PLAN DE FORMACIÓN DESTINADO A ADMINISTRACIONES PÚBLICAS COMPETENTES EN LA GESTION DE LA RED NATURA 2000 MARINA EN EL MARCO DEL PLAN DE RECUPERACIÓN, TRANSFORMACIÓN Y RESILIENCIA

(2022-2025)

CURSO "IDENTIFICACIÓN Y DISTINCIÓN DE ESPECIES MARINAS VULNERABLES DE OTRAS ESPECIES SIMILARES DE INTERÉS PESQUERO U OBJETO DE INFRACCIÓN"

MÓDULO PRÁCTICO
Identificación de especies de *visu*

SESIÓN 1: Macrófitos

Responsables: Marc Terradas / Yolanda Fernández Torquemada

Clave fanerógamas marinas (& *Ruppia* spp.) modificada de Afonso-Carrillo y Sansón (1999), Cabioc'h et al. (1995) y Mateo y Crespo (2014).

1. **Plantas pequeñas** constituidas por rizomas frágiles de hasta 1 mm de diámetro, que originan **hojas opuestas**, **elípticas** y pecioladas, de hasta 30 mm de largo y 8 mm de ancho; nerviación pinnada y margen finamente serrulado
   ……….***Halophila decipiens***

   Plantas más grandes, con **hojas agrupadas en haces** y de nerviación paralela

   ………..2

2. **Rizomas "leñosos"**, de 1 a 2 cm de diámetro, con "escamas" (peciolos); hojas de más de 6 mm de anchura (normalmente 7-11 mm), recorridas por 13-17 nervios paralelos; rizomas horizontales y verticales; inflorescencias monoicas pedunculadas
   ……….***Posidonia oceanica***

   Rizomas de menor tamaño……………………………………………………………………………………………3

3. **Hojas de menos de 6 mm de ancho** (normalmente 3- 5 mm), recorrida por **7-9 nervios** paralelos; ápices de las hojas redondeados con pequeños **dientes marginales**; rizomas (rosáceos) de unos 5 mm; rizomas horizontales y verticales; **vainas abiertas**; 1 raíz (normalmente ramificada) por nudo; inflorescencias dioicas, flor masculina pedunculada

   ……..*Cymodocea nodosa*

   Hojas de menos de 12 mm de ancho (normalmente 3- 9 mm), recorrida por **3-11 nervios** paralelos; ápices de las hojas lisos ovalados o mucronados; rizomas de unos 5 mm; **únicamente rizomas horizontales**; 5 -12 raíces no ramificadas; **vainas cerradas**; inflorescencias en espiga

   …….***Zostera marina***

   Hojas de menos de 2 mm de ancho, recorrida por **3-5 nervios** paralelos; ápices de las hojas generalmente emarginados y sin dientes marginales; **rizomas de unos 2 mm**; rizomas horizontales y verticales; 2-8 raíces no ramificadas; **vainas abiertas**; inflorescencias en espiga

   ……..***Zostera noltei***

   ** **Haces menos aparentes** que en las especies anteriores; las **hojas, muy finas (0.5-1 mm),** se disponen **de forma alterna o subopuestas**, poseen un **ápice finamente denticulado**, y una **vaina envolvente abierta y ensanchada en la base**; con **1-3 nervios**; rizoma delgado (0.8-1 mm), muy ramificado; flores monoicas de:

   a) Pedúnculo floral largo (8-60 cm) y espiralado……………………………………………………***Ruppia cirrhosa***
   b) Pedúnculo floral más corto (2-5 cm) y recto……………………………………………………***Ruppia maritima***

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MÓDULO PRÁCTICO
Identificación de especies de *visu*

SESIÓN 2: Invertebrados coloniales

Responsable: Alfonso A. Ramos Esplá

DIVERSIDAD DE LA FAUNA MARINA: ANIMALES COLONAILES

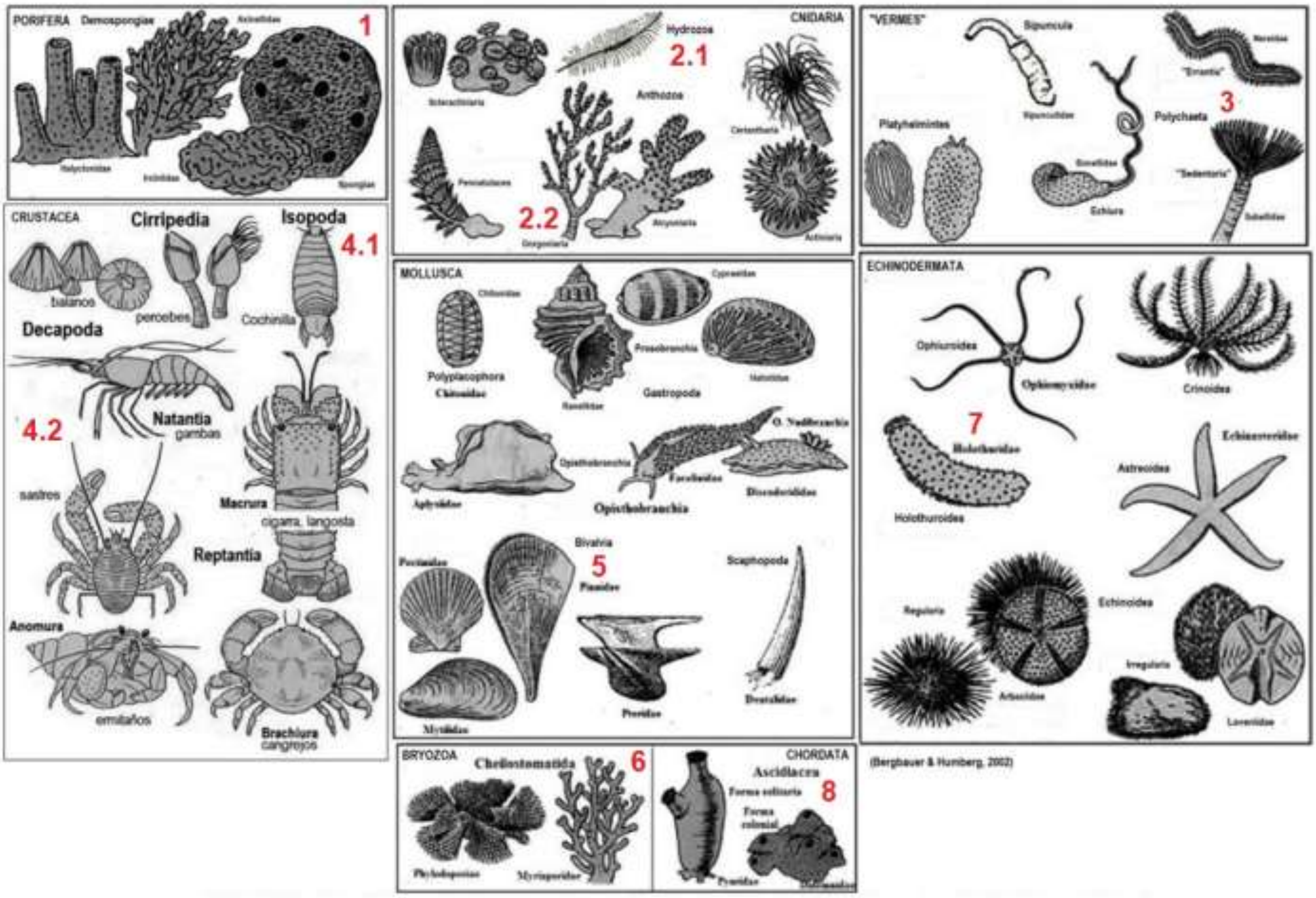


Figura 1. Megazoobentos (Taxones nivel superior: Phylum, Clase, Orden)*.

Animales coloniales

- 1. Porifera (pg. 2).
- 2. Cnidaria:
    - 2.1 Hydrozoa (pg. 4);
    - 2.2 Anthozoa: Gorgoniaria (pg. 5).
- 6. Bryozoa (pg. 6).
- 8. Chordata: Ascidiacea (pg. 7).

1. PORIFERA

Las esponjas son animales coloniales con una gran variedad de formas (incrustantes, masivas, ramificadas, tubulares, foliosas.. Fig.1.1).Salvo algunas contadas especies, la forma externa y la coloración no son buenos caracteres para su clasificación. Su esqueleto interno (espongina, espículas,Fig.1.2)permite una adecuada determinación. Las esponjas que podemos observar en nuestras costas pertenecen a las Clases: Calcarea (espículas calcáreas) y Demospongiae (espículas silíceas y/o espongina)

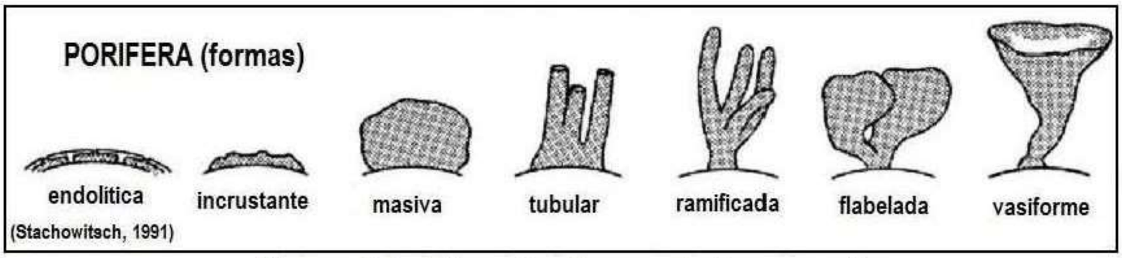


Figura 1.1. Diferentes formas de las esponjas

Para observar las espículas y/o la espongina, se cortará un pequeño trozo de esponja y se colocará en un vidrio de reloj con lejía (disolución de la materia orgánica). Posteriormente, se observarán las espículas y/o espongina. Con el fin de conocer si son calcáreas o demospongias, se pondrá una gota de ácido clorhídrico (salfumán).

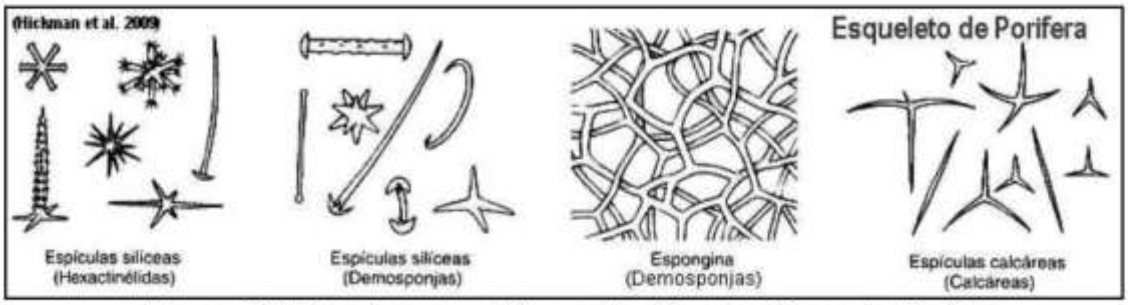


Figura 1.2. Estructura esquelética en las diferentes Clases de Porifera

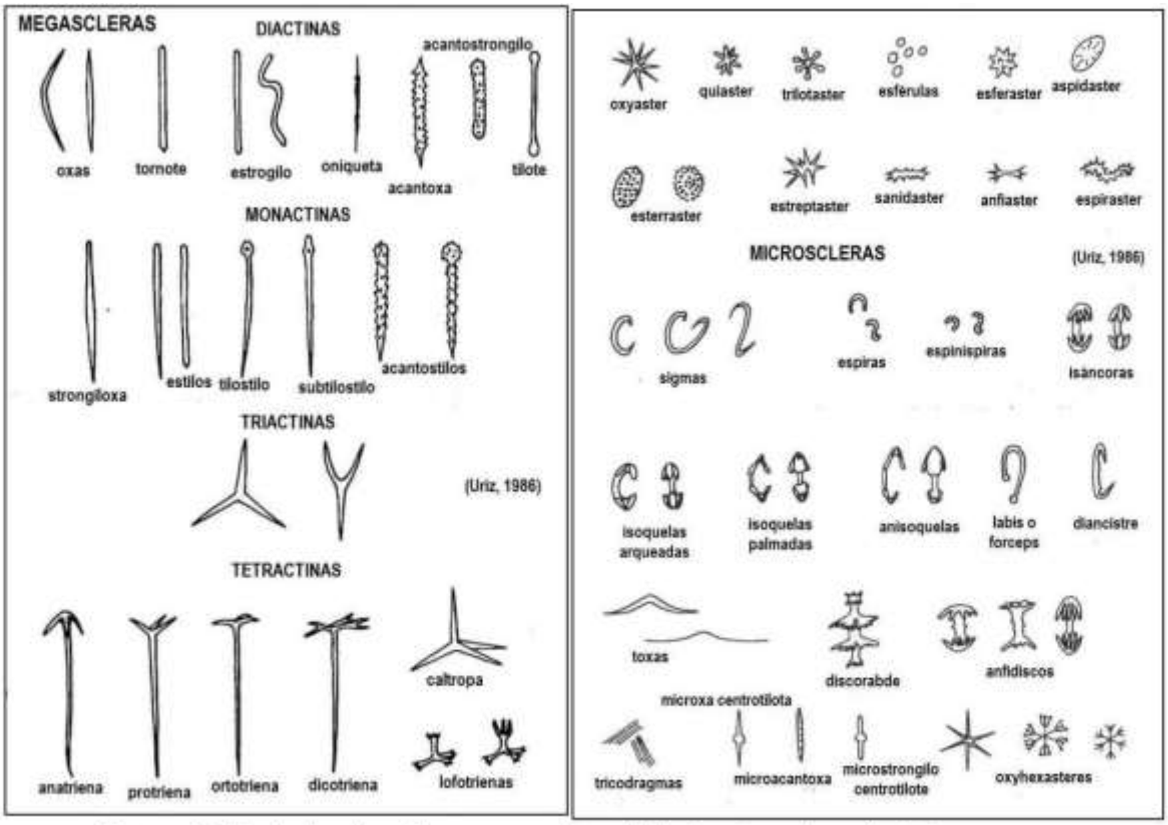


Figura 1.3 Espículas de poríferos: megascleras (dcha.) y microscleras (izda.)

Clasificación de Clases y Ordenes de Porifera

1- Sin espículas ni espongina **Clase Homoscleromorpha**
- Con espículas calcáreas **Clase Calcarea (2)**
- Con espículas silíceas de 6 radios (hexactinas) **Clase Hexactinellida***
- Con espículas silíceas (no de 6 radios) y/o espongina **Clase Demospongiae (3)**

(*) Especies profundas y polares

2- Esponjas con estructura tubular delicada, en forma retícular **Orden Clathrinida**
- Formas arbóreas, sacciformes o irregulares, no reticuladas. **O. Leucosolenida**

3- Sin espículas silíceas, sólo fibras de espongina (a veces pueden presentar granos de arena o espículas alóctonas) **(4)**
- Con espículas silíceas, con o sin espongina **(6)**

4- Fibras de espongina reticuladas, forma generalmente masiva **(5)**
- Fibras de espongina, principalmente dendríticas, o bien sin esqueleto; forma generalmente digitiforme **O. Dendroceratida**

5- Fibras diferenciadas en primarias y secundarias **O. Dictyoceratida**
- Fibras todas semejantes **O. Verongida**

6- Megascleras sólo mono o diactinas **(7)**
- Megascleras tetractinas ('Tetractinomorpha') **(11)**

7- Megascleras de tipo tilostilo (a veces estrongiloxas o estilos); microscleras (si presentes) tipo áster **O. Hadromerida**
- Megascleras de tipo oxa, estilo, estrogilo o tilostilo (en este último caso, con microscleras queloides o sigmoides) **(8)**

8- Microscleras casi siempre presentes (queloides o sigmoides) **O. Poecilosclerida**
- Microscleras excepcionalmente presentes (aster, sigma o toxa) **(9)**

9- Textura espicular de tipo reticulado, espículas oxas, raramente, estogilos; microscleras, si presentes, toxas o sigmas **O. Haplosclerida**
- Textura no reticulada; oxas y estilos **(10)**

10- Textura axial o plumorreticulada; oxas, estilos y, a veces, acantostilos; micoscleras (si presentes) tipo áster; **O. Agelasida**
- Esqueleto formado por oxas con disposición confusa, o por estilos o estrogilos con disposición plumosa; **O. Halichondrida**

11- Consistencia firme, compacta y coriácea **O. Chondrosida**
- Consistencia blanda **(12)**

12- Microscleras tipo aster **O. Astrophorida**
- Microscleras tipo spinispiras **O. Spirophorida**

2. CNIDARIA: Hydrozoa y Anthozoa (bentónicos)

Los cnidarios bentónicos (parte de Hydrozoa, Anthozoa) se clasifican por la forma de las colonias, pólipos, esqueleto (escleritos) y cnidocitos. Debido a la limitación de tiempo, nos basaremos en la forma de la colonia y de los pólipos (hidrozoos); así como, en los escleritos en Gorgoniaria.

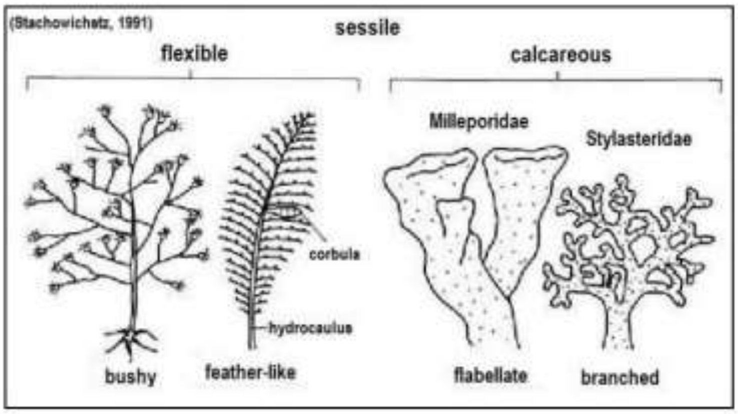


Figura 2.1. Colonias de hidrozoos.

2.1 Clase Hydrozoa (hidropólipos)

Los hidrozoos (o animales "agua"), normalmente forman colonias (Fig.5.1) flexibles filiformes, ramificadas o no (arbustivas, en pluma); o calcáreas (como el "coral de fuego" y el coral de "encaje"). Los pólipos de la Clase Hydrozoa (o hidropólipos,Fig.5.2) se dividen en dos órdenes según presenten teca o cubierta (O. Leptohecata o Thecaphora) o no (O. Anthothecata o Athecata). Las familias del Orden Anthotheca se distinguen, principalmente, por la forma (filamentosos, en botón) y disposición de los tentáculos (1 ó 2 verticilos). Dado que los zooides están retraídos, se intentará llegar a la familia (posiblemente, género y especie) por la forma de las colonias. Las familias del Orden Leptothe-cata, por la forma de las tecas

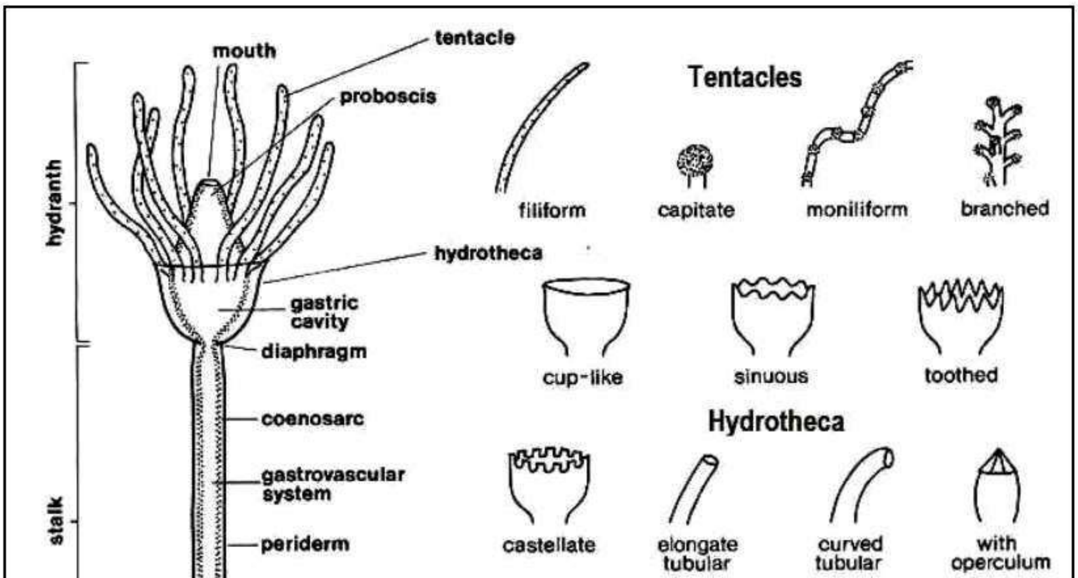


Figura 2.2 Partes de un hidropólipo, diferentes formas de tentáculos y de la hidroteca.

2.2 Clase Anthozoa: Orden Alcyonacea ('Gorgoniaria')

Las gorgonias se caracterizan por su forma ramificada con un esqueleto axial calcáreo o córneo rodeado por el cenénquima con piezas esqueléticas o escleritos.

Clave dicotómica de gorgonias del Mediterráneo Ibérico (Fig. 2.3)

1- Esqueleto enteramente calcificado, rígido y normalmente rojo **Familia Coralliidae** (*Corallium rubrum*)
– Eje formado de partes calcáreas, alternadas con nudos córneos **F. Isididae** (*Isidiella elongata*)
– Eje córneo, más o menos flexible **(2)**

2- Escleritos irregulares en escama y en flecha; colonia con ramificación pennada, pólipos en verticilos; escleritos **F. Primnoidae** (*Callogorgia verticillata*)
– Escleritos de forma diferente; colonias con ramificación diferente **(3)**

3- Colonia ramificada en todas las direcciones, con ramas finas a menudo hacia abajo; color rojo ladrillo, anaranjado o amarillo **F. Gorgonidae** (*Leptogorgia sarmentosa*)
– Colonia con ramificación diferente o poco ramificada, normalmente en un plano **(4)**

4- Colonia poco ramificada, ramas largas y dirigidas hacia lo alto; escleritos en doble maza rugosos; colonia rojiza **F. Ellisellidae** (*Ellisella paraplexauroides*)
– Sin los caracteres anteriores en conjunto **(5)**

5- Colonias con la superficie rugosa y con grandes escleritos (fusiformes, estrellados, rugosos) **F. Paramuriceidae** (*Paramuricea clavata*)
– Colonias con la superficie lisa, finamente granulada y con escleritos pequeños (algunos mazudos) **F. Plexauridae** (*Eunicella*) **(6)**

6- Colonias poco ramificadas y ramas dirigidas hacia lo alto; color blanco, grisáceo o verdoso *Eunicella singularis*
– Colonias muy ramificadas **(7)**

7- Color generalmente blanco; ramas terminales finas *Eunicella verrucosa*
– Color amarillento oscuro; ramas terminales cilíndricas *Eunicella cavolini*

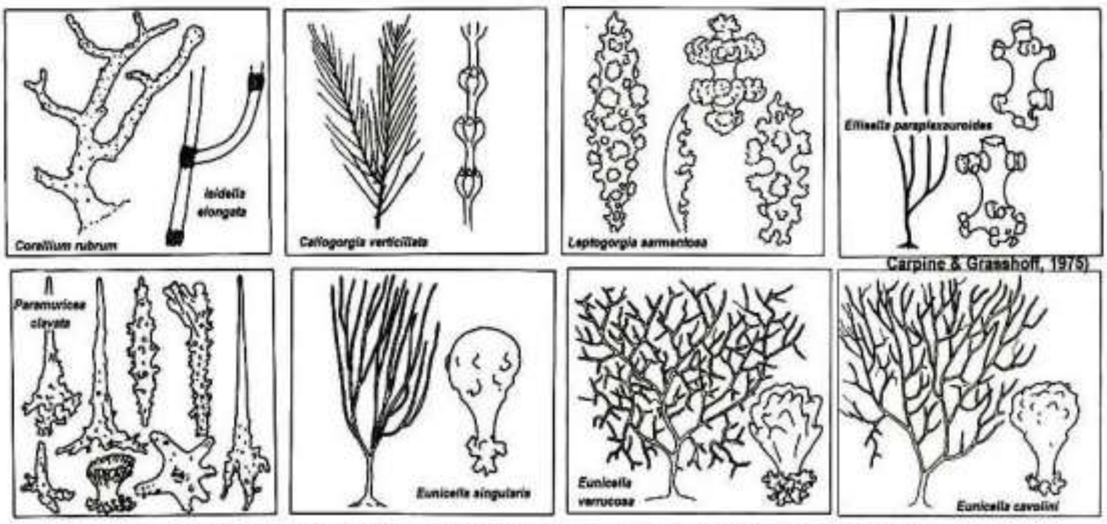


Figura 2.3. Especies de gorgonias en el Mediterráneo Ibérico.

6. BRYOZOA

Los briozoos (o animales "musgo") son lofoforados (corona de tentáculos) que forman colonias de diversas formas (Fig. 6.1) y con individuos o zooides constituidos por dos partes: el cistido o caparazón (calcáreo, quitinoso o córneo) y el pólipo' (cuerpo con los tentáculos) que se retrae en el anterior. Los cistidos tienen un importante valor taxonómico, aparte de su constitución, pueden presentar formas cilindrica, vesicular y de caja (Fig. 6.2).

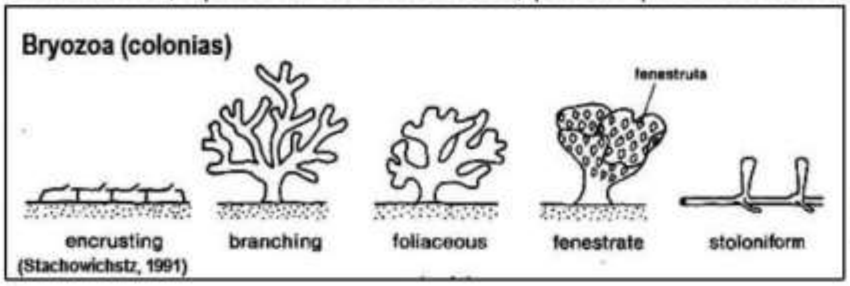


Figura 6.1. Formas de colonias de briozoos

Clasificación de Bryozoa marinos (Ordenes y Subórdenes)

1- Colonias calcificadas

- Zooides tubulares (totalmente calcificados), con abertura siempre terminal: **O. Cyclostomatida**
- Zooides no tubulares, normalmente aplastados y con forma de caja, abertura no terminal **O. Cheilostomatida**
  - La pared frontal del zooide es membranosa **Suborden Anasca**
  - La pared frontal está calcificada **Suborden Ascophora**

2- Colonias no calcificadas, zooides tubulares o vesiculares con abertura terminal **O. Ctenostomatida**

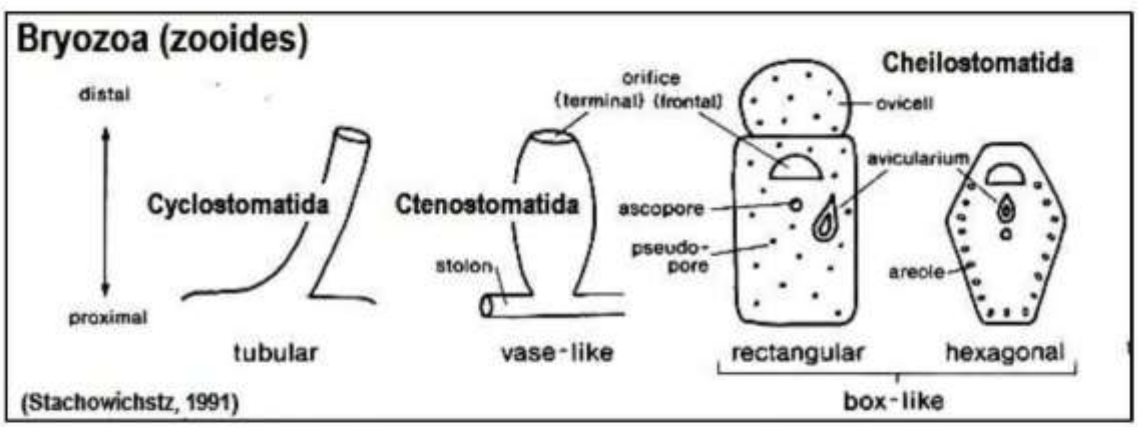


Figura 6.2. Formas y partes de los zooides de Bryozoa

8. CHORDATA: ASCIDIACEA

Las ascidias presentan dos tipos de organización: colonial y solitaria (Fig. 8.1). Las coloniales presentan diversas formas: estoloniales, incrustantes, masivas, pedunculadas (fig. 13) y están formadas por zooides rodeados por la túnica. Algunas familias presentan espículas calcáreas en estrella (Didemnidae) o en disco (Polycitoridae).

