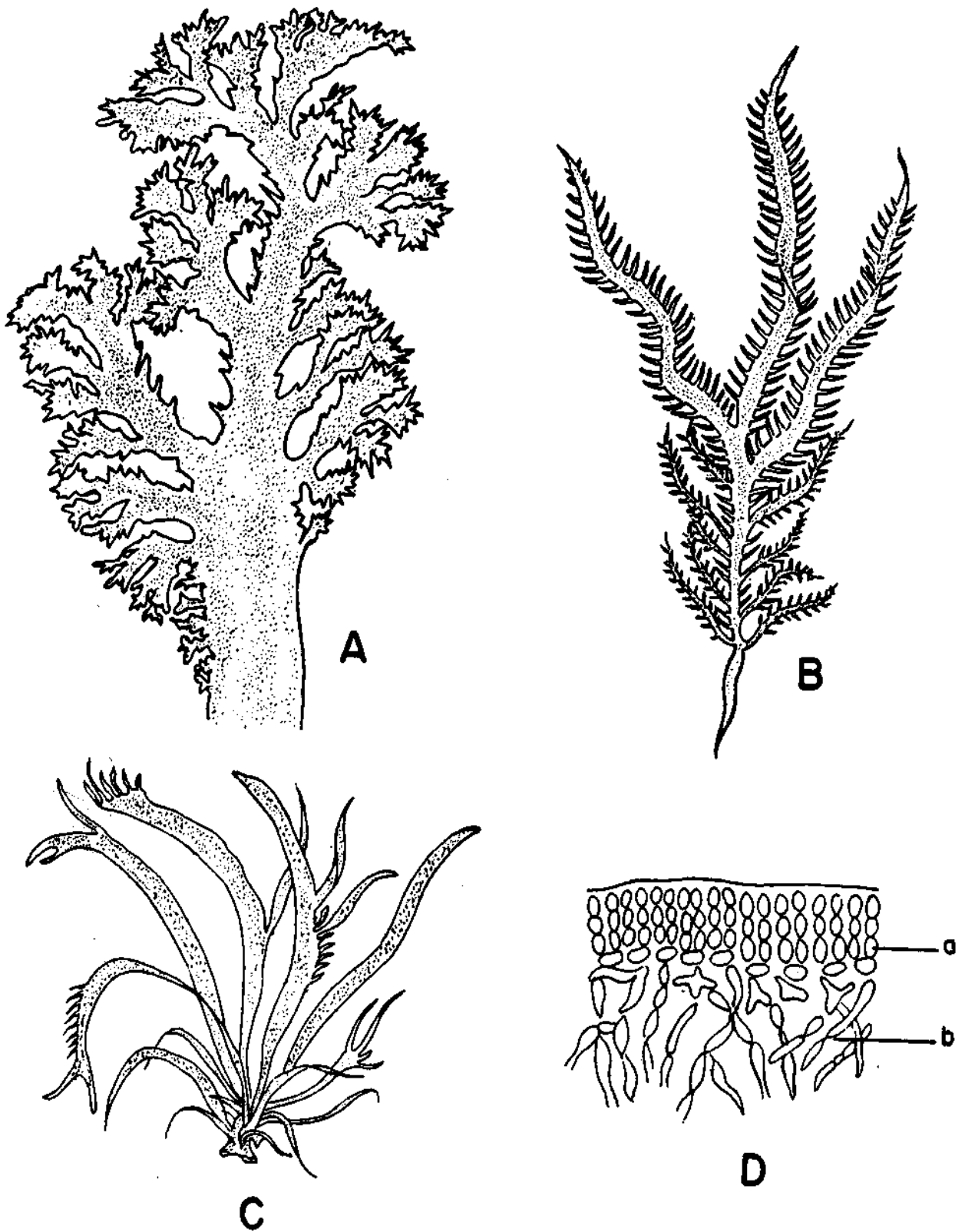


Fig. 10 Red seaweeds of Indian coast (contd.) A. *Halymenia floresia* - part of plant (X 2)
 B. *Grateloupia filicina* (X 2) C. *Grateloupia lithophila* (X 1) D. *Grateloupia lithophila* - transverse
 section of thallus (X 150) a - cortex; b - medulla

