Comparative Anatomy & Evolution of Vertebrates

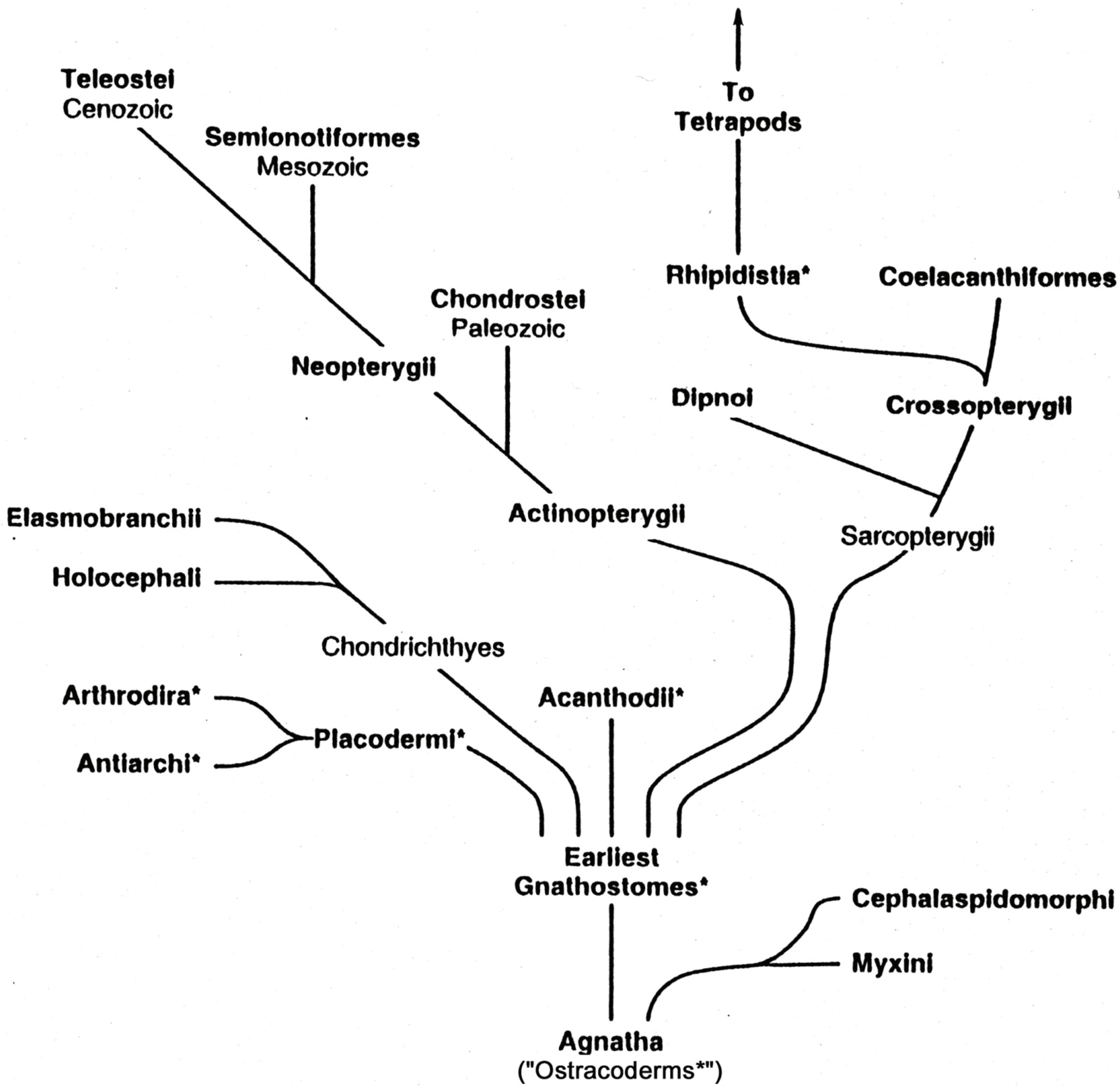


FIGURE 44. Ancestral Lineage of the Fishes. Extinct groups are marked by an asterisk.

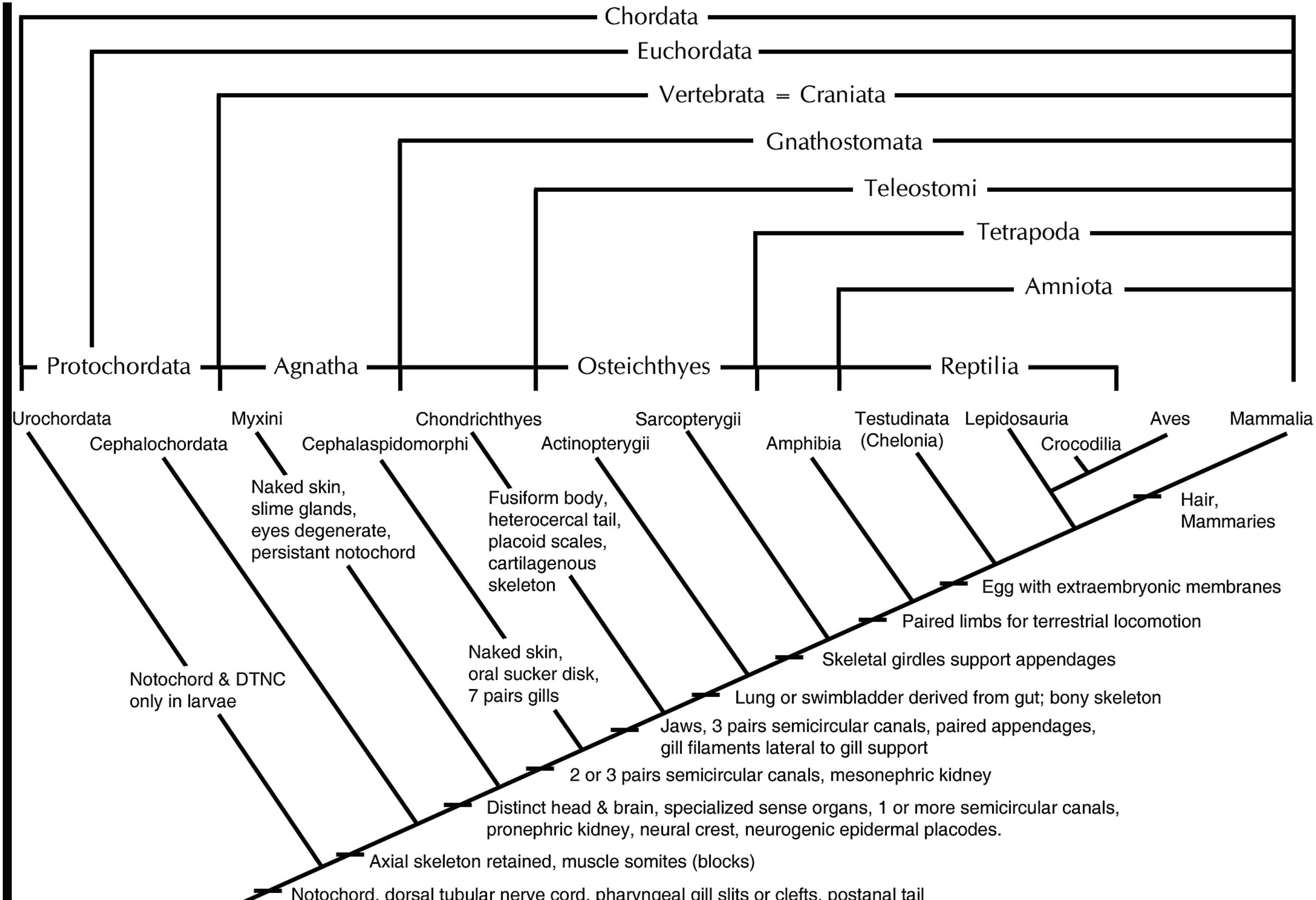


FIGURE 46. **Cladogram of the living vertebrates.** Functional group arrangements are depicted above the cladogram.

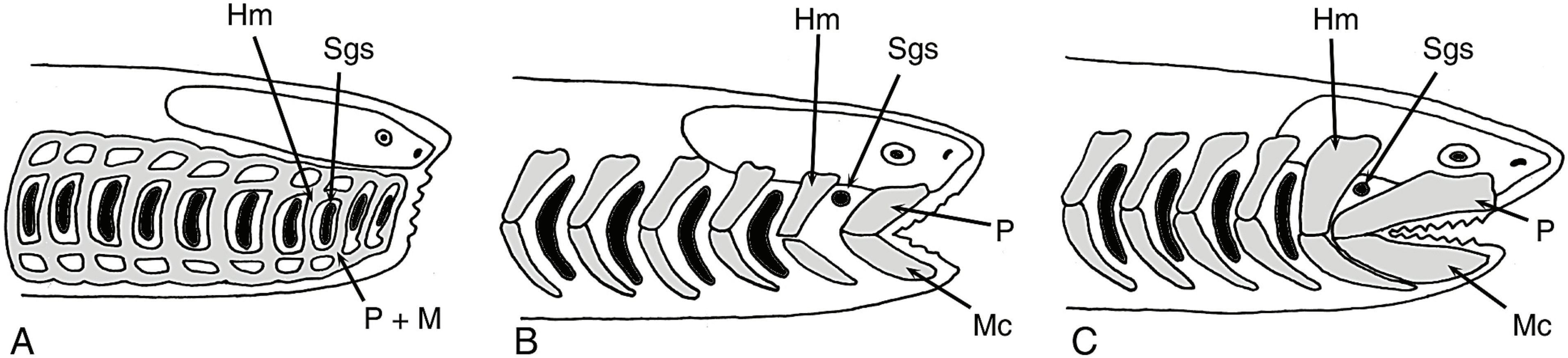


FIGURE 59. Evolution of the vertebrate jaw and hyoid arch. A. Primitive jawless condition. Primitive Silurian fish converted anterior gill slits into a spiracular opening on the upper head, allowing water to be drawn into the pharynx without fouling the gills. **B.** The spiracular gill slit (*Sgs*) has been reduced and primitive jaws have formed, the hyomandibular arch (*Hm*) remains unspecialized. Palatoquadrate or pterygoquadrate (*P*) bone forms the upper "jaw"; mandibular bone or Meckel's cartilage (*M*) forms the lower jaw. **C.** Condition seen in primitive jawless fishes: hyomandibular arch has become a jaw support and intervening gill slit reduced to a dorsolateral spiracle. Gill slits in black, pharyngeal elements in gray.

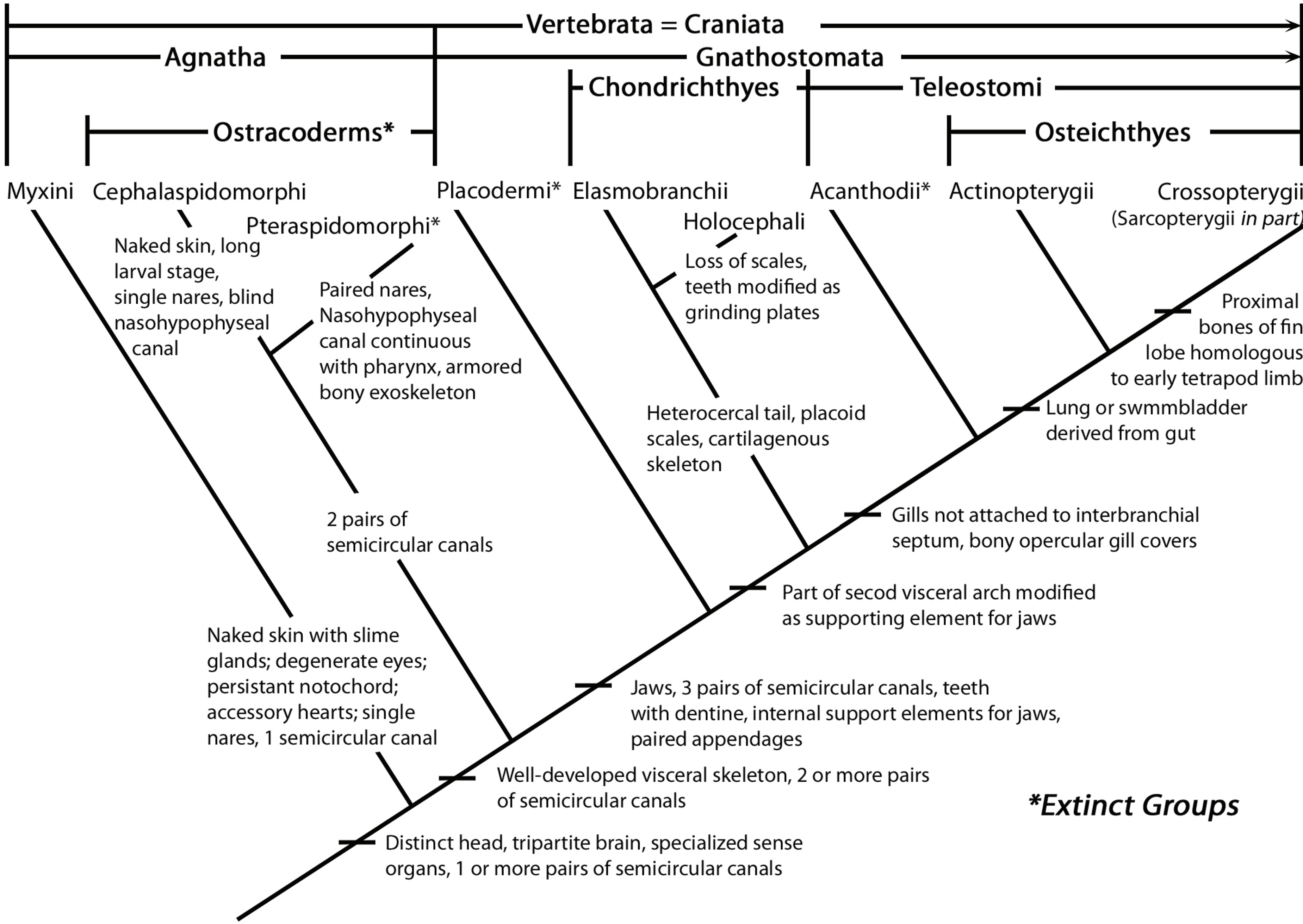


FIGURE 47. Cladogram of the Fishes. Functional group arrangements are depicted above the cladogram. The ostracoderms are extinct and include extinct members of the Cephalaspidomorphi.

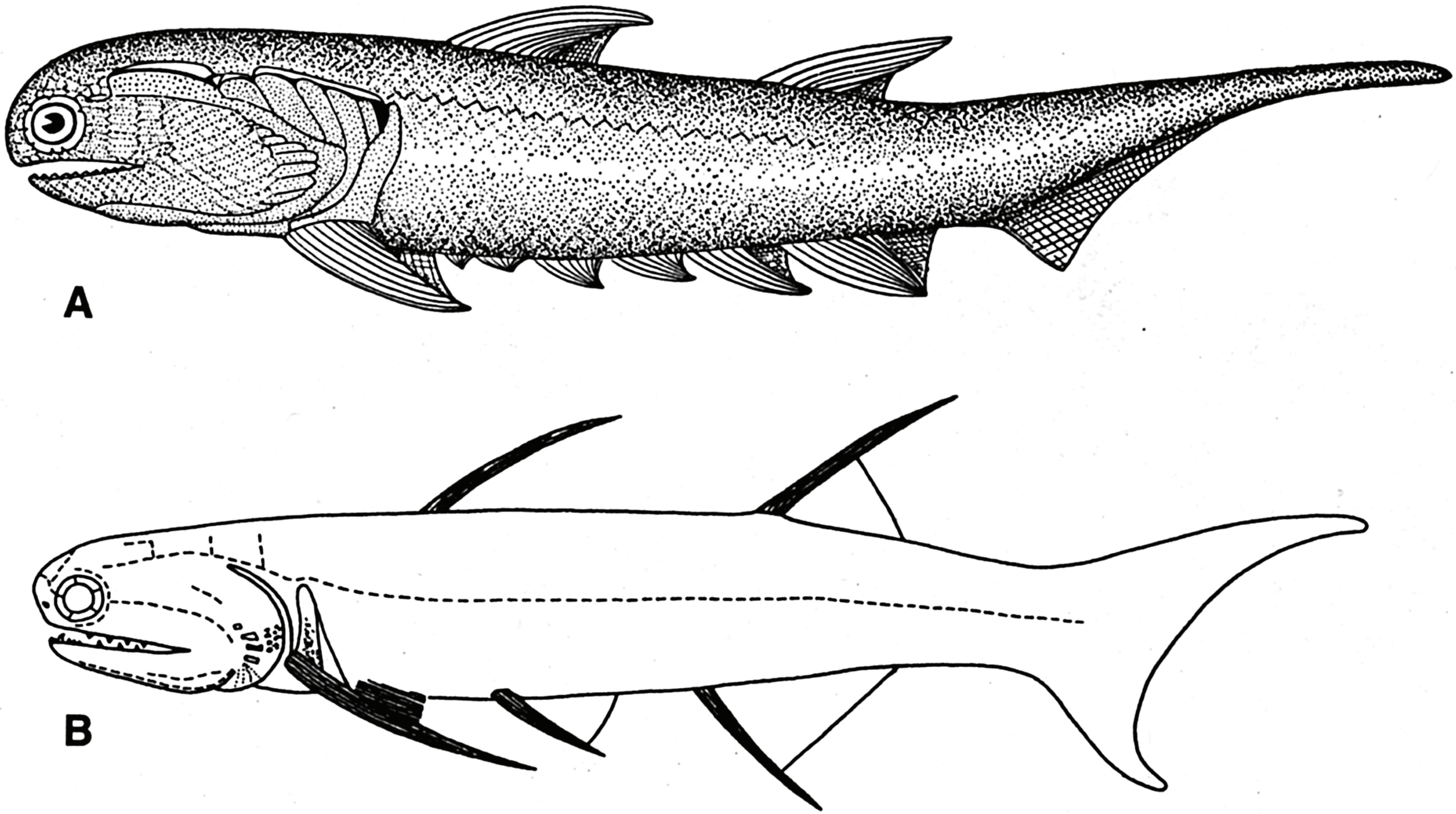


FIGURE 61. **Acanthodians (Gnathosoma: Acanthodii), primitive jawed fishes often called the spiny sharks.** A. *Climatius*, a form with heavy scales and very large fin spines. B. *Ischnacanthus*, a form with greatly reduced armor and thin spines.

