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(TELEOSTEI).

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COELOMIC ORGANS OF PERCIFORM FISHES (TELEOSTEI)

by

HIN KIU MOK

A dissertation submitted to the Graduate
Faculty in Biology in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy, The City University
of New York.

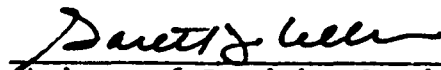
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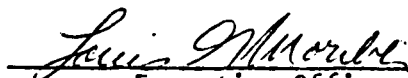
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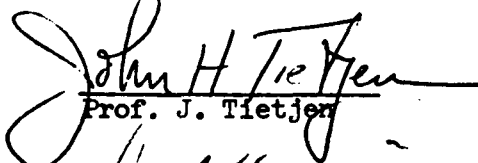

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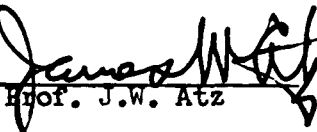
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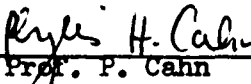
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Abstract

COELOMIC ORGANS OF PERCIFORM FISHES (TELEOSTEI)

by

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Adviser: Professor Gareth J. Nelson

Coelomic organs of some representative species of 110 perciform families and other major groups of actinopterygians were studied. Classifications of their intestinal patterns, kidney configurations, gas secreting complexes (only for perciforms), relative size of liver-lobes, features of the left liver-lobes, and the development of the posterior cardinal system were treated. The distributions of the various types of these structures in actinopterygians were recorded. Studies of individual variation and developmental changes of these structures in several species were conducted. Taxonomic variation of these structures provides some clues to the interrelationships of some taxa at various taxonomic levels. Generic relationships of the Centrarchidae and Chaetodontidae were hypothesized on the basis of evidence revealed by detailed comparisons of the kidney morphology (in both families) and intestinal pattern (in Chaetodontidae). Hypotheses concerning the interrelationships of various actinopterygian groups were proposed. These groups are : Actinistia, Polypteri-

formes, Osteoglossiformes, Otophysi, Umbridae, Holocentridae, Channidae, Hexagrammidae, Aplodactylidae, Apogonidae, Centrarchidae, Cepolidae, Chaetodontidae, Cheilodactylidae, Chironemidae, Cichlidae, Cirrhitidae, Embiotocidae, Gerridae, Kyphosidae, Latrididae, Leiognathidae, Owstoniidae, Pomacanthidae, Pomacentridae, Mugilidae, Labridae, Kurtidae, Acanthuridae, Scombridae, Stromateoidei, Anabantoidei, Pleuronectiformes, and Tetraodontiformes.

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Footnotes:

- 1) After Parker, 1892.
- 2) Including 36 specimens.
- 3) After Matsubara et al., 1963
- * Standard length unknown because only the digestive tract of the specimen was available.
- *** See text for detailed description.

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Footnotes:

- 1) Mok, 1975.
- * Dominant type unknown due to the small sample size

of the examined species.

** Dominant type undistinguishable due to the equal
occurring frequencies of the types.

+ Presence of an intestinal pattern

++ Dominant type of the group concerned.

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Footnotes:

* Dominant type unknown due to the small sample size
of the examined species.

** Dominant type undistinguishable due to the equal
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+ Presence of a kidney type.

++ Dominant type of the group concerned.

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- I-52. Intestinal patterns of callionymids. A, Callionymus sp.