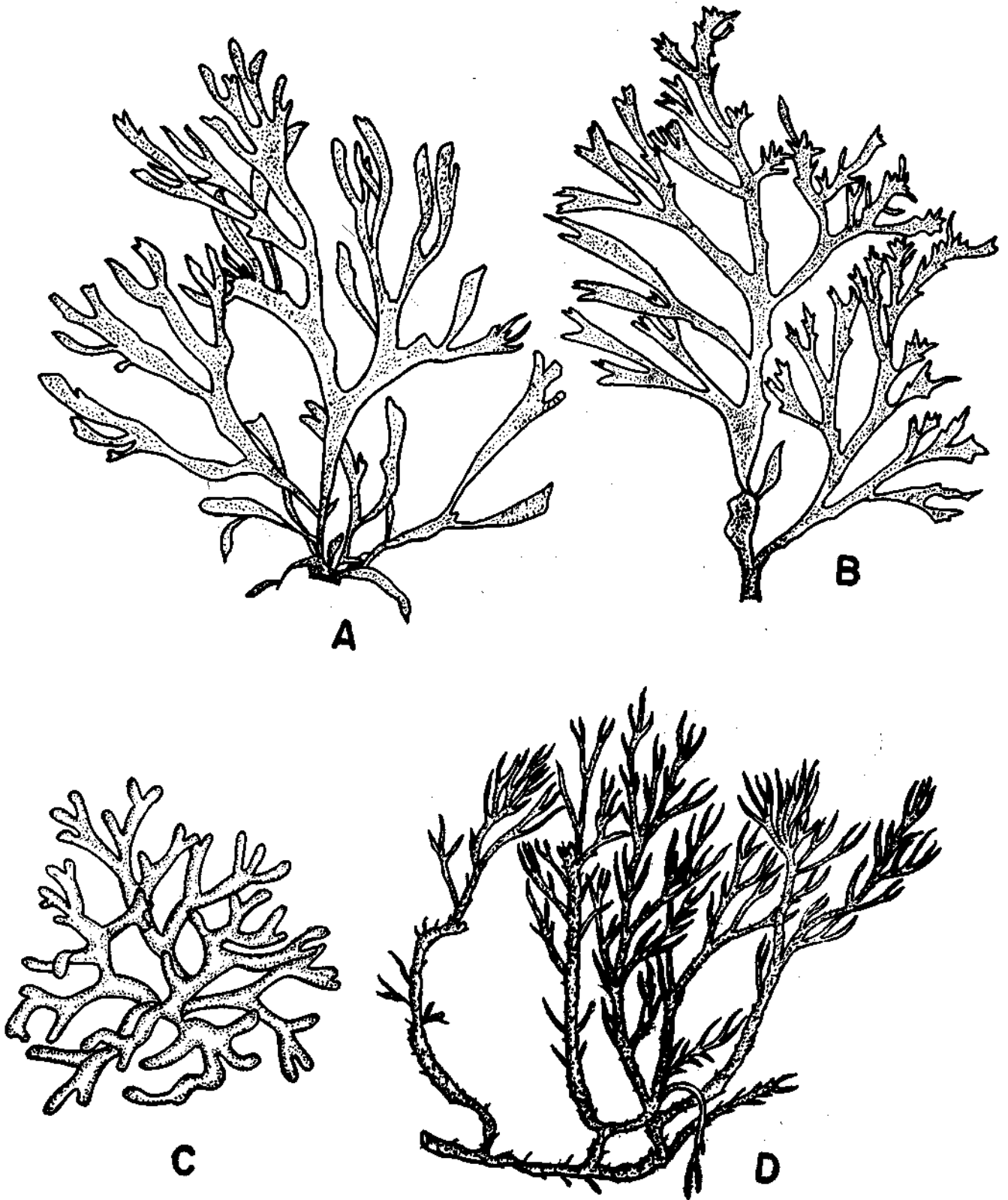


Fig. 11. Red seaweeds of Indian coast (contd.) A. *Gracilaria corticata* (X 1) B. *Gracilaria foliifera* - part of a plant (X 1) C. *Gracilaria crassa* (X 1) D. *Gracilaria edulis* (X 1)