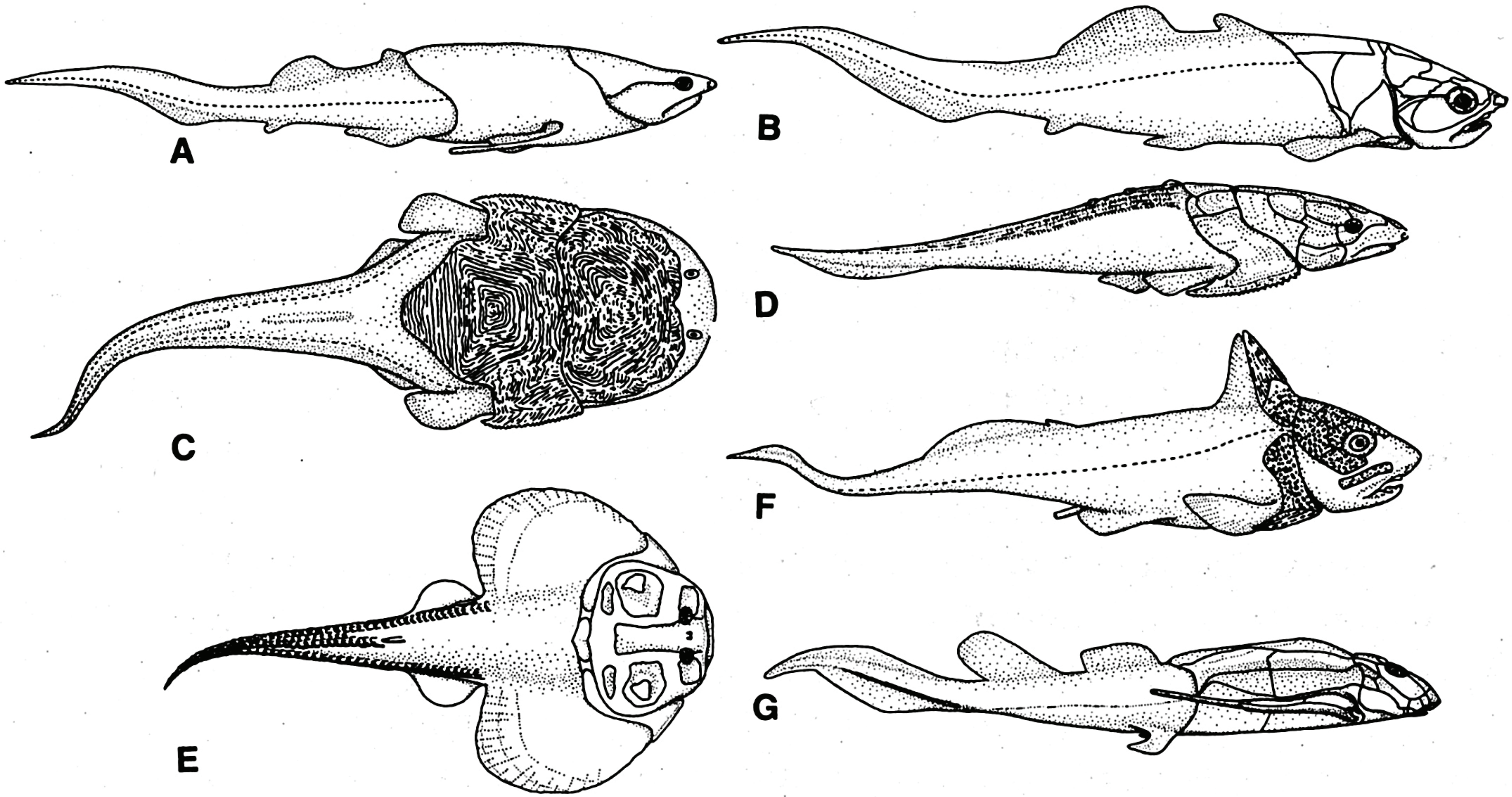
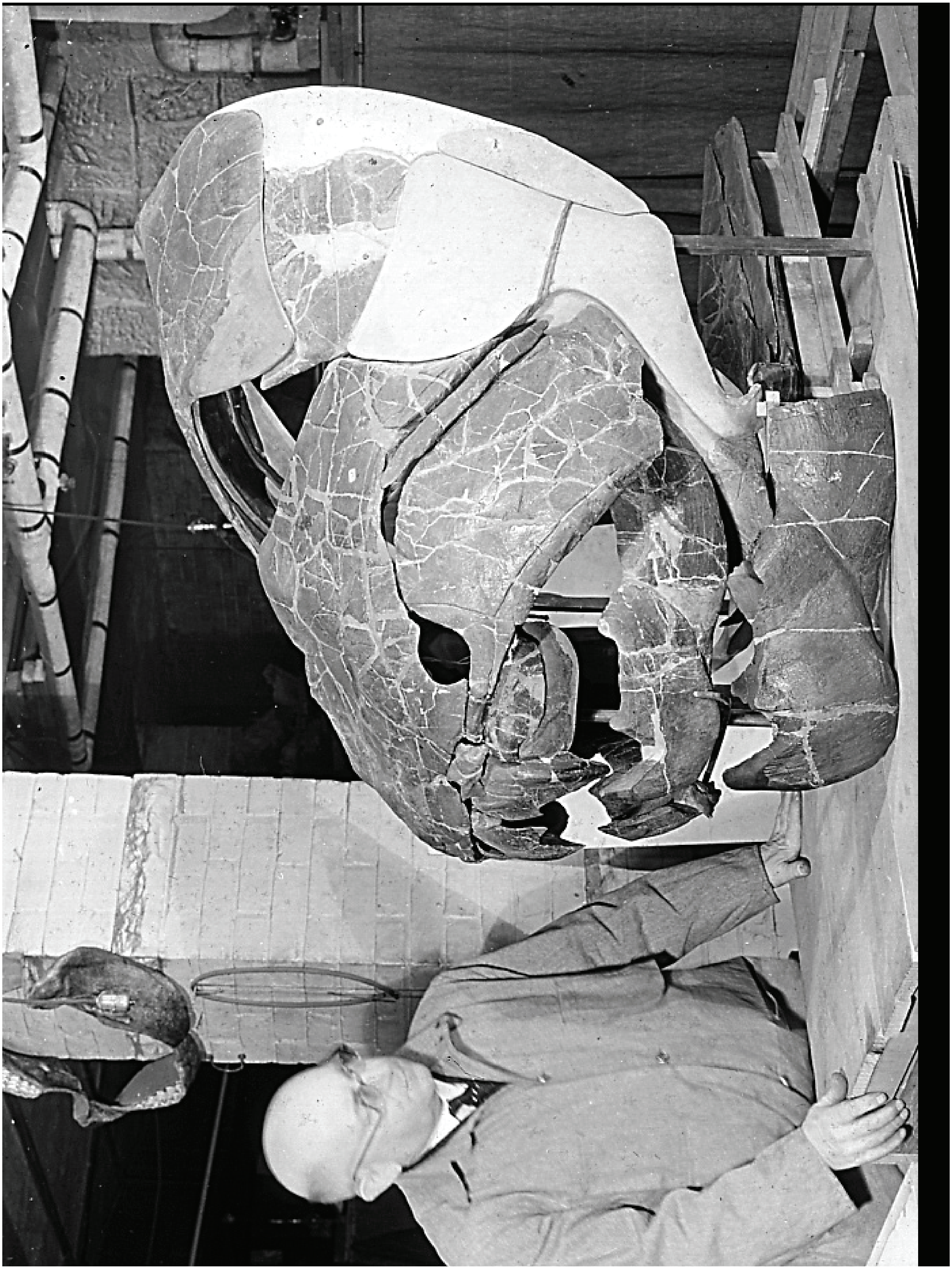
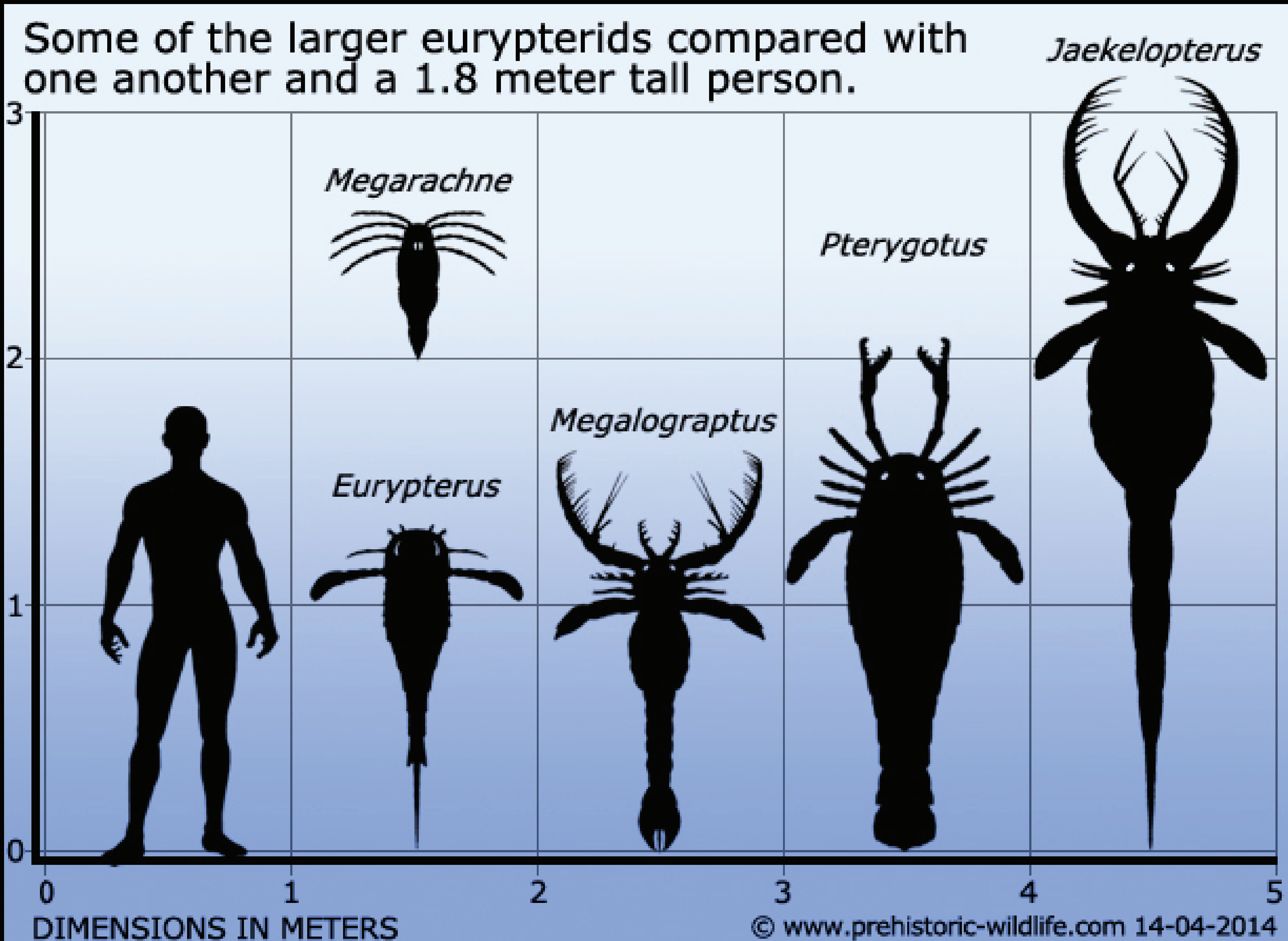


FIGURE 60. Representative placoderms (Gnathosoma: Placodermi). A. *Arctolepis.* B. *Coccosteus.* C. *Phyllolepis.* D. *Lunaspis.* E. *Gemuendina.* F. *Rhamphodopsis.* G. *Bothriolepis.* C & E in dorsal view, all others in lateral view. (*After Stensio*).



Class Merostomata: Subclass Eurypterida



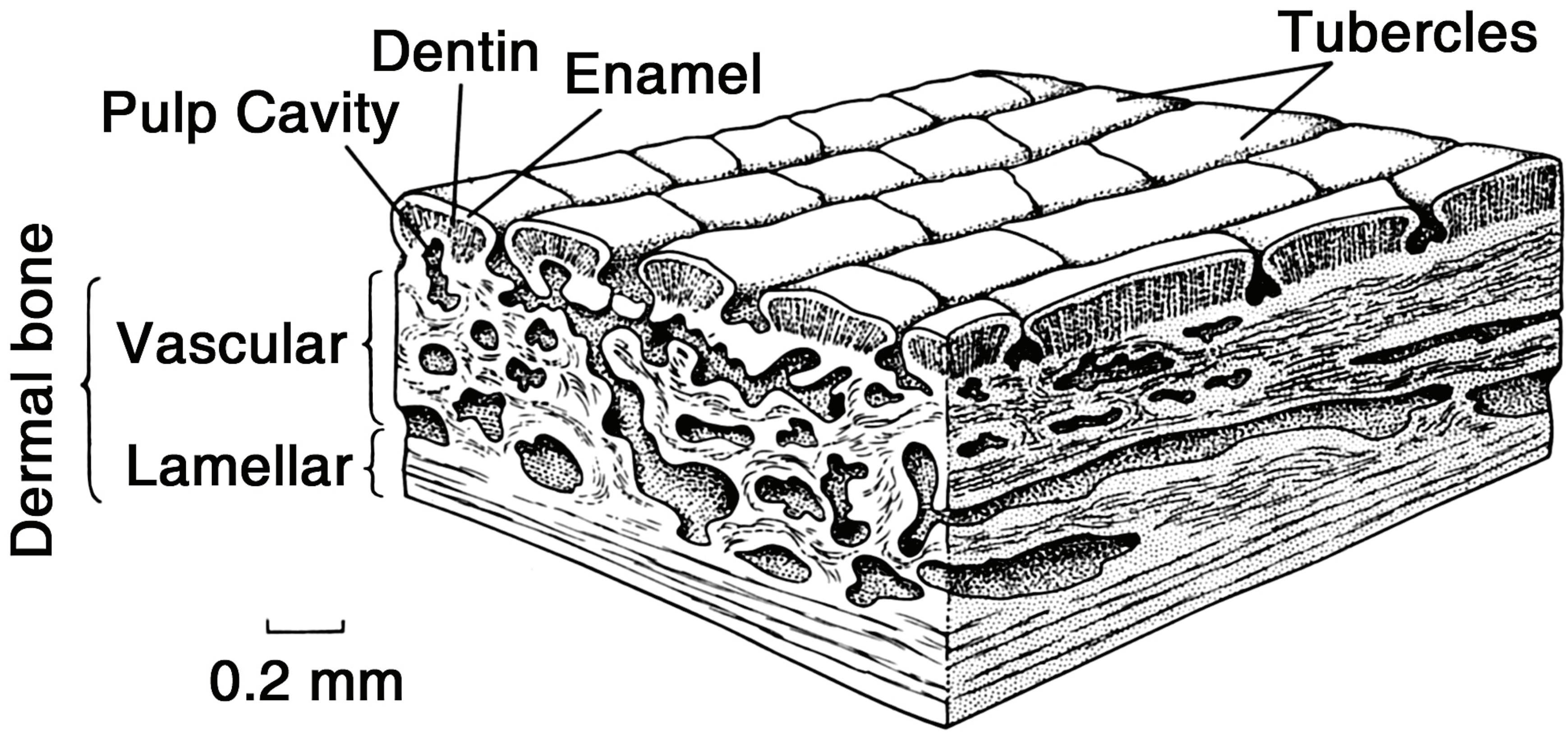


FIGURE 62. Section through an enlarged ostracoderm scale. The surface consists of raised tubercles capped with dentin and enamel enclosing a pulp cavity. These tubercles rest upon a foundation of dermal bone, part of the heavy dermal armor covering the body.