- B, C. japonicus. C, C. lunatus. D, C. richardsoni.
- I-53. Intestinal patterns of gobioids. A, Acanthogobius flavimanus. B, Coryphopterus glaucofrenum. C, Eleotris fusca. D, Gobius hadropterus. E, G. fluviatilis. F, Periophthalmus koelreuteri. G, Plagiogrammus sp. H, Gobioides sp.. I, Sericagobioides lighti. J, Kraemeria samoensis. K, Trypauchenichthys sp. The pattern of Gobioides sp. is shown in its ventral view...P.
- I-54. Intestinal patterns of kurtids. A, Kurtus indicus. B, K. gulliveri.
- I-55. Intestinal patterns of acanthurids. A, Zebrasoma flavescens. B, Z. scopas. C, Z. veliferum. D, Z. rostratum. E, Naso annulatus. F, N. hexacanthus. G, Ctenochaetus striatus. H, Acanthurus nigrofuscus. I, A. bahianus. J, A. thompsoni. K, Prionurus microlepidotus. L, Paracanthurus hepatus. Fine stippling: loop a; heavy stippling: loop b.
- I-56. Intestinal pattern of Zanclus cornutus (Zanclinae, Acanthuridae).
- I-57. A, gross stomach morphology of Zebrasoma flavescens. B, anterior section of the intestinal pattern of Z. flavescens. C, anterior section of the intestinal pattern of Naso annulatus. D, anterior section of the intestinal pattern of N. hexacanthus.
- I-58. Two hypotheses regarding the relationship of acanthurines and Zanclus. The possible character states of loop a in the living and hypothetical ancestors are indicated. s - simple state; c - complex state...P.
- I-59. Intestinal patterns of siganids. A, Lo vulpinus. B, Siganus rostratus. C, Siganus sp.
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- I-61. Intestinal patterns of stromateoids. A, Psenopsis anomala (Centrolophidae). B, Cubiceps sp.. C, Nomeus gro-novii. D, Psenes cyanophrys (Nomeidae). E, Pampus ar-genteus (77 mm). F, P. argenteus (90 mm). G, Peprilus sp. (67 mm). H, Peprilus sp. (84 mm). I, Stromateus fiatola (Stromateidae). J, Tetragonurus cuvieri (Te-tragonuridae). Small arrows indicate the coiling di-rections of the tip of loop a (stippling); large ar-rows indicate the folding direction of the anterior section of the intestine; double-line arrows indicate the leftward folding of the intestine.
- I-62. Intestinal patterns of anabantoids. A, Anabas testu-dineus. B, Ctenopoma nanus. C, C. congicus. (Anabant-idae). D, Belontia sp.. E, Betta splendens. F, Macro-podus opercularis. G, Colisa lalia. H, Trichogaster trichopterus (Belontiidae). I, Helostoma temmincki (Helostomatidae). J, Osphronemus goramy (Osphromen-idae). Small arrows point to the two spiral masses of the intestine.
- I-63. Intestinal patterns of chondrosteans. A, Acipenser stellatus. B, Polyodon spathula. Anterior to the top.
- I-64. Ventral view of the intestinal pattern of Lepisosteus oculatus (Ginglymodi).
- I-65. Intestinal pattern of Amia calva (Halecomorphi). P.
- I-66. Intestinal pattern of Elops saurus (Elopidae). P.
- I-67. Intestinal pattern of Megalops cyprinoides (Megalop-idae).
- I-68. Intestinal pattern of Albula vulpes (Albulidae). P.
- I-69. Intestinal patterns of anguillids and muraenids. A, Anguilla rostrata. B, Gymnothorax moringa.
- I-70. Intestinal patterns of clupeids. A, Coilia sp.. B, Clupea sp.. C, Dorosoma sp.. D, Pomolobus pseudoharen-gus.
- I-71. Intestinal pattern of Anchoa mitchilli (Engraulidae).
- I-72. Intestinal patterns of characoids. A, Astyanax sp.. B, Ephippicharax sp.. C, Micralestes sp.. D, Citharinus

- citharus. E, Distichodus maculatus. Heavy stippling: loop a.
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- I-74. Ventral view of the simplified illustrations of two cyprinoid intestinal patterns showing the straight and U-shaped stomachs and the section 1, 2, and 3 of the intestine. Heavy stippling: loop a; fine stippling: loop e.
- I-75. Ventral view of the intestinal patterns of some ostariophysan fishes. A, B, Cyprinus carpio (45 and 56 mm, respectively). C, Carassius auratus. D, C. auratus (left side view). E, Hemiculter kneri. F, Notropis cornutus. G, N. hudsonius. H, N. rubellus. I, Catostomus latipinnis. J, Erimyzon oblongatus. K, L, Hypentelium nigricans (45 and 63 mm, respectively). M, Psilorhynchus balitora.
- I-76. Ventral view of the intestinal patterns of gyrinocheilids and homalopterids. A, Gyrinocheilus aymonieri. B, Gastromyzon punctulatus. C, Hemimyzon zebroidus.
- I-77. Ventral view of the intestinal patterns of cobitids. A, Barbatula posteroventralis. B, Leptobotia fasciata. C, Nemachilus sp.
- I-78. Ventral view of the intestinal patterns of Bagrus sp. (Bagridae).
- I-79. Ventral view of the intestinal pattern of Callichthys sp. (Callichthyidae).
- I-80. Ventral view of the intestinal pattern of Clarias fuscus (Clariidae).
- I-81. Ventral view of the intestinal pattern of Ictalurus melas (Ictaluridae).
- I-82. Ventral view of the intestinal patterns of loricarids. A, Hypostomus sp.. B, Loricaria cataphracta.
- I-83. Ventral view of the intestinal pattern of Plotosus

lineatus (Plotosidae).