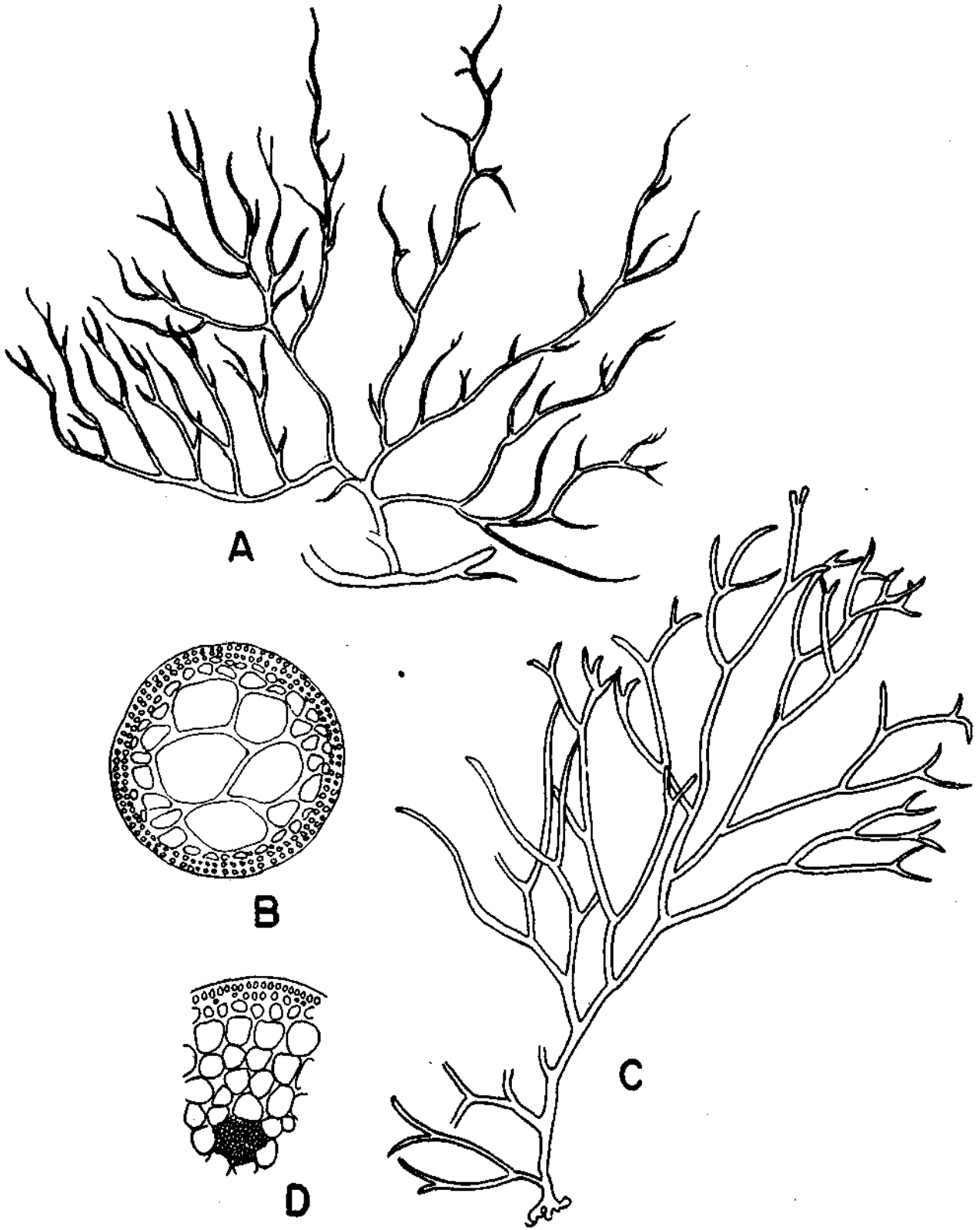
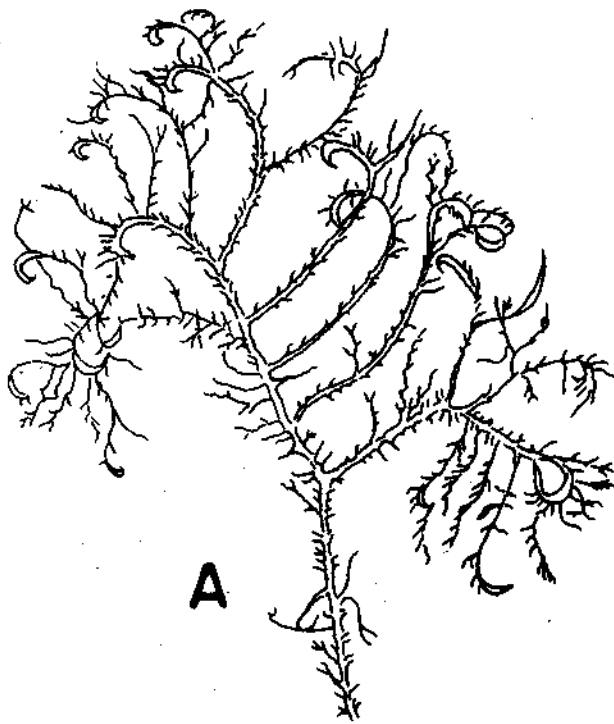
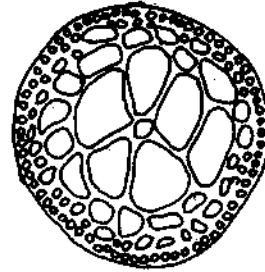