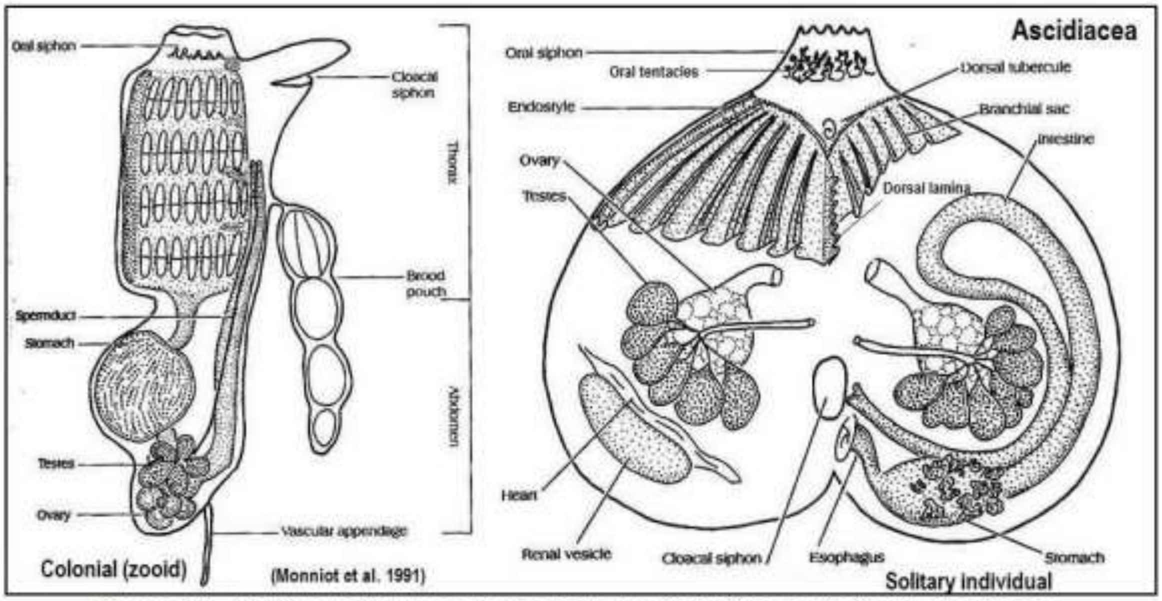


Figura 8.1. Morfología interna de un zoide y un individuo solitario de Ascidiacea.

Clasificación de Ascidiacea (Ordenes y Familias)

1- Ascidia colonial; cuerpo dividido en 2 o 3 regiones **Orden Aplousobranchia (3)**

– Ascidia, normalmente, solitaria (algunas coloniales); cuerpo en forma de saco **(2)**

2- Ascidia solitaria; branquia sin pliegues sólo con senos longitudinales. **O. Phlebobranchia**

– Ascidia solitaria o colonial; branquia con pliegues longitudinales **O. Stolidobranchia**

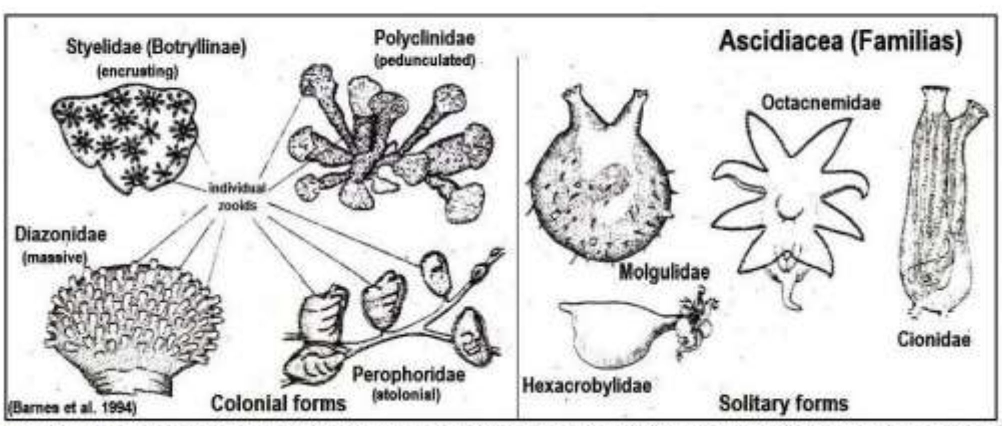
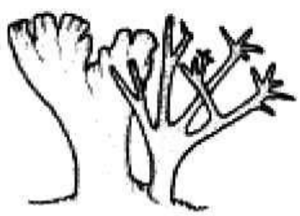


Figura 8.2. Formas de colonias e individuos solitarios de Ascidiacea (Familias)

GUÍA DE IDENTIFICACIÓN

Cálices con septos presentes, esqueleto sin verrugas redondeadas.
Clase **Anthozoa** (Orden **Scleractinia**). (**4**)

1.
- Cálices con septos presentes, esqueleto sin verrugas redondeadas. Clase **Anthozoa** (Orden **Scleractinia**) (**4**)
- Cálices sin septos, esqueleto con verrugas redondeadas. Clase **Hydrozoa** (Hidrocorales) (**2,3**)



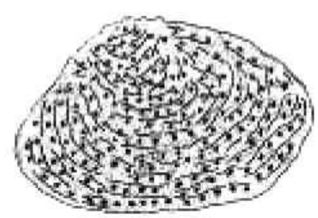
2. Cálices ausentes, esqueleto con pequeños poros (< 1mm), dispuestos al azar. ***Millepora***

3. Esqueleto con poros dispuestos en forma de cálices, verrugas redondeadas y embebidas sobre el esqueleto ***Stylaster***

4. Forma del corallum
Orden Scleractinia
Clase Anthozoa

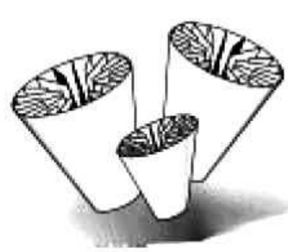
4a. Colonias ramificadas en uno o varios planos. (**5**)

4b. Colonias masivas, hemiesféricas o en forma de colina (**11**)

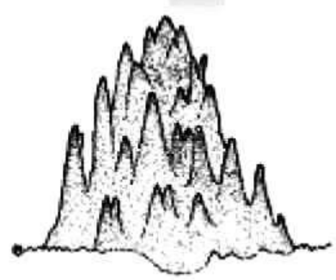


4c. Colonias en forma de plato o incrustantes (**22**)

4d. Corales solitarios, cónicos o cilíndricos, libres o fijos. (**24**)

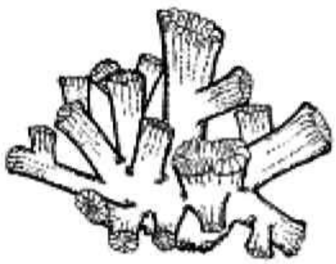


4e. Coral pseudocolonial, pólipos unidos por la base. en una matriz común o a un coralito parental (**32**)

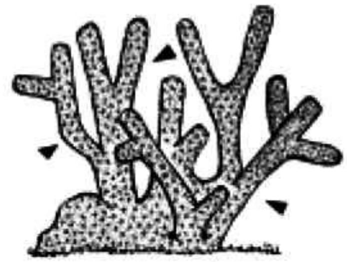


4f. Coral en forma de pilares: ***Dendrogyra cylindrus***

5. Colonias ramificadas en uno o varios planos
Posición de los cálices en las ramas

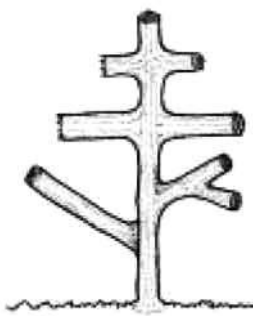


5a. Colonias con los cálices en los extremos de las ramas **(6)**

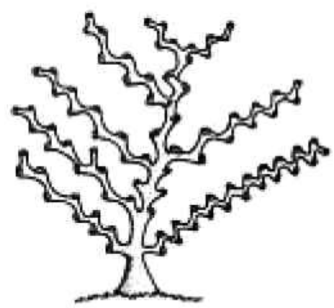


5b. Colonias con los cálices en toda la superficie de las ramas **(7)**

6. Colonia con los cálices en los extremos de las ramas
Tamaño de los cálices, diámetro sobre el eje mayor

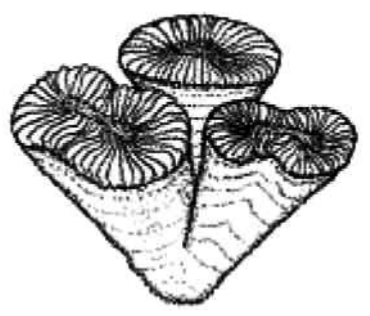


6a. Colonias con cálices <5mm y ramificaciones en ángulo recto: ***Cladocora***



6b. Colonias con cálices <5mm y ramificaciones en zig-zag: ***Madrepora***

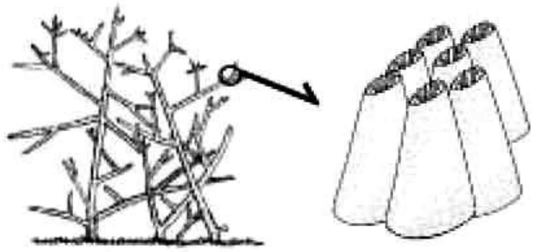
6c. Colonias con cálices medianos (2cm): ***Eusmilia fastigiata***



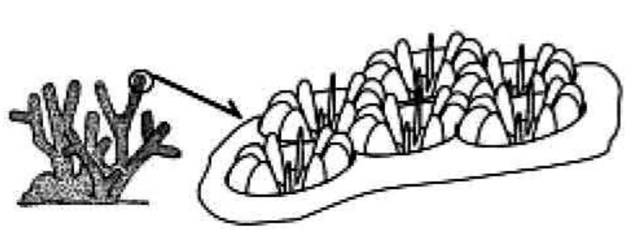
6d. Colonias con cálices grandes (>4cm) sobre el eje mayor ***Mussa angulosa***

7. Colonias con los cálices sobre la superficie de las ramas

Posición de los cálices con respecto a la matriz del esqueleto



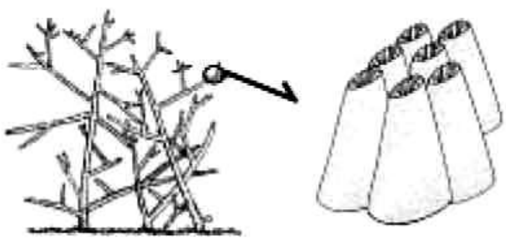
7a. Cálices sobresalen de la matriz del esqueleto **(8)**



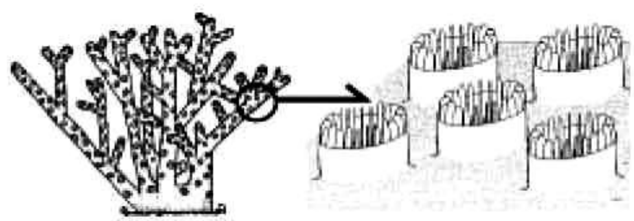
7b. Cálices embebidos en la matriz del esqueleto **(9)**

8. Colonias con los cálices sobresaliendo de la matriz del esqueleto

Distancia entre los cálices



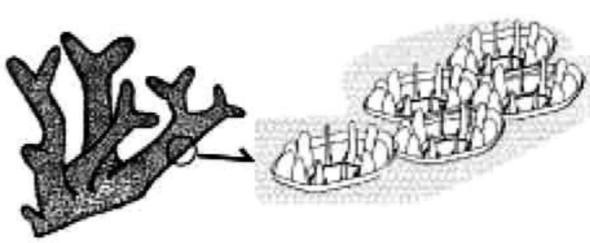
8a. Espacio entre cálices muy reducido, casi ausente: ***Acropora***



8b. Espacio entre cálices relativamente amplio: ***Oculina***

9. Cálices embebidos en la matriz del esqueleto.

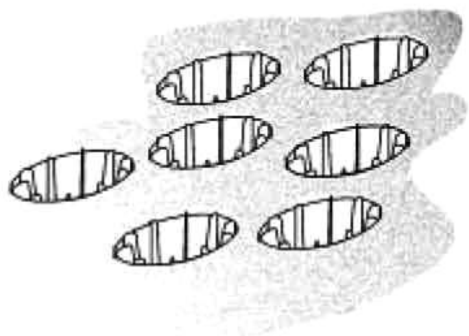
Grado de calcificación del esqueleto



9a. Esqueleto poroso: ***Porites***

9b. Esqueleto sólido. **(10)**

10. Esqueleto solido
Desarrollo de los septos

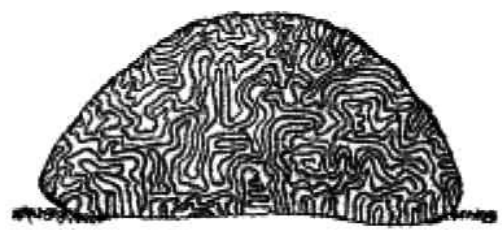


10a. Septos reducidos no proyectados: ***Pocillopora***

10b. Septos desarrollados y proyectados de la matriz del esqueleto: ***Madracis***

11. Colonias hemisféricas o en forma de colina
Cálices individuales o en meandros

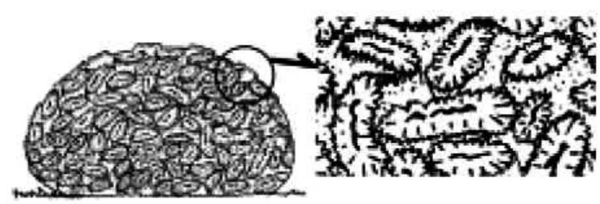
11a. Colonias con cálices definidos, circulares, irregulares o elípticos **(12)**



11b. Colonias con cálices sin límites definidos, dispuestos en series o formando meandros **(19)**

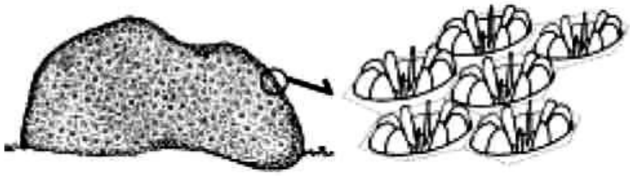
12. Colonias con cálices definidos
Forma del contorno de los cálices: circular, elíptico o irregular

12a. Colonias con los cálices redondeados **(13)**



12b. Colonias con los cálices elípticos o irregulares **(18)**

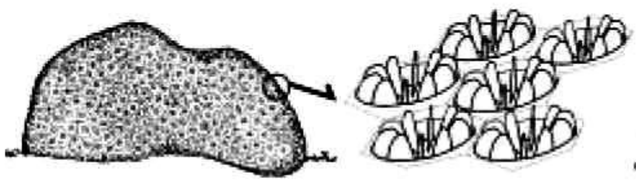
13. Colonias con los cálices redondeados
Posición de los cálices con respecto a la matriz del esqueleto



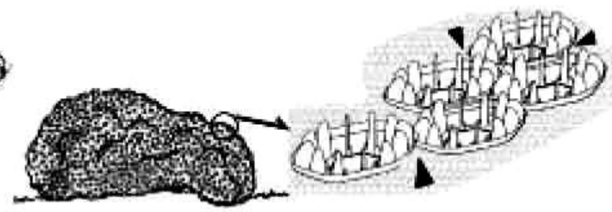
13a. Colonias con los cálices embebidos en la matriz del esqueleto **(14)**

13b. Colonias con los cálices proyectados de la matriz del esqueleto **(17)**

14. Cálices embebidos
Espacio entre cálices

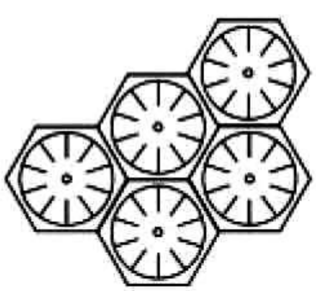


14a. Espacio entre cálices relativamente amplio **(15)**

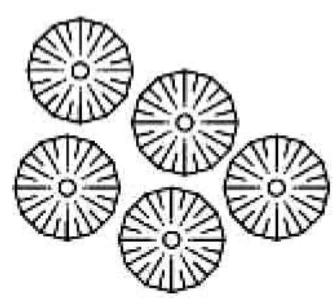


14b. Espacio entre cálices reducido o ausente **(16)**

15. Espacio entre cálices relativamente amplio
Número de septos por cálice

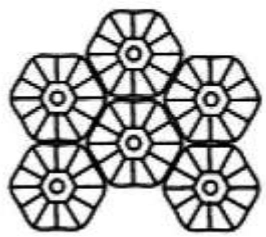


15a. Cálices hasta 12 septos: ***Madracis***



15b. Cálices con 24 septos, lóbulos presentes: ***Stephanocoenia***

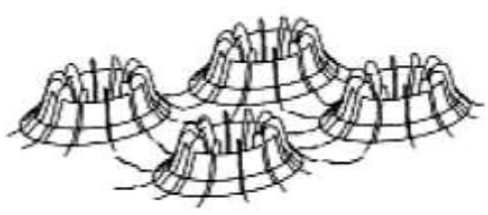
16. Espacio entre cálices reducido o ausente
Número de septos por cálice y diámetro del cálice



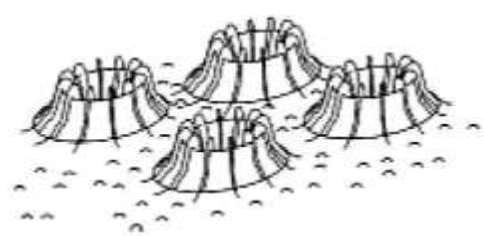
16a. Cálices (<2mm) hasta con 12 septos: ***Porites***

16b. Cálices (>2,5mm) con más de 30 septos: ***Siderastrea***

17. Colonias con cálices proyectados de la matriz del esqueleto
Ornamentación del espacio entre cálices

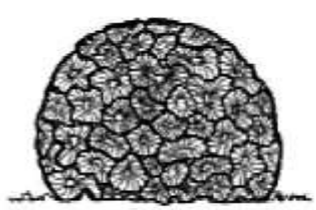


17a. Espacio entre cálices con estrías que se prolongan desde los septos, usualmente conectando los cálices entre sí: ***Monastrea***

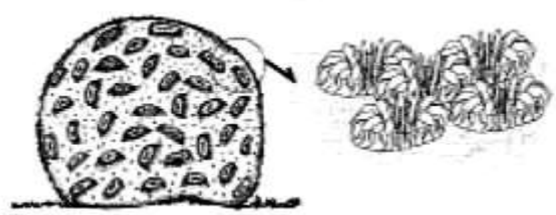


17b. Espacio entre cálices con pequeñas protuberancias a manera de vesículas ***Solenastrea***

18. Colonias con los cálices elípticos o irregulares
Forma del borde interno de los septos



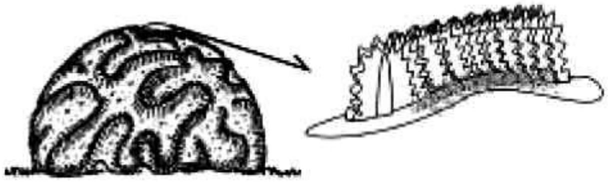
18a. Cálices embebidos en la matriz del esqueleto y con septos dentados: ***Isophyllastrea rigida***



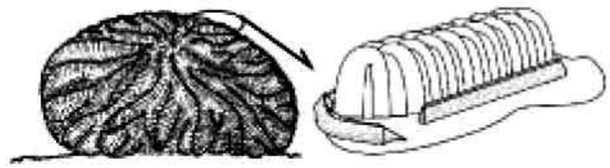
18b. Cálices proyectados de la matriz del esqueleto, septos dentados: ***Favia fragum***

18c. Colonias con cálices elípticos o alargados, proyectados de la matriz del esqueleto y septos lisos: ***Dichocoenia stokesi***

19. Colonias con cálices no definidos dispuestos en series formando meandros
Forma del borde de los septos



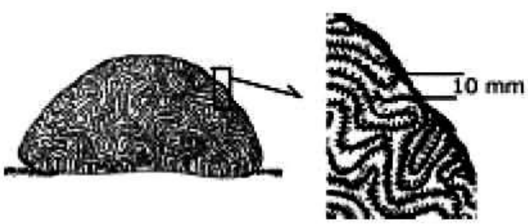
19a. Colonias con septos provistos de dientes prominentes: ***Isophyllia sinuosa***



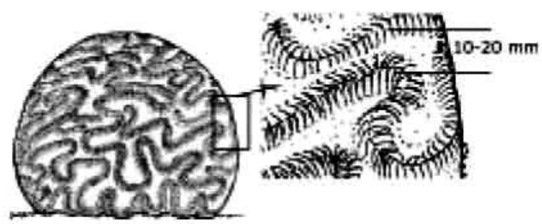
19b. Colonias con septos completamente lisos: ***Meandrina meandrites***

19c. Colonias con septos finamente aserrados. **(20)**

20. Colonias con septos finamente aserrados
Ancho de los valles

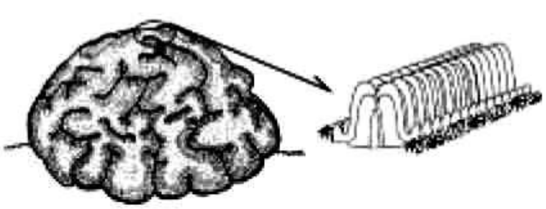


20a. Valles relativamente delgados (<10mm ancho): ***Diploria***

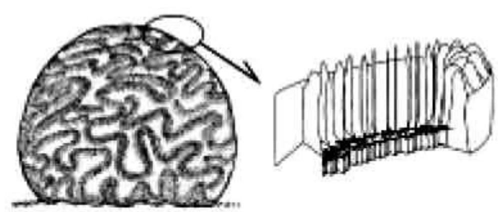


20b. Colonias con los valles relativamente anchos (10-20cm). **(21)**

21. Valles relativamente anchos
Número de septos por centímetro



21a. Colonias con 12 a 24 septos/cm: ***Manicina***



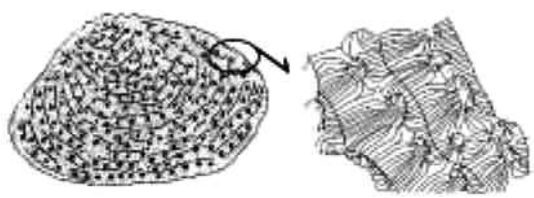
21b. Colonias que presentan <12 septos/cm: ***Colpophylla***

22. Colonias en forma de platos o incrustantes
Alineación y tamaño de los cálices, textura de los septos

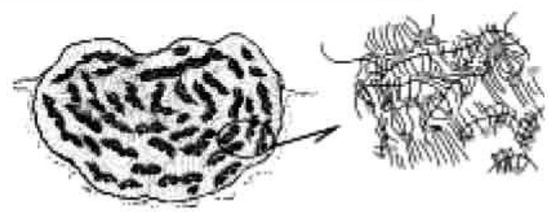
22a. Colonias con cálices pequeños <10mm. (**23**)

22b. Colonias con cálices relativamente grandes (>10mm). Septos con dientes desarrollados: ***Mycetophyllia***

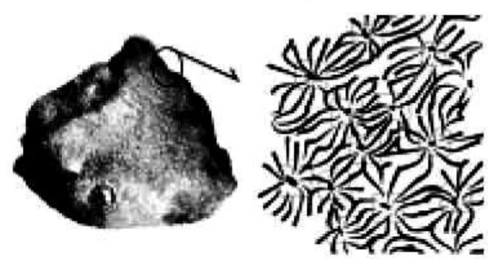
23. Colonias con cálices pequeños, menores de 10 mm de diámetro. Septos lisos
Diferenciación de los cálices



23a. Colonias con los cálices perfectamente delimitados y embebidos completamente en la matriz del esqueleto. Colinas desarrolladas: ***Agaricia***

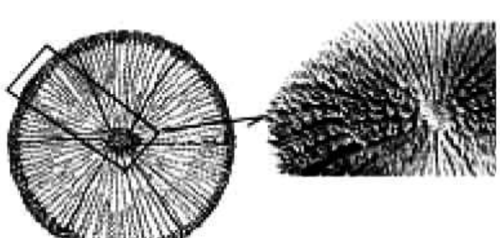


23b. Colonias con los cálices perfectamente delimitados, unidos a la matriz de esqueleto lateralmente. Colinas desarrolldas: ***Helioseris***

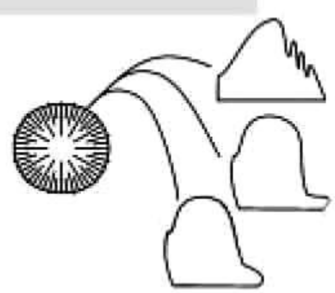


23c. Colonias con cálices no muy bien definidos, embebidos en la matriz del esqueleto. Colinas poco desarolladas o discontinuas ***Pavona***

24. Corales solitarios, cónicos o cilíndricos, libres o fijos
Ornamentación de los septos

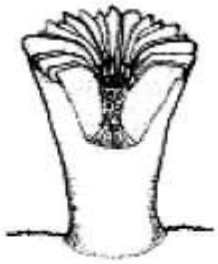


24a. Corales con septos provistos de dientes prominentes prominentes ***Scolymia***

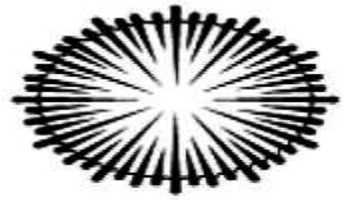


24b. Corales con el borde de los septos liso, finamente aserrado o dividido en lóbulos. (**25**)