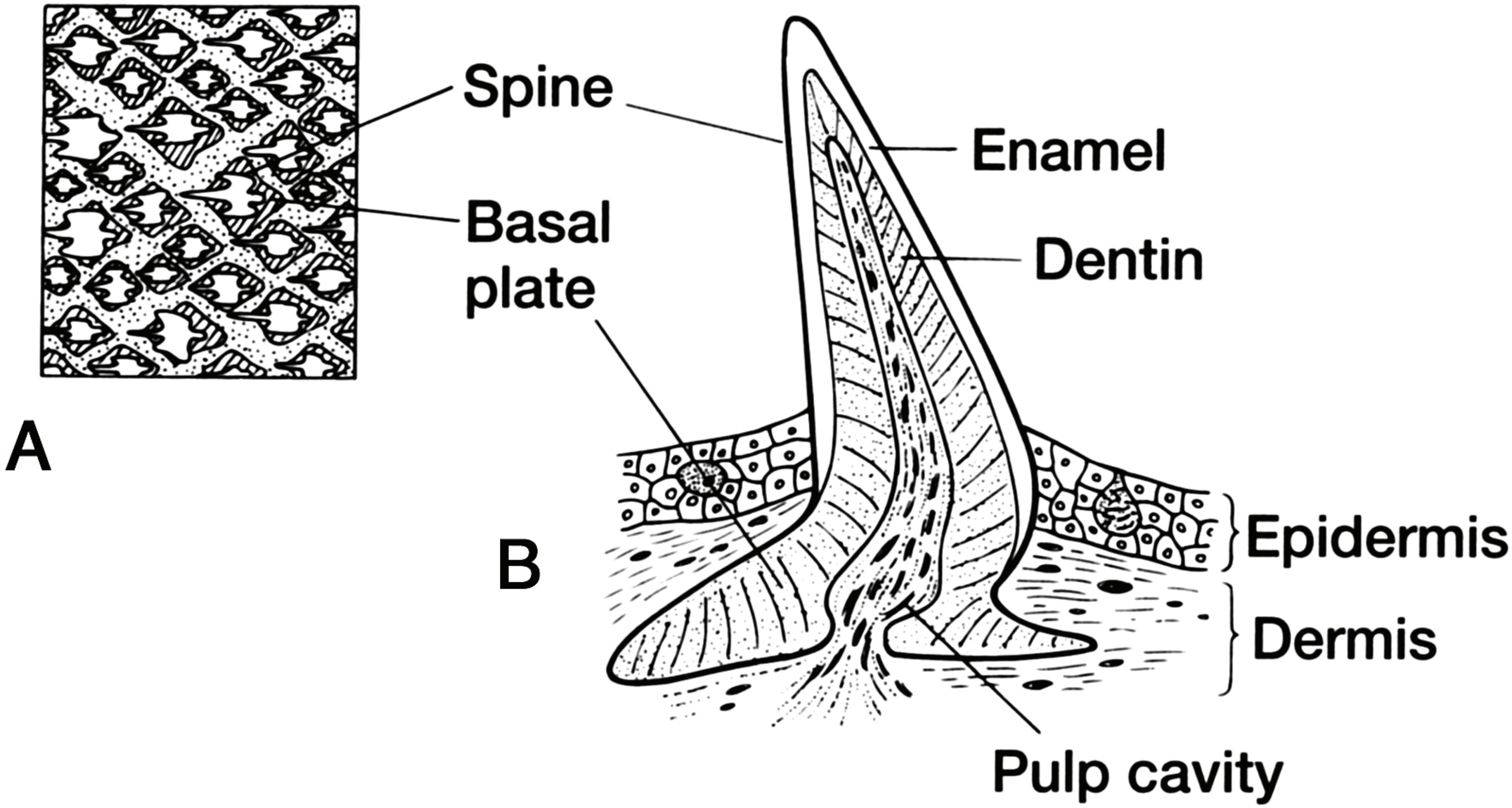


FIGURE 63. Placoid scales of the sharks. **A.** Surface view of the skin showing regular arrangement of projecting placoid scales. **B.** Section through a placoid shark scale. The projecting shark scale consists of enamel and dentin enclosing a pulp cavity.

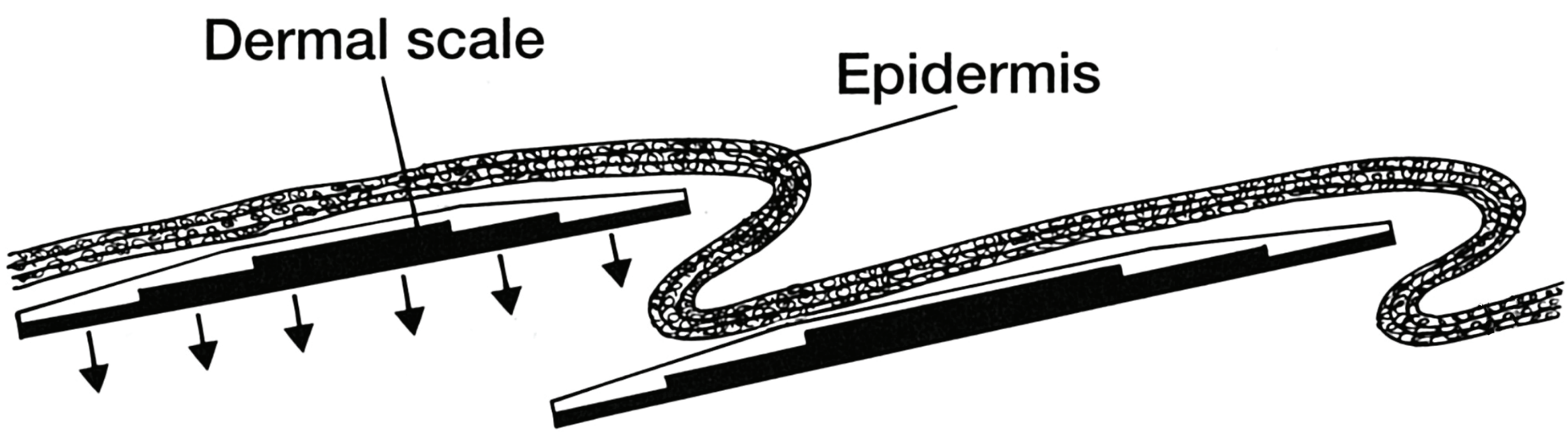


FIGURE 64. **Bony fish skin showing arrangement of dermal scales within the skin.** Arrows indicate direction of scale growth.

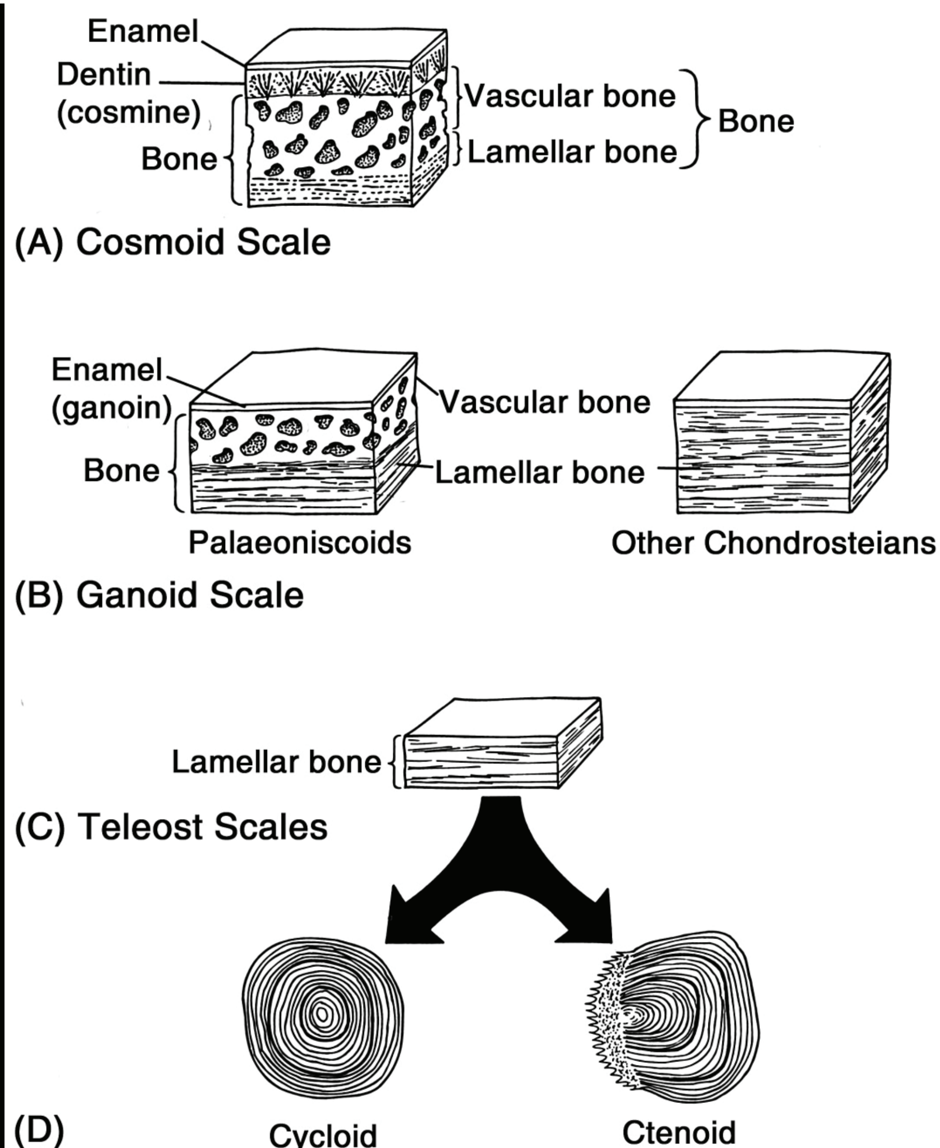


FIGURE 65. Scale types among bony fishes. A. Cross section of a cosmoid scale, characteristic of the sarcopterygii. **B.** Cross section of a ganoid scale, characteristic of the chondrostei. Ganoid scales take two forms: *Paleoniscus* and other primitive forms produced scales that retained the vascular bone layer while later chondrosteians, including extant forms, have lost the vascular bony layer. **C.** Cross section of a teleost scale. **D.** Surface structure of the two types of scales found among teleosts: cycloid and ctenoid scales. *(After Kardong).*

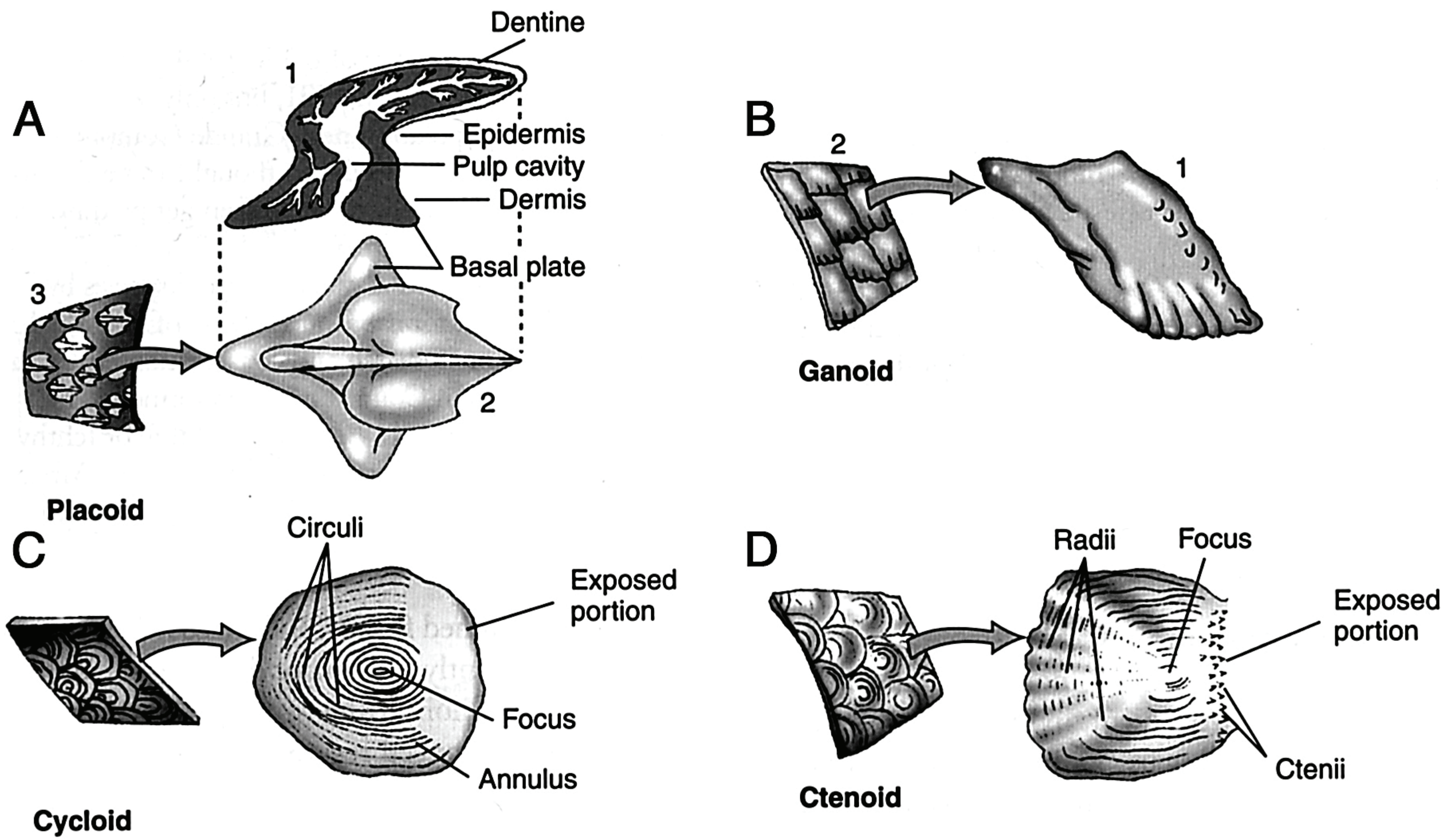
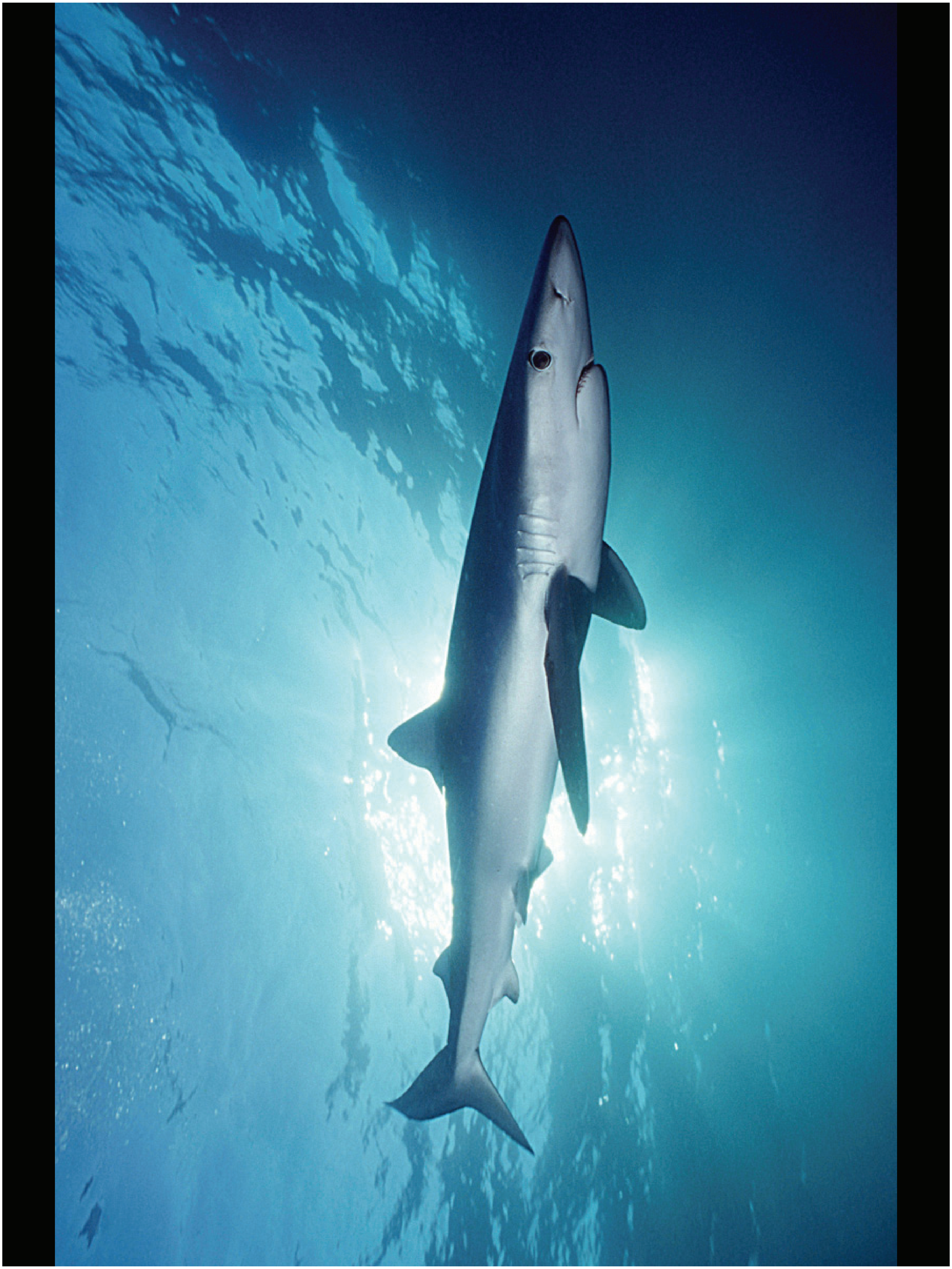
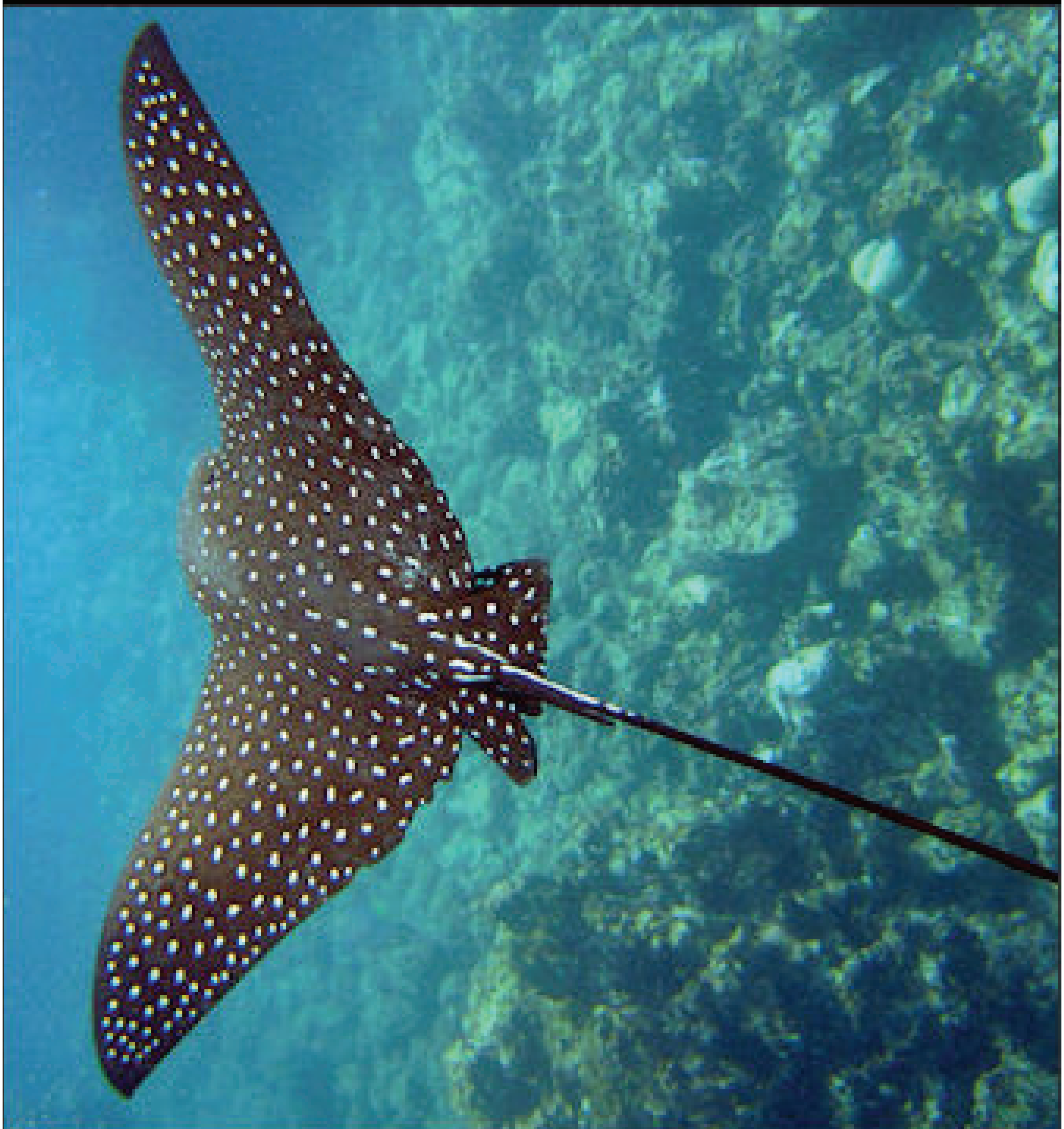


FIGURE 66. Overview of scale types. A. Placoid scale (1, saggital; 2, dorsal; 3, normal arrangement on skin. Note that scales are not overlapping.) **B.** Ganoid scale (1, single scale; 2, normal arrangement on skin. Note slight overlap of scales.) **C.** Cycloid scale. **D.** Ctenoid scales. Note that cycloid and ctenoid scales overlap extensively when in their normal arrangement on the skin.