Fig. 12. Red seaweeds of Indian coast (contd.) A. *Gracilaria verrucosa* (X 1)
 B. *Gracilaria verrucosa* - transverse section of the frond (X 60) C. *Sarconema furcellatum* (X 1)
 D. *Sarconema furcellatum* - transverse section of the thallus (X 150)



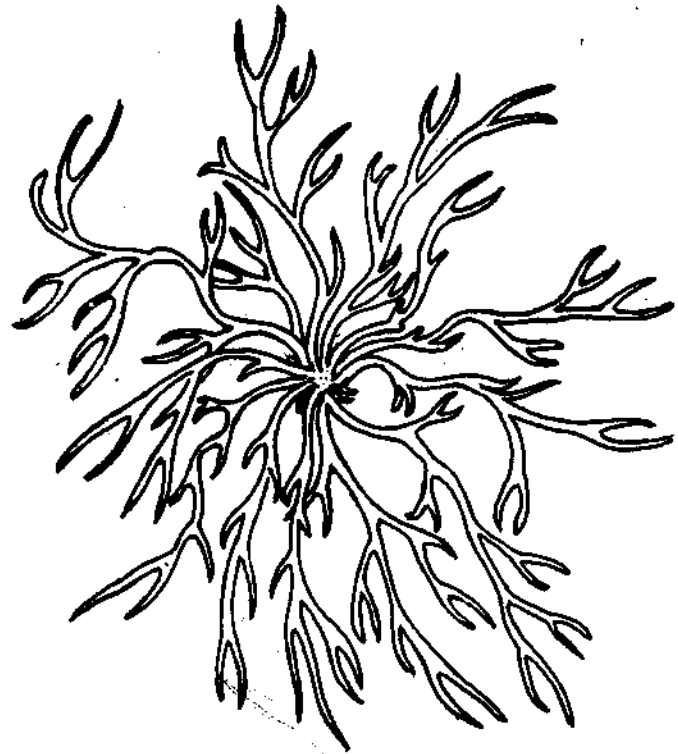
A



B



C



D

Fig. 13. Red seaweeds Indian coast (contd.) A. *Hypnea musciformis* (X 1) B. *Hypnea* - transverse section of thallus (X 75) C. *Centrocerks clavulatum* - part of a filament with whorls of spines at each node (X 50) D. *Gigartna acicularis* (X 3)