25. Corales con el borde los septos liso, finamente aserrado o dividido en lóbulos
Desarrollo de la columnela

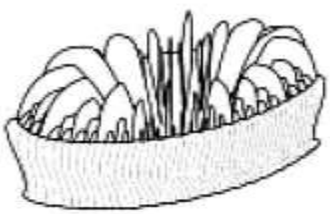


25a. Corales con la columnella desarrollada. **(26)**



25b. Corales con la columnella vestigial o ausente. **(30)**

26. Corales con la columnela desarrollada
Forma del coral

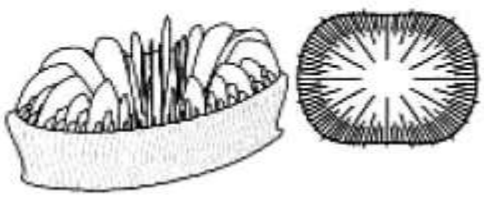


26a. Corales cilíndricos. **(27)**

26b. Corales en forma de copa. **(28)**

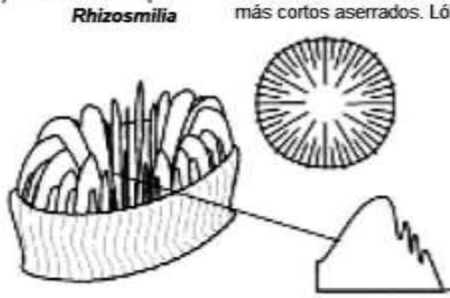
26c. Corales con base plana o cónica, no anclados al substrato. **(29)**

27. Corales cilíndricos
Número de ciclos, forma del borde del septo, tipo de lóbulos



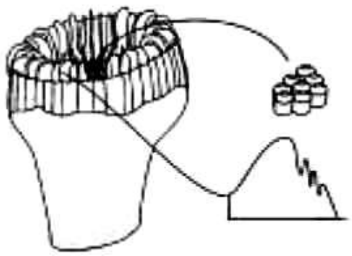
27a. Corales con 5 ciclos de septos (96 septos). Borde de los septos lisos. Lóbulos no divididos: ***Rhizosmilia***

27b. Corales con 4 ciclos de septos (48 septos), borde de los septos más cortos aserrados. Lóbulos no divididos: ***Colangia***

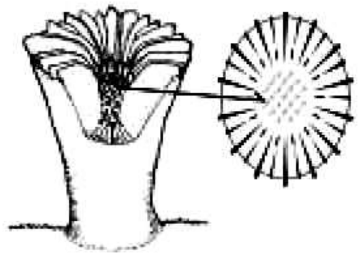


27c. Corales con 4 ciclos (48 septos), borde de los septos aserrado. Lóbulos divididos: ***Astrangia***

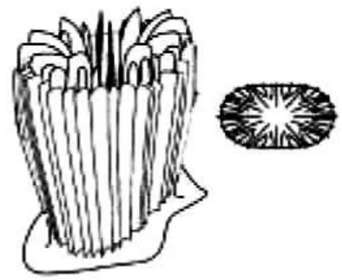
28. Corales en forma de copa
Estructura del esqueleto, forma de los elementos de la columnela



28a. Corales con el esqueleto sólido. Septos con lólbulos divididos.Columnela con elementos en forma de bastones; ***Paracyathus***

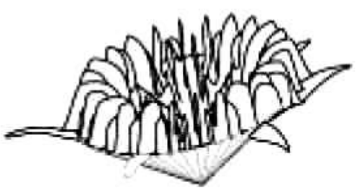


28b. Corales con el esqueleto sólido. Septos con lóbulos completos. Elementos de la columnela en forma de cintas: ***Caryophyllia***

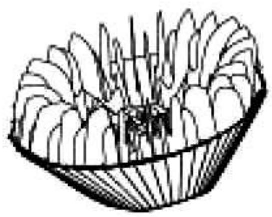


28c. Corales con esqueleto poroso, con o sin lóbulos. Columnella con elementos arremolinados: ***Balanophyllia***

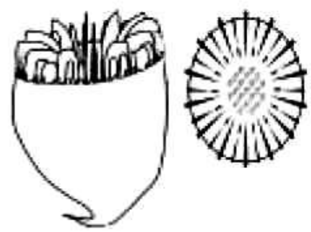
29. Corales con base plana o cónica, no anclados al sustrato
Forma de la base



29a. Corales con la base cónica, terminada en punta: ***Deltocyathus***



29b. Corales con la base plana o un poco curva a modo de taza: ***Stephanocyathus***



29c. Corales con la base cónica terminada en una punta fina que se encuentra doblada alrededor de 90º con respecto al cálice: ***Caryophyllia***

30. Corales con la columnela vestigial o ausente
Forma de vida

30a. Corales anclados a un substrato. **(31)**

30b. Corales de vida libre: ***Flabellum***

31. Corales anclados a un sustrato
Coloración del esqueleto

31a. Corales con el esqueleto blanco: ***Javania***

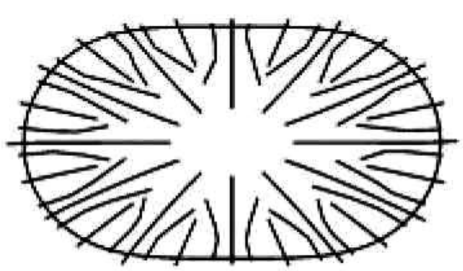
31b. Corales con el esqueleto rojizo: ***Polymyces***

32. Corales pseudocoloniales, pólipos unidos por la base en una matriz común o con un coralite parental
Grado de calcificación del esqueleto.

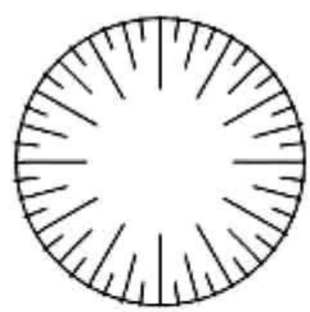
32a. Corales con el esqueleto poroso. **(33)**

32b. Corales con el esqueleto sólido. **(34)**

33. Corales con el esqueleto poroso
Disposición de los septos

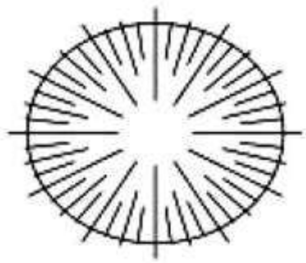


33a. Coralito ovalado, septos rectos y doblados: ***Balanophyllia*** o ***Rhizopsammia***

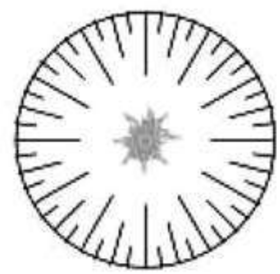


33b. Coralito circular, septos rectos: ***Tubastrea***

34. Corales con el esqueleto compacto
Desarrollo de la columnela

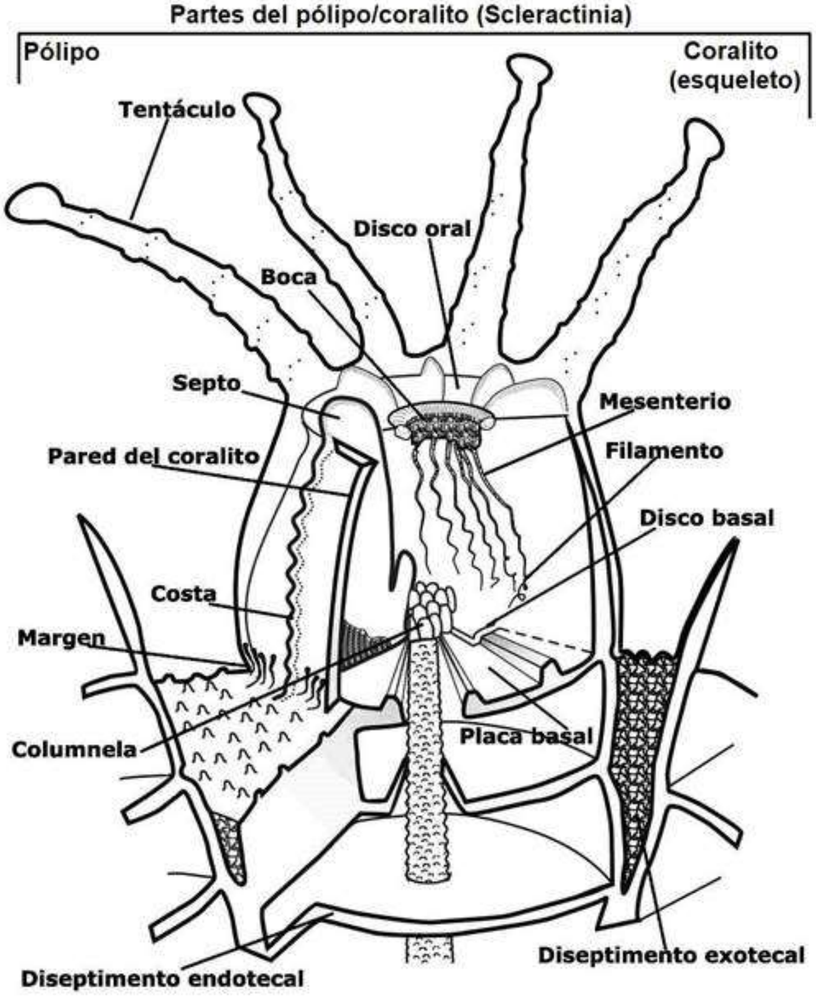


34a. Corales sin columnella: ***Thalamophyllia***



34b. Corales con columnela: ***Anomocora***

Partes del pólipo/coralito (Scleractinia)



PLAN DE FORMACIÓN DESTINADO A ADMINISTRACIONES PÚBLICAS COMPETENTES EN LA GESTION DE LA RED NATURA 2000 MARINA EN EL MARCO DEL PLAN DE RECUPERACIÓN, TRANSFORMACIÓN Y RESILIENCIA

(2022-2025)

CURSO "IDENTIFICACIÓN Y DISTINCIÓN DE ESPECIES MARINAS VULNERABLES DE OTRAS ESPECIES SIMILARES DE INTERÉS PESQUERO U OBJETO DE INFRACCIÓN"

MÓDULO PRÁCTICO
Identificación de especies de *visu*

SESIÓN 3: Moluscos, crustáceos / equinodermos

Responsables: Yolanda Fernández Torquemada / Alfonso A. Ramos Esplá

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Looking for morphological evidence of cryptic species in *Asterina* Nardo, 1834 (Echinodermata: Asteroidea). The redescription of *Asterina pancerii* (Gasco, 1870) and the description of two new species

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Abstract. Three species of the genus *Asterina* are known to inhabit the Mediterranean Sea and the north-eastern Atlantic Ocean: *Asterina gibbosa* (Pennant, 1777), *A. pancerii* (Gasco, 1870) and *A. phylactica* Emson & Crump, 1979. Differentiation of these species has primarily been based only on subtle characters (some highly debatable), such as colour or size. Therefore, this study aimed to review the morphological data characterising members of the genus, to incorporate new characters that may clarify morphological analyses and to couple morphological data with molecular evidence of differentiation based on the analysis of partial sequences of the cytochrome *c* oxidase subunit I (COI) and 18S rDNA (18S) genes and two anonymous nuclear loci (AgX2 and AgX5). The different lineages and cryptic species identified from the molecular analysis were then morphologically characterised, which was challenging given the limited number of diagnostic characters. Two of the five monophyletic lineages obtained molecularly (COI divergence >4%), further supported by differences in morphological characters and reproductive behaviour, are proposed as new species: *Asterina martinbarriosi*, sp. nov. from the Canary Islands, Spain (eastern central Atlantic Ocean) and *Asterina vicentae*, sp. nov. from Tarragona, north-eastern Spain (western Mediterranean Sea).

Keywords: Asteroidea, mitochondrial DNA, morphology, nuclear DNA.

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Introduction

Speciation in marine invertebrates can occur with little obvious morphological variation among divergent lineages (Palumbi 1992; Knowlton 1993, 2000; Bickford *et al*. 2007). Therefore, species characterisations increasingly rely on molecular techniques when morphological diagnostic characters are lacking. The presence of long-undetected cryptic macrofaunal species has been recently demonstrated for sea star taxa, resulting in new species descriptions based on differences in reproductive and molecular characters (Hart *et al*. 1997; Williams 2000; Flowers and Foltz 2001; Hart *et al*. 2003).

Members of Asterinidae have broad distributions and mainly live in shallow-water communities (Clark and Downey 1992; Waters *et al*. 2004). In 2004, a major morphological and molecular revision of asterinid genera by O'Loughlin and Waters ascribed new genera and species to the family (O'Loughlin and Waters 2004; O'Loughlin and Rowe 2005, 2006). Subsequently, Mah and Blake (2012) recognised 25 genera and 147 asterinid species worldwide.

The genus *Asterina* is currently restricted to a monophyletic group of seven known species: *A. gibbosa* (Pennant, 1777), from the north-eastern Atlantic and Mediterranean Sea; *A. fimbriata* Perrier, 1875, from the south-western Atlantic; *A. pancerii* (Gasco, 1870), endemic to the Mediterranean Sea; *A. phylactica* Emson & Crump, 1979, from European coasts (Vicent *et al*. 2004); *A. stellifera* (Möbius, 1859), from the tropical Atlantic, and *A. gracilispina* Clark, 1923 and *A. hoensonae* (O'Loughlin, 2009), both endemic to South Africa. Species belonging to this genus are small starfishes typically pentagonal or subpentagonal in shape, with convex abactinal and flat actinal surfaces.

A proper taxonomic description of *Asterina* species is difficult given the remarkable similarity and simplicity displayed among species, thus limiting the number of potentially informative morphological characters. In this study, we focus on the known species from the Mediterranean Sea and north-eastern Atlantic Ocean that have overlapping geographic ranges, namely *A. gibbosa*, *A. pancerii* and

*These authors contributed equally to this study.

A. phylactica. These species are very similar and have been distinguished mainly by ambiguous characters such as size, colour or habitat distribution (although sympatric populations of *A. gibbosa* and *A. phylactica* do exist). Tortonese (1965) differentiated *A. pancerii* from *A. gibbosa* primarily on the number of dental plate spines, while Clark and Downey (1992) distinguished these species by shape, skeletal plates and suboral spines. However, according to O'Loughlin and Waters (2004), these two species are likely conspecific, a hypothesis also shared by Tanti and Schembri (2006), who found intermediate characteristics in specimens from Malta. Given the apparently high level of intraspecific variation, new independent evidence is needed to determine whether *A. gibbosa* and *A. pancerii* are distinct species or a single variable species. Differences in reproductive strategies and life histories differentiate *A. gibbosa* from *A. phylactica*, while morphological differences between these two species are limited to size and pigmentation.

Because the *Asterina* species studied here lack a pelagic larval phase (instead producing benthic egg masses from which newly metamorphosed crawling juveniles hatch) (Emson and Crump 1976, 1979), genetic isolation between populations and geographic areas, leading to possible speciation, is hypothesised. A system of species complexes or cryptic entities may also be involved.

The main aim of this study was to independently test the validity of these species, first molecularly, then, once specific genetic differences have been identified, by an '*a posteriori*' comparative morphological study for phenotypic characters that differentiate monophyletic clades (Blanquer and Uriz 2008), thus synergising approaches (Schlick-Steiner *et al*. 2007). The ultimate goals were to identify stable and repetitive features that morphologically characterise the species of this genus and to assess the homoplasy of previously used morphological or ecological characters compared with molecular data. To do this, we examined the original species descriptions, and then, in light of the molecular analysis, added new morphological information from different representative populations along the distribution range. This study included, when available, the holotypes or neotypes of previously described species. The comparative morphological study focussed mainly on characters considered the most useful for taxonomic differentiation among members of this family (O'Loughlin and Waters 2004), such as the occurrence of pedicellariae and the alignment of the abactinal ray plates.

Materials and methods

Sampling sea stars

Specimens were collected between 2004 and 2011 from several localities throughout the Mediterranean Sea and north-eastern Atlantic Ocean (Table 1). Specimens were collected from under boulders and stones in the intertidal zone or along shallow rocky bottoms, and on seagrass meadows of *Posidonia oceanica* (Linnaeus) Delile, 1813 and *Cymodocea nodosa* (Ucria) Ascherson, 1870. Samples were preserved in absolute ethanol at 4°C until analysed. Voucher material was deposited at the Museo Nacional de Ciencias Naturales (MNCN) in Madrid, Spain.

Samples from the collections of the Museo Civico di Storia Naturale 'Giacomo Doria' (Genova, Italy) and the Natural History Museum (London, UK), including the neotype of *Asterina pancerii* [C.E 38096] and the holotype of *Asterina phylactica* [No. 1977.11.3.1], were also studied.

Molecular study

Genomic DNA extraction

Fifteen specimens of *Asterina* spp. from 10 localities were used for DNA extraction and barcoding. DNA was extracted from two or three tube feet per specimen. Tube feet were digested with 180 µL of ATL buffer and 20 µL of proteinase K (Qiagen, Hilden, Germany) at 56°C overnight in the dark, with gentle agitation. DNA was then purified using the Qiagen BioSprint 15 DNA Blood Kit, according to the manufacturer's protocol for tissues. DNA was eluted in 200 µL of AE buffer (10 mM Tris-HCl, 0.5 mM EDTA; pH 9.0). DNA quality and quantity were checked by gel electrophoresis and a Nanodrop ND-1000 spectrophotometer (Thermo Fisher Scientific, Wilmington, USA).

PCR amplification and sequencing

A 945 base pair (bp) fragment of the cytochrome *c* oxidase subunit I (COI) gene was amplified using newly designed forward and reverse primers Ag-COI-F2 and Ag-COI-R, which corresponds to base pairs 12163 to 13107 of the complete mitochondrial genome of *Patiria pectinifera* (GenBank accession no. D16387: Asakawa *et al*. 1995). These primers were combined with the internal primers Ag-COI-Fint or Ag-COI-Rint, when necessary. All primer sequences and combinations used are detailed in Table 2. PCR amplifications were performed in a final volume of 50 µL with 1X reaction buffer (75 mM Tris-HCl, pH 9.0; 2 mM $MgCl_2$; 50 mM KCl; 20 mM $(NH4)_2SO_4$), 0.2 mM of each dNTP (Biotools), 0.25 µM of each primer, 1.25 U Biotools DNA Polymerase (Biotools) and 2 µL of DNA (0.25 ng μL^{-1}). The thermal cycling profile was 94°C for 4 min, followed by 40 cycles at 94°C for 45 s, 46°C for 1 min, and 72°C for 1 min and a final elongation step at 72°C for 10 min. All PCR products were checked on 0.8% agarose gels stained with SYBR Safe (Invitrogen). The amplified PCR products were purified using a standard sodium acetate/absolute ethanol precipitation method (Sambrook *et al*. 1989).

For the type material, it was necessary to design new internal primers (Ag-COI-R2, Ag-COI-F3, Ag-COI-R3, Ag-COI-F4, Ag-COI-R4, Ag-COI-F5 and Ag-COI-R5) (see Table 2 for primer combinations). PCR conditions and the cycling profile were as described above, except an annealing temperature of 48°C was used. Due to the minute amount and quality of DNA obtained, PCR products were cloned into the pGEM-T Easy vector (Promega), according to a TA cloning protocol. Briefly, purified PCR products were ligated into the pGEM-T vector (Promega) and transformed into One Shot TOP10 chemically competent *Escherichia coli* cells (Invitrogen). Recombinant colonies were identified by blue/white screening. Positive clones were sequenced with M13 primers using the conditions described above.

For the nuclear 18S rRNA gene, 733 bp were amplified using the newly designed forward and reverse primers Ag-18S-F

Table 1. Localities and examined material

	Latitude	Longitude	Codes of specimens analysed
A. gibbosa			
A Guarda, Pontevedra	41°53′49.25″N	8°52′46.43″W	Ag0461
Avencas, Cascais	38°41′7.81″N	9°21′19.61″W	Ag0586–0587
La Santa, Lanzarote	29°6′56.49″N	13°39′39.97″W	Ag0013–0018, Ag0020–0023
Laredo, Cantabria	43°25′3.00″N	3°24′39.60″W	Ag0617
O Grove, Pontevedra	42°27′37.25″N	8°54′54.83″W	Ag0034–0052, Ag0353–0354, Ag0525–0528
Pontevedra	42°25′16.28″N	8°40′6.04″W	Ag1002–1005
Pto Cruz, Fuerteventura	28°4′0.90″N	14°30′18.70″W	Ag0578, Ag0581
Carnicería, Fuerteventura	28°4′38.46″N	14°28′55.60″W	Ag0670
Agua Amarga, Almería	36°56′17.42″N	1°55′54.97″W	Ag0727
Benalmádena, Málaga	36°35′36.00″N	4°30′60.00″W	Ag0383
El Mojón, Alicante-Murcia	37°50′57.40″N	0°45′41.35″W	Ag0059–0060
Congreso, Chafarinas	35°10′29.69″N	2°26′19.78″W	Ag0054
Isabel II, Chafarinas	35°10′54.56″N	2°25′37.09″W	Ag1011
Aruta Island, Sardinia	39°54′37.47″N	8°23′52.63″E	Ag1042–1044
Los Escullos, Almería	36°47′45.23″N	2°3′43.93″W	Ag0542–0546
Naples	40°47′36.76″N	14°11′46.88″E	Ag0517
Pinarellu, Corsica	41°40′10.90″N	9°22′58.03″E	Ag0465
Pollensa, Mallorca	39°54′21.50″N	3°6′21.70″E	Ag0148–0175
Prawle Point, Devon	50°12′30.07″N	3°46′56.97″W	Ag0468
Cesareo, Gulf of Taranto	40°15′18.75″N	17°53′43.25″E	Ag0845–0846
Galatxo, Tarragona	40°35′11.9″N	0°37′20.0″E	Ag0549
Putzu Iddu, Sardinia	40°1′25.16″N	8°24′24.95″E	Ag1046
Tiboûda, Cape Three Forks	35°25′24.16″N	2°57′9.74″W	Ag1006
Barbate, Cádiz	36°10′60.00″N	5°56′54.00″W	Ag0375–0376
Benzú, Ceuta	35°55′2.20″N	5°22′23.08″W	Ag1035–1040
Tarifa, Cádiz	36°0′6.66″N	5°36′27.42″W	Ag0368
San García, Cádiz	36°6′17.40″N	5°25′50.46″W	Ag0390–0391
A. martinbarriosi, sp. nov.			
Bajío el Apio, Tenerife	28°31′40.74″N	16°24′30.20″W	Ag1013–1018
La Santa, Lanzarote	29°6′56.49″N	13°39′39.97″W	Ag0019
Las Barranqueras, Tenerife	28°32′16.33″N	16°23′52.90″W	Ag0849
Pto Güímar, Tenerife	28°17′43.87″N	16°22′20.41″W	Ag0009–0011, Ag0075–0078, Ag0213–0217, Ag0369
Socorro Güímar, Tenerife	28°19′16.23″N	16°21′35.88″W	Ag0005
A. pancerii			
Bacoli, Naples	40°47′29.15″N	14°5′13.66″E	Ag1132[A]
Moraira, Alicante	38°41′9.58″N	0°8′43.63″E	Ag0218–0223
A. phylactica			
Prawle Point, Devon	50°12′30.07″N	3°46′56.97″W	Ag0492, Ag0496, Ag0498, Ag0508–0510
West Angle Bay, Dyfed	51°41′41.31″N	5°5′58.84″W	Ag1155[B]
El Calón, Almería	37°18′56.87″N	1°42′5.88″W	Ag0255–0258
Alborán, Almería	35°56′54.82″N	3°2′0.96″W	Ag0513
Medas, Girona	42°2′42.53″N	3°13′27.84″E	Ag0224, Ag0226–0228, Ag0230, Ag0232–0244
San García, Cádiz	36°6′17.40″N	5°25′50.46″W	Ag0407
A. vicentae, sp. nov.			
Galatxo, Tarragona	40°35′11.9″N	0°37′20.0″E	Ag0547–0548
Trabucador, Tarragona	40°37′44.4″N	0°44′21.2″E	Ag0550
A. stellifera			
Rio de Janeiro	22°52′56.45″S[C]	42°0′12.16″W[C]	
Rio de Janeiro	22°52′56.45″S[C]	42°0′12.16″W[C]	Ag1158
Montevideo, Uruguay	–	–	Ag1173
P. miniata			
Monterey, California	36°37′15″N	121°54′16″W	Ag1174

[A]Neotype of *Asterina pancerii.*
[B]Holotype of *Asterina phylactica.*
[C]Approximate geographical coordinates.

Table 2. Primers used in this study

Mitochondrial primer pairs: Ag-COI-F2+Ag-COI-R were used to amplify a 945-bp fragment of COI. Alternatively, this DNA region was amplified in two rounds of PCR using these primers and internal primers (Ag-COI-F2+Ag-COI-Rint and Ag-COI-Fint+AgCOI-R). The primer pairs F2/R2 to F5/R5 were used to amplify this region from the *Asterina pancerii* neotype. Nuclear primer pairs: Ag-18S-F+Ag-18S-R were used to amplify a 733-bp fragment of 18S. The other 18S primers listed were used to amplify fragments from the *Asterina pancerii* neotype and the *Asterina stellifera* specimen. For the anonymous nuclear loci, AgX2-F+AgX2R were used to amplify a 402–411-bp fragment, and AgX5-F+AgX5-R a 414–416-bp fragment. AT, annealing temperature

Primer	Sequence (5′–>3′)	AT
Mitochondrial primer pairs		
Ag-COI-F2	AATTATAAACCATGCAGCTA	46°C
Ag-COI-R	GCCATTCAKCTAAANACCTT	
Ag-COI-F2		46°C
Ag-COI-Rint	GTAGTAATAAATTTRATRGAGGC	
Ag-COI-Fint	ATATTTTCCCTTCACCTTGC	46°C
Ag-COI-R		
Ag-COI-F2		48°C
Ag-COI-R2	AGTGCGTGRGCRGTTACTA	
Ag-COI-F3	CAAGACGACCAAATTTATAA	48°C
Ag-COI-R3	AGTARAAGRAAAGARGGTGG	
Ag-COI-F4	ATGGCTTTTCCTCGAATGAAT	48°C
Ag-COI-R4	GTGAAGGGRAAATATTGCTA	
Ag-COI-F5	GCACATGCCGGAGGCTCTGT	48°C
Ag-COI-R5	CAGGRTCAAAGAAGGTNGTRTT	
Nuclear primer pairs		
Ag-18S-F	CCTGCCAGTAGTCATATGCTTG	60°C
Ag-18S-R	GCCTGCTTTGAACACTCCA	
Ag-18S-F		50°C
Ag-18S-R1	GGGTTGGTCTTGTTCCTAATAA	
Ag-18S-F2	GGATAACTGTGGTAATTCTAGAGC	50°C
Ag-18S-R2	TGATAGGGCAGACATTCG	
Ag-18S-F3	ACTCTGGATAACCTGGCCGATCG	50°C
Ag-18S-R3	GGTAGCCGTTTCTCAAGC	
Ag-18S-F4	GGAGAATCAGGGTTCGAT	50°C
Ag-18S-R4	CCAATAGATCCTCGTTAAAGG	
Ag-18S-F5.1	GACTCTTTCGAGGCCCTGTA	50°C
Ag-18S-R5.1	GCCCAAGATCCAACTACGAG	
Ag-18S-F6	CGGTAATTCCAGCTCCA	50°C
Ag-18S-R		
AgX2-F	GAATTCCGCATTTCCTGTGT	56°C
AgX2-R	AACCCGTTGTGTGATGTCAA	
AgX5-F	TAGAGAAGTTGGCGCTCACA	56°C
AgX5-R	ATCAAAAGCCCCGTGAAAAG	

and Ag-18S-R or in combination with the internal primers Ag-18S-Fint or Ag-18S-Rint (Table 2). PCR amplifications were performed in a final volume of 25 µL with 1X reaction buffer (trade secret), 0.5 µM of each primer, 1.25 U MyTaq DNA Polymerase (Bioline) and 1 µL of DNA (2 ng μL^{-1}). The thermal cycling profile was 95°C for 1 min, followed by 35 cycles at 95°C for 15 s, 60°C for 15 s, and 72°C for 30 s and a final elongation step at 72°C for 10 min. PCR products were checked on 0.8% agarose gels stained with SYBR Safe (Invitrogen). The amplified PCR products were purified using ExoSAP-It (Isogen).