- I-84. Intestinal pattern of Salmo gairdneri (Salmonidae).
- I-86. Intestinal pattern of Esox americanus (Esocidae).
- I-85. Intestinal pattern of Talismania sp. (Aplepocephalidae).
- I-87. Intestinal pattern of Myctophum sp. (Myctophidae).
Arrow indicates the downward bending of the intestine.
- I-88. Intestinal pattern of Amblyopsis spelaea (Amblyopsidae) shown in ventral view.
- I-89. Ventral view of the intestinal pattern of Chaunax sp. (Chaunacidae).
- I-90. Ventral view of the intestinal pattern of Ogcocephalus nasutus (Ogcocephalidae). Arrow indicates the coiling direction of loop a (stippled area)..... P.
- I-91. Intestinal pattern of Lepophidium sp. (Ophidiidae).
- I-92. Ventral view of the intestinal pattern of Zoarces viviparus (Zoaridae).
- I-93. Intestinal pattern of Antennarius tridens (after Suyehiro, 1942:Fig. 190).
- I-94. Intestinal pattern of Anableps dovii (Anablepidae).
- I-95. Intestinal patterns of cyprinodontids. A, Cyprinodon variegatus. B, Profundus punctatus. Arrow indicates the downward bending of the anterior section of the intestine; heavy line represents the sinistral loop anterior to the rectum.
- I-96. Intestinal pattern of Oryzias latipes (Oryziatidae).
Arrow indicates the downward bending of the anterior section of the intestine.
- I-97. Intestinal pattern of Belonesox belizanus (Poeciliidae).
- I-98. Intestinal pattern of Poecilia vivipara (Poeciliidae).
Heavy line represents the sinistral loop anterior to the rectum.
- I-99. Intestinal pattern of Polymixia sp. (Polymixiidae).
Fine arrows point to the small loops in the posterior section of the intestine; large arrow indicates the downward bending of the anterior section of the intestine.

- I-100. Intestinal pattern of Holocentrus rufus (Holocentridae).
- I-101. Intestinal pattern of Xenolepidichthys dalgleishi (Grammicolepididae).
- I-102. Intestinal pattern of Zenion hololepis (Macrurocyttidae).
- I-103. Intestinal pattern of Velifer hypselopterus (Veliferidae).
- I-104. Intestinal pattern of Apeltes quadracus (Gasterosteidae).
- I-105. Intestinal pattern of Macrorhamphosus scolopax (Macrorhamphosidae).
- I-106. Intestinal pattern of Hippocampus hudsonius (Syngnathidae).
- I-107. Intestinal patterns of scorpaeniforms. A, Pterygotigla hemisticta. B, Hexagrammos decagrammus. C, Pleuragrammus antarcticum. D, Ophiodon elongatus.
- I-108. Intestinal pattern of Psettodes erumeri (Psettodidae).
- I-109. Intestinal patterns of bothids. A, Bothus ocellatus. B, B. lunatus. C, Paralichthys albigutta. D, P. dentatus. E, Rhombosolea tapirina. F, Syacium papillosum. G, Taeniopsetta radula. H, Tephrineches sinensis.
- I-110. Intestinal patterns of pleuronectids. A, Ammotretis elongatus. B, Citharichthys spilopterus. C, Eopsetta grigorjewi. D, Glypterocephalus zachirus. E, Limanda sp.. F, Liopsetta exilis. G, Platyichthys stellatus. H, Pleuronichthys cornutus. I, Pseudopleuronectes americanus.
- I-111. Intestinal patterns of scophthalmids. A, Scophthalmus maculata. B, Scophthalmus aquosus.
- I-112. Intestinal patterns of cynoglossids. A, Cynoglossus interruptus. B, C. monopus. C, Parplagusia bilineata. D, Symphurus sp.. E, S. plagiusa.
- I-113. Intestinal patterns of soleids. A, Achirus lineatus. B, Heteromycteris japonicus. C, Synaptura marginata (after Matsubara et al., 1963). D, Trinectes macula-

tus. E, Zebrias zebra.

- I-114. A hypothetical scheme showing the possible interrelationships among the 11 types of intestinal patterns generally found in actinopterygians.