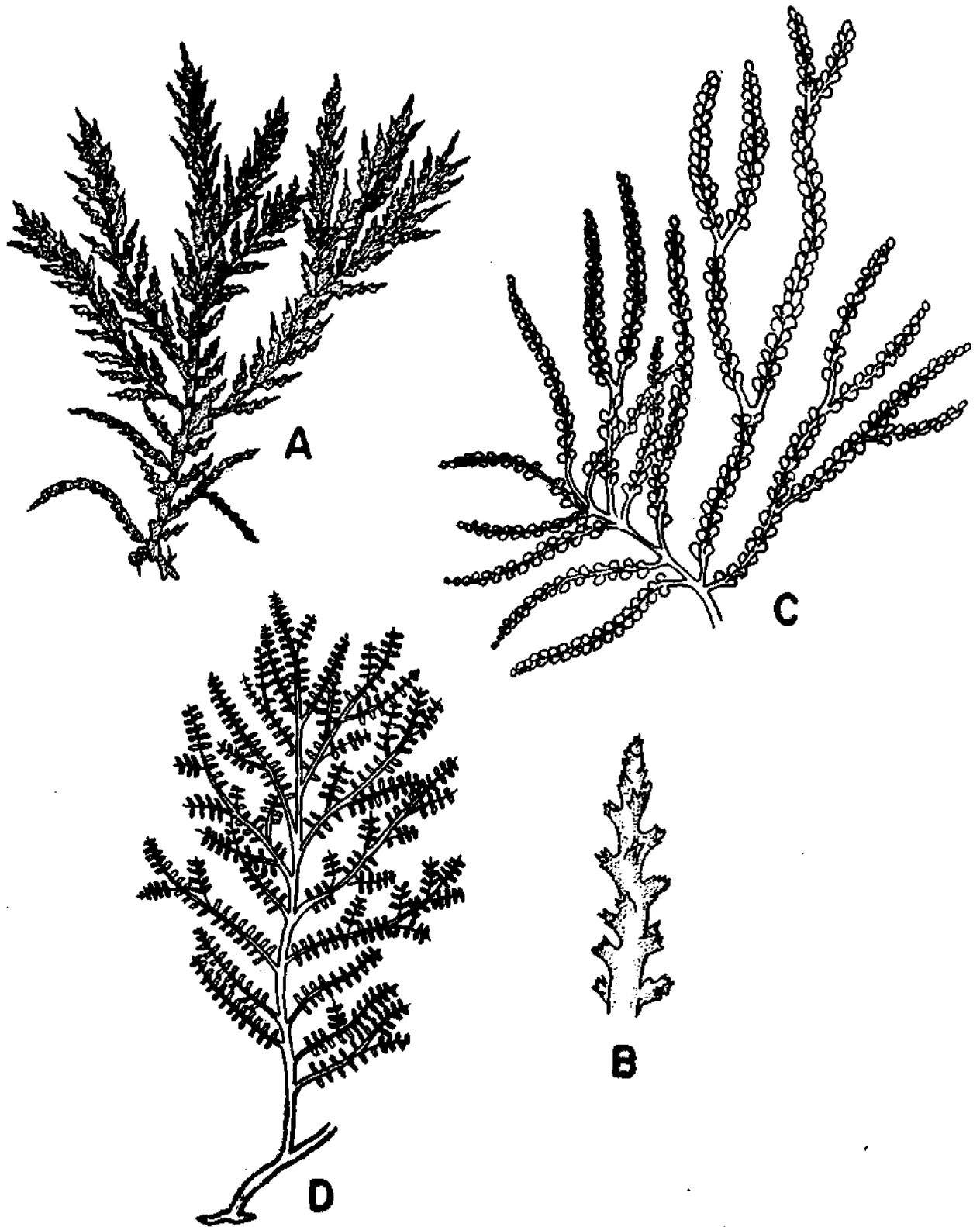
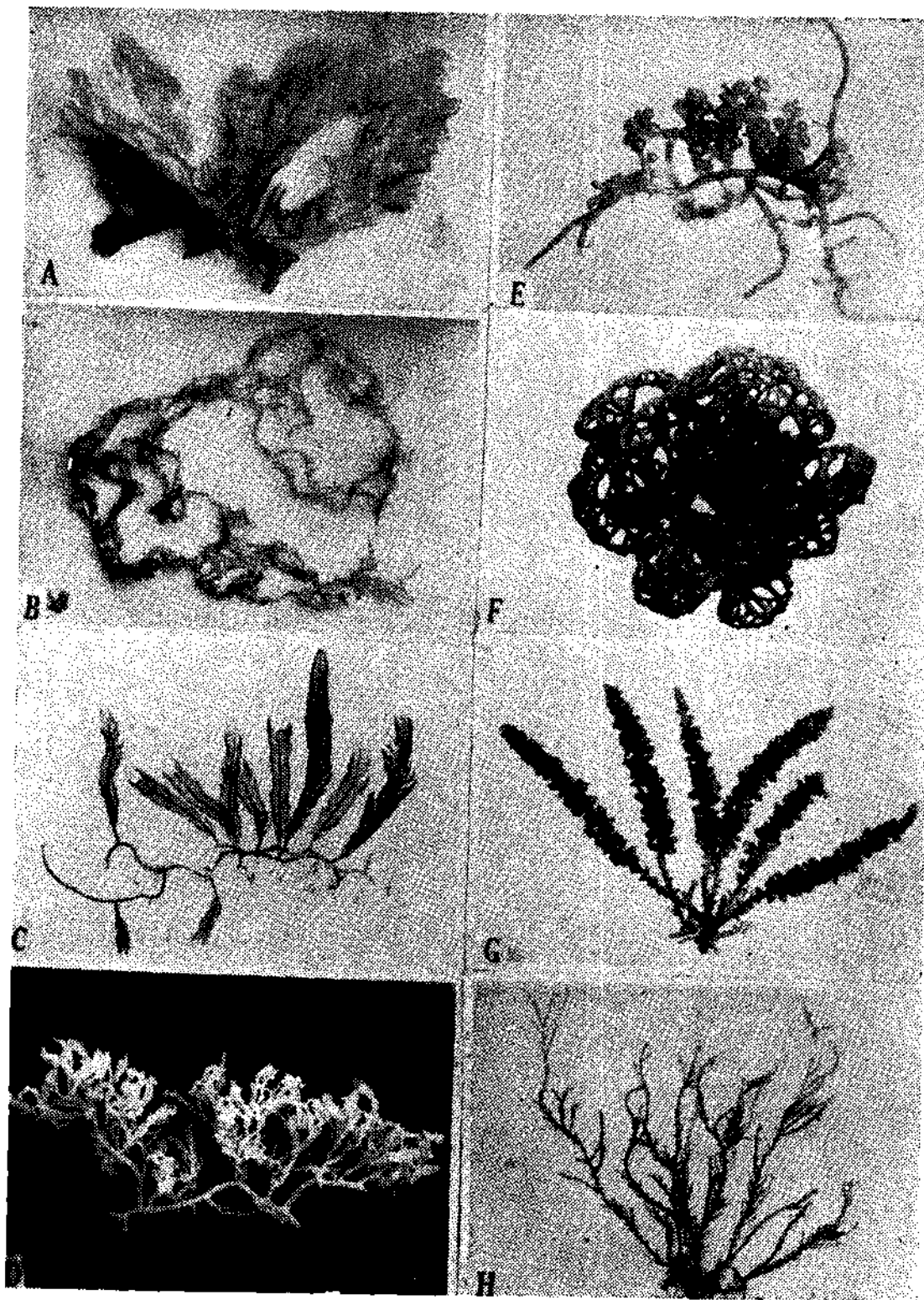
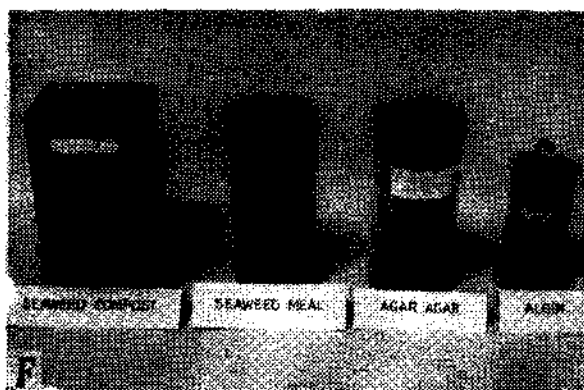