New internal primers (Ag-18S-R1, Ag-18S-F2, Ag-18S-R2, Ag-18S-F3, Ag-18S-R3, Ag-18S-F4, Ag-18S-R4, Ag-18S-F5.1 Ag-18S-R5.1 and Ag-18S-F6) were necessary to amplify the type material (see Table 2 for primer combinations). PCR conditions and cycling profiles were as described above, except an annealing temperature of 50°C was used. We also amplified two anonymous nuclear loci AgX2 (402–411 bp) and AgX5 (414–416 bp). These loci were isolated from a partial genomic library previously used to identify microsatellite markers for *A. gibbosa* (Acevedo *et al*. 2009). These fragments, which lack repeat motifs, were selected and amplified using newly designed forward and reverse primers AgX2-F, AgX2-R, AgX5-F and AgX5-R (see Table 2). PCR amplifications were performed in a final volume of 50 µL with 1X reaction buffer (75 mM TRIS-HCl, pH 9.0; 2 mM $MgCl_2$; 50 mM KCl; 20 mM $(NH4)_2SO_4$), 0.2 mM of each dNTP (Biotools), 0.5 µM of each primer, 1.25 U Biotools DNA Polymerase (Biotools) and 2 µL of DNA (0.25 ng μL^{-1}). The thermal cycling profile was 94°C for 4 min, followed by 40 cycles at 94°C for 45 s, 56°C for 1 min and 72°C for 1 min and a final elongation step at 72°C for 10 min. All PCR products were checked on 0.8% agarose gels stained with SYBR Safe (Invitrogen). The amplified PCR products were purified using either a standard sodium acetate/absolute ethanol precipitation method (Sambrook *et al*. 1989) or ExoSAP-IT reagent (Isogen).

Sequencing reactions were performed using the ABI BigDye 3.1 Cycle Sequencing Kit (Applied Biosystems) and run on an ABI 3730 Genetic Analyzer.

DNA sequences were deposited in GenBank; accession numbers are listed in Table 3.

Molecular data treatment

COI, 18S, AgX2 and AgX5 consensus sequences were obtained by assembling sequences from both strands using Sequencher 4.10.1 (Gene Codes Corporation). Primer regions were trimmed and doubtful positions checked manually. No gaps were needed to align sequences for COI and 18S; however, AgX2 and AgX5 alignments required gaps. After checking the congruence between the tree topologies obtained by different molecular data, a combined matrix consisting of mitochondrial and nuclear data was analysed with PartitionFinder to determine how best to group the different genes or codon positions in COI in the final analysis. On the basis of these results, 18S and each codon partition of COI were considered independently, and AgX2 and AgX5 jointly. A final analysis by Bayesian inference, using MrBayes 3.1.2. (Huelsenbeck and Ronquist 2001), was then performed to determine phylogenetic relationships and identify independent lineages. The invgamma distribution and nst = mixed settings were applied in this analysis, which ran for 250 million generations in two parallel runs, sampling every 25 000 generations. After checking for concordance and stationarity of both runs, a 10% burn-in of retained trees was performed. Branch supports were evaluated by posterior probabilities. Maximum parsimony (MP) analysis was also performed using PAUP 4.0a140b (Swofford 2002), and a heuristic search with tree bisection and a reconnection algorithm; branch supports were tested by 1000 bootstrap replicates (Felsenstein 1985). The best-fit model for nucleotide evolution, determined using jModelTest (Posada 2008) under the Bayesian Information Criterion, was 012212+I+F. A Maximum Likelihood (ML) analysis was then performed using PhyML 3.0 (Guindon and

Table 3. GenBank accession numbers by species analysed

Species	Specimen	COI	18S	AgX2	AgX5
A. gibbosa	Ag0617	MF279276	MF279284	MF279306	MF279291
	Ag0042	MF279277	MF279285	MF279307	MF279292
	Ag0468	MF279278	MF279286	MF279308	MF279293
A. martinbarriosi, sp. nov.	Ag0010	KP768159	KX347563	MF279309	MF279294
	Ag0076	KP768161	KX347565	MF279310	MF279295
	Ag0369	MF279279	MF279287	MF279311	MF279296
A. pancerii	Ag1132[A]	KP768174	KX347575	–	–
	Ag0219	KP768172	KX347577	MF279312	MF279297
	Ag0220	KP768173	KX347578	MF279313	MF279298
	Ag0222	MF279275	MF279283	MF279314	MF279299
A. phylactica	Ag0492	KP768165	KX347569	MF279315	MF279300
	Ag0496	MF279280	MF279288	MF279316	MF279301
	Ag0513	MF279281	MF279289	MF279317	MF279302
A. vicentae, sp. nov.	Ag0547	KP768168	KX347572	MF279318	MF279303
	Ag0548	KP768169	KX347573	MF279319	MF279304
	Ag0550	KP768170	KX347574	MF279320	MF279305
A. stellifera	ASBJ2	KP768175[B]	–	–	–
	Ag1173	KX347562	KX347579	–	–
P. miniata	Ag1174	MF279282	MF279290	–	–

[A]Neotype of *Asterina pancerii.*
[B]Sequence data were provided by Harilaos A. Lessios.

Gascuel 2003). ML supports were calculated with 1000 bootstrap replicates. *Asterina stellifera* was used as a sister group and *Patiria miniata* (Brandt, 1835) as the outgroup. Uncorrected COI divergences among lineages were also calculated in PAUP.

Mesquite software was used to reconstruct the most probable ancestral character states for morphological characters, estimated through likelihood (when possible) or parsimony principles (Maddison and Maddison 2016).

To determine the number of groups (species) established on the basis of COI genetic distances and the gap between intra- and interspecific variability, divergences were tested in the web-based ABGD (Automatic Barcode Gap Definition) program (Puillandre *et al*. 2012) (http://www.abi.snv.jussieu.fr/public/abgd/abgdweb.html). A prior for the maximum percentage value of intraspecific divergence, ranging from 0.001 to 0.1, was set. Twenty recursive steps within the primary partitions were defined. As the COI sequence of the *A. pancerii* neotype was shorter (636 bp) than the other sequences (945 bp), it was necessary to remove the last 309 characters to avoid artefacts (their inclusion artificially increased divergence values in ABGD).

Morphological study

Terminologies and descriptions of characters used in this study were mainly as in O'Loughlin (2002), O'Loughlin *et al*. (2003), O'Loughlin and Waters (2004) and Clark and Downey (1992).

In total, 166 specimens from all localities shown in Table 1 were analysed morphologically. Commonly used external characters, including the major and minor radii, the numbers of abactinal and actinal spines, furrow and adambulacral fan spines, and oral and suboral spines and the presence or absence of pedicellariae, were measured and studied. The position of the abactinal plates and two newly defined characters, relative size and morphology of the preoral spines, were also recorded as potentially discriminative characters.

The major radius (R, from the centre of the star to the tip of an arm) and minor radius (r, from the centre of the star to the centre of the interradius between two arms) were measured using a Leica MZ 16 A stereomicroscope mounted with a Nikon ds F1 camera connected to a computer with the NIS-Elements 2.2 software. The ratio between R and r is indicative of overall shape and whether the star is more or less pentagonal, which is sometimes a useful initial (macroscopic) feature to distinguish species.

To provide microscopic details of characters, some specimens were analysed under a stereoscope or scanning electron microscope. Tissues were cleaned using a 30% bleach solution (protocol modified from O'Loughlin and Waters 2004), rinsed in distilled water and preserved in 70% ethanol. Samples not treated with bleach were dried for 1 h at room temperature to remove any remaining ethanol. Samples were sputter-coated with gold by cathodic pulverisation. Photographs were taken at low vacuum mode on a FEI QUANTA 200 scanning electron microscope and at high vacuum mode on a JSM-840 scanning electron microscope.

To provide a comprehensive dataset, morphological data from the literature were also included in the final matrix.

Statistical analysis

The 166 individuals were analysed for 12 morphological variables that were classified into three groups (based on the type of quantitative variable represented): 10 discrete, 1 continuous and 1 presence or absence. The IBM SPSS Statistics 22.0 software for Macintosh was used for analyses.

A descriptive analysis of each variable was performed. One-way ANOVA and Kruskal–Wallis tests were used to verify statistical differences between species.

All morphological variables, when available, were subjected to normality tests, using the best represented species (*Asterina gibbosa*, 104 individuals).

A classification tree was made using the growing method CHAID (Chi-square Automatic Interaction Detection) with a maximum tree depth of 3, and 10 and 5 minimum cases in the parent and child nodes, respectively. The decision tree procedure creates a tree-based classification model. It classifies cases by predicting the values of a dependent variable (species) based on the values of independent variables. In this study, we considered 12 independent variables (the number of spines were counted per plate): minimum and maximum number of abactinal and actinal spines, number of furrow and adambulacral fan spines, maximum number of oral and suboral spines, alignment of the abactinal plates, morphology of the oral spines, presence or absence of pedicellariae and star shape as measured by the ratio R/r (R = major radius, and r = minor radius).

Discriminant analyses tested selected morphological variables to be subsequently used as taxonomic characters.

The homogeneity of variance and groups (species) were analysed with the Wilks' Lambda statistic. Eigenvalues were used to determine the percentage of explained variance of each function.

The variable (morphological characters) composition of each function was established on the basis of standardised canonical discriminant function coefficients. The functions were visualised with a scatterplot by groups (species).

Reproductive biology

Species for the reproductive behaviour study were *A. gibbosa*, from O Grove (Pontevedra, Spain), *A. phylactica* from Prawle Point (Devon, UK) and five specimens from Puertito de Güímar (Tenerife, Spain). Two 100-L aquariums were set up with a constant temperature of 19°C and salinity at 35‰. Marine water was prepared by mixing previously oxygenated fresh water and aquarium marine salt. Nitrates and pH levels were measured regularly to maintain stable conditions. Individuals were fed the bivalve species *Chamelea gallina* (Linnaeus, 1758) and *Glycymeris glycymeris* (Linnaeus, 1758) equally.

Results

Molecular analyses

A 945-bp fragment of COI was obtained for each of the 15 freshly collected *Asterina* specimens, the sister group *A. stellifera* and the outgroup *Patiria miniata*. Unfortunately, the type material of each species was poorly preserved for molecular studies. However, using newly designed primers to amplify smaller fragments, a 626-bp fragment was obtained for the neotype of *A. pancerii*. No PCR products were obtained for the holotype of *A. phylactica*.

For the 18S nuclear gene, a 733-bp fragment was amplified for each of the 15 specimens and for *P. miniata*. For the *A. pancerii* neotype and *A. stellifera*, sequences spanning this fragment region were obtained by joining smaller fragments amplified using internal primers. The anonymous nuclear loci AgX2 and AgX5 were amplified for all individuals, except the neotype of *A. pancerii* and *A. stellifera*, likely due to their poor preservation. These loci were also not amplified from *P. miniata* due to the specificity of the nuclear markers for *Asterina*.

Phylogenetic inference and divergence values

Overall, the phylogenetic analyses revealed five independent lineages: *A. gibbosa*, *A. phylactica* and *A. pancerii*, three previously described species, and *Asterina martinbarriosi*, sp. nov. and *Asterina vicentae*, sp. nov., two new species to be described below (Fig. 1). Although terminal nodes (representing species) were fully supported by posterior probabilities and bootstrap values, the relationships between the different lineages were not as well established, except for *A. phylactica* and *A. martinbarriosi*, sp. nov., which diverged first and grouped as sister taxa in all analyses (posterior probability 0.98 and bootstrap values of 99% and 83% for MP and ML, respectively). The relationship between *A. gibbosa*, *A. pancerii* and *A. vicentae*, sp. nov. was well supported only by MP (Fig. 1). A sister-group relationship between *A. pancerii* and *A. vicentae*, sp. nov. was well supported in the BI analysis (0.93 posterior probability), yet in both the MP and ML analyses, *A. gibbosa* and *A. pancerii* were sisters but with weak bootstrap supports.

The COI gene showed the largest interspecific divergence values. Intraspecific COI variation ranged from 0% (*A. vicentae*, sp. nov.) to 0.63% for *A. phylactica* (Table 4). Interspecific COI divergences ranged between 4.16% (*A. phylactica*–*A. martinbarriosi*, sp. nov.) and 7.99% (*A. pancerii*–*A martinbarriosi*, sp. nov.). Interspecific variation between the sister group *A. stellifera* (from the western Atlantic Ocean) and the other *Asterina* taxa analysed here ranged from 8.61 to 10.37%. Divergences of these taxa ranged from 18.52 to 20.27% when compared with the outgroup (*P. miniata*). Given these values, the ABGD analysis supported the presence of five lineages.

For the nuclear markers, 18S had only five variable positions, two of which were parsimony informative. One of these substitutions was observed in *A. martinbarriosi*, sp. nov. specimens and the other in *Asterina vicentae*, sp. nov. The two anonymous nuclear markers AgX2 and AgX5 had 34 and 37 parsimony-informative sites, respectively. For these markers, the largest interspecific divergence values were found between the two newly described species (7.7% for AgX2) and between *A. pancerii* and *A. martinbarriosi*, sp. nov. (2.7% for AgX5) (Table S1). However, intra- and interspecific values for both markers overlapped in *A. gibbosa*, *A. pancerii* and *A. vicentae*, sp. nov. comparisons.

The likelihood reconstruction analysis of putative ancestral features showed a 0.52 probability of having incubator behaviour, 0.73 of having a subpentagonal shape and 0.99 of having pedicellariae (Fig. S1). The other characters showed polymorphic states in certain species and, therefore, were not

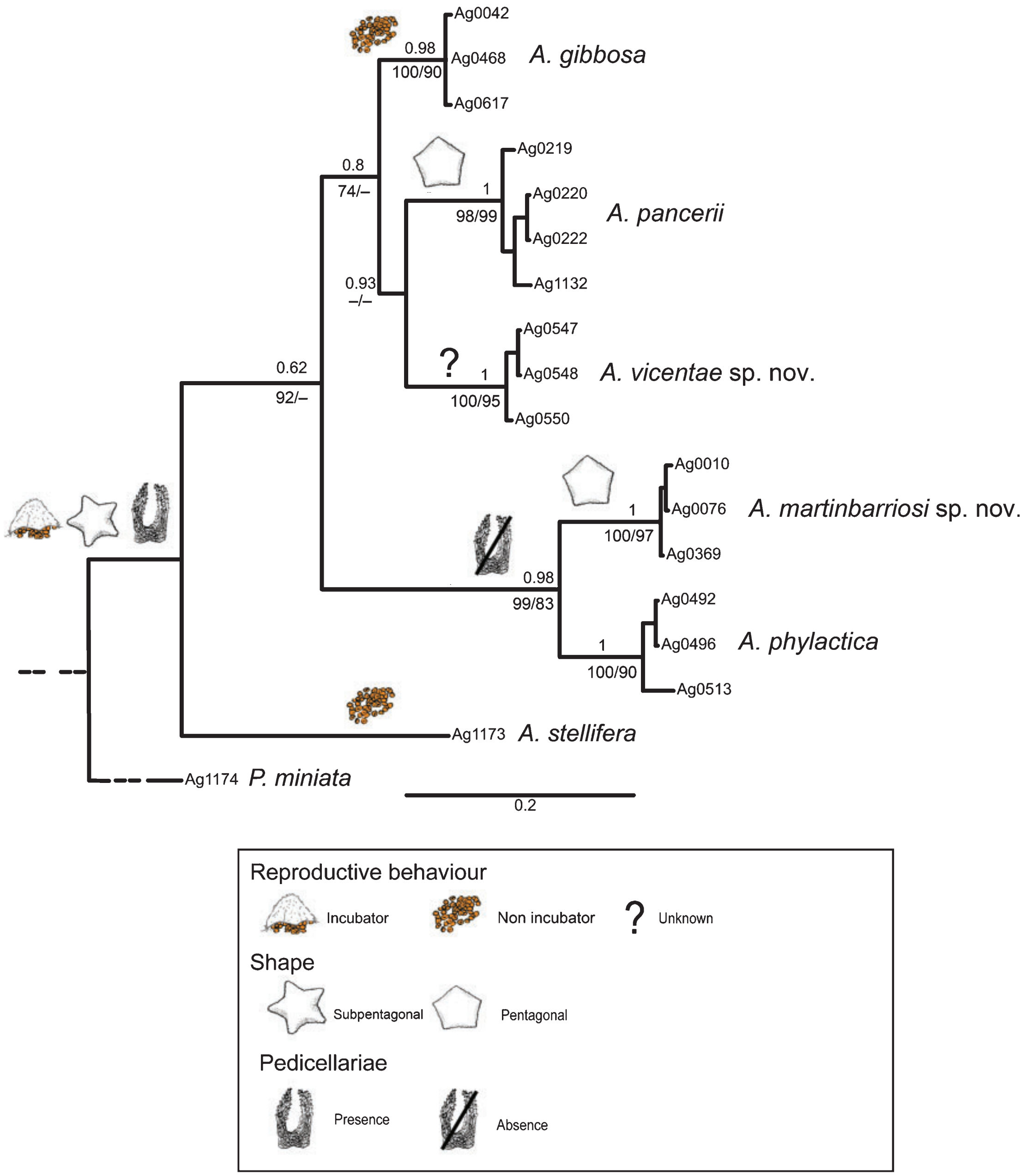

Fig. 1. Bayesian inference tree obtained from the analysis of the combined dataset consisting of the COI and 18S genes, and the two anonymous nuclear loci, AgX2 and AgX5. Bayesian posterior probabilities are indicated above the branches, MP and ML bootstrap values are shown below the branches (MP/ML). Characteristic features for different species or clades, including reproductive behaviour (with/without incubator behaviour or unknown), shape (subpentagonal/pentagonal) and the presence or absence of pedicellariae, are also indicated on the tree.

evaluated in terms of probabilities but rather through parsimony assessment (see state reconstruction in Fig. S1).

Morphological statistical analysis

Analysis of the normality of the variables (Table S2), based on kurtosis and skewness values, showed two normal variables (maximum number of abactinal spines and R/r) and one with a binomial distribution (morphology of the oral spines).

The results of the non-parametric Kruskal–Wallis and one-way ANOVA tests showed significant differences among species for all the variables considered ($P < 0.05$).

A classification tree was generated using CHAID. At each step, CHAID chooses the independent variable (morphological

Table 4. Uncorrected divergences in percentage among *Asterina* spp. based on COI
Data in bold are the intraspecific divergences

COI	*A. gibbosa*	*A. pancerii*	*A. phylactica*	*A. martinbarriosi*, sp. nov.	*A. vicentae*, sp. nov.	*A. stellifera*	*P. miniata*
A. gibbosa	**0.07**						
A. pancerii	5.16	**0.48**					
A. phylactica	7.62	7.91	**0.63**				
A. martinbarriosi, sp. nov.	7.87	7.99	4.16	**0.14**			
A. vicentae, sp. nov.	5.43	5.60	7.55	7.94	**0**		
A. stellifera	8.61	10.21	10.37	10.26	9.10	–	
P. miniata	18.87	20.27	18.98	19.05	19.15	18.52	–

characters) that has the strongest interaction with the dependent variable (species). Categories of each predictor are merged if they are not significantly different with respect to the dependent variable. Species were best classified by four independent variables: the morphology of the oral spines, alignment of the abactinal plates, and the maximum and minimum number of abactinal spines (Fig. S2). The CHAID analysis provided a useful validation tool for exploratory and confirmatory classification analyses.

Complementary discriminant function analyses were performed using three variables: the ratio R/r for shape, the maximum number of abactinal spines, and the morphology of the oral spines. Two variables (maximum number of abactinal spines and R/r) were found to be highly significant discriminant functions (Wilks' lambda: $P < 0.05$).

Of the cross-validated test, 84.9% of the specimens were correctly classified, following the pre-established groups (by species). Scatterplots showed five groups corresponding to the five putative species, although with some overlap mainly due to the number of *A. gibbosa* specimens and their differentiation (Fig. S3). Thus, when *A. gibbosa* was removed from the analysis, greater resolution between the other species was observed (Fig. S4). In this second discriminant analysis, the variable 'morphology of the oral spines' was also removed as it represents an exclusive character state for *A. gibbosa*. Furthermore, the furrow spines resulted as a new discriminant variable. As in the first discriminant analysis, the two variables having significant Wilks' lambda values were the ratio R/r and maximum number of abactinal spines. The percentage of cross-validated grouped cases correctly classified was 67.7%.

Morphological descriptions

Family **Asterinidae** Gray, 1840

Genus ***Asterina*** Nardo, 1834

Type species: *Asterina gibbosa* (Pennant, 1777)

The studied specimens of *A. gibbosa*, *A. pancerii* and *A. phylactica* were consistent with the original descriptions of Pennant (1777), Gasco (1870) and Emson and Crump (1979), respectively, and the reviews of Clark and Downey (1992), O'Loughlin and Waters (2004) and O'Loughlin and Rowe (2006). Nevertheless, new data were added for *A. pancerii* as it was analysed molecularly for the first time.

Additional observations for the other species are noted below. Table 5 lists the morphological characteristics analysed and shows the extent of intraspecific variability.

Asterina gibbosa (Pennant, 1777)

(Fig. 2)

Molecular characterisation

Analysis of the COI fragment showed *A. gibbosa* having a mean interspecific divergence between 5.16 and 7.87%, with respect to the other lineages; intraspecific divergence was 0.07% (Table 4). The lineage was fully supported in the phylogenetic reconstruction (Fig. 1).

Asterina pancerii (Gasco, 1870)

(Fig. 3)

Asteriscus pancerii Gasco, 1870: 86–90. – Gasco, 1876: 38–40.
Asterina gibbosa var. *pancerii* Koehler, 1924: 133–134.
Asterina pancerii Oliver *et al.* 1997: 103–107. – Tanti & Schembri, 2006: 163–165; Moreno *et al.*, 2008: 626–629.
For further information see Clark and Downey, 1992: 186.

Material examined

Neotype. C.E. 38096. Bacoli, Naples (Italy). Additional material examined from Moraira, Alicante (Spain) (see Table 1).

Description (based on the additional material examined)

Pentagonal (Fig. 3*A*). Range of R 3.92–12.47 mm; 5 rays discrete, wide at base, short, rounded distally; not convex abactinally, flat actinally, sides not steep, margin acute; single conspicuous madreporite; pedicellariae present (Fig. 3*B*); not fissiparous; actinal gonopores; glassy convexities on plates; absence of superambulacral and superactinal plates. Live colour of aboral surface red and orange on the central disc with white radial areas, oral surface little pigmented.

Abactinal. Plates closely imbricate and tesselated, without apparent longitudinal alignment covered by raised spine-bearing tubercules; small papulate areas covering no more than $^1/_3$ of the abactinal surface; papulae 2 or 3 (Fig. 3*C*); stout, truncate to capitate, spines distally, longitudinally ribbed, series of variable number 3–6.

Margin. No relevant differences between abactinal and marginal plates; superomarginal and inferomarginal plates

Table 5. Morphological characters studied
Bold numbers represent the most usual values. PS, preoral spines; L, lateral spines

		A. gibbosa	*A. pancerii*	*A. vicentae*, sp. nov.	*A. phylactica*	*A. martinbarriosi*, sp. nov.
Major radius, R (mm)	Range	1.84–22.91	3.92–12.47	5.23–13.79	1.50–7.53	3.31–6.1
Minor radius, r (mm)	Range	1.37–14.41	2.84–9.21	2.76–7.67	0.88–4.18	2.18–4.1
Ratio R/r	Range	1.27–2.01	1.23–1.35	1.58–1.89	1.36–2.13	1.20–1.69
	Mean value	1.54	1.30	1.76	1.52	1.42
	Shape	Subpentagonal	Pentagonal	Subpentagonal	Subpentagonal	Pentagonal
	Rays	5 acute	5 no evident	5 acute	5 acute	5 no evident
Pedicellariae		Present	Present	Present	Absent	Absent
Abactinal surface	Papular area	Large	Small/disc	Large	Medium	Medium
	Spines per plate	3–14	3–8	4–6	3–9	3–10
Margin	Superomarginal spines	Pedicellariae/3	Pedicellariae	Pedicellariae	2–4	1 or 2
	Inferomarginal spines	5–8	4–6	5	4–6	3 or 4
Actinal surface	Interradial plates	Not tessellated	Tessellated	Not tessellated	Slightly imbricate	Slightly imbricate
	Spines per plate	2–**3**	**1**–**2**–3	2	**1**–2	1
	Subamulacral spines	2–**3**	**1**–**2**–3	1	**1**–2	1
	Adambulacral spines fan	1–**2**–3	2–3	3	**1**–2	1
	Furrow spines	**2**–3–4	2–3–4	2	1–**2**	**2**–3
Oral spines	Total number per plate	1PS+**4**–5	1PS+2–**3**	1PS+3–4	1PS+2–**3**	1PS+3
	Size of preoral spines	Correlated	PS = $^{2}/_{3}$L	PS = $^{2}/_{3}$L	PS = 2L	PS = 2L
	Shape of preoral spines	V-shaped	V-shaped	V-shaped	U-shaped	U-shaped
	Suboral spines	1–**2**–**3**–4–5	1	1	0[A]	0[A]

[A]Rarely, one spine appeared in some of the suboral plates in a few specimens.

longitudinally elongate, up to about one pedicellaria and 4–6 spinelets per plate respectively.

Actinal. Interradial plates overlap but clearly distinct; two complete series of adradial actinal plates and spines; actinal spines per plate (Fig. 3*D*): oral 4 ($^{2}/_{3}$ longer than lateral spines; no gap to 2 or 3 distally progressively increasing in length), V-shaped; suboral 1 (Fig. 3*F*); furrow spines 2–3–4 (Fig. 3*E*); adambulacral fan spines 2 or 3; actinal interradial and adradial 1–2–3 spines. No differences found in subambulacral plates with respect to the actinal ones.

Brooding

Adults protect the egg masses from which juveniles hatch directly (Templado *et al*. 2004; Moreno *et al*. 2008).

Distribution

An endemic Mediterranean species that has been sighted throughout the basin. Along the Spanish Mediterranean coasts, it has been recorded for localities of Almería and Murcia in south-eastern Spain (Luque and Templado 2004; Templado *et al*. 2004; Moreno *et al*. 2008), the Columbretes Islands in north-eastern Spain (Templado *et al*. 2002), the Balearic islands of Ibiza and Mallorca (Ballesteros *et al*. 1987; Oliver *et al*. 1997) and Alicante in eastern Spain (present study). Other localities include Marseille, Portofino (Liguria), the Gulf of Naples (type locality), Malta (Tanti and Schembri 2006), Greece, Tripoli (Libya), the Marmara Sea (Tortonese 1965) and the Turkish coast (Öztoprak *et al*. 2014). However, specimens collected from south-eastern Spain that were morphologically identified as *A. pancerii* (Moreno *et al*. 2008) actually correspond to *A. phylactica* on the basis of the molecular evidence provided in this study. Furthermore, our molecular data, mainly of the *A. pancerii* neotype, indicate that the presence of *A. pancerii* can be confirmed only for Moraira (Alicante, eastern Spain) and the Tyrrhenian Sea. Therefore, all previous records, particularly those for which molecular data are lacking, should be reviewed.

In terms of habitat, this species is closely associated with *P. oceanica* meadows found between 5 and 20 m deep, where it is nocturnally active (Galán *et al*. 1982; Templado *et al*. 2004; Moreno *et al*. 2008). It has also been found in maërl bottoms 40 m deep in the Columbretes Islands (Templado *et al*. 2002).