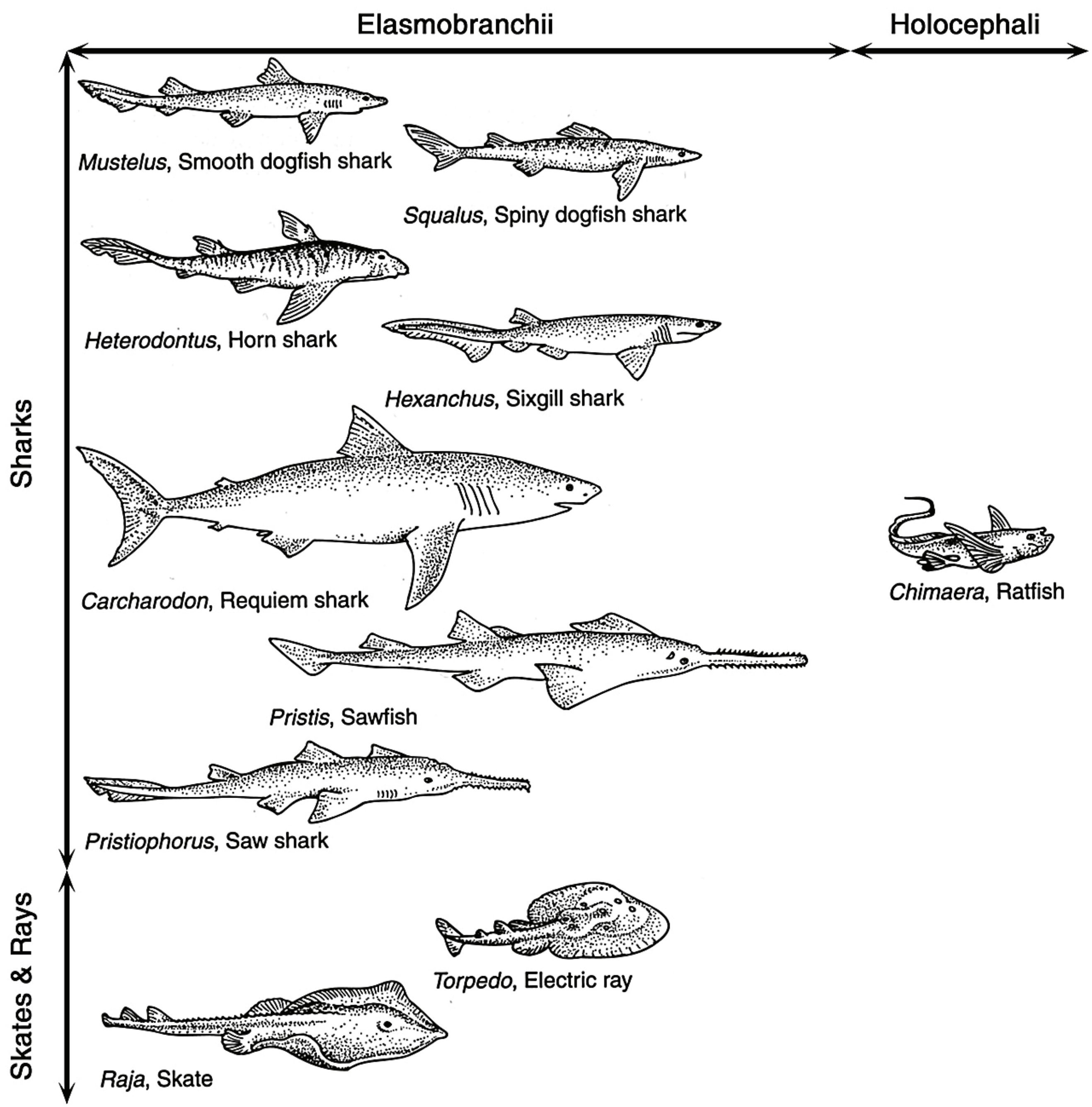
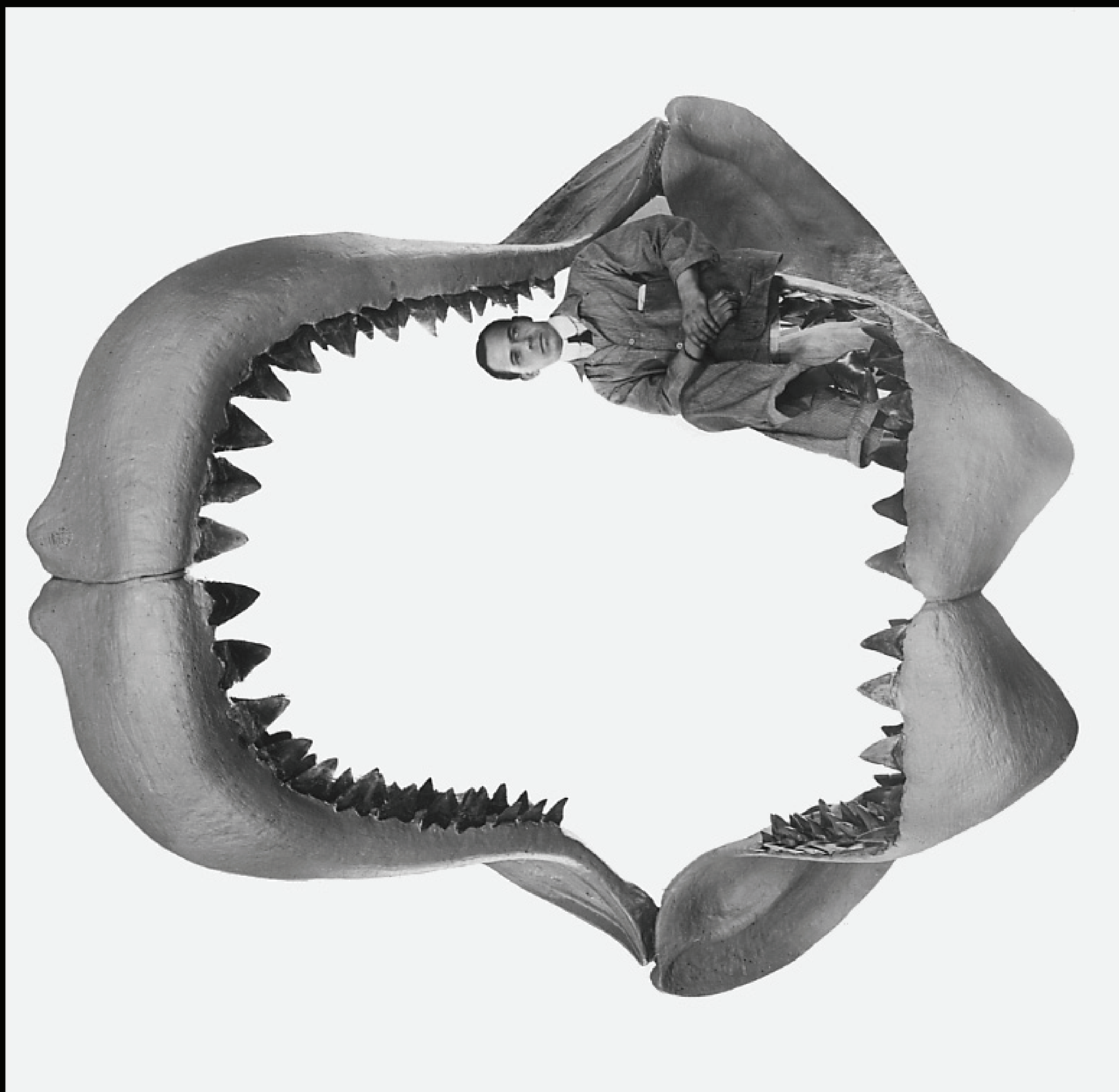
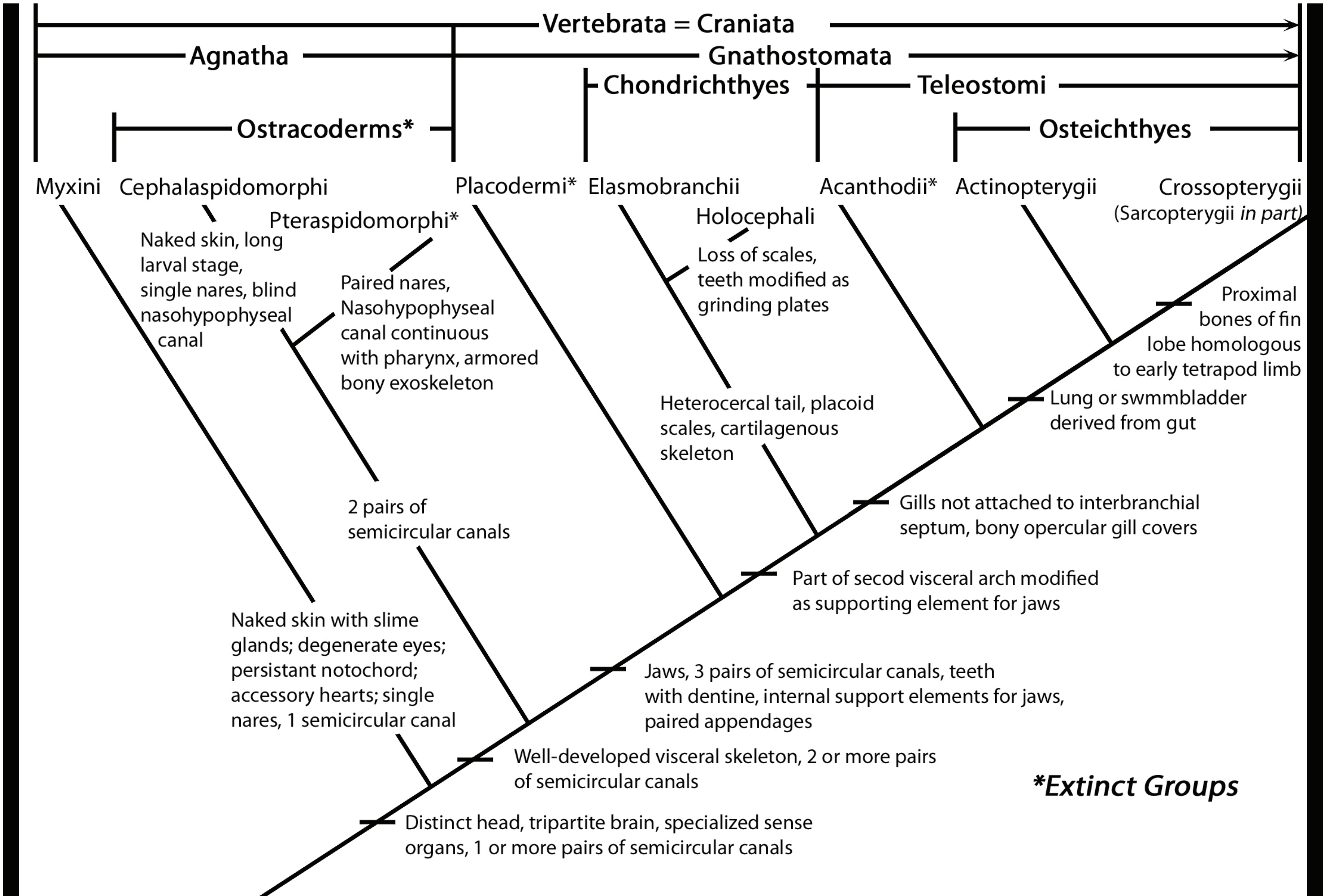


FIGURE 68. Representative living chondrichthyans, sharks, skates, rays, and ratfish.





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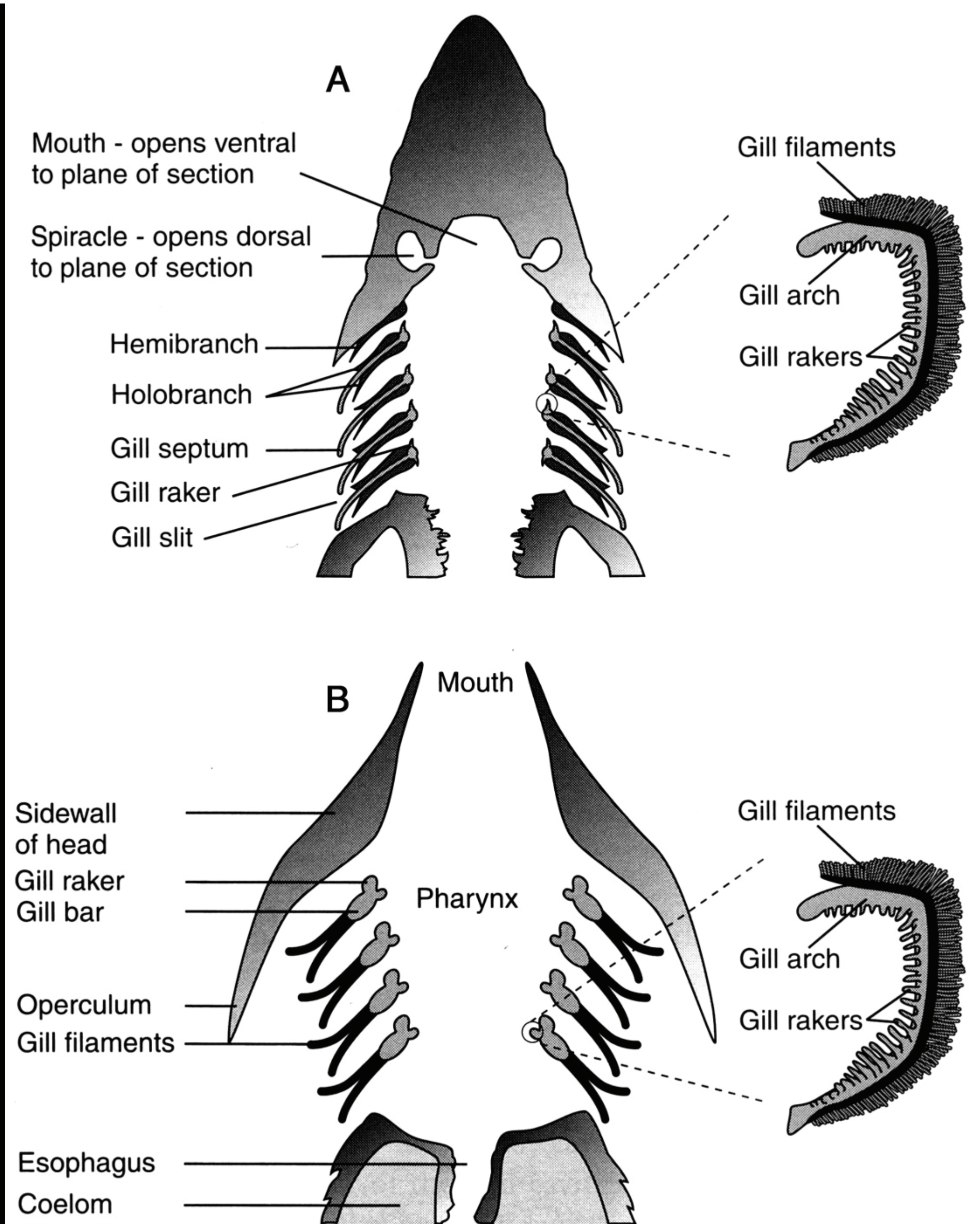