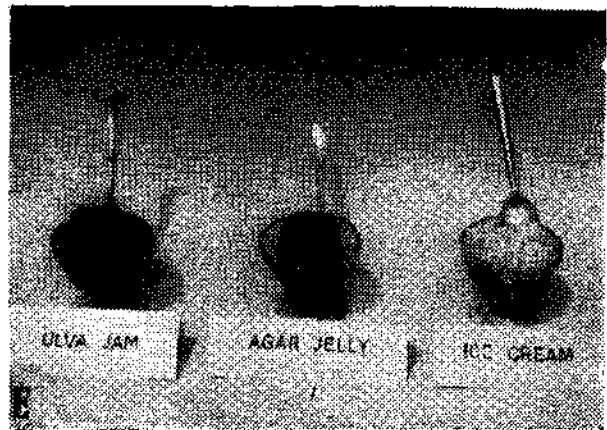
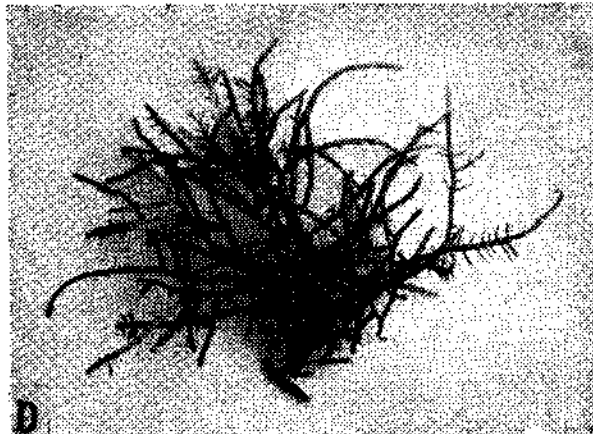
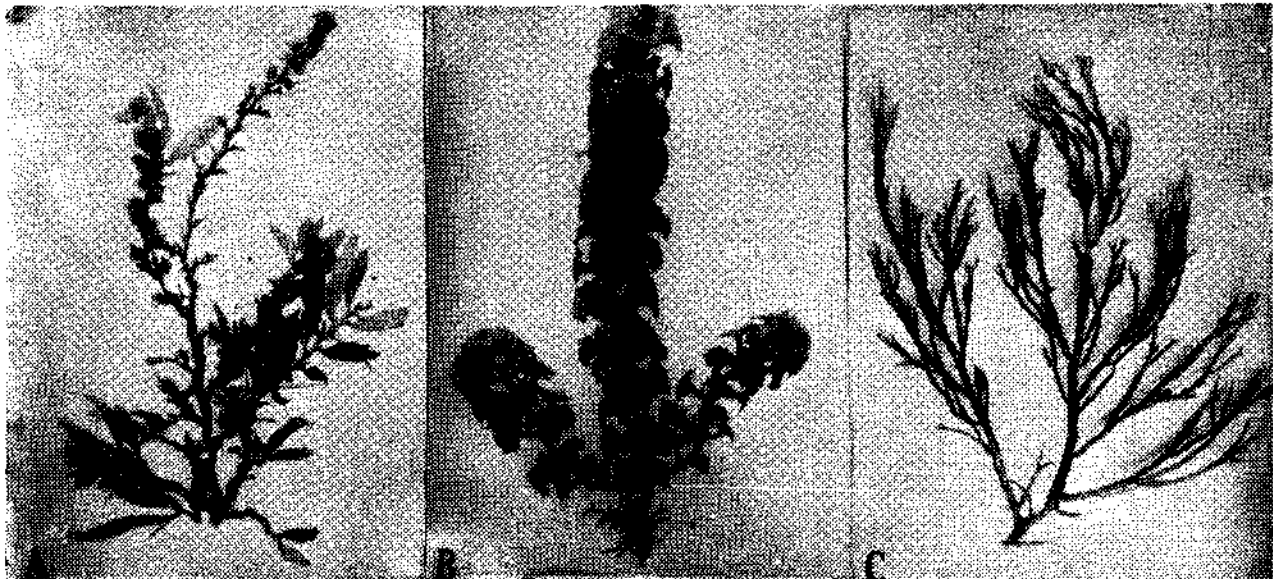