Remarks

The neotype of this species was molecularly (for the first time) and morphologically analysed, and all results support the status of the species. *Asterina pancerii* is included in Appendix II (Strictly Protected Fauna Species) of the Bern Convention, in Annex II (List of Endangered or Threatened Species) in the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean from the Barcelona Convention and in the Spanish Catalogue of Threatened Species (Templado *et al*. 2004). Therefore, it is important to determine the actual presence and distribution of this species and other cryptic species in this complex.

Molecular characterisation

Interspecific divergence of this species based on COI sequences was between 5.16 and 7.99%; intraspecific divergence was

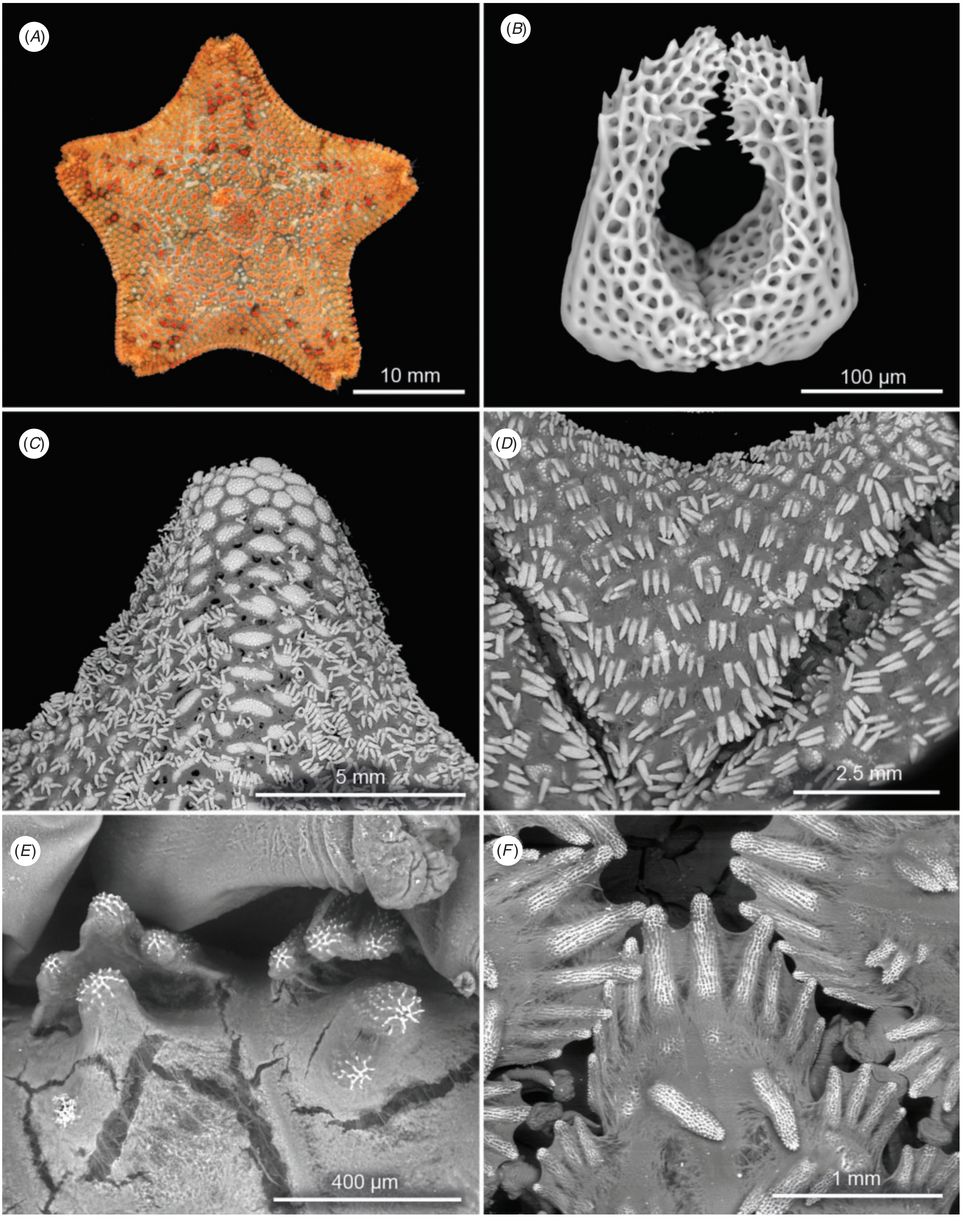

Fig. 2. *Asterina gibbosa. A*, general view, shape and live colour; *B*, pedicellaria; *C*, abactinal surface with longitudinally aligned plates; *D*, interradial actinal surface; *E*, furrow and adambulacral fan spines; *F*, oral plate with one or two suboral spines per plate.

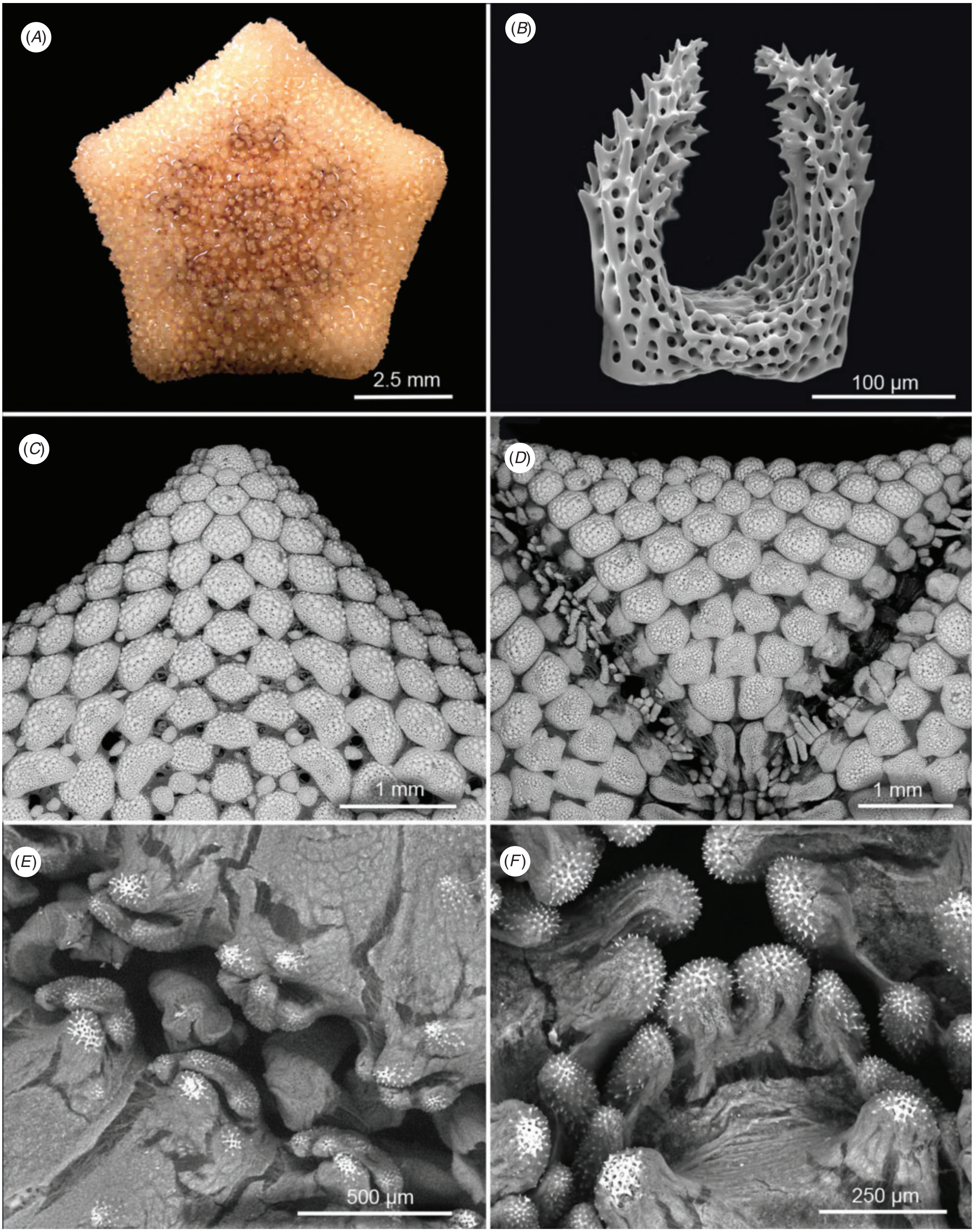

Fig. 3. *Asterina pancerii*. *A*, general view, pentagonal shape (R/r = 1.24); *B*, pedicellaria; *C*, abactinal surface plates together as a mosaic; *D*, interradial plates of the actinal surface paved; *E*, furrow and adambulacral fan spines; *F*, oral plate showing oral spines and one suboral spine per plate.

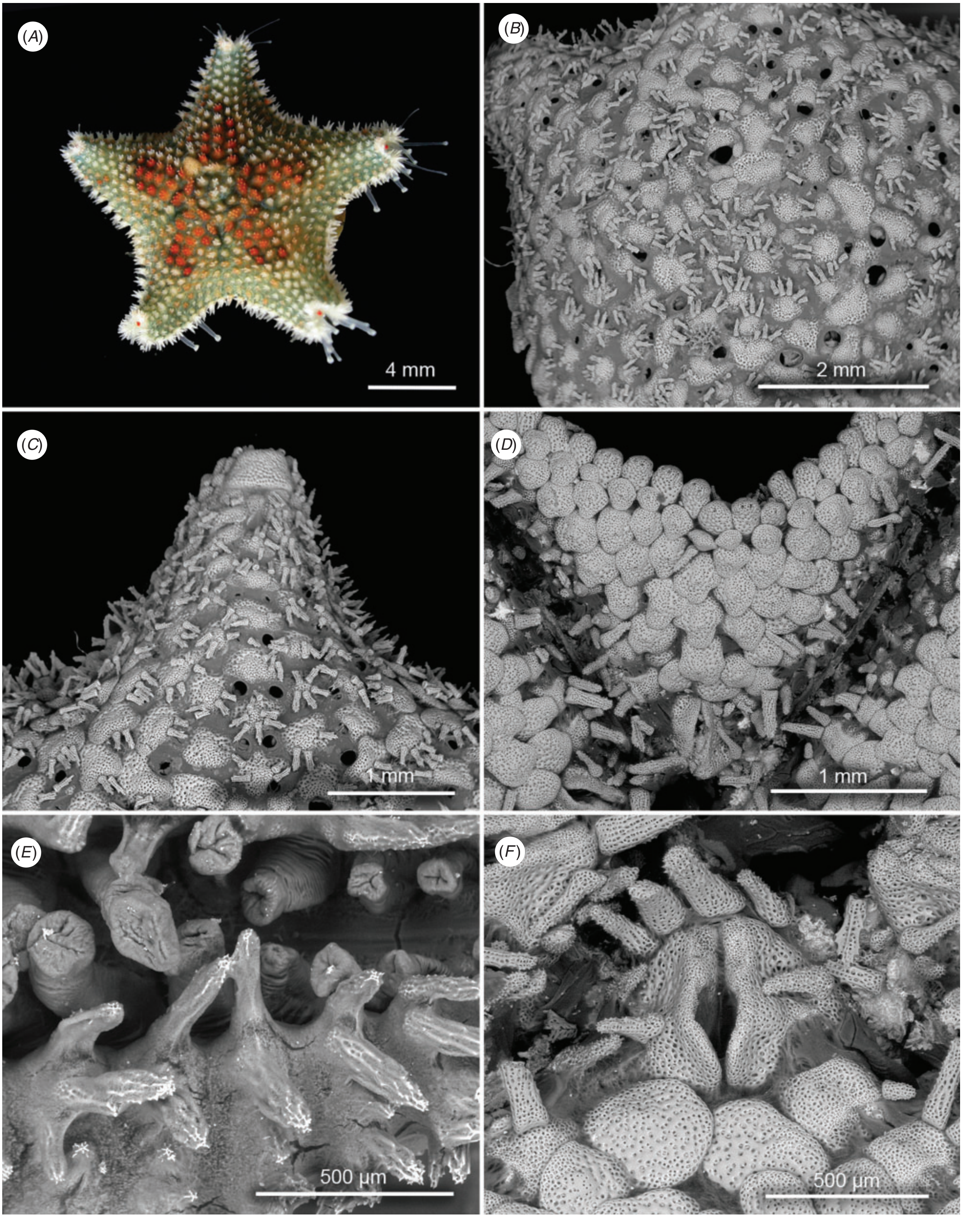

Fig. 4. *Asterina phylactica*. *A*, general view, shape and live colour; *B*, groups of abactinal spines; *C*, abactinal surface plates longitudinally aligned in rows; *D*, slightly imbricate interradial plates of the actinal surface; *E*, furrow and adambulacral fan spines; *F*, oral plate and oral spines.

0.48% (Table 4). The lineage was fully supported in the phylogenetic reconstruction (Fig. 1).

Asterina phylactica Emson & Crump, 1979

(Fig. 4)

Molecular characterisation

Interspecific divergence of this species based on COI sequences was between 4.16 and 7.91%; intraspecific divergence was 0.63% (Table 4). This lineage was fully supported in the phylogenetic reconstruction (Figure 1).

Asterina martinbarriosi, sp. nov.

(Fig. 5)

Material examined

Holotype. MNCN 29.02/984 (Ag010). Spain, Tenerife, Puertito de Güímar, under stones (0–5 m deep). February 2005, Iván Acevedo col.

Paratypes. MNCN 29.02/985 (Ag005). El Socorro, Tenerife, Canary Islands, under stones (0–5 m deep). December 2004, Javier Martín Barrios col. MNCN 29.02/986 (Ag075) and MNCN 29.02/987 (Ag076).

Additional material examined. From Bajío el Apio, Tenerife and La Santa, Lanzarote, Canary Islands (see Table 1).

Description of holotype

Subpentagonal (Fig. 5*A*), R = 3.77 mm; r = 2.63 mm (R/r = 1.43); 5 rays discrete, wide at base, short, rounded distally; not convex abactinally, flat actinally, sides not steep, margin acute; single conspicuous madreporite; not fissiparous; actinal gonopores; glassy convexities on plates; absence of superambulacral and superactinal plates. Live colour of aboral surface green with dark brown radial areas, paler in colour on the interradial plates, oral surface little pigmented.

Abactinal. Plates granular and openly imbricate in regular series; radial aligned up to three rows with large papulate areas; papulae 1 or 2; spinelets stout, truncate to capitate, spines distally, longitudinally ribbed, series of variable number 3–10 (Fig. 5*B*, *C*).

Margin. No relevant differences between abactinal and marginal plates; superomarginal and inferomarginal plates longitudinally elongate, up to ~1 or 2 and 3 or 4 spinelets per plate, respectively.

Actinal. Interradial plates in longitudinal series; complete series of adradial actinal plates and spines. Actinal spines per plate: oral 4 (1 long proximal twice as long as the lateral spines; gap to 3 short distally increasing in length), U-shaped; no suboral spines (Fig. 5*F*); furrow spines 2 or 3 (Fig. 5*E*); adambulacral fan spines 1; actinal interradial and adradial with a single spine (Fig. 5*D*). No differences found in subambulacral plates with respect to the actinal ones.

Brooding

Specimen aggregations and egg laying were both observed under aquarium conditions. Adults protected the broods, adopting a humped position as described for *A. phylactica* (Emson and Crump 1979; Crump and Emson 1983).

Distribution

Tenerife and Lanzarote, Canary Islands, Spain (Table 1). Mainly found on rocks in tidal pools at depths of 2 m.

Remarks

Morphology

The body shape and peculiar shape of the preoral spines most resembles *A. phylactica*. However, *A. martinbarriosi*, sp. nov. can be distinguished from *A. phylactica* by having more abactinal spines per plate and only a single actinal spine (Table 5). Based on the major radius, the sizes of the paratypes, and additional material examined, is from 3.31 to 6.1 mm (minimum and maximum R values). The absence of pedicellariae distinguishes *A. martinbarriosi*, sp. nov. from *A. gibbosa*, *A. pancerii* and *A. vicentae*, sp. nov. (see below).

Molecular characterisation

Interspecific divergence based on COI sequences was between 4.16 and 7.99%; intraspecific divergence was 0.14% (Table 4). The lineage was fully supported in the phylogenetic reconstruction (Fig. 1).

Etymology

Named after Javier Martín Barrios, who collected the material described here.

Asterina vicentae, sp. nov.

(Fig. 6)

Material examined

Holotype. MNCN 29.02/981 (Ag550). El Trabucador, Tarragona, NE Spain, in *P. oceanica* meadows, June 2007, Diana Piorno col.

Paratypes. MNCN 29.02/982 (Ag547), MNCN 29.02/983 (Ag548). Galatxo Point, Tarragona, NE Spain, in *P. oceanica* meadows, June 2007, Diana Piorno col.

Description of holotype

Subpentagonal, R = 13.79 mm; r = 7.67 mm (R/r = 1.80); 5 rays conspicuous, rounded distally; not convex abactinally, flat actinally, sides not steep, margin acute (Fig. 6*A*); single conspicuous madreporite; pedicellariae present (Fig. 6*B*); actinal gonopores; glassy convexities on plates; absence of superambulacral and superactinal plates. Live colour unknown.

Abactinal. Abactinal plates granular, openly imbricate longitudinally, covered by raised spine-bearing tubercules very evident and radial and proximal interradial plates; large papulate areas aligned up to three rows covering 2/3 of the abactinal surface; papulae 2 or 3; spinelets stout, truncate to capitate, spines distally, longitudinally ribbed, series of variable number 4–7 (Fig. 6*C*).

Margin. No relevant differences between abactinal and marginal plates; superomarginal and inferomarginal plates longitudinally elongate, up to about one pedicellaria and 5 spinelets per plate, respectively.

Actinal. Interradial plates in regular series; complete series of adradial actinal plates and spines. Actinal spines per plate: oral 4 or 5 ($^2/_3$ longer than lateral spines; no gap to 3 or 4 distally

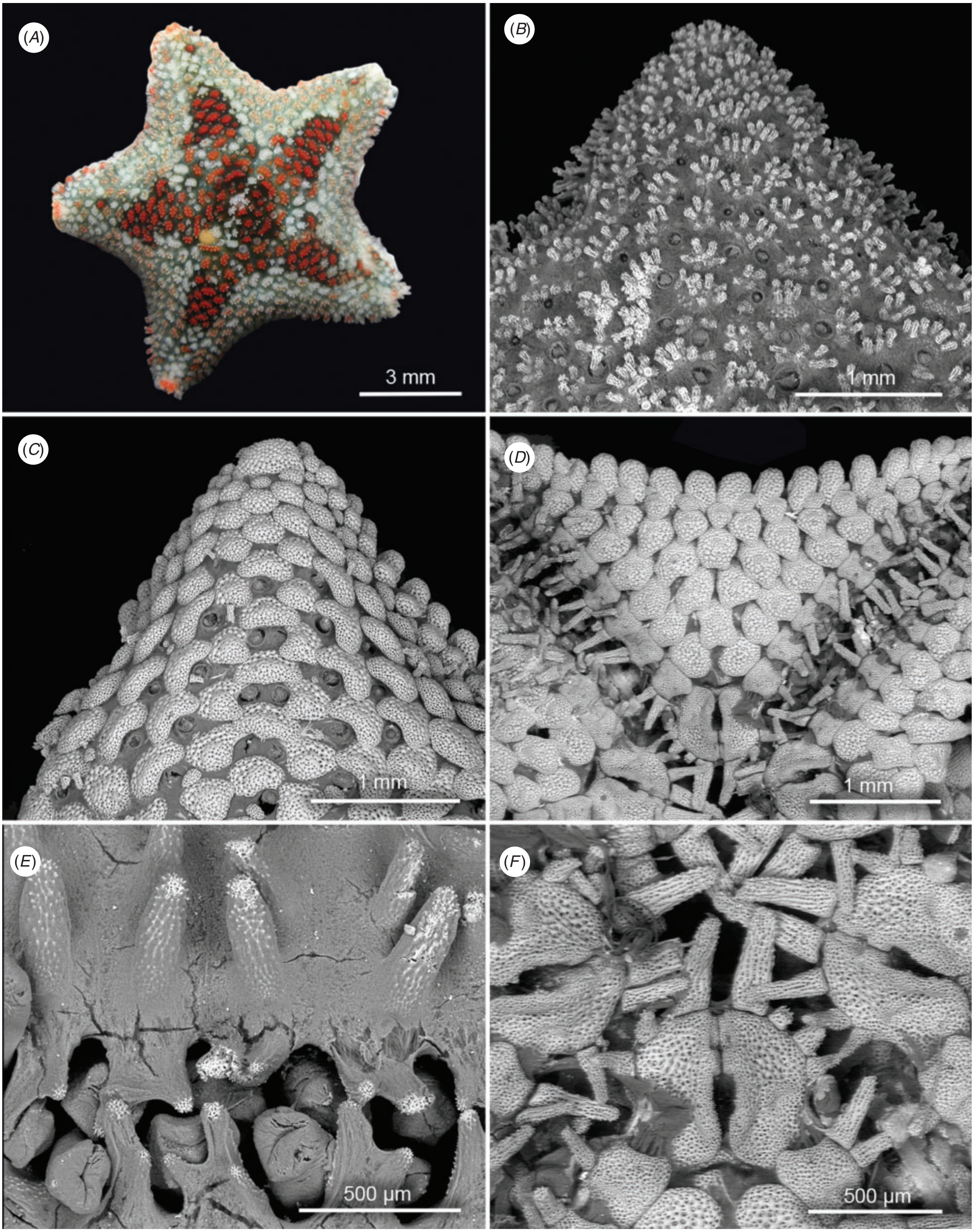

Fig. 5. *Asterina martinbarriosi*, sp. nov., MNCN 29.02/984. *A*, general view, shape and live colour; *B*, groups of abactinal spines; *C*, abactinal surface plates longitudinally aligned in rows; *D*, slightly imbricate interradial plates of the actinal surface; *E*, furrow and adambulacral fan spines; *F*, oral plate without suboral spines.

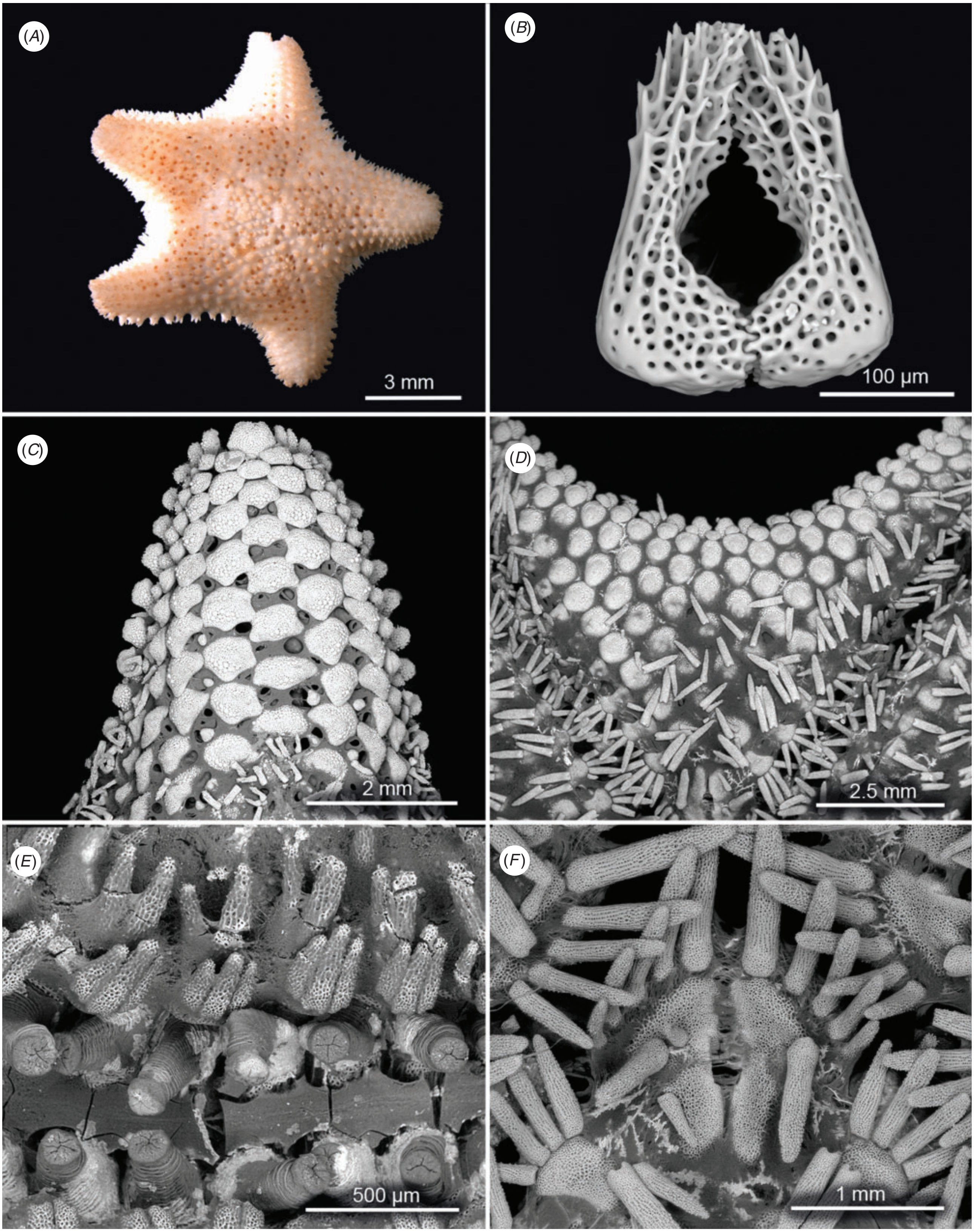

Fig. 6. *Asterina vicentae*, sp. nov., MNCN 29.02/981. *A*, general view and shape (R/r = 1.80); *B*, pedicellaria; *C*, abactinal surface with longitudinally aligned plates (tissues removed); *D*, interradial actinal surface with actinal spines; *E*, furrow and adambulacral fan spines; *F*, oral plate showing oral spines and one suboral spine per plate.

progressively increasing in length), V-shaped; suboral 1 (Fig. 6*F*); furrow spines 2 (Fig. 6*E*); adambulacral fan spines 3; subambulacral spines 1; actinal interradial and adradial spines 2 each (Fig. 6*D*).

Brooding

Reproductive behaviour was not observed as no live specimens were collected by the authors.

Distribution

Tarragona coast at Galatxo Point and El Trabucador, Spain (Table 1), associated with *P. oceanica* meadows.

Remarks

Morphology

The subpentagonal-shaped body most resembles *A. gibbosa* rather than *A. pancerii*. However, it differs from *A. gibbosa* in the number of abactinal spines, having at most 6 spines per plate (compared with 14 in *A. gibbosa*). *Asterina vicentae*, sp. nov. is distinguished from other *Asterina* species (*A. fimbriata*, *A. gracilispina* and *A. stellifera*) by having actinal gonopores instead of abactinal ones. It also differs from *A. phylactica*, *A. martinbarriosi*, sp. nov. and *A. hoensonae* (O'Loughlin 2009) by having pedicellariae (Table 5). Based on the major radius, the sizes of the paratypes and additional material examined range from 5.23 to 13.79 mm (minimum and maximum R value).