FIGURE 70. **Comparative gill structure among Chondrichthyes and Teleostomi.** **A.** Gill structure in sharks. Valves formed from individual gill septa guard each gill chamber. The gills themselves are attached to the interbranchial gill septum. Note that both hemibranch and holobranch gills are present. **B.** Gill structure in teleosts. The gills are covered by a common operculum and individual gills are not attached to an interbranchial gill septum. Hemibranch gills absent. **Insets.** A single gill arch. Gill filaments play a role in gas exchange, whereas the gill rakers strain water entering the gill chamber from the pharynx. *(after Hildebrand.)*

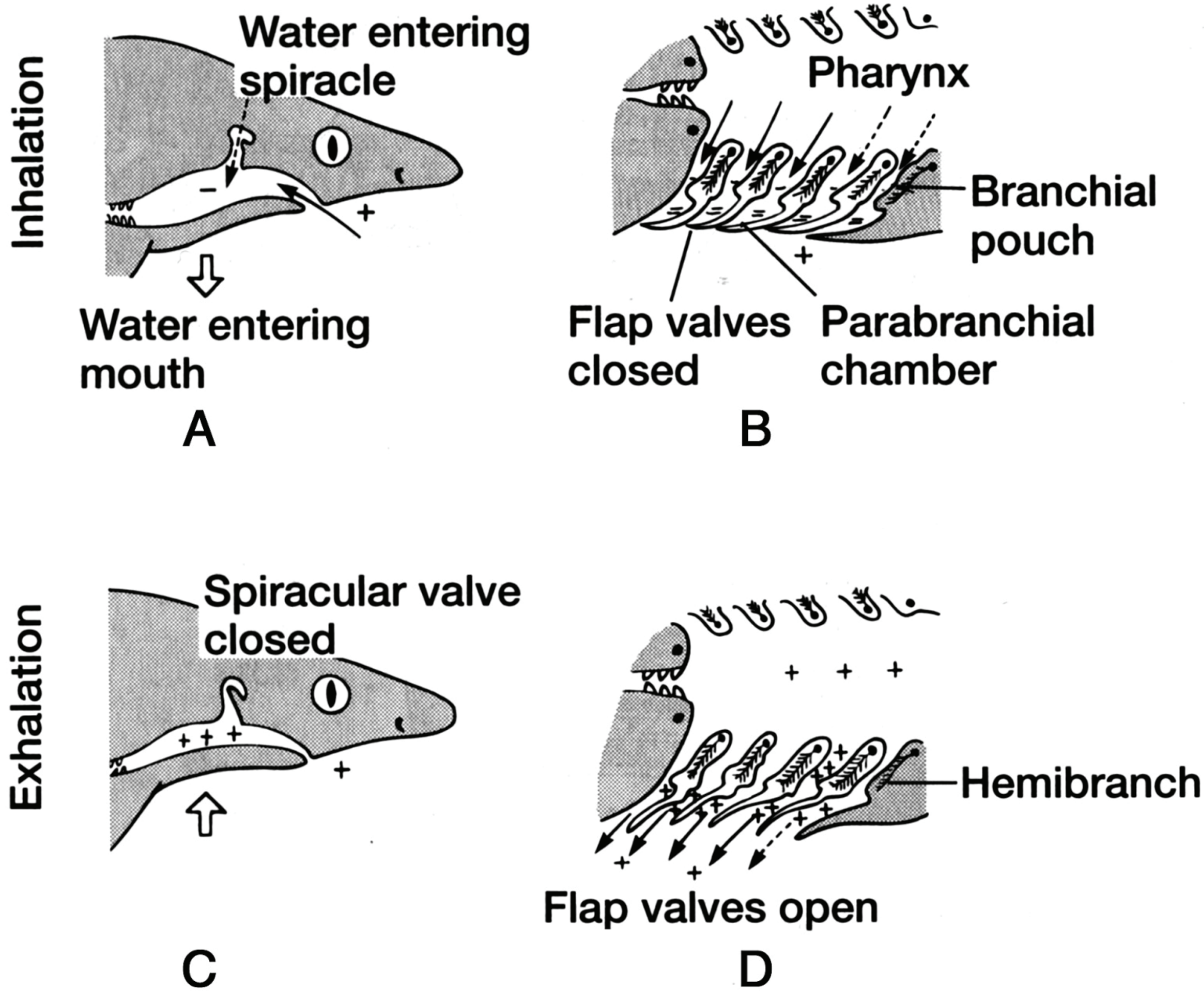


FIGURE 71. Gill ventiliation in sharks. Lateral (**A**, **C**) and frontal (**B**, **D**) views. Relative positive and negative pressures are indicated by + and - , respectively. The ventilation mechanism consists of a buccal pump that draws water in and forces is across the gill curtain and outside. Note that the flap valves close during inhalation and that relative pressures are always lower in the parabranchial chamber than in the pharynx. Thus water moves unidirectionally across the gills in a pulsing but continuous flow. *(After Hughes and Ballintijn).*

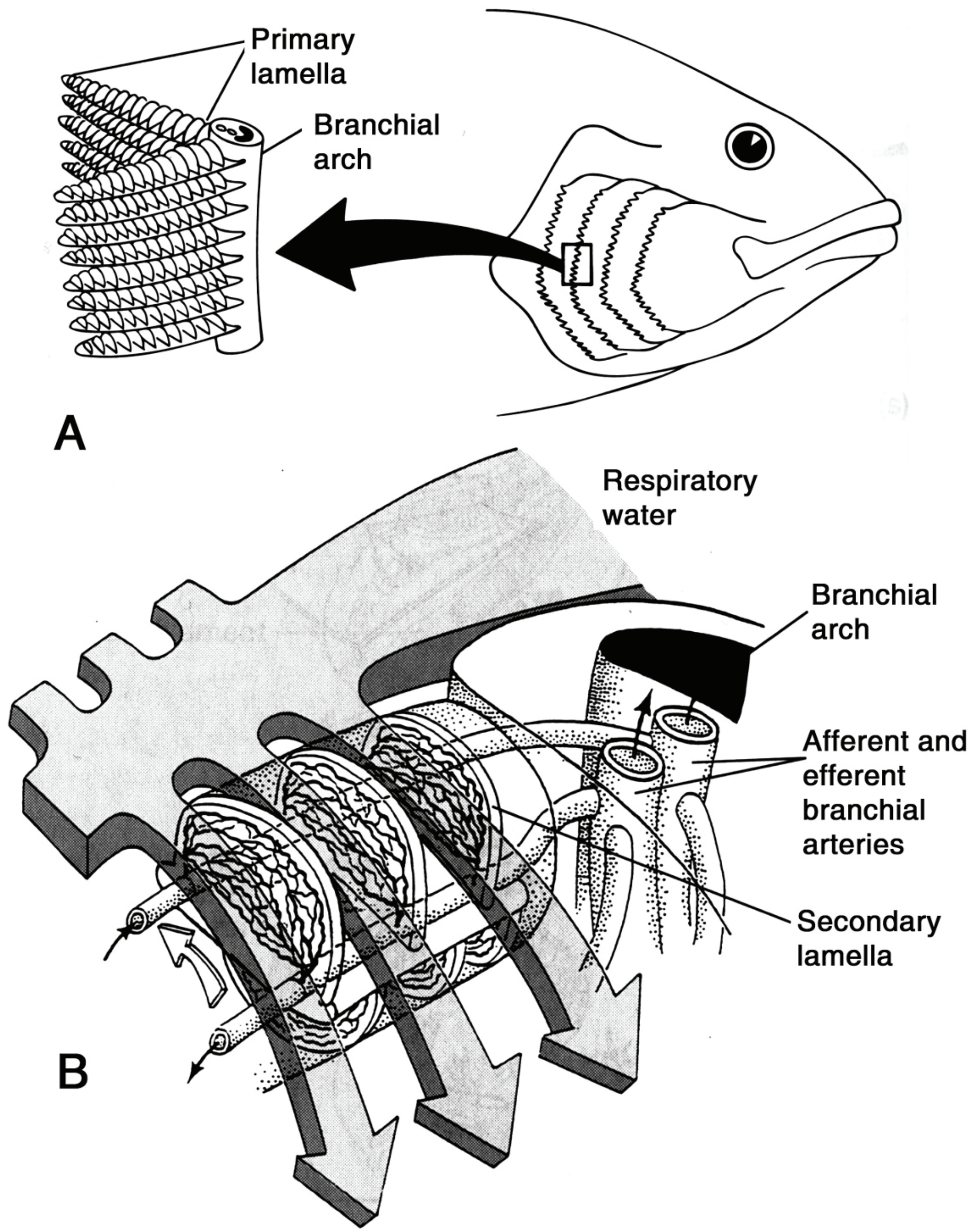


FIGURE 72. Gill ventilation in teleosts. A. One gill bar is removed, showing the stack of gill lamellae. **B.** Water flow is directed across the secondary lamellae opposite to that of blood flowing within each secondary lamella. This establishes a countercurrent multiplier exchange between the respiratory water stream and the blood stream. *(After Kardong)*

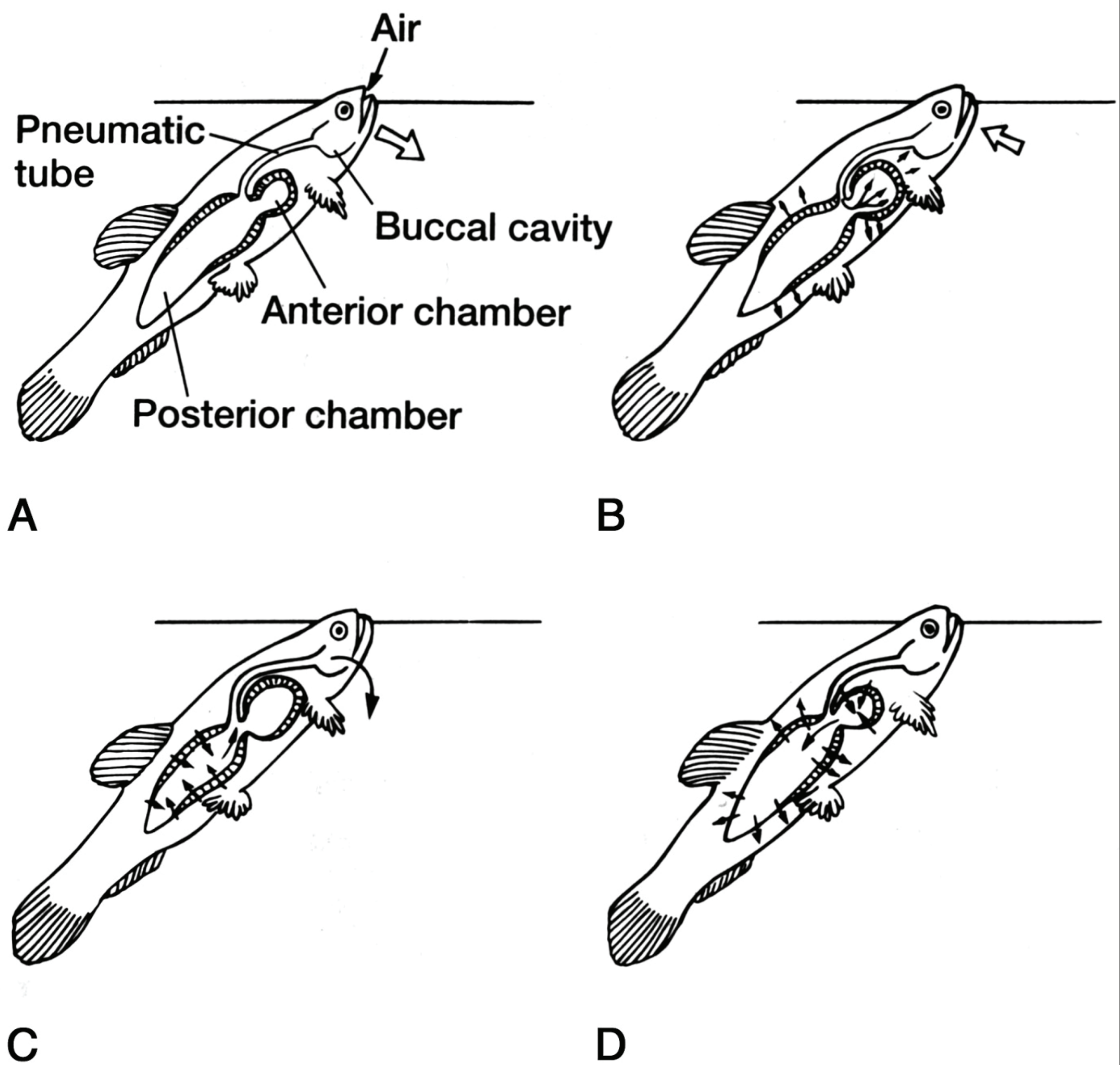


FIGURE 73. Air-breathing fishes. Most air-breathing fishes use a pulse pump to fill their air bladders or lungs, which are able to separate spent and incoming air during ventilation. The mouth breaks the surface (**A**) so that air drawn in along the pneumatic tube preferentially enters the anterior air chamber (**B**). Spent air in the posterior chamber is forced out through the pneumatic tube and exits under the operculum (**C**). The sphincter between anterior and posterior chambers opens, allowing air to replenish the posterior chamber as well. (*after Tandall, Burggren, Farrell, and Haswell; Kardong*)

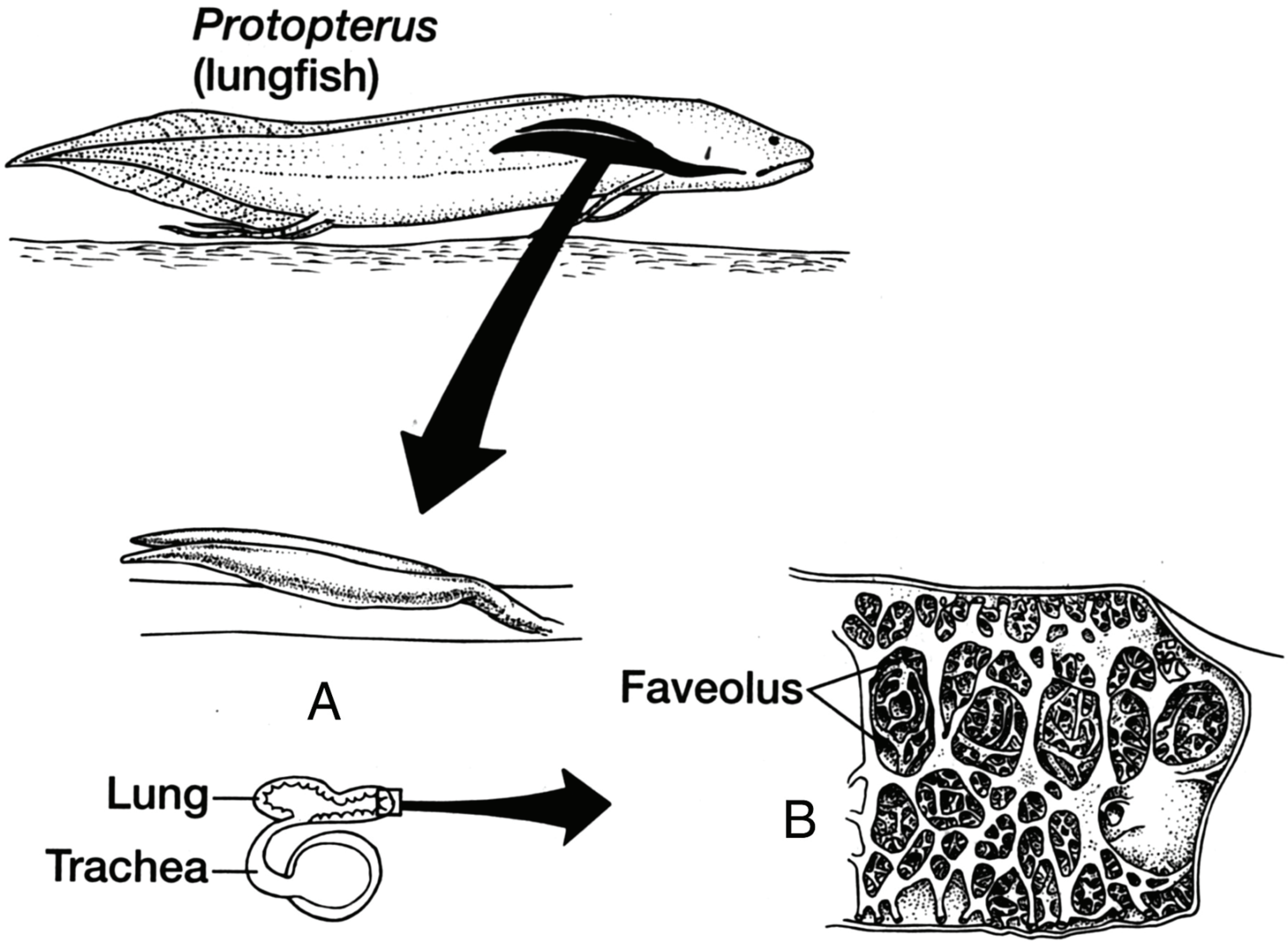


FIGURE 74. Lungs of the lungfish *Protopterus*. A. View of the lungs from the right side and in cross section. **B.** Enlargement of the internal wall of the lung. The lung is subdivided internally, forming small compartments or faveoli. Faveoli are most numerous in the anterior part of the lung. Approximate location of the lungs is indicated by the darkened area (top) in the lateral view of the fish's body.