Fig. 14. Red seaweeds of Indian coast (contd.) A. *Acanthophora spicifera* (X 1) B. *Acanthophora spicifera* special part of the plant (X 5) C. *Laurencia papillosa* (X 1.5) D. *Laurencia obtusa* (X 3)

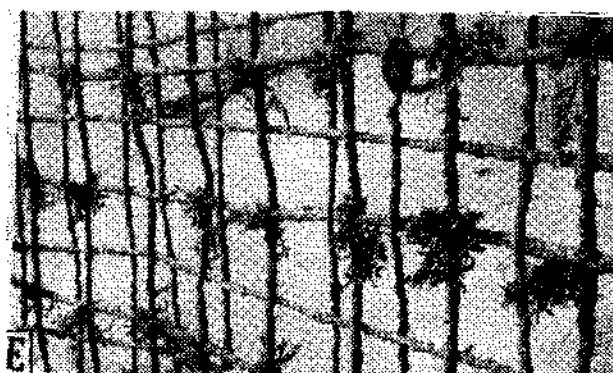
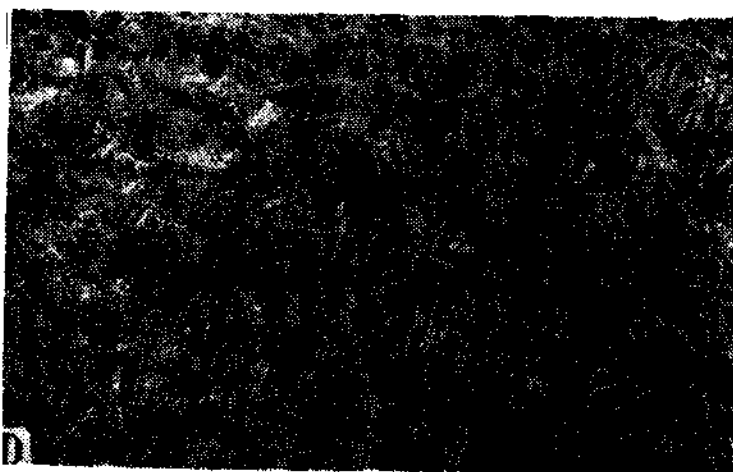
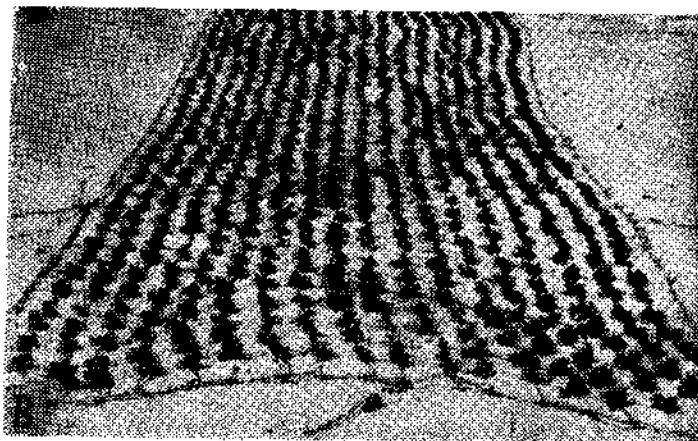
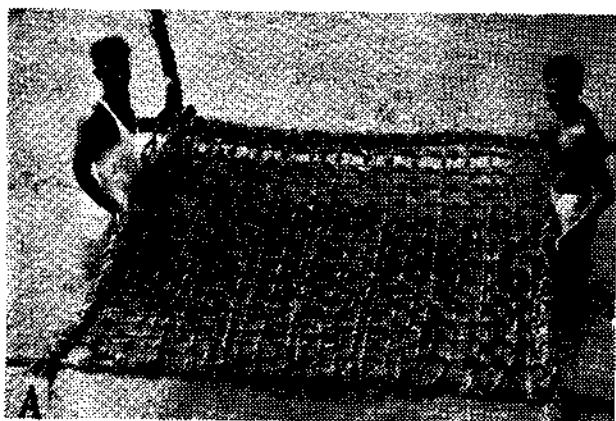


Some of the economically important seaweeds occurring along the Indian coast
 A. *Ulva lactuca*, B. *U. reticulata*, C. *Caulerpa sertularioides*, D. *C. serrulata*,
 E. *C. racemosa*, F. *Hydroclathrus clathratus*, G. *Laurencia papillosa*,
 H. *Acanthophora spicifera*.