Molecular characterisation

Interspecific divergence based on COI sequences was between 5.43 and 7.94%; intraspecific divergence was null. These divergence values support the description of this new species (Table 4). Furthermore, the lineage was fully supported in the phylogenetic reconstruction (Fig. 1).

Etymology

Dedicated to María Vicenta Gutiérrez Ramírez, the first author's grandmother, for instilling her with passion for the sea and the life inhabiting it.

Discussion

Finding phenotypic and biological characters that distinguish highly genetically divergent sibling species, especially in groups with a shortage of discrete characters or with high phenotypic plasticity (e.g. *Asterina*), can be difficult. However, morphological and biological differences can be discerned by carefully studying live specimens collected at different localities along the entire distribution range and by combining different analytical methodologies. Here, using an integrative approach, our results support the classification of three previously described species and have revealed two new species, *A. vicentae*, sp. nov. and *A. martinbarriosi*, sp. nov., within the genus *Asterina* in the Mediterranean and eastern central Atlantic.

Both nuclear and mitochondrial evidence point to the existence of two new species, increasing the number of known *Asterina* taxa in the western Mediterranean and north-eastern Atlantic to five. Our molecular analyses consistently recovered five lineages, and COI divergence values ranged between 4.16 and 7.99%, with the highest intraspecific divergence being 0.63%. Divergences between 2.7% and 4.3% have been reported between species of the asterinid genus *Patiriella* from south-eastern Australia (Hart *et al*. 2003) and 2.3% between sibling species of *Cryptasterina* (Puritz *et al*. 2012). Therefore, the values obtained in this study are congruent with those observed for other asterinid groups. Unfortunately, 18S analyses showed extreme sequence similarity between *Asterina* species and even with the outgroup; therefore, this marker is uninformative for species delimitations for this group. The anonymous nuclear markers had interspecific divergence values that ranged from 0.2% to 7.7% for AgX2 and 0.3% to 2.7% for AgX5. On the basis of these two markers, *A. phylactica* and *A. martinbarriosi*, sp. nov. are easily differentiated from each other and from the other species. However, interspecific divergence values between *A. gibbosa*, *A. pancerii* and *A. vicentae*, sp. nov. overlapped with intraspecific values; therefore, these species could not be clearly differentiated with these markers.

Moreover, as regards a phylogenetic species definition, the five lineages recovered as species appeared as fully supported clades. Accordingly, the results of the ABGD analysis established five groups that we attribute to five different species, three previously known and two newly described. The clear gap between intra- and interspecific divergences enables a phenetic distinction among these taxa.

Characteristics that primarily define the two groups recovered in the phylogenetic analyses (*A. gibbosa* + *A. pancerii* + *A. vicentae*, sp. nov. and *A. phylactica* + A. *martinbarriosi*, sp. nov.) include the number of suboral spines per plate and the existence of pedicellariae. Reproductive behaviour may also prove to be able to differentiate groups. While *A. phylactica* and *A. martinbarriosi*, sp. nov. brood benthic eggs, *A. gibbosa* attaches its egg masses to benthic rocks. If this behaviour is considered a possible synapomorphy, the other two species in the group (*A. vicentae*, sp. nov. and *A. pancerii*) are hypothesised to also lay benthic eggs. However, the reproductive behaviour of *A. vicentae*, sp. nov. is unknown, and previous data for *A. pancerii* indicated an incubator behaviour (Templado *et al.* 2004). In the latter case, the samples studied by Templado *et al*. (2004) appear to have been misidentified and actually represent the species *A. phylactica* (authors' observation). Thus, more studies investigating the reproductive behaviour of both *A. vicentae*, sp. nov. and *A. pancerii* are needed to determine whether this trait can discriminate species.

Our molecular analyses, and the discovery of new lineages, have provided new morphological characters for distinguishing species of *Asterina*, such as relative size and shape of the oral spines (Table 5). This latter character constitutes a synapomorphy for *A. phylactica* and A. *martinbarriosi*, sp. nov. and distinguishes *A. gibbosa* from *A. vicentae*, sp. nov. and *A. pancerii* (Fig. S1). As a result, differentiation of these five *Asterina* species in the western Mediterranean and north-eastern Atlantic is supported by both morphological and molecular analyses.

Within the Asterinidae, genetic and developmental features often appear to diverge more rapidly than morphological characters (Hart *et al*. 1997), as evidenced by the species studied here. High genetic variation coupled with discrete morphological differentiation may be associated with recent speciation processes (Schluter 2000), but morphological simplicity and the retention of ancestral features (Puritz *et al*. 2012) may conceal the true diversity of the family.

Although cryptic species seem morphologically indistinguishable, in this case, after an exhaustive morphological study, new lineage-specific characters have been identified, and new species morphologically described. However, the morphological identification of each species was not based on any individual morphological character but rather on a combination of characters, as demonstrated by the discriminant analyses. Here, the main morphological characters differentiating species, following statistical analyses, are those related to the adambulacral and abactinal spines and the shape of the starfish (R/r). This result shows that controversial characters, such as colour and size (Emson and Crump 1979), which can be homoplastic or highly variable, can be avoided in species distinctions for this genus.

Further complicating species distinctions is the sympatric distribution (and the similarity of habitat types) observed in these cryptic species. The distributions of the five studied species overlap, with *A. gibbosa* having the widest distribution, overlapping with the other Mediterranean and western Atlantic species, and the new ones showing the most restricted distributions. Furthermore, although the ecology and life histories of Asterinidae are poorly known (Farias *et al*. 2012), this family is considered a cosmopolitan taxon and, at least in this study, most species appear to inhabit similar habitats, e.g. shallow waters. *Asterina pancerii* and *A. vicentae*, sp. nov. seem to be closely, or possibly exclusively, associated with *P. oceanica* meadows, while the other three species live mainly in shallow or intertidal rocky bottoms, similar to the western Atlantic species *A. stellifera* (Farias *et al*. 2012). Life history data, such as differences in spawning strategies (Byrne 2006), may help to better clarify the systematics of this group (Hart *et al*. 1997). Although we attempted to reconstruct the reproductive ancestral state for the studied species, our results showed that there was an equal probability of having incubator behaviour or not. However, two species, *A. gibbosa* and *A. martinbarriosi*, sp. nov., were successfully reproduced in captivity. *Asterina gibbosa* attaches benthic eggs to rocks without any brood protection, while *A. martinbarriosi*, sp. nov. aggregates before spawning, adopting a humped posture during egg deposition, and broods benthic eggs, as occurs in *A. phylactica* (Emson and Crump 1979). *Asterina pancerii* also incubates its eggs, although this behaviour is considered an unusual characteristic among Mediterranean echinoderms, possibly representing an adaptation of living in seagrass ecosystems (Gambi and Morri 2008). Unfortunately, the reproductive behaviour of *A. vicentae*, sp. nov. could not be observed as no live specimens were collected here. Differences in reproductive behaviours might be the only barrier among habitat-sharing species, thus enhancing sympatric speciation processes.

Finally, some of the species studied here are included in Red Lists, and therefore, the results provided may contribute to the conservation of these species. Although European species of *Asterina* collectively have a broad distribution range, some true biological species within this complex have more limited distributions, making them more threatened. Molecular evidence has revealed that several endangered species are in fact cryptic species complexes that have fewer populations and smaller distributions, and hence are more critically endangered (Bickford *et al*. 2007; Calvo *et al*. 2009). Therefore, the accurate identification and description of cryptic species within *Asterina* have important implications for conservation and natural resource protection and management.

Conflicts of interest

The authors declare no conflicts of interest.

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Familia PINNIDAE

La familia Pinnidae comprende tres géneros y 22 especies presentes en mares tropicales someros. Presenta los mayores bivalvos con concha de los mares europeos, pudiendo llegar *Pinna nobilis* Linnaeus, 1758, a medir un metro de longitud. Se trata del molusco con concha más grande de Europa, siendo sólo superada en peso y volumen por *Tridacna gigas* Linnaeus, 1758, del Indo-Pacífico. Las otras dos especies de la familia presentes en Andalucía son *Pinna rudis* Linnaeus, 1758 y *Atrina pectinata* (Linnaeus, 1767), ambas de talla muy grande.

Estos bivalvos viven parcialmente enterrados en el sedimento. Así, *P. nobilis* es característica de las praderas de *Posidonia oceanica*, aunque también se encuentra en fondos de arena, en detrítico, o en praderas de *Cymodocea nodosa*, mientras que *P. rudis* es típica de fondos de roca o bordes de pradera de *Posidonia*, y *A. pectinata* de fondos fangosos más profundos, del piso circalitoral profundo y del piso batial. La concha es triangular y alargada; el extremo donde se encuentra el umbo es agudo y se hinca en el sustrato. La parte que no queda enterrada, generalmente más de la mitad de la concha, es aplanada y más o menos redondeada, aunque varía entre las especies y con el crecimiento; por ejemplo en *P. nobilis*, los juveniles son de perfil más triangular.

La superficie de la concha tiene estrías de crecimiento y numerosas costillas radiales, más o menos grandes según las especies. Así, *A. pectinata* puede tener la concha lisa o poseer pocas costillas finas con escamas pequeñas, *P. nobilis* tiene numerosas costillas y escamas pequeñas, que suelen perderse en los ejemplares de gran talla, mientras que *P. rudis* se distingue por presentar grandes costillas con escamas muy sobresalientes. Las valvas internamente son de color pardo o castaño con la mitad o el tercio anterior nacarado, con marcas de crecimiento en el músculo aductor posterior, que se han utilizado para estimar de la edad. Los individuos de gran tamaño de *P. nobilis* pueden contener perlas. La charnela carece de dientes y el ligamento, que es externo y dorsal, se sitúa cerca del extremo anterior. El animal es grande, con amplios ctenidios. Posee un pie reducido, dos músculos aductores (anterior y posterior), y un característico penacho de filamentos (biso) muy desarrollado para fijarse más firmemente al sustrato.

Todas las especies de la familia se alimentan filtrando el agua de mar que pasa entre sus branquias a través de los sifones. Las especies de esta familia presentan una glándula impar pre-oral, cuya función parece ser excretora. Existe, además, un órgano paleal que se creía tenía la función de limpiar la cavidad del manto, pero estudios recientes en *A. pectinata* indican que es capaz de secretar ácido. Este tipo de células secretoras de ácido se encuentran en otros moluscos, como en algunos opistobranquios (con clara función defensiva), pero no se conocía entre los bivalvos. Parece ser que la abertura de las valvas de *Pinna nobilis* sigue ritmos circadianos y circalunares (Garcia-March *et al.*, 2008)

La especie *P. nobilis* es hermafrodita protándrica; el mismo individuo primero es macho y posteriormente hembra. Las poblaciones muy explotadas no son viables, ya que se suelen extraer los ejemplares mayores que son precisamente las hembras con mayor capacidad reproductora. Las larvas son planctónicas y pasan unos 5-10 días en aguas abiertas antes de su fijación en un sustrato adecuado. Se observan juveniles de 3-4 cm en septiembre en aguas someras. Por el contrario, *A. pectinata* es una especie dioica. En esta especie la gametogénesis en ambos sexos se inicia en febrero, y la maduración dura desde marzo a septiembre; en este periodo las hembras son capaces de realizar varias puestas.

El crecimiento en *P. nobilis* es bastante rápido para lo detectado en otros moluscos. Se ha estimado la edad de ejemplares procedentes de Almería, así, hay ejemplares de 60 cm con 8 años de edad y otros menores (45 cm) pero más viejos (13 años). Esta especie puede llegar a vivir más de 20 años. La rápida tasa de crecimiento de *P. nobilis* permite una suficiente resolución para realizar estudios de reconstrucción de temperaturas de la superficie del agua mediante el uso de isótopos estables de oxígeno y carbono obtenidos de la concha.

Estos extraordinarios bivalvos han sido recolectados desde la antigüedad -época romana- para la utilización del biso en manufacturas textiles en el centro del Mediterráneo. Aunque las especies son comestibles, en Europa se han capturado más como elemento ornamental o de coleccionismo. Sin embargo, *A. pectinata*, que posee una distribución circumpolar, es consumida en Japón, Taiwán y Filipinas, donde las poblaciones están sobreexplotadas. El descenso de las poblaciones y de las tallas máximas ha conducido a la inclusión de *P. nobilis* dentro de los Catálogos Español y Andaluz de Especies Amenazadas en la categoría “vulnerable”. Tanto *P. nobilis* como *P. rudis* se han incluido, también en la categoría “vulnerable”, en el Libro Rojo de los Invertebrados de Andalucía (2008).

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En este ejemplar de *Pinna rudis* de la pradera de *Posidonia* de Calahonda (Málaga) se puede apreciar las valvas enreabiertas y el lóbulo interno del manto formando una cortina protectora perpendicular a éstas. La gamba *Pontonia pinnophylax* (Otto, 1821) es un huésped habitual del interior de todas las especies andaluzas de Pinnidae.

Pinna nobilis Linnaeus, 1758 – **Nacra**

Especie muy grande, de hasta un metro de longitud, aunque generalmente mide entre 40 y 80 cm. Concha triangular, con el extremo anterior apuntado y el posterior más o menos recto en los juveniles y marcadamente redondeado en los adultos. Escultura formada por numerosas costillas radiales pequeñas, con escamas estrechas, cortas y muy delicadas, que suelen desaparecer en los ejemplares de gran talla. Ligamento largo y estrecho. Color pardo claro. Interior con la mitad anterior nacarada, una pequeña impresión muscular anterior y una grande posterior, situada en el centro de las valvas. La zona nacarada presenta un surco no nacarado central, típico del género.

Hábitat: Característica de la biocenosis de *Posidonia oceanica*, se encuentra también en arena, en fondos detríticos y en praderas de *Cymodocea nodosa*, entre 2 y 40 m de profundidad.

Distribución: Especie endémica del Mediterráneo, en Andalucía es frecuente todavía en algunas zonas del Levante Almeriense, escasa en Granada, y rara en la costa oriental de Málaga. Las citas de la bahía de Algeciras han sido confirmadas recientemente, aunque en la zona su presencia es puntual. Incluida en la categoría "vulnerable" en los Catálogos Español y Andaluz de Especies Amenazadas, y en la misma categoría en el Libro Rojo de los Invertebrados de Andalucía (2008).

Pinna rudis Linnaeus, 1758 – **Nacra de roca**

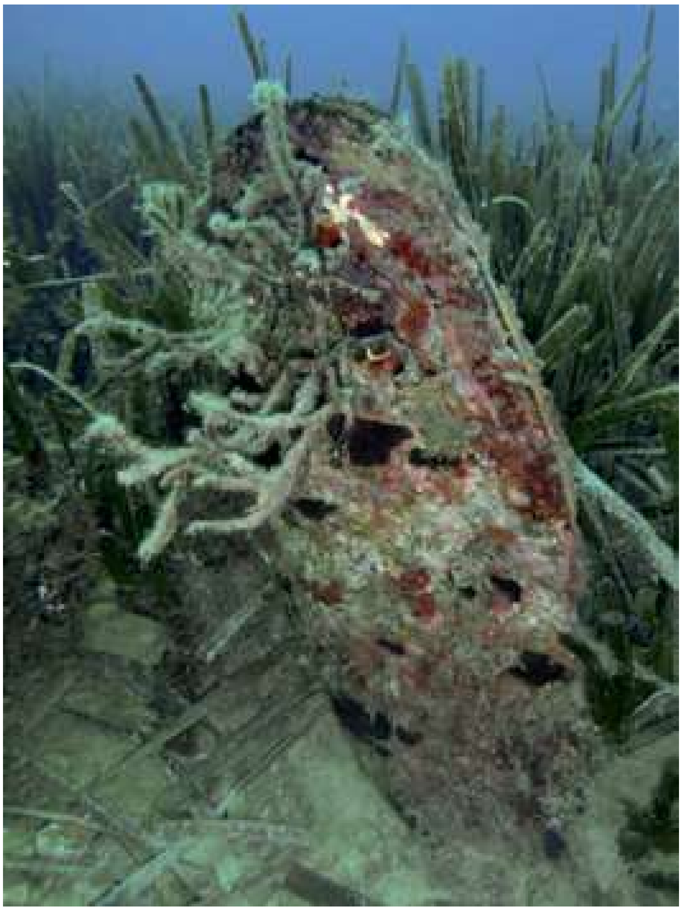
[= *Pinna pernula* Röding, 1798]

Es la especie tipo del género. Especie más pequeña que la anterior, aunque también es muy grande; puede llegar a medir 50 cm de longitud. La concha es triangular y con el extremo posterior más redondeado en los adultos que en los juveniles, posee pocas costillas anchas y unas escamas muy grandes y elevadas. Estas escamas son más evidentes y llamativas en los ejemplares pequeños, y casi desaparecen en los individuos de mayor tamaño. Color castaño e interior nacarado en el extremo anterior. La zona nacarada presenta un surco central sin nácar, característico del género. Existe una pequeña impresión muscular anterior, cercana al umbo, y una gran impresión desde el centro hacia el lado posterior.

Hábitat: Vive preferentemente en fondos rocosos infralitorales, aunque en ocasiones se encuentra en arena, fondos detríticos y en praderas de *Posidonia oceanica*. Se encuentra desde 2 a 40 metros de profundidad.

Distribución: Especie anfiatlántica ya que aparece en la costa americana en el Caribe y en el Atlántico oriental desde las islas Azores y el sur de la Península Ibérica hasta Angola, también en Canarias, las islas de Cabo Verde, Ascensión y Santa Helena. En el Mediterráneo vive en la cuenca occidental. En Andalucía está presente en todas las zonas rocosas, incluida la isla de Alborán, aunque siempre es escasa. Incluida en la categoría "vulnerable" en el Libro Rojo de los Invertebrados de Andalucía (2008).

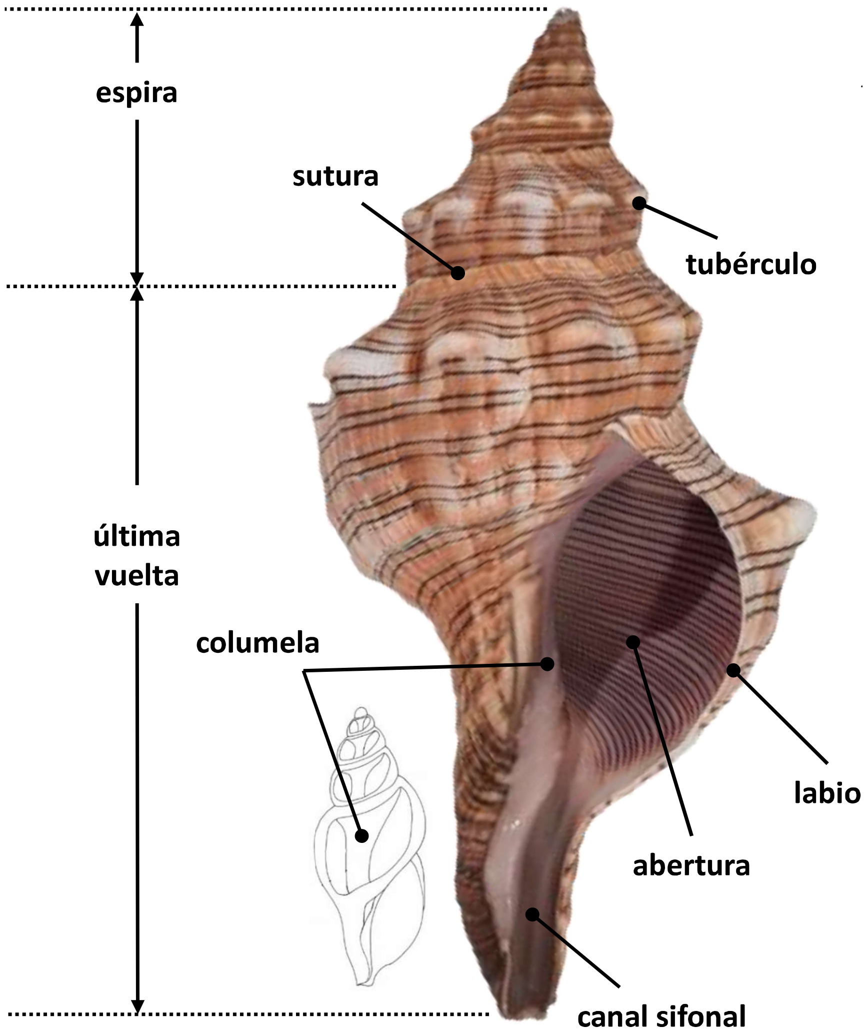
Atrina pectinata (Linnaeus, 1767)
[= *Atrina fragilis* (Pennant, 1777)]
Concha triangular, frágil, de hasta 35 cm aunque generalmente menos, más fina y delicada que las del género *Pinna*. Escultura formada por finas costillas radiales poco numerosas y mucho más estrechas que los interespacios; en algunos ejemplares no se observan las costillas. Internamente el extremo anterior es nacarado, con una impresión muscular anterior pequeña y una posterior más grande.
Las especies del género Atrina *se diferencian de Pinna por la ausencia del profundo seno situado en la parte media anterior y que separa la zona nacarada en dos.*
Hábitat: En fondos fangosos de los pisos circalitoral y batial, entre 150 y 600 m de profundidad; ocasionalmente desde los 10 metros en el entorno de puertos o estuarios donde el fondo es fangoso.
Distribución: Indo-Pacífico, desde Japón hasta Nueva Zelanda, donde algunos autores consideran que vive la subespecie: *Atrina pectinata zelandica* (Gray, 1835). En Japón se han realizado estudios genéticos y se distinguen hasta 4 formas distintas. En el Atlántico europeo vive desde Gran Bretaña hasta Mauritania; Mediterráneo. En Andalucía está presente en todas las costas, incluida la isla de Alborán.

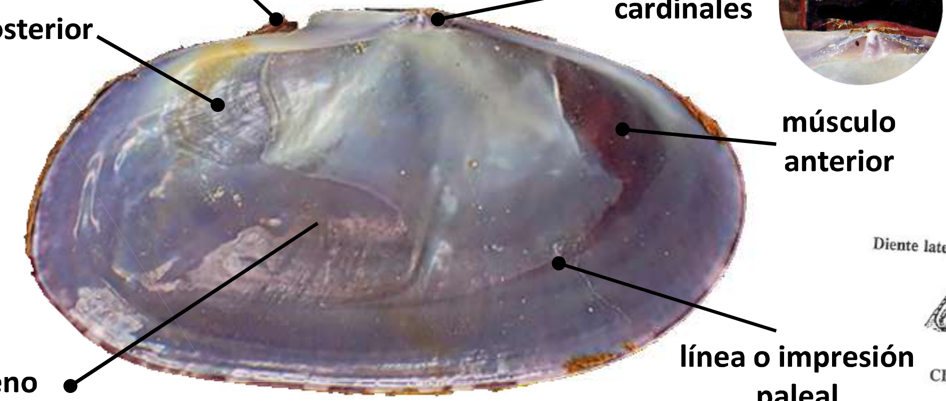


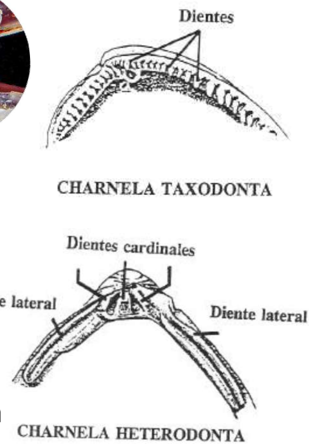
Los individuos de gran tamaño de *Pinna nobilis*, como este de las praderas de *Posidonia oceanica* del Levante Almeriense, constituyen un microcosmos de epibiontes. Sobre las valvas crecen algas, briozoos, poliquetos, tunicados y otros moluscos.

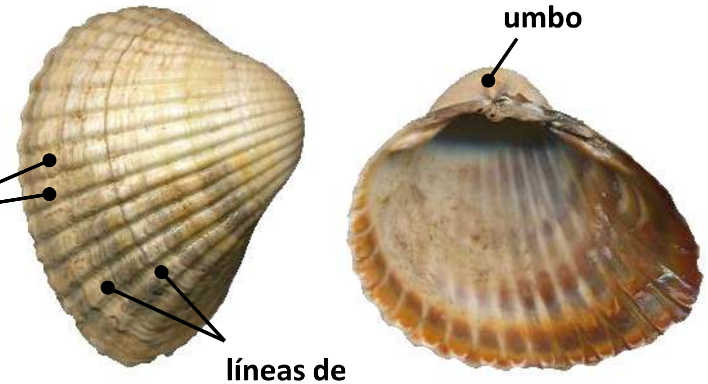
Gastropoda-Bivalvia

caracteres taxonómicos e identificación









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Catálogo	Actualizado	Orden	Superfamilia	Familia	Nombre común	Población referida	Categoría del Catálogo
MOLLUSCA	Cl. GASTROPODA						
Ranela olearia	*Ranella olearium* (Linneaeus, 1758)	Littorinimorpha	Tonnoidea	Ranellidae		Mediterráneo	
Charonia lampas lampas	*Charonia lampas* (Linnaeus, 1758)	Littorinimorpha	Tonnoidea	Charoniidae	Caracola		Vulnerable
Charonia tritonis variegata	*Charonia variegata* (Lamarck, 1816)	Littorinimorpha	Tonnoidea	Charoniidae	Bucio	Mediterráneo	
Tonna galea	*Tonna galea* (Linnaeus, 1758)	Littorinimorpha	Tonnoidea	Tonnidae	Tonel	Mediterráneo	
Dendropoma petraeum	*Dendropoma lebeche* Templado, Richter & Calvo, 2016	Littorinimorpha	Vermetoidea	Vermetidae			Vulnerable
Erosaria spurca	*Naria spurca (Linnaeus, 1758)*	Littorinimorpha	Cypraeoidea	Cypraeidae		Mediterráneo	
Schilderia achatidea	*Schilderina achatidea* (J.E. Gray, 1837)	Littorinimorpha	Cypraeoidea	Cypraeidae		Mediterráneo	
Luria lurida	*Luria lurida* (Linnaeus, 1758)	Littorinimorpha	Cypraeoidea	Cypraeidae		Mediterráneo	
Zonaria pyrum	*Zonaria pyrum* (Gmelin, 1791)	Littorinimorpha	Cypraeoidea	Cypraeidae		Mediterráneo	
Gibbula nivosa	*Steromphala nivosa* (Adams, 1853)	Trochida	Trochoidea	Trochidae		Mediterráneo	
Mitra zonata	*Episcomitra zonata* (Marryat, 1819)	Neogastropoda	Mitroidea	Mitridae		Mediterráneo	
Nucela lapilus	*Nucella lapillus* (Linnaeus, 1758)	Neogastropoda	Muricoidea	Muricidae			
Tritia tingitana (Pallary, 1901).	*Tritia tingitana* (Pallary, 1901)	Neogastropoda	Buccinoidea	Nassariidae	Caracolilla de Tánger		Vulnerable
Cymbula nigra	*Cymbula safiana* (Lamarck, 1819)		Patelloidea	Patellidae		Mediterráneo	
Patella candei candei	*Patella candei* A. d'Orbigny, 1840		Patelloidea	Patellidae	Lapa majorera		En peligro de extinción
Patela ferruginea	*Patella ferruginea* Gmelin, 1791		Patelloidea	Patellidae	Lapa ferruginea		En peligro de extinción
Patella ulyssiponensis aspera	*Patella aspera* Röding, 1798		Patelloidea	Patellidae			
	Cl. BIVALVIA						
Lithophaga lithophaga	*Lithophaga lithophaga* (Linnaeus, 1758)	Mytilida	Mytiloidea	Mytilidae		Mediterráneo	
Pholas dactylus	*Pholas dactylus* Linnaeus, 1758	Myida	Pholadoidea	Pholadidae		Mediterráneo	
Pinna nobilis	*Pinna nobilis* Linnaeus, 1758	Ostreida	Pinnoidea	Pinnidae	Nacra, Nácar		En peligro de extinción
Pinna rudis	*Pinna rudis* Linnaeus, 1758	Ostreida	Pinnoidea	Pinnidae		Mediterráneo	

Catálogo	Actualizado	Orden	Superfamilia	Familia	Nombre común	Población referida	Categoría del Catálogo
ECHINODERMATA	Cl. Asteroidea						
Asterina pancerii	*Asterina pancerii* (Gasco, 1876)	Valvatida		Asterinidae	Estrella del capitán pequeña		
Ophidiaster ophidianus	*Ophidiaster ophidianus* (Lamarck, 1816)	Valvatida		Ophidiasteridae	Estrella púrpura	Mediterráneo	
	Cl. Echinoidea						
Centrostephanus longispinus	*Centrostephanus longispinus* (Philippi, 1845)	Diadematoida		Diadematidae			

CRUSTACEA	Cl. Malacostraca						
Munidopsis polymorpha	*Munidopsis polymorpha* Koelbel, 1892	Decapoda	Galatheoidea	Munidopsidae	Jameíto		En peligro de extinción
Ocypode cursor (Linnaeus, 1758)	*Ocypode cursor* (Linnaeus, 1758)	Decapoda	Ocypodoidea	Ocypodidae		Mediterráneo	
Panulirus echinatus	*Panulirus echinatus* Smith, 1869	Decapoda		Palinuridae	Langosta herreña		En peligro de extinción
	Cl. Thecostraca						
Pachylasma giganteum (Philippi, 1836)	*Pachylasma giganteum* (Philippi, 1836)	Balanomorpha	Chthamaloidea	Pachylasmatidae		Mediterráneo	
	Cl. Remipedia						
Speleonectes ondinae	*Morlockia ondinae* García-Valdecasas, 1985	Nectiopoda		Morlockiidae	Remípedo de los jameos		En peligro de extinción

PLAN DE FORMACIÓN DESTINADO A ADMINISTRACIONES PÚBLICAS COMPETENTES EN LA GESTIÓN DE LA RED NATURA 2000 MARINA (2022-2025)

Identificación y distinción de especies marinas vulnerables de otras especies similares de interés pesquero u objeto de infracción

Octubre-noviembre 2024

Acción impulsada por la Fundación Biodiversidad del Ministerio para la Transición Ecológica y el Reto Demográfico en colaboración con la Dirección General de Biodiversidad, Bosques y Desertificación (MITECO) y el Centro de Investigaciones Marinas de la Universidad de Alicante para su desarrollo en el marco de los fondos del Plan de Recuperación, Transformación y Resiliencia (PRTR) de la Unión Europea-NextGenerationEU.