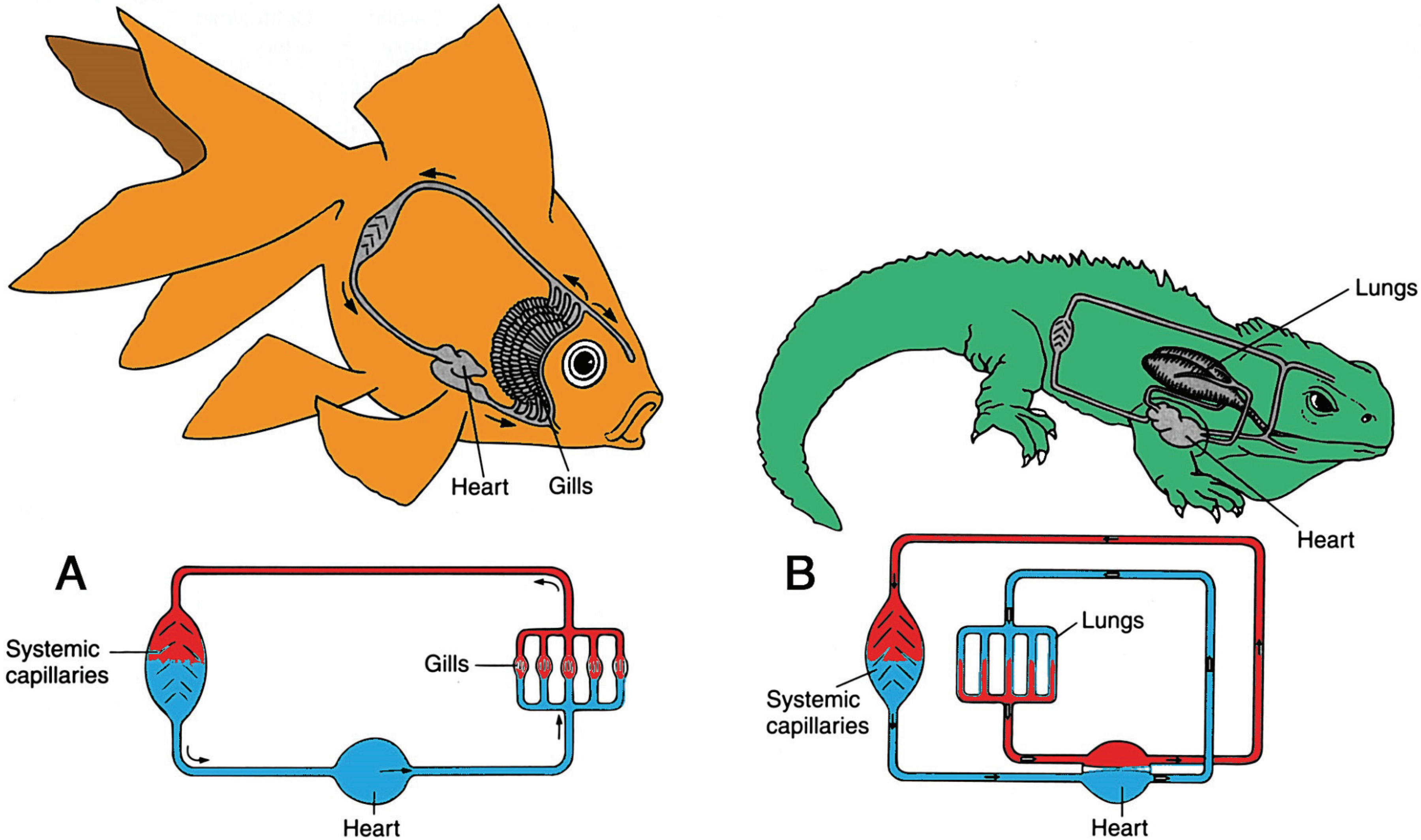


FIGURE 75. Comparison of single and double circuit circulation among vertebrates.
A. Single circuit circulation in fishes utilizes the heart, gills and systemic capillaries in series. Each drop of blood passes through the heart only once in each cycle through the body.
B. Double circuit circulation in amniotes utilizes two circuits: the pulmonary circuit includes the heart and lungs while the systemic circuit includes the heart and systemic capillaries. Thus each drop of blood passes through the heart twice in each cycle through the body. (Arrows indicate the path of blood flow.) *(After Linzey)*

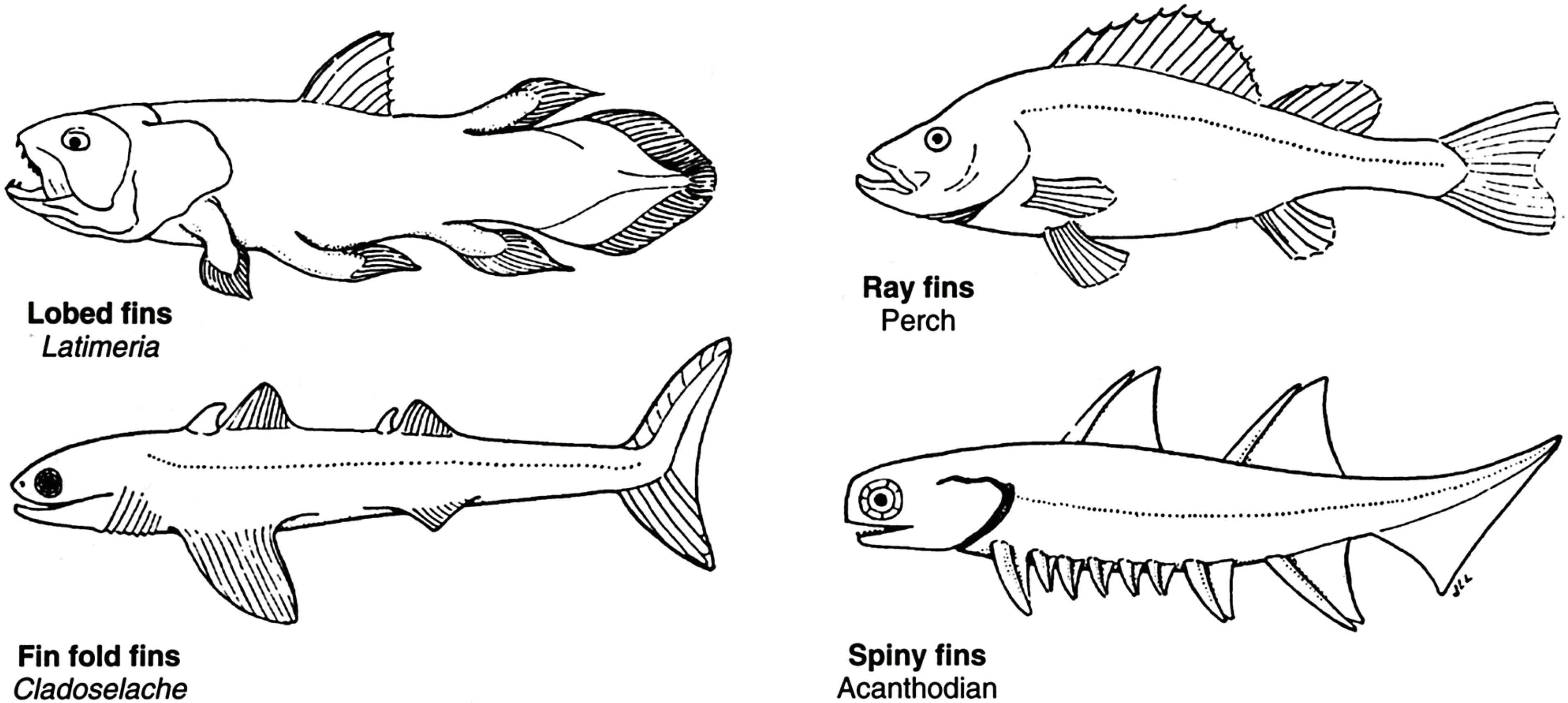


FIGURE 76. Various fin types in bony fishes.

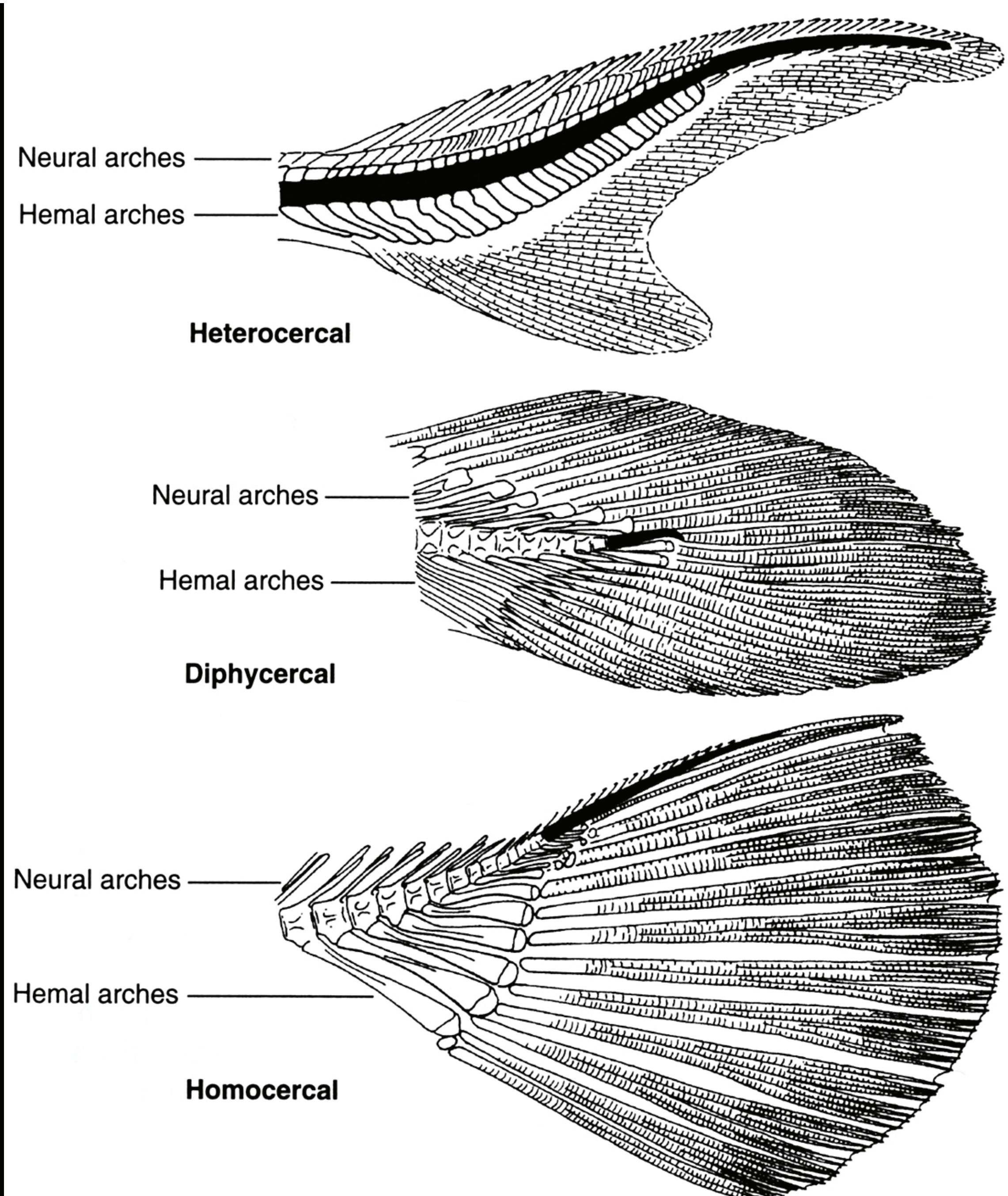


FIGURE 77. Basic caudal fin types among bony fish.

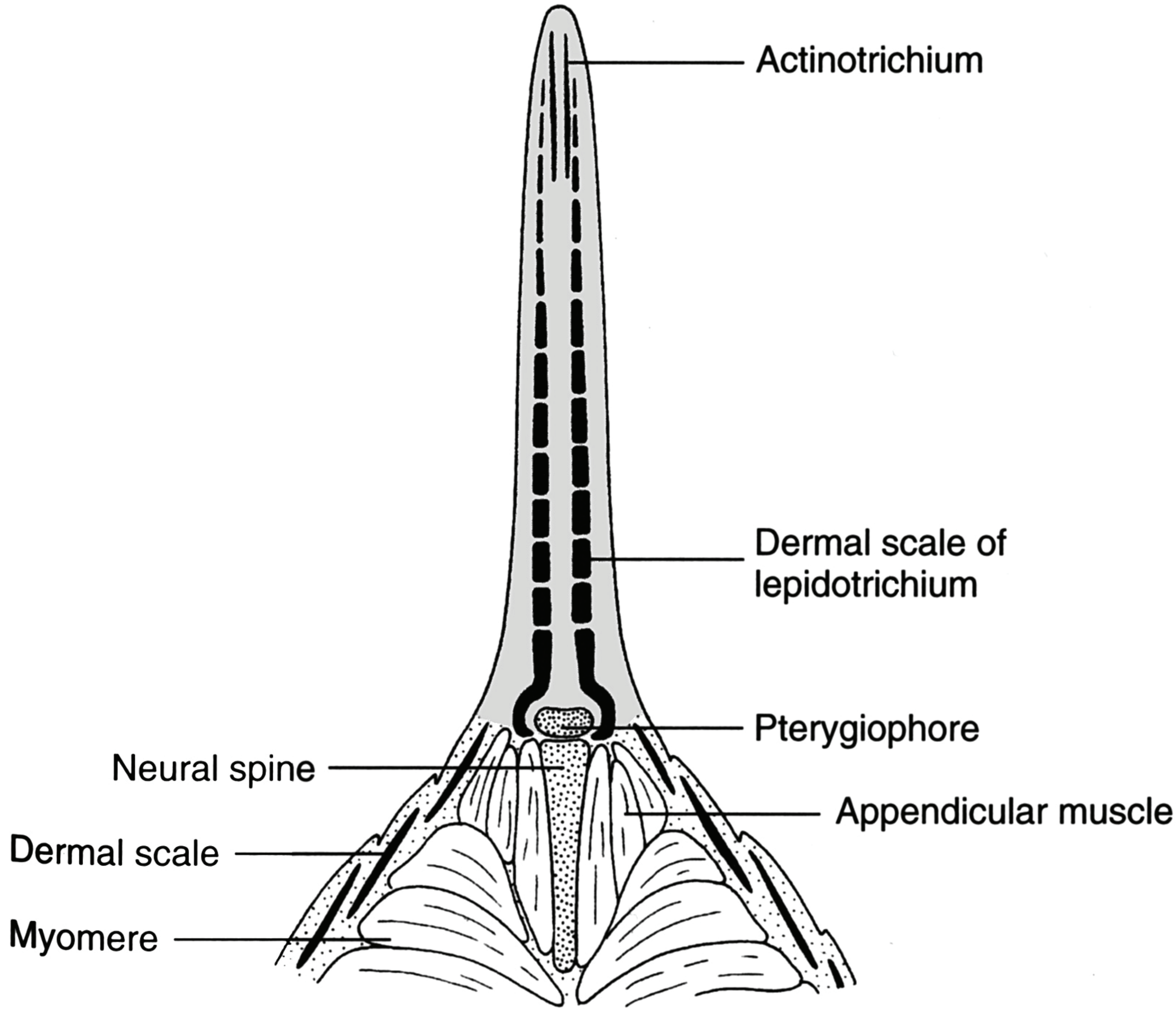


FIGURE 78. Diagrammatic cross section demonstrating dorsal fin structure in a teleost.

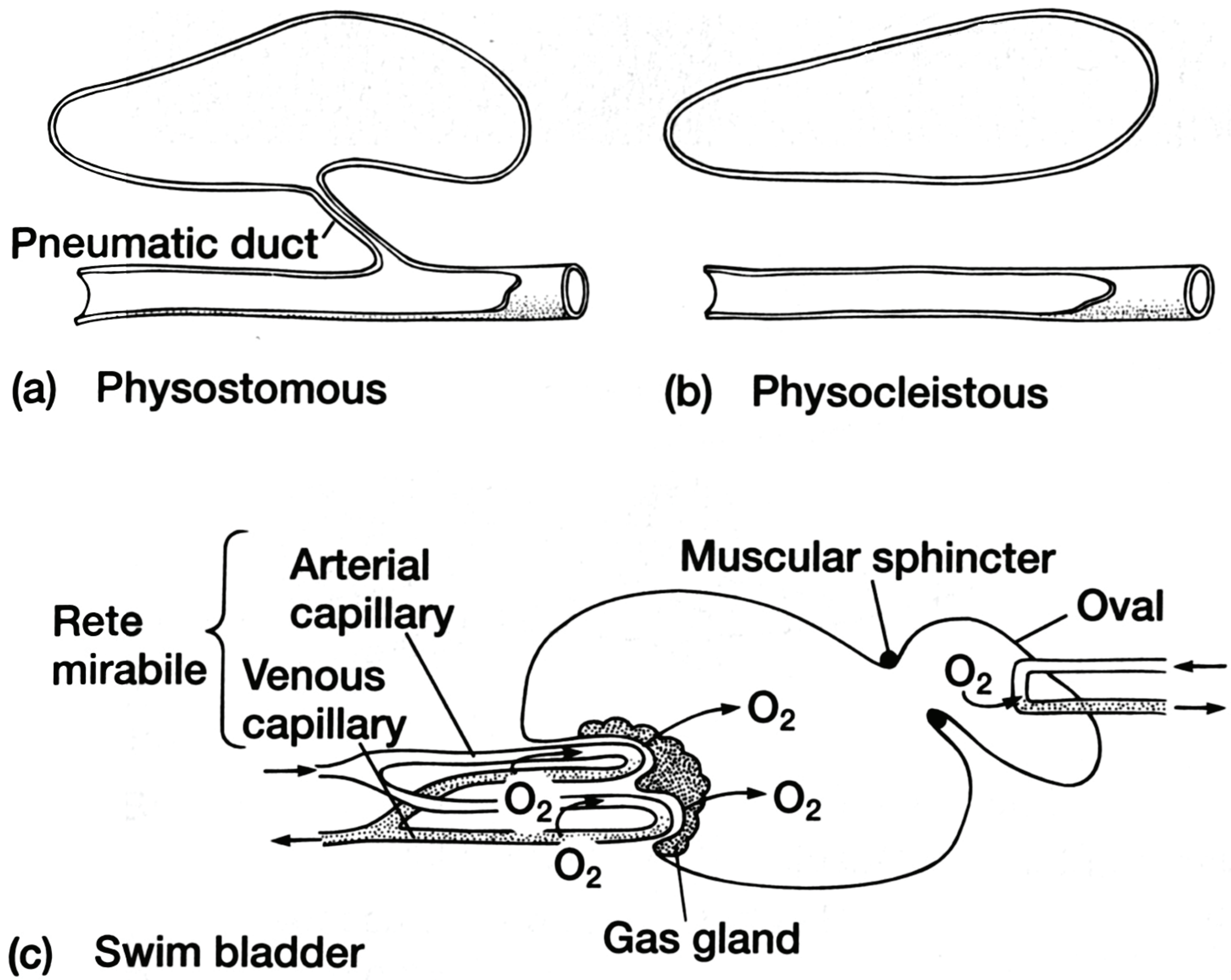


FIGURE 79. **Swim bladder types among the Osteichthyes.** **A.** Physostomus fish maintain the primitive swim bladder configuration with a pneumatic duct connecting the swim bladder to the pharynx. Gas volume is regulated as fish actively gulp or release environmental air through the pneumatic duct. **B.** Physocleistrous fish have lost the connecting pneumatic duct. Air volume must be regulated by releasing or resorbing gas through the blood stream. **C.** Gas regulation in physocleistrous fish is acheived by releasing gas in the blood stream via the gas gland and rete mirabile or reabsorbing gas from the ovale.