Some of the economically important seaweeds, seaweed products and a stage in processing of seaweeds.

- A. *Sargassum wightii*, B. *Turbinaria ornata*, C. *Gracilaria edulis*, D. *Gelidiella acerosa*,
 E. Food products made out of seaweeds, F. Seaweed products of economic importance,
 G. *Gelidiella acerosa* plants spread on the beach sand for drying.



Different stages of seaweed culture:

- A. Fragments of *G. edulis* introduced in the twists of the coir rope of 2 x 2m size net.
- B. HDP rope net (5 x 2m size) with seed material (*Gracilaria edulis*).
- C. 60 days growth of *G. edulis* in coir net of 5 x 2m size
- D. A portion of the coir net showing 60 days growth of *G. edulis*.
- E. Sprouting *Sargassum weightii* plants from fragments in the coir net.
- F. Harvestable size of (5 months growth) plants of *Gelidium acerosa* on the coral stone



- Different stages of seaweed culture and a stage in processing the seaweed and storage of them.
- A. Seeding of HDP rope net with fragments of *Gracilaria edulis*, keeping the net inside water.
 - B. HDP rope net showing *Gracilaria edulis* after 70 days growth.
 - C. Formalin-treated *Sargassum* plants being removed from the tank.
 - D. 15 days growth of *G. edulis* after introduction in the coir net.
 - E. Storing of dried *Sargassum* plants in the shed before marketing.
 - F. HDP rope culture net showing *Gelidiella acerosa* just before harvest — 60 days growth.

Sargassum and *Turbinaria* spp as raw material. Species of *Ulva*, *Chaetomorpha*, *Enteromorpha*, *Caulerpa*, *Codium*, *Colpomenia*, *Hydroclathrus*, *Rosenvingea*, *Chnoospora*, *Porphyra*, *Halymenia*, *Grateloupia*, *Gracilaria*, *Hypnea*, *Rhodomenia*, *Centroceras*, *Acanthophora* and *Laurencia* are being utilized as human food in Japan, China, Korea, Indonesia, Philippines, USA and many other countries, but in India the seaweed as food is yet to be popularised.

Distribution of Seaweeds in India

Along the coastline of India, the littoral and sublittoral rocky areas support a good growth of different seaweeds (agarophytes, alginophytes and other edible seaweeds). There is luxuriant growth of seaweeds along the southeast coast of Tamil Nadu, from Mandapam to Kanyakumari; Gujarat coast; Lakshadweep Island and the Andaman and Nicobar Islands. Fairly rich seaweed beds are present in the vicinity of Bombay, Ratnagiri, Goa, Karwar, Varkala, Kovalam, Vizhinjam, Visakhapatnam and few other places such as Chilka and Pulicat lakes.

The distribution of economically important seaweed resources of India has been

mapped by Thivy (1958). Umamaheswara Rao (1969 b and 1972 c) gave accounts on the four most important agar- and algin-yielding seaweeds, *Gracilaria*, *Gelidiella*, *Sargassum* and *Turbinaria*. *Gracilaria edulis* grows in lagoons and protected areas, attached to pebbles and shells in muddy substratum. *G. crassa* grows in shallow nearshore areas and *G. verrucosa* on sandy bottoms of saltwater lakes and other protected areas with its basal part buried in sand or attached to small stones. Many *Gracilaria* species have been reported from localities between Mandapam and Kanyakumari. *Gelidiella acerosa* (= *Gelidium micropterum*) is found on surf-exposed areas of the coral reef and is therefore restricted to the Mandapam area and northwest part of Kathiawar peninsula, Gujarat (Thivy, 1958). *Turbinaria conoides*, *T. decurrens* and *T. ornata* need hard substratum and are found mainly on sheltered parts in the two coral reef areas mentioned above. *Gracilaria corticata* and species of *Sargassum*, *Ulva*, *Enteromorpha* and *Chaetomorpha*, which thrive in littoral habitats, have a more continuous distribution all along the intertidal rocky areas of the Indian coastline

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