Identificación y distinción de especies marinas vulnerables de otras especies similares de interés pesquero u objeto de infracción

Sesión 4: Práctica de identificación de especies de visu. Peces.

Ponente: José Miguel González Correa

12 de noviembre de 2024

GOBIERNO DE ESPAÑA
VICEPRESIDENCIA TERCERA DEL GOBIERNO
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO
Fundación Biodiversidad
Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU
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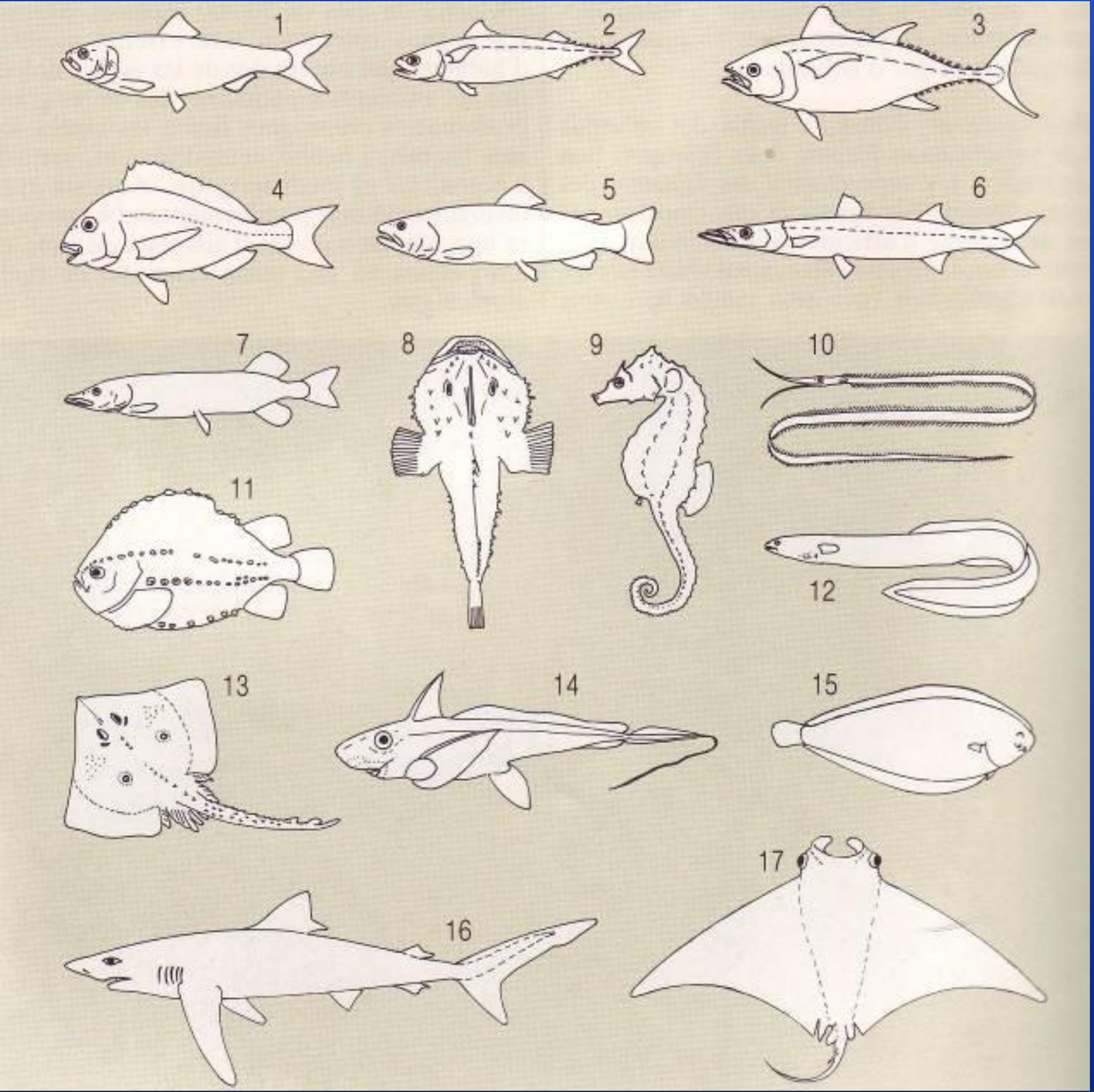
“El menor movimiento es de importancia para toda la naturaleza. El océano entero se ve afectado por una piedra.”

Blaise Pascal

Subtipo	Superclase	Clase	Subclase	Suborden
Cefalocordados				
Vertebrados	**Peces**	**Ciclóstomos**		
		Condrictios	**Seláceos**	
			Bradiodontos	
		Osteictios	**Actinopterigios**	**Condrósteos**
				Holósteos
				Teleósteos
			Braquiopterigios	
			Crosopterigios	
			Dipneustos	
		Anfibios		
		Reptiles		
		Aves		
		Mamíferos		



Formas corporales

-Fusiforme

-Comprimida

-Deprimida

-Anguiliformes

-Filiformes

-Otras (Hippocampus)

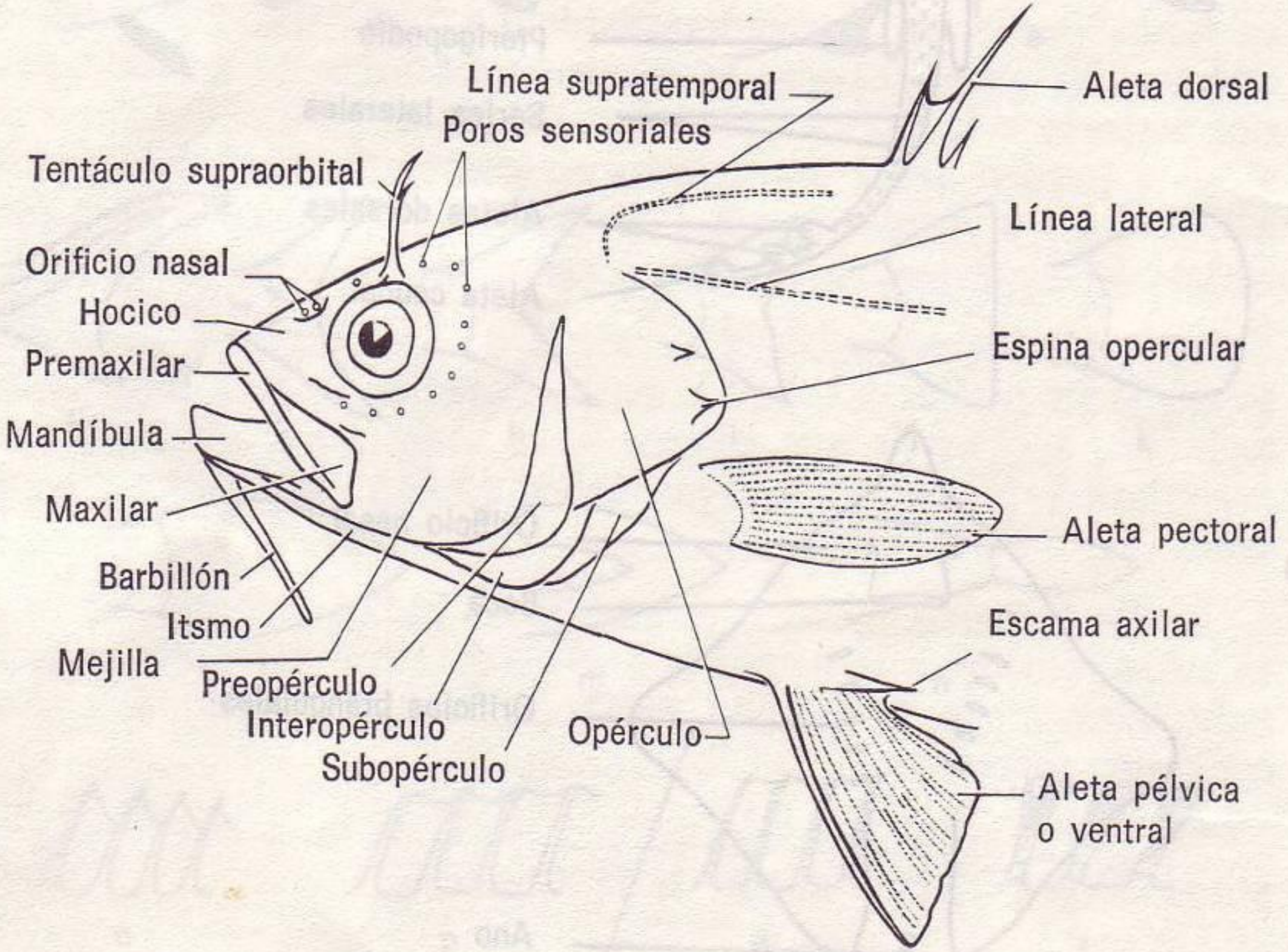
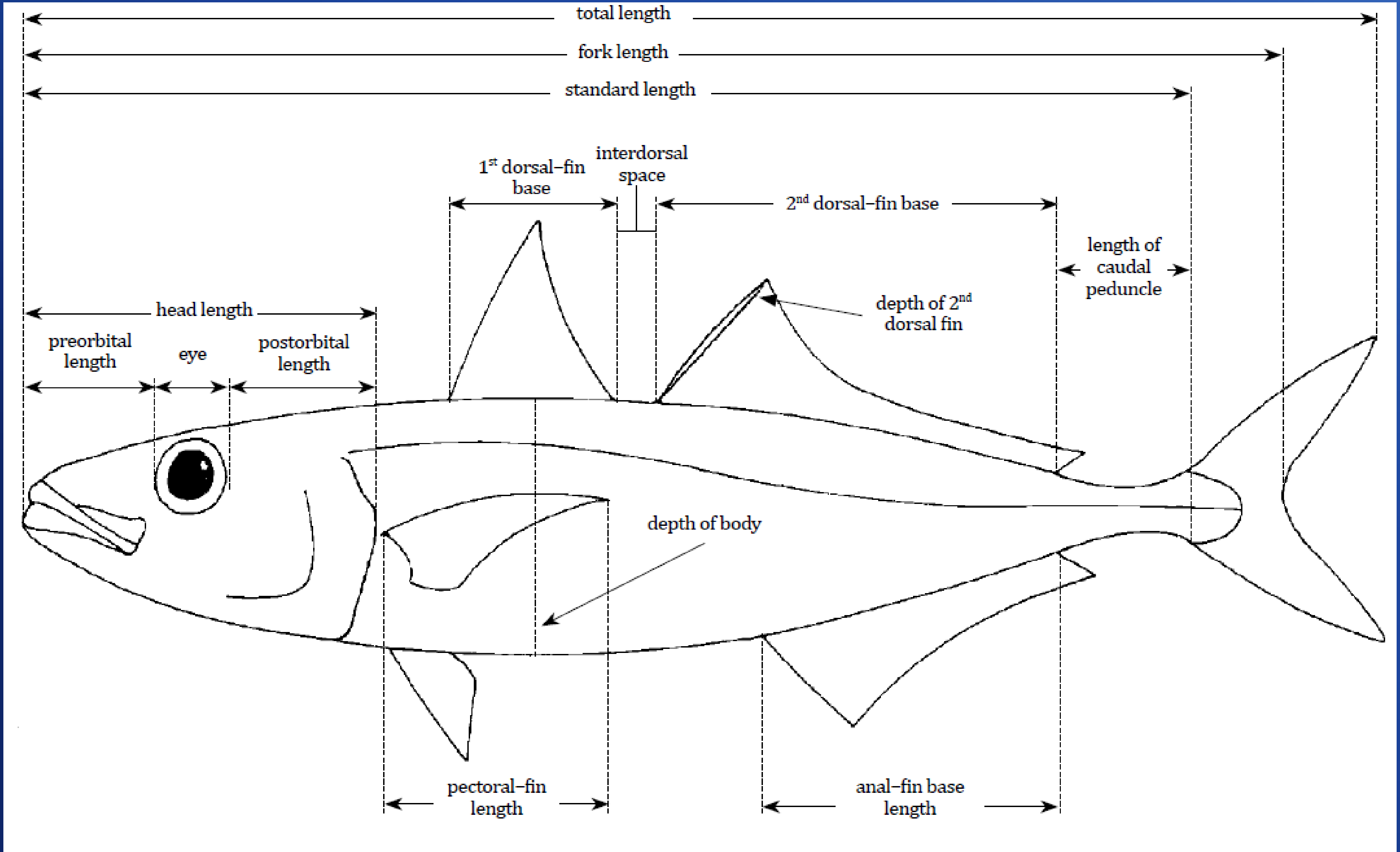
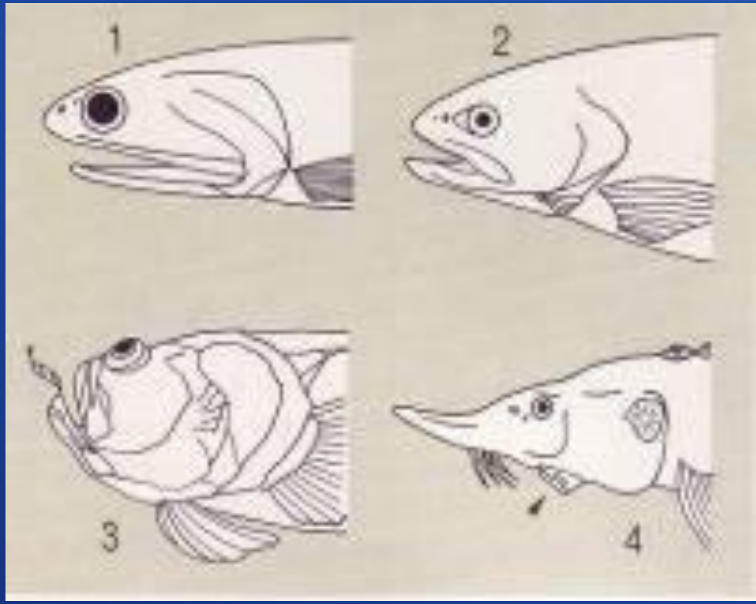


Fig. 5. — Visión lateral de la cabeza de un Teleósteo imaginario


total length
fork length
standard length
1st dorsal–fin base
interdorsal space
2nd dorsal–fin base
length of caudal peduncle
depth of 2nd dorsal fin
head length
preorbital length
eye
postorbital length
depth of body
pectoral–fin length
anal–fin base length

Lophius piscatorius (superior)



Engraulis encrasicholus (subterminal)

Torpedo torpedo (inferior)

Posición de la boca

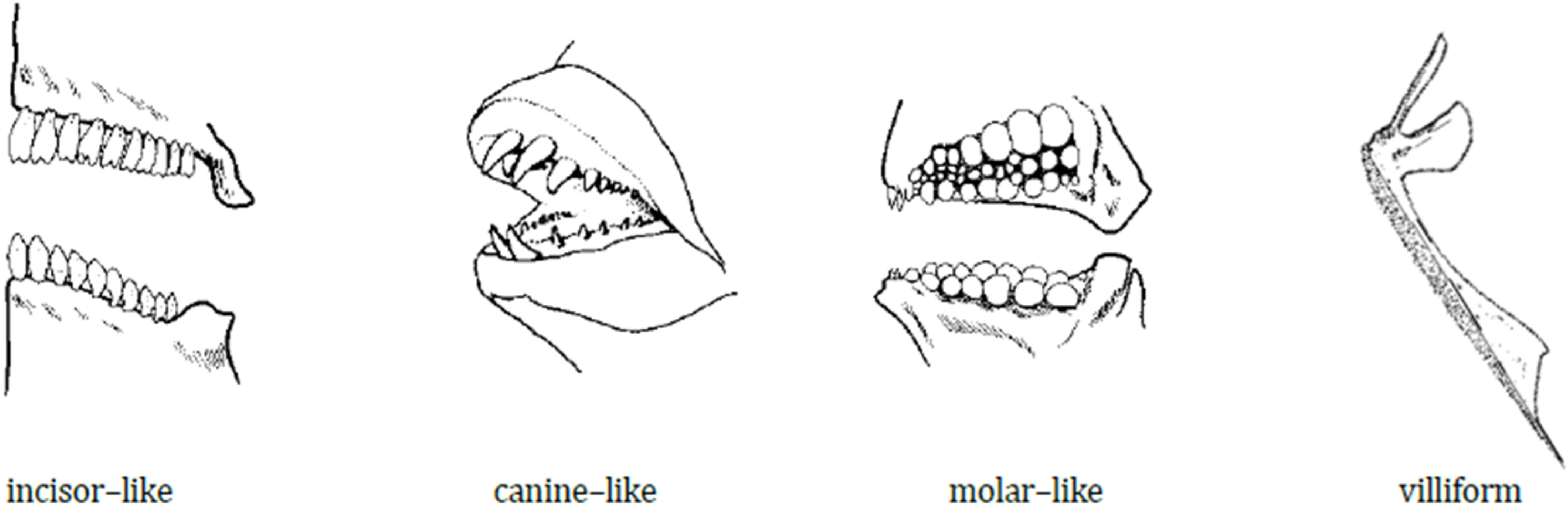
-1 subterminal

-2 terminal

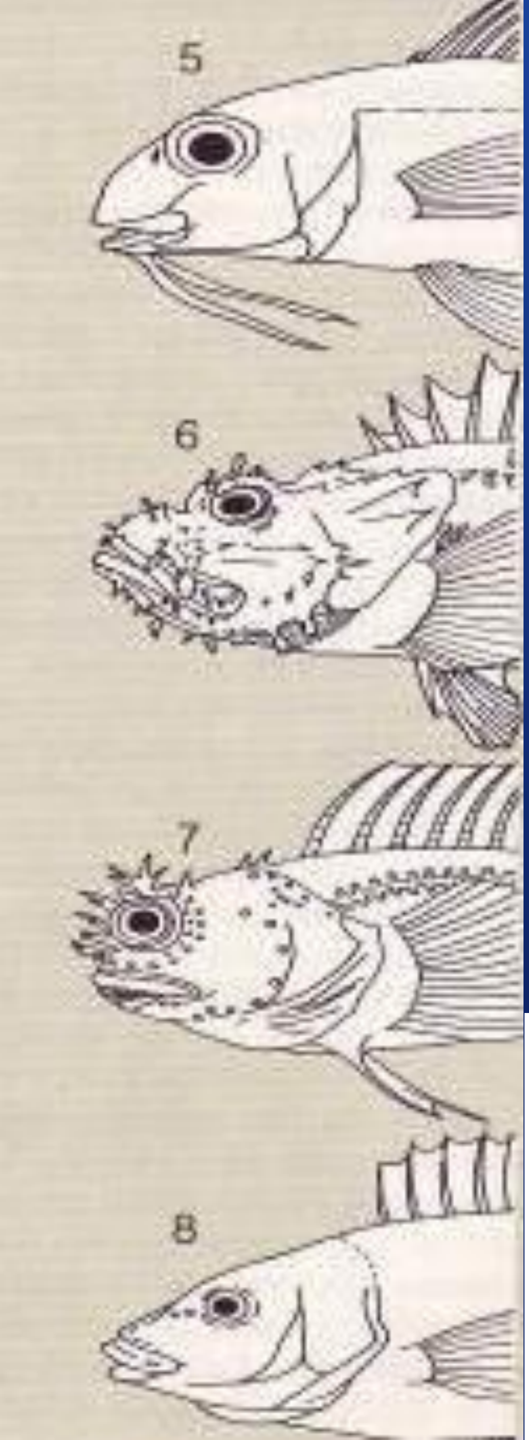
-3 superior

-4 inferior

Thunnus thynnus (terminal)



Common types of teeth

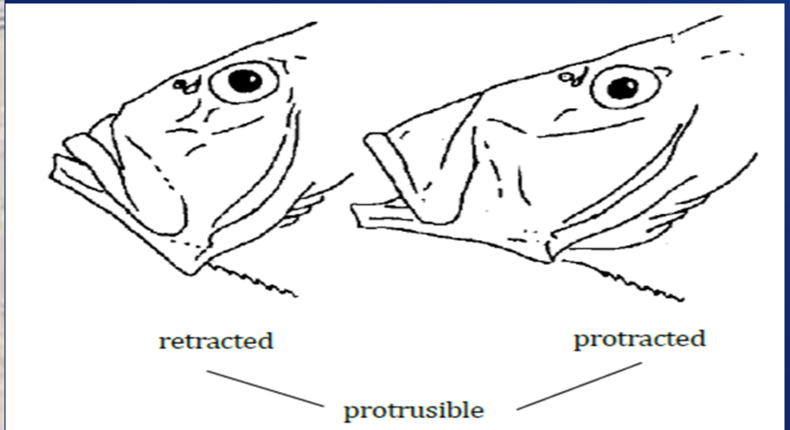


-5 Barbas sensoriales (Mullus)

-6 Espinas y crestas cefálicas (Scorpaena)

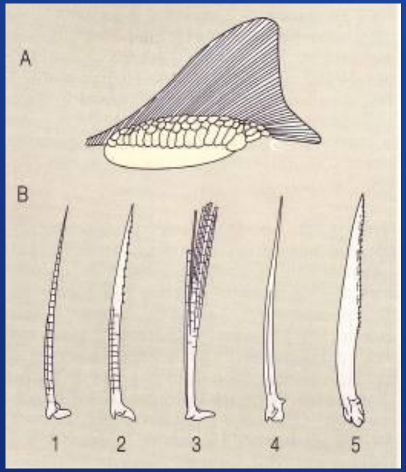
-7 Cirros o tentáculos (Blenius)

-8 Expansiones labiales (Labrus)



Las aletas

A- Cartilaginosos.



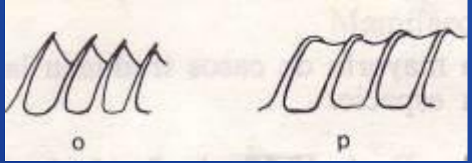
B- Óseos

B-1,2 y 3 blandos o segmentados

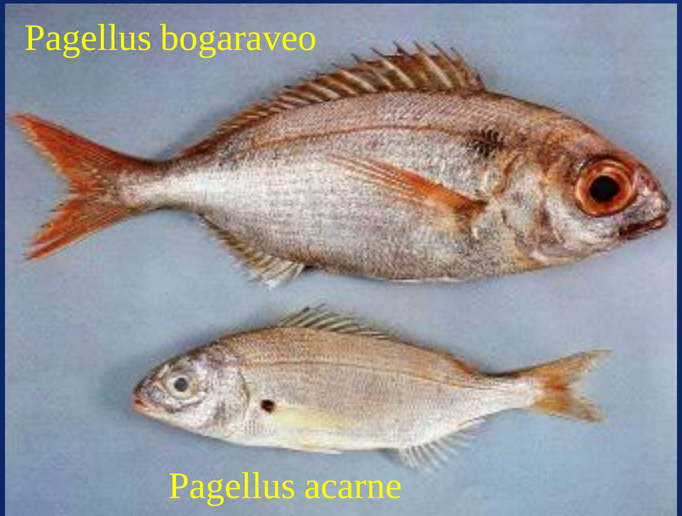
Simples Ramificados (mixtos)

B- 4, 5 duros o espinosos, no segmentados.

acerados flexibles



La fórmula radial: el número de radios espinosos indicado con cifras romanas y el de radios segmentados con cifras arábigas. Primero se nombran los segmentados simples y después los ramificados.