- II-1. A, Diagrammatic ventral view of a centrarchid kidney.
B, Kidney shapes of the 24 types of kidneys generally found in actinopterygians.
- II-2. Kidney shape of Chimaera phantasma (Chimaeridae).
- II-3. Kidney shapes of selachimorphs. A, Scoliodon terraenovae. B, Squalus acanthias.
- II-4. Kidney shapes of batoidimorphs. A, Taeniura meyeri. B, Urogymnus africanus.
- II-5. Kidney shape of Latimeria chalumnae (Latimeriidae).
- II-6. Kidney shape of Protopterus annectens (Protopteridae).
- II-7. Kidney shapes of polypterids. A, Polypterus ornatipinnis. B, Calamoichthys calabaricus.
- II-8. Kidney shapes of chondrosteans. A, Acipenser stellatus. B, Polyodon spathula.
- II-9. Kidney shapes of lepisosteids. A, Lepisosteus oculatus. B, L. platyrhincus.
- II-10. Kidney shape of Amia calva (Amiidae).
- II-11. Kidney shapes of osteoglossomorphs. A, Osteoglossum bicirrhosum. B, Pantodon buchholzi. C, Hiodon alosoides. D, Notopterus sp. E, Xenomystus nigri. F, Gymnarchus niloticus. G, Gnathonemus sp. H, Mormyrops deliciosus. I, Petrocephalus sp.
- II-12. Kidney shape of Elops saurus (Elopidae).
- II-13. Kidney shape of Megalops cyprinoides (Megalopidae)
- II-14. Kidney shape of Albula vulpes (Albulidae).
- II-15. Kidney shape of anguilliforms. A, Anguilla rostrata. B, Gymnothorax moringa.
- II-16. Kidney shapes of clupeids. A, Coilia sp.. B, Clupea sp. C, Dorosoma sp. D, Pomolobus pseudoharengus. E, Sardinops sp.
- II-17. Kidney shape of Anchoa mitchilli (Engraulidae).

- II-18. Kidney shape of Chirocentrus dorab (Chirocentridae).
- II-19. Kidney shapes of characoids. A, Astyanax sp.. B, Ephippicharax sp.. C, Micralestes sp.
- II-20. Kidney shapes of gymnotoids. A, Electrophorus electricus. B, Gymnotus sp. C, Eigenmannia virescens (182 mm). D, E. virescens (178 mm).
- II-21. Kidney shapes of cyprinids. A, Cyprinus carpio. B, Carassius auratus. C, Hemiculter kneri.
- II-22. Kidney shapes of catostomids. A, Catostomus latipinnis. B, Hypentelium nigricans.
- II-23. Kidney shapes of homalopterids. A, Gastromyzon punctulatus. B, Hemimyzon zebroidus.
- II-24. Kidney shapes of cobitids. A, Botia citraurata. B, Leptobotia elongata.
- II-25. Kidney shape of Arius felis (Ariidae).
- II-26. Kidney shape of bagrids. A, Bagrus sp. B, Leiocassis sp.
- II-27. Kidney shape of Callichthys sp. (Callichthyidae).
- II-28. Kidney shape of Clarias fuscus (Clariidae).
- II-29. Kidney shape of Ictalurus melas (Ictaluridae).
- II-30. Kidney shape of Loricaria cataphracta (Loricariidae).
- II-31. Kidney shape of Rhamdia sp. (Pimelodidae).
- II-32. Kidney shape of Plotosus lineatus (Plotosidae).
- II-33. Kidney shape of Salmo gairdneri (Salmonidae).
- II-34. Kidney shapes of osmerids. A, Mallotus villosus. B, Osmerus sp.
- II-35. Kidney shape of Argentina sp. (Argentinidae).
- II-36. Kidney shape of Galaxias sp. (Galaxiidae).
- II-37. Kidney shape of Esox americanus (Esocidae).
- II-38. Kidney shapes of umbrids. A, Dallia pectoralis. B, Umbra pygmaea. C, U. limi.
- II-39. Kidney shape of Talismania sp. (Aplepocephalidae).
- II-40. Kidney shape of Myctophum sp. (Myctophidae).
- II-41. Kidney shape of Synodus synodus (Synodontidae).
- II-42. Kidney shapes of amblyopsid and percopsids. A, Amblyopsis spelaea. B, Percopsis omiscomaycus. C, P. tran-

smontana.

- II-43. Kidney shape of Opsanus tau (Batrachoididae).
- II-44. Kidney shapes of gobioides. A, Gobiesox strumosus.
B, Tomicodon sp.
- II-45. Kidney shape of Histrio histrio (Antennariidae)
- II-46. Kidney shapes of chaunacids and ogocephalids. A.
Chaunax sp. B, Ogocephalus nasutus.
- II-47. Kidney shape of Microgadus tomcod (Gadidae).
- II-48. Kidney shape of Lepophidium sp. (Ophidiidae).
- II-49. Kidney shape of Zoarces viviparus (Zoaridae).
- II-50. Kidney shapes of exocoetids. A, Halocypselus evolans.
B, Hemiramphus brasiliensis.