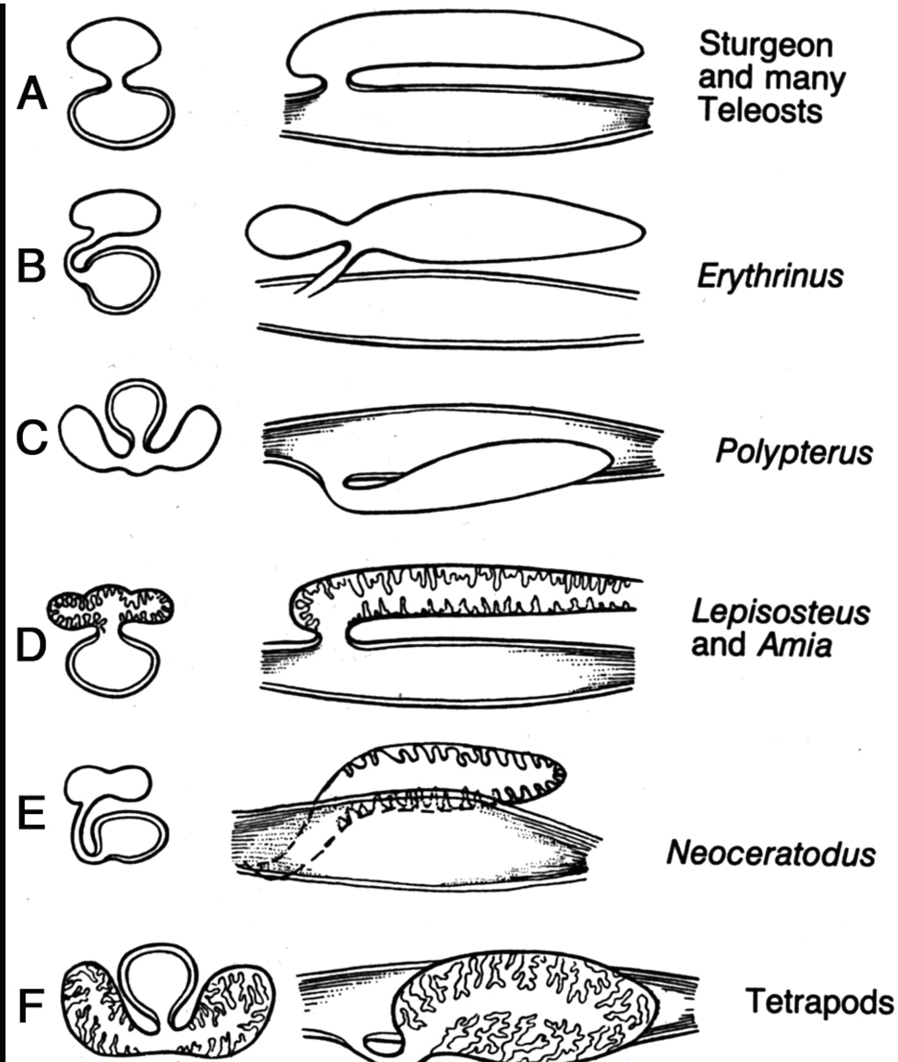


FIGURE 80. **Diagrammatic cross & longitudinal seections of the swim bladder or lung in various fishes and tetrapods. A.** Typical dorsal swim bladder observed in actinopterygians including sturgeons and many soft-rayed fish. **B.** An unusual type found in climbing perches. Note the lateral opening suggestive of a transition from lung to air bladder. **C.** Bichirs are a relic actinopterygian group with a paired ventral lungs. This is probably the primitive condition that gave rise to all other lung or air bladder types. **D.** Gars and bowfins are examples of holosteans. Their air bladdders have a folded inner surface capable of some overt respiratory function. **E.** Australian lungfish have bilobed lungs with a sacculated lining adapted for respiratory function. Note that although the lung is rotated dorsally the opening remains ventral in position. **F.** Tetrapod lungs are characterized by complex internal structure, lateral position, and an opening that is ventral in position *(After Dean, 1985; Lagler, 1962.)*

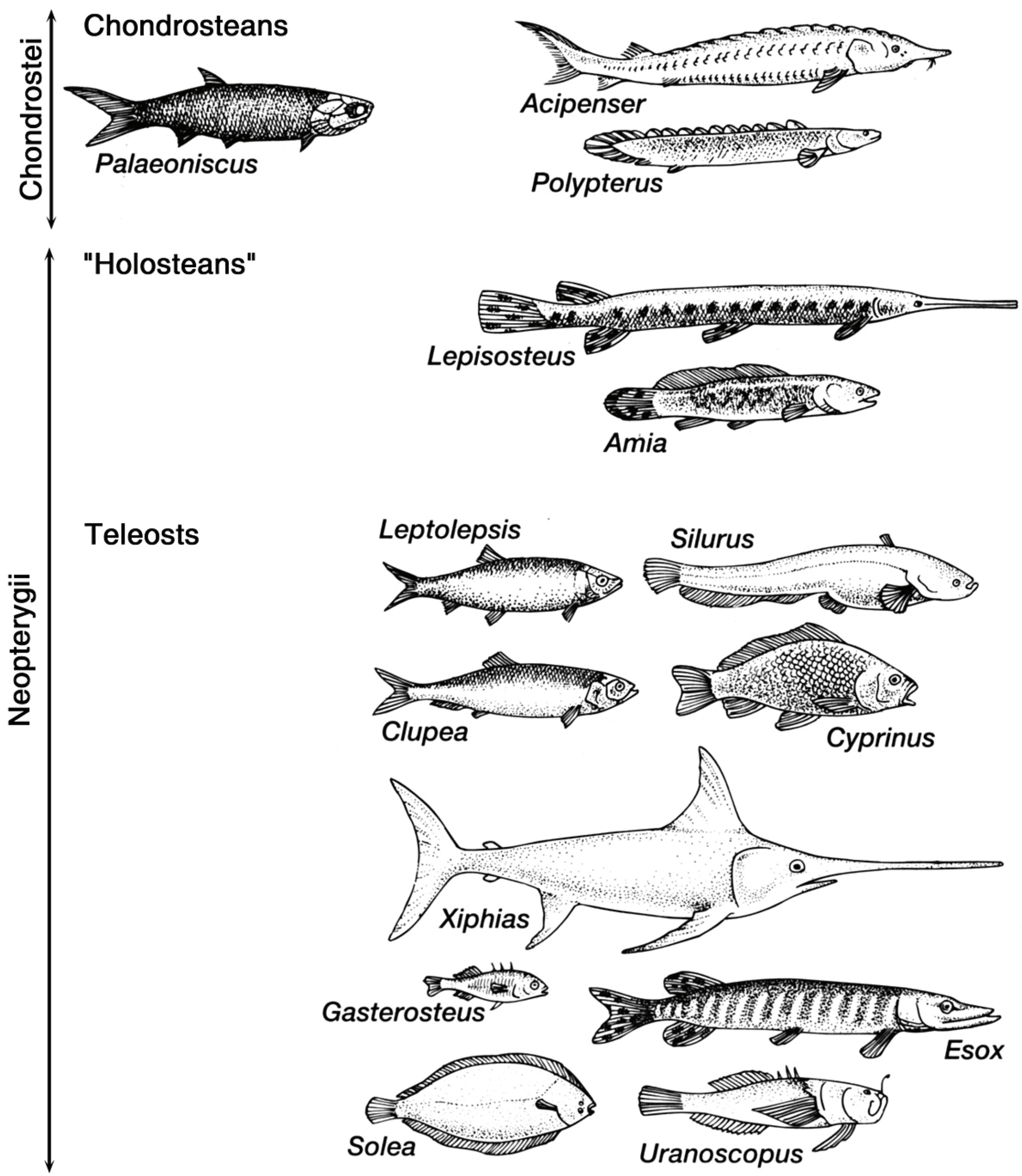


FIGURE 81. Representative Actinopterygians representing the subclasses Chondrostei and Neopterygii.

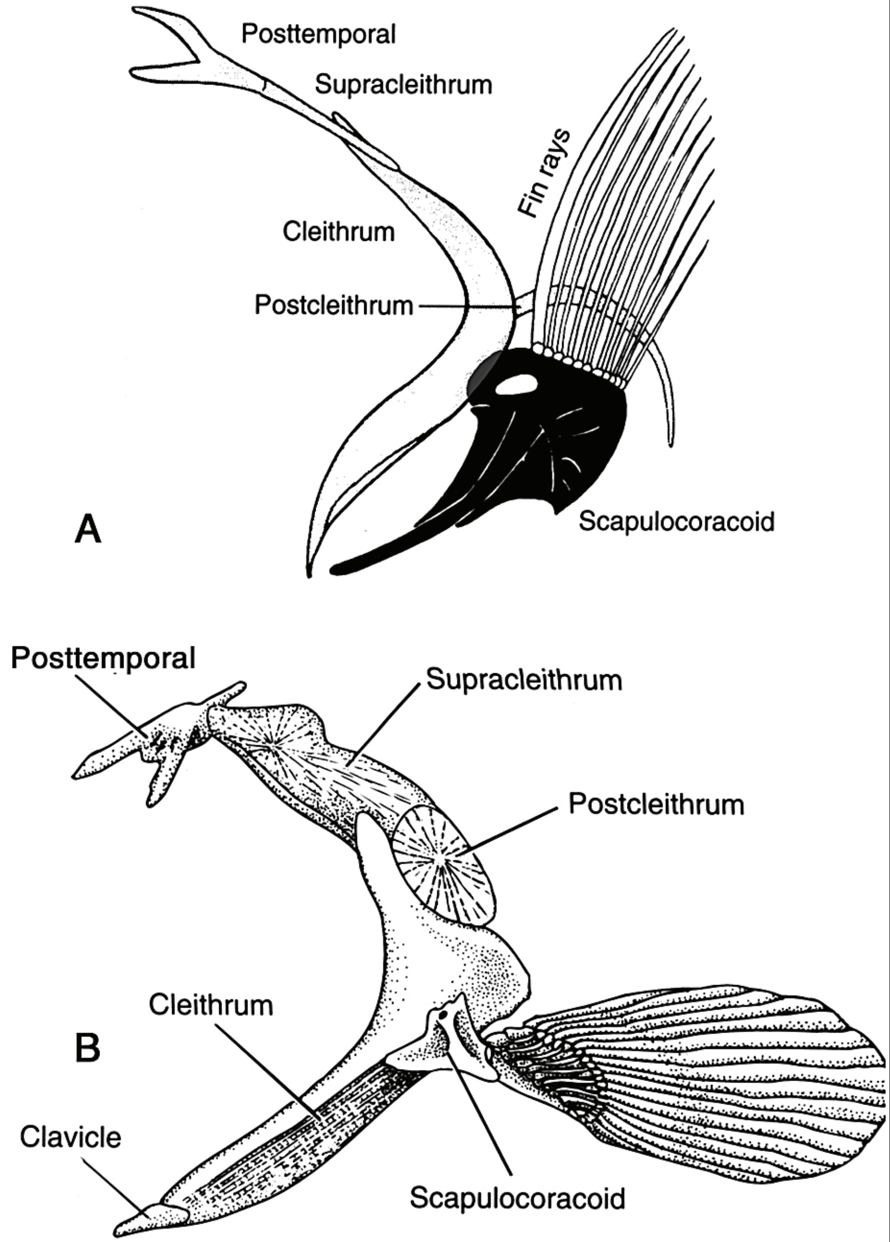


FIGURE 82. Actinopterygian appendicular skeleta. Pectoral girdles of **A.** a generalized modern Teleost and **B.** *Amia,* a primitive actinopterygian.

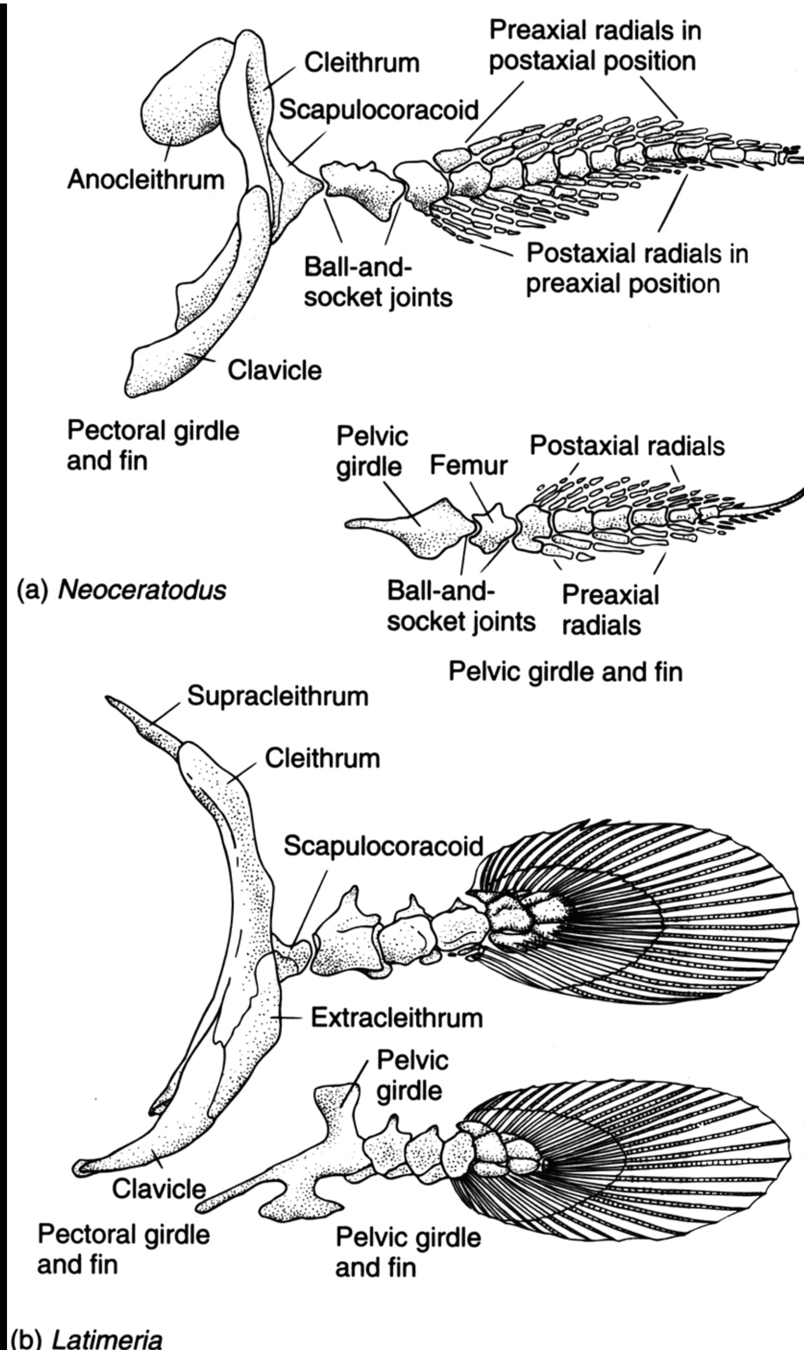
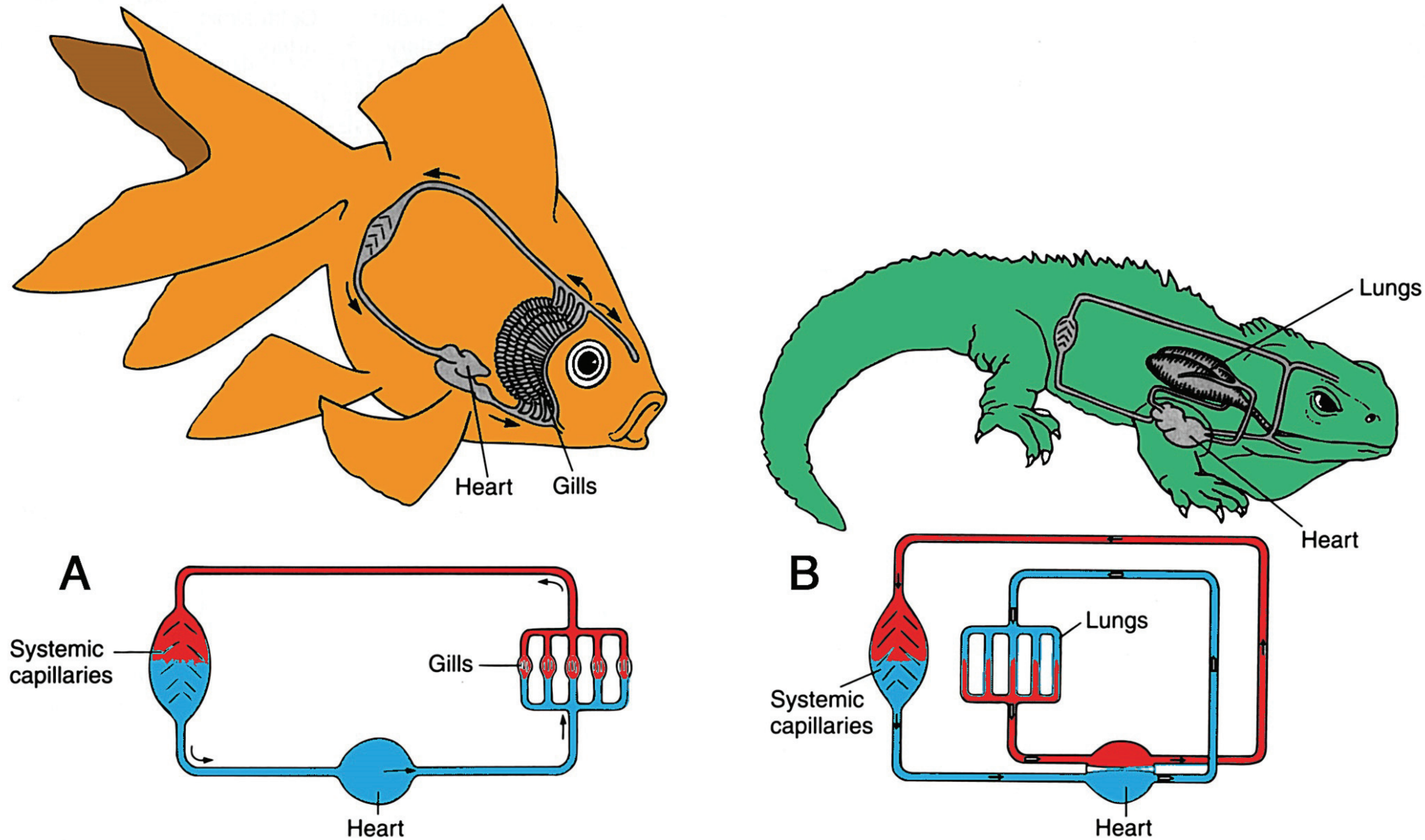


FIGURE 83. **Sarcopterygian appendicular skeleta.** Pectoral and pelvic girdles of **A.** Lungfish and **B.** Coelocanths.