D XII-XIII+11-13,
A III+11-12

D XII-XIII+10-12,
A III+ 9-10

Sardina pilchardus

D 4+13-14,
A 2+15-19

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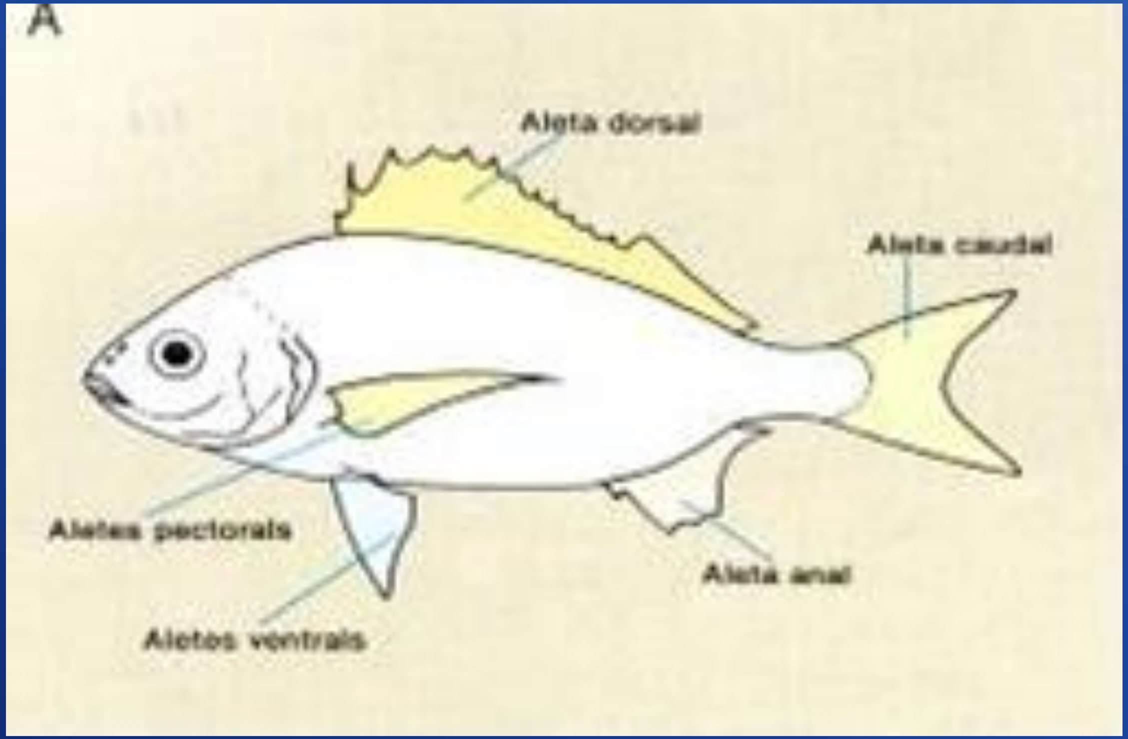
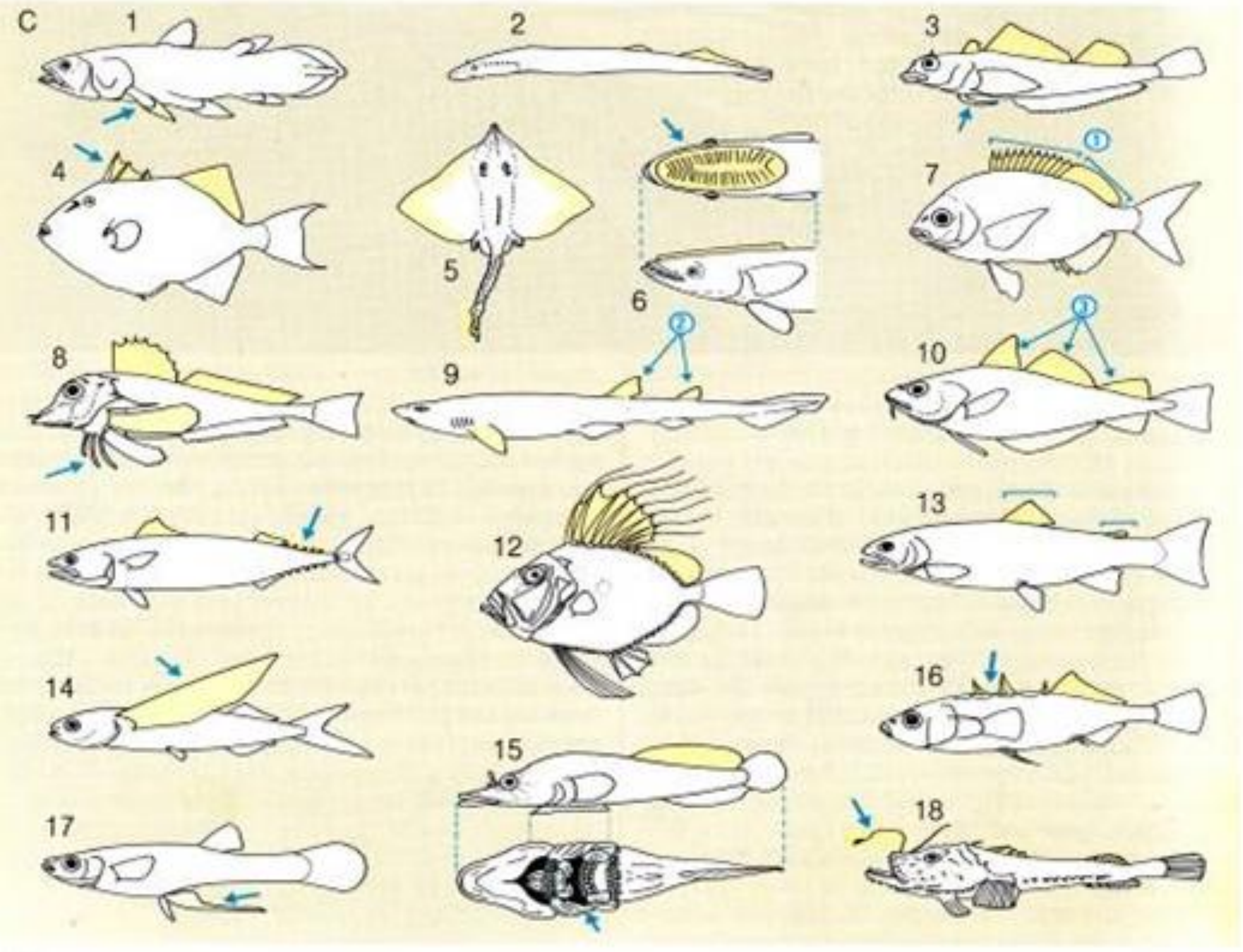
Las aletas

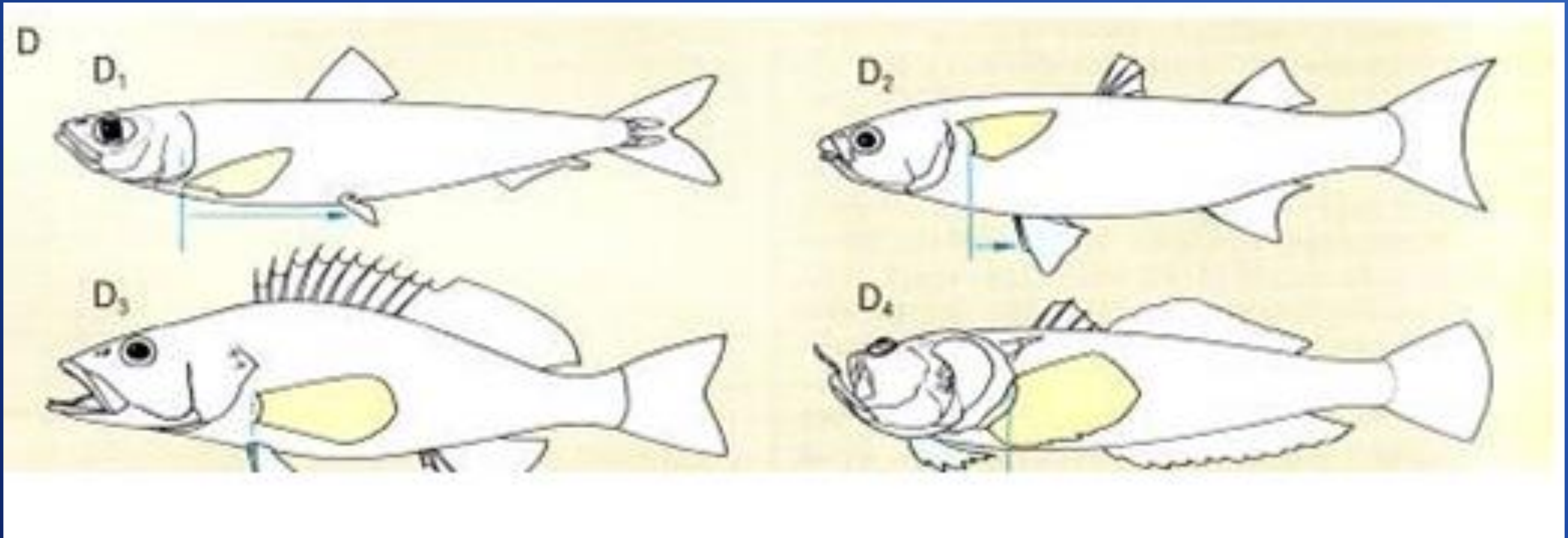


A- Disposición general

- Aletas pares: pectorales y pélvicas o ventrales
- Aletas impares: dorsal, anal y caudal



Las aletas: morfología y funcionalidad



D- Tipos de aletas ventrales según su punto de inserción.

D1- abdominales

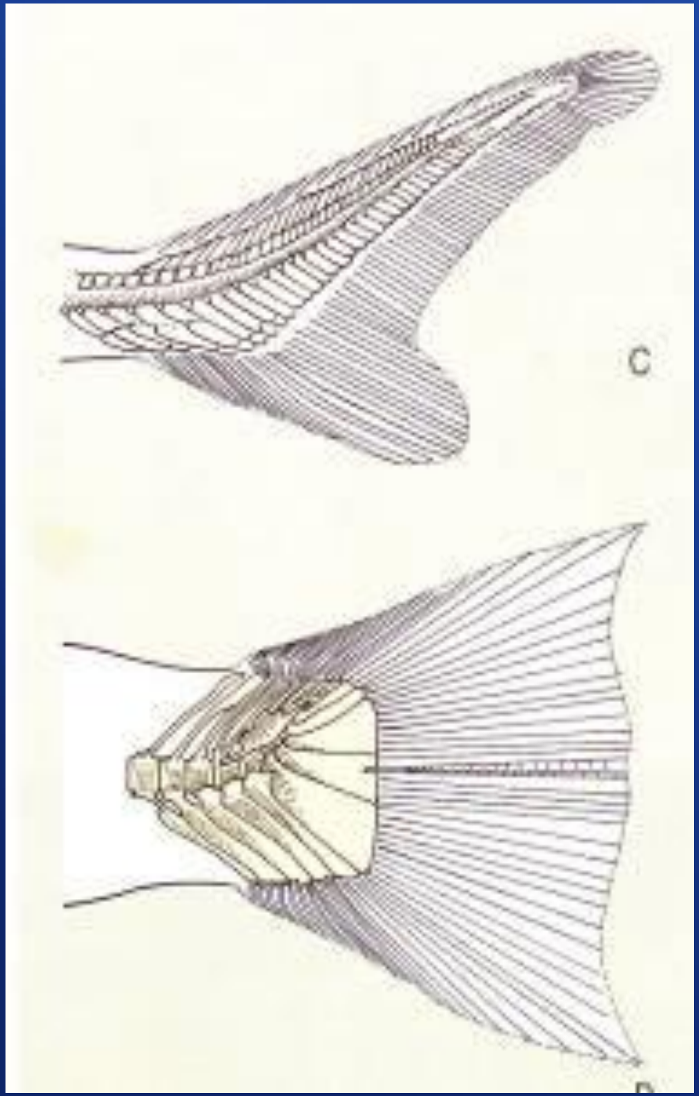
D2- subabdominales

D3- torácicas

D4- yugulares

Las aletas

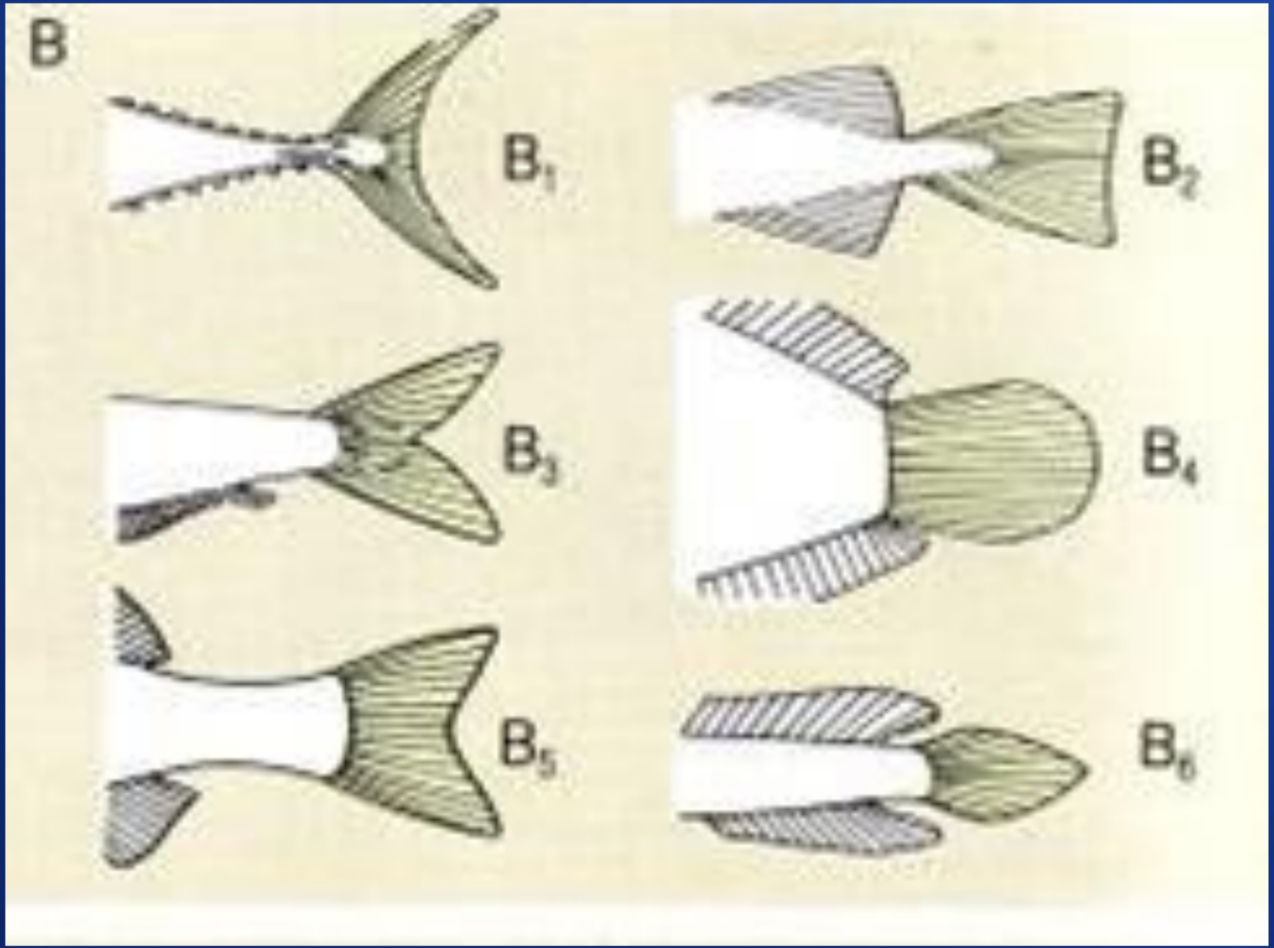
Aleta caudal



Heterocerca (seláceos)

Homocerca

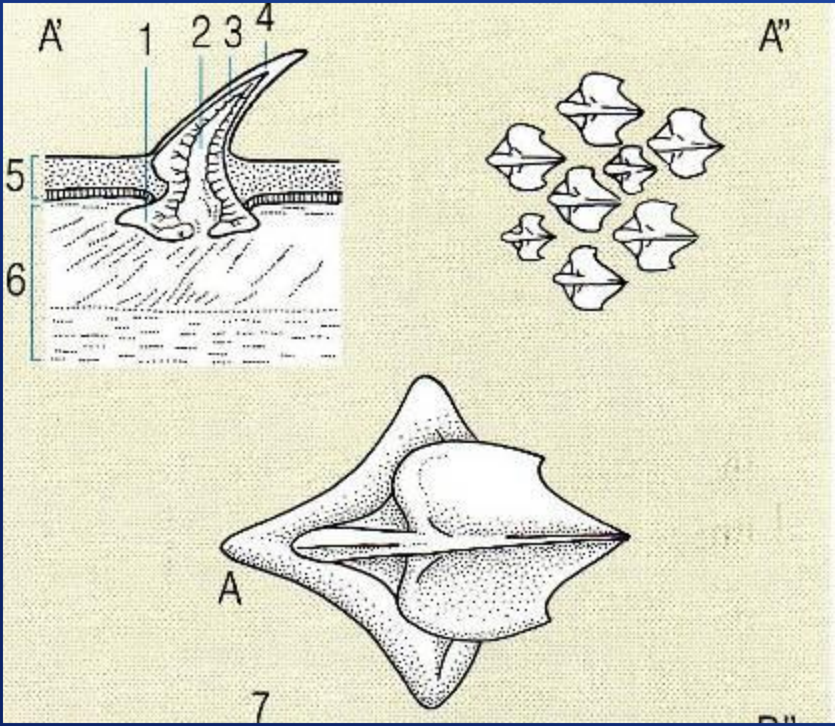
Las aletas



B- Tipos de aletas caudales

- B1- Media luna (atunes)
- B2- Partidas (Escórpora
- B3- Escotadas (sardinas)
- B4-Redondeadas (lenguado)
- B5-Hendidas (llobarro)
- B6-Apuntadas (góbidos)

Las aletas

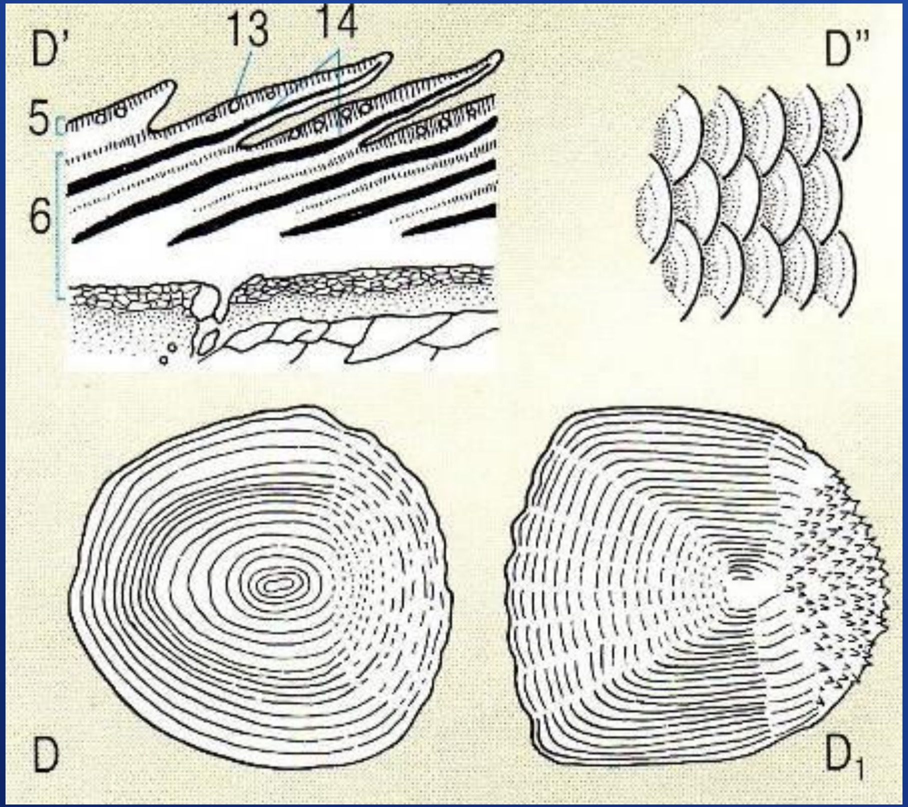


-En peces cartilaginosos: dentículos dérmicos o escamas placoides

-En peces óseos, elasmoideas:

D- Cicloideas

D1-Ctenoideas



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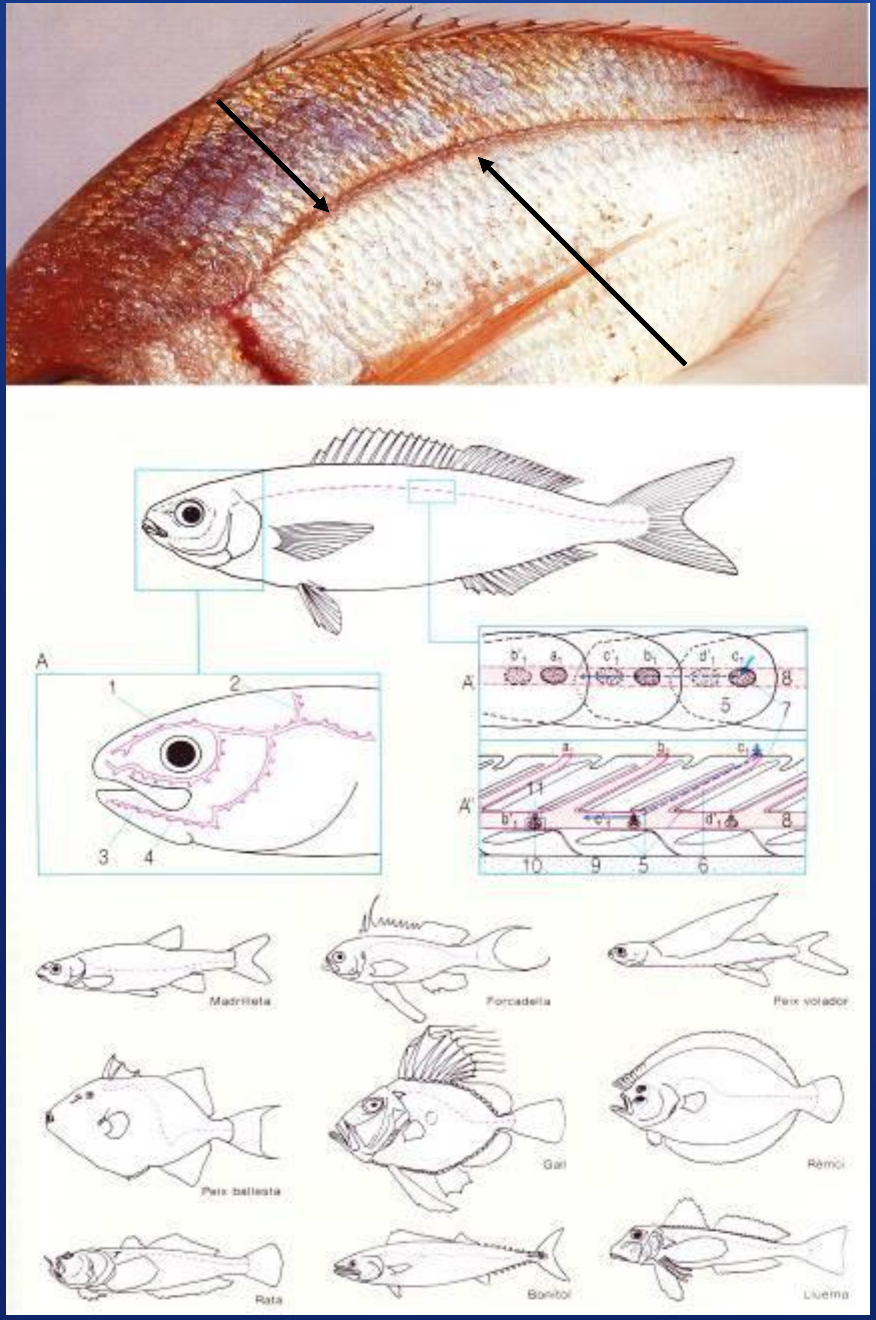
La línea lateral



-Sistema sensorial de presión (neuromastos)

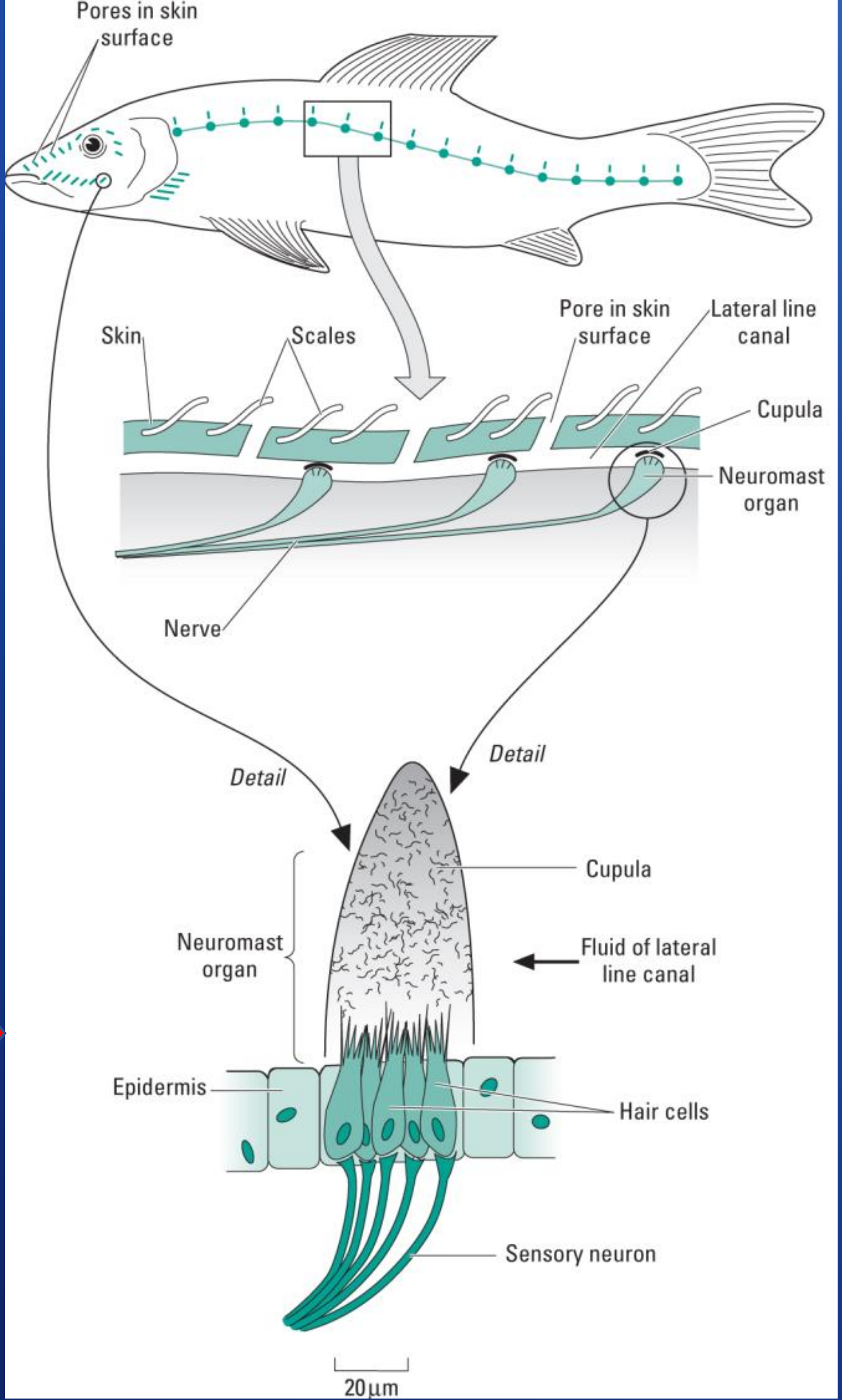
-Utilizada para detectar presas, otros peces (dentro del cardumen) y obstáculos.

-El número de escamas que recorre la línea lateral, las escamas transversales y la disposición de los canales en la cabeza es utilizada para la clasificación.

-La disposición de la línea lateral define los hábitos de la especie.

La línea lateral

- Neuromastos están incluidos en la línea lateral



PLAN DE FORMACIÓN DESTINADO A ADMINISTRACIONES PÚBLICAS COMPETENTES EN LA GESTIÓN DE LA RED NATURA 2000 MARINA (2022-2025)

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Acción impulsada por la Fundación Biodiversidad del Ministerio para la Transición Ecológica y el Reto Demográfico en colaboración con la Dirección General de Biodiversidad, Bosques y Desertificación (MITECO) y el Centro de Investigaciones Marinas de la Universidad de Alicante para su desarrollo en el marco de los fondos del Plan de Recuperación, Transformación y Resiliencia (PRTR) de la Unión Europea-NextGenerationEU.

Gracias por su atención