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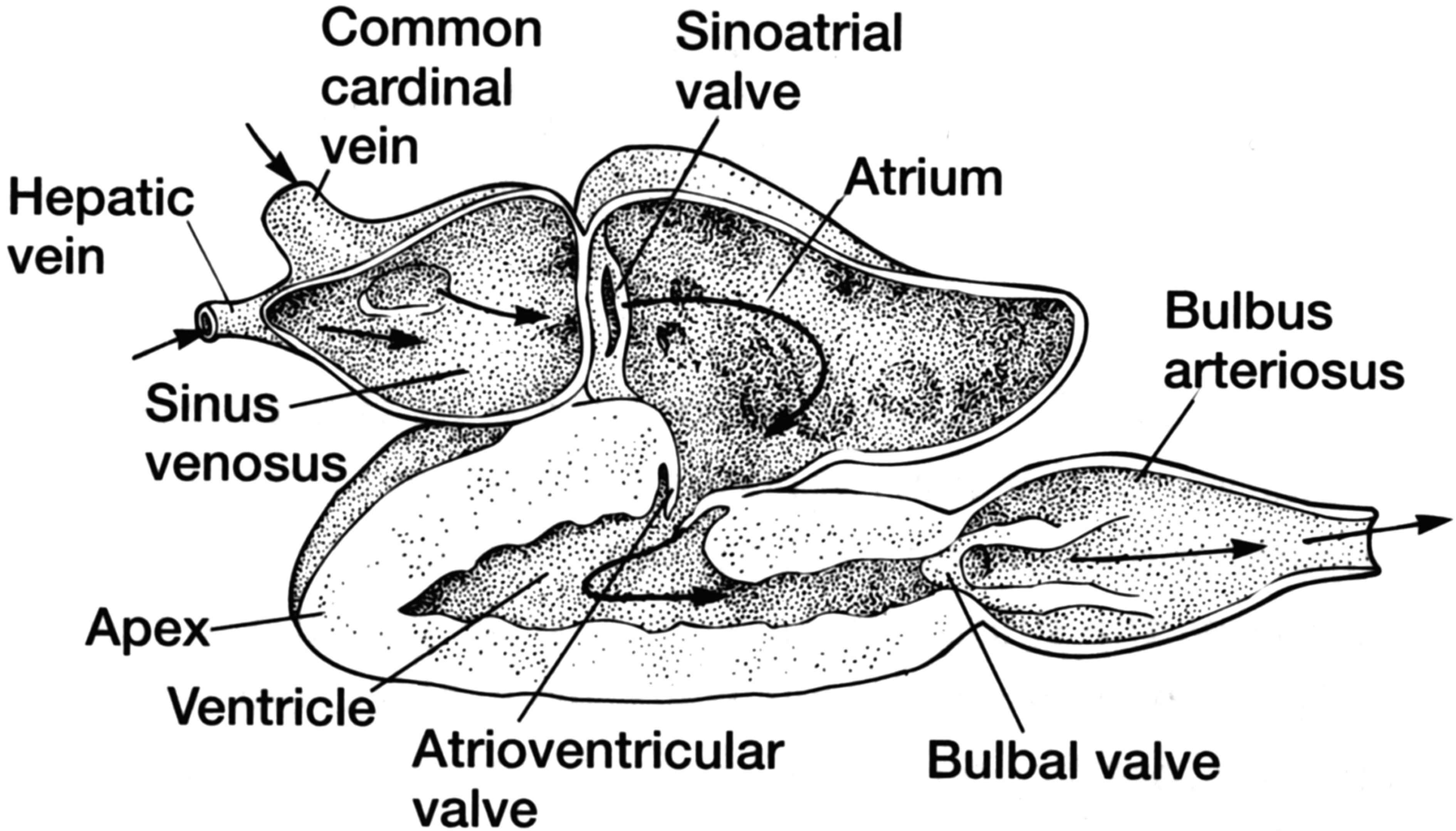


FIGURE 84. Teleost heart structure.

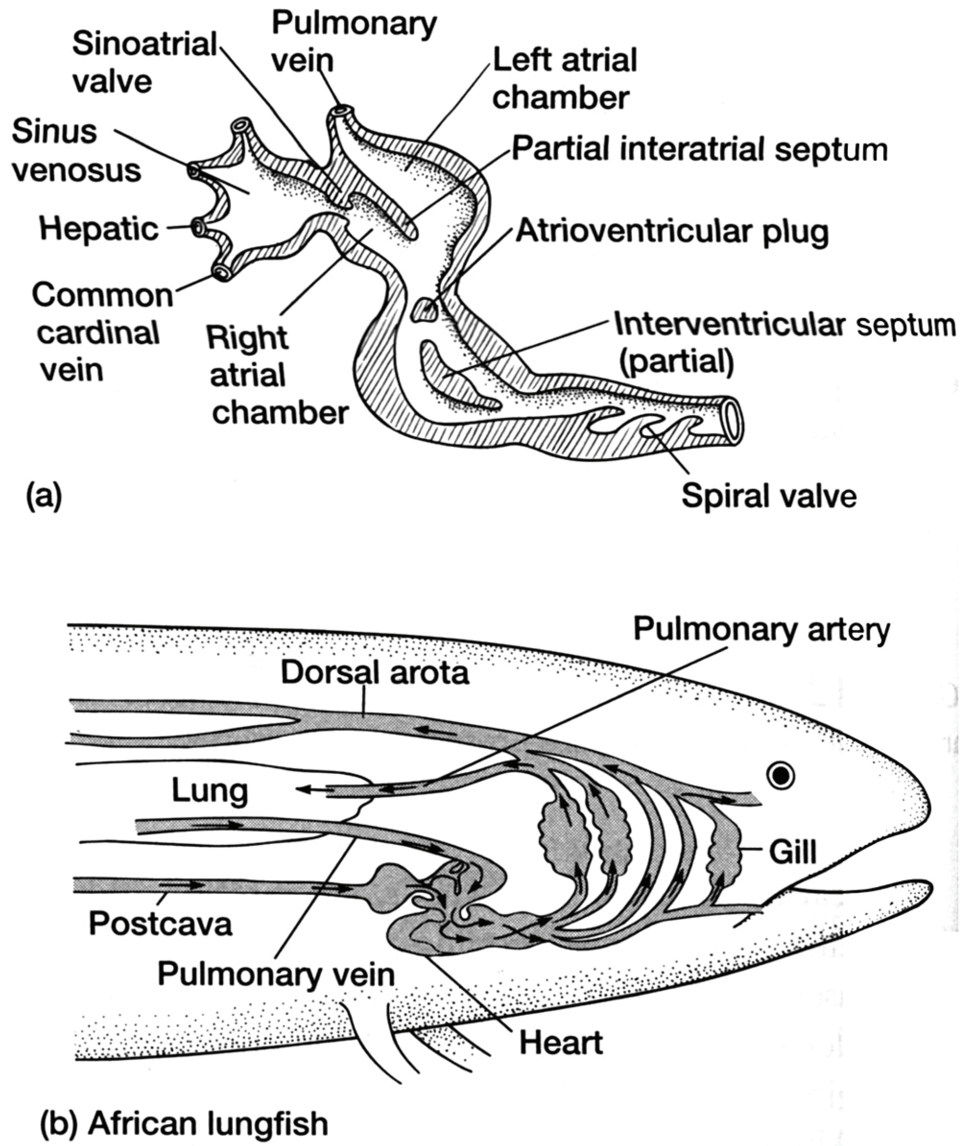


FIGURE 85. **Dipnoian heart structure: Heart of the African Lungfish *Protopterus.*** **A.** Internal structure of the heart. **B.** Path of blood flow. When the lungfish breathes air, venous bllod returning from the systemic tissues flows through the heart and tends to be directed to the last aortic arch (VI) where the pulmonary artery carries most of the deoygenated blood to the lung. Blood high in oxygen returning from the lung passes through the heart and then tends to enter aortic arches without gills (III, IV), shunting oxygenated blood to the general systemic circulation. Thus a primitive dual circuit circulatory system is acheived. The five aortic arches phylogenetically represent the 2nd through 6th arches (II-VI). Arches II, V, and VI carry gills.

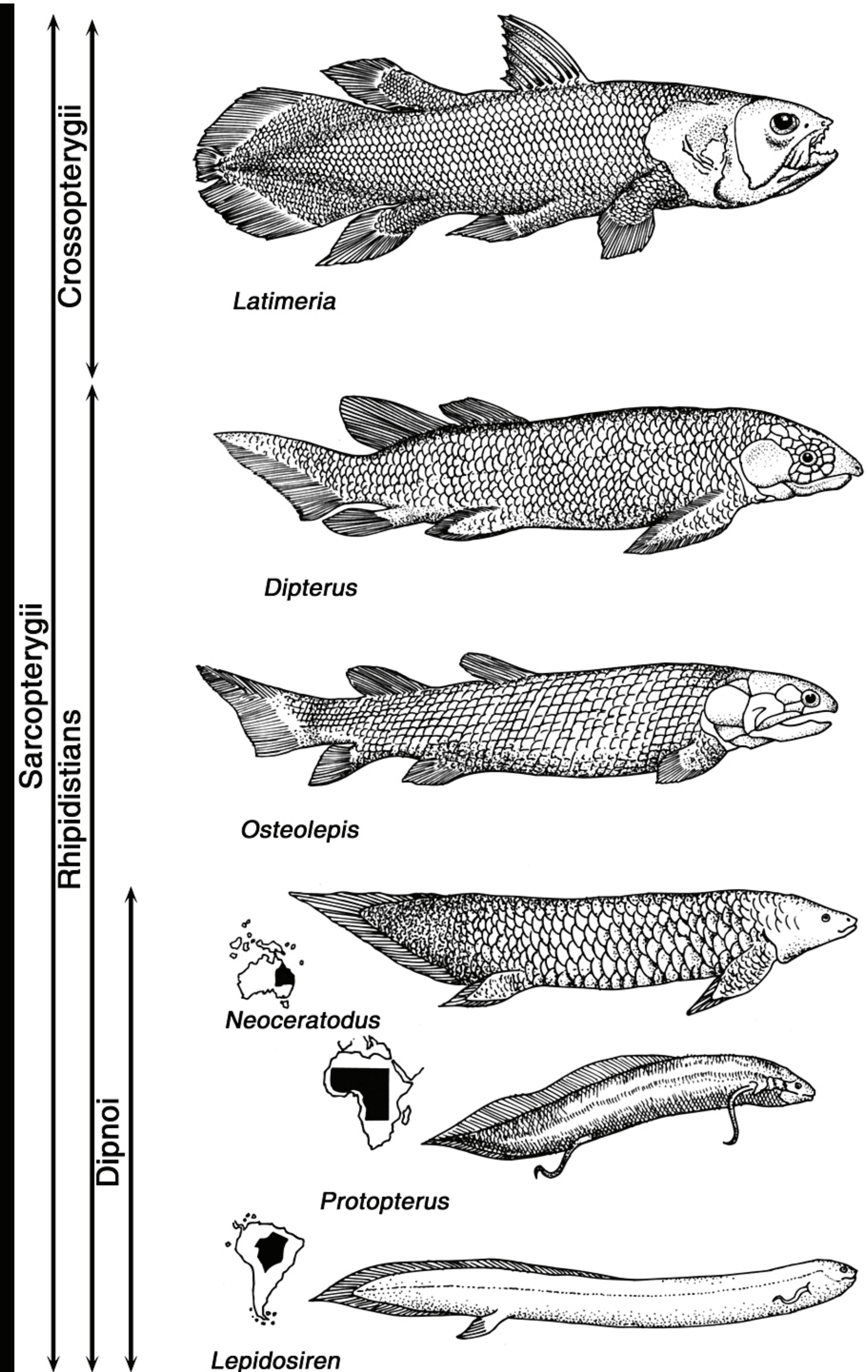
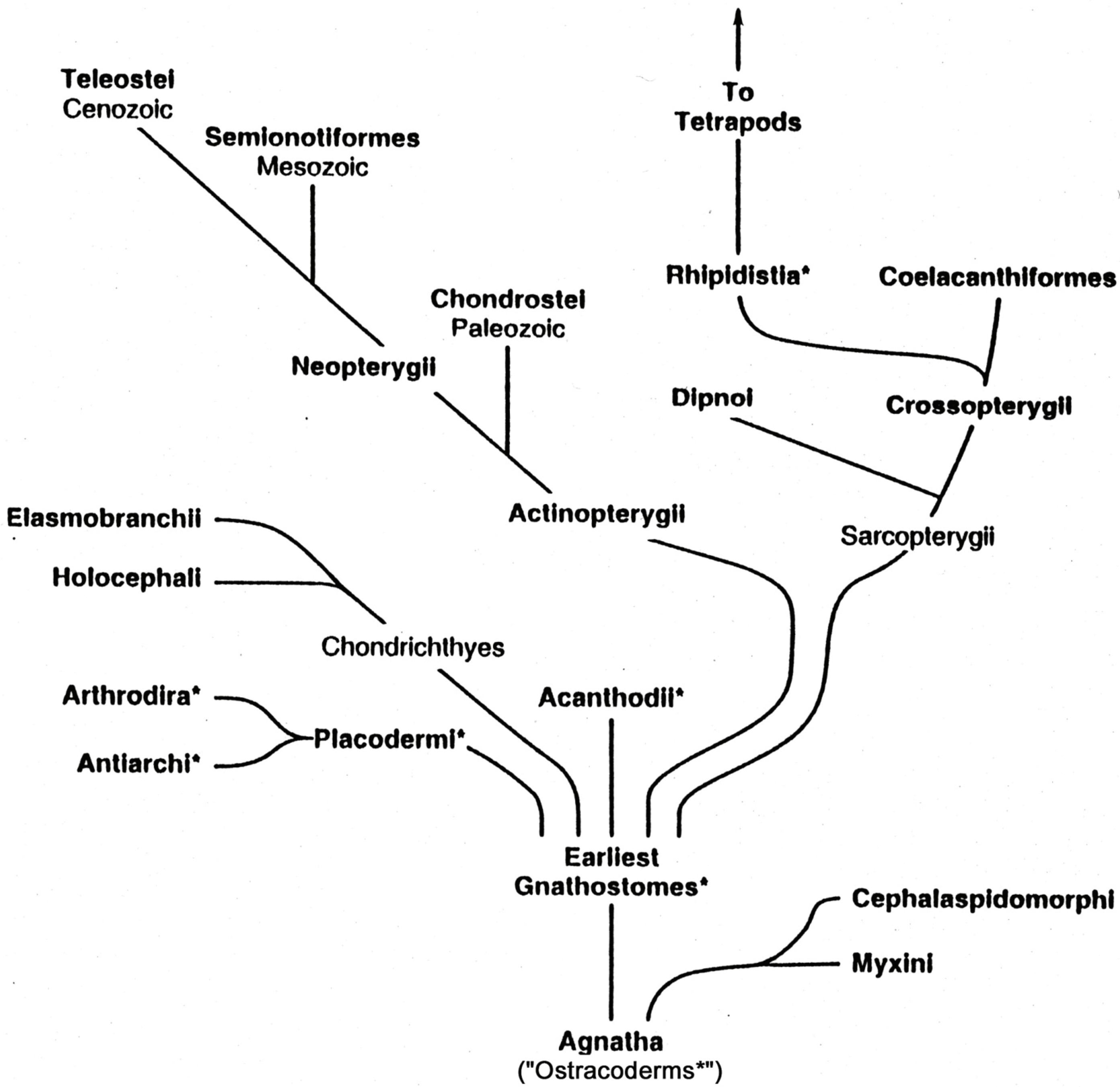


FIGURE 86. Representative Sarcopterygians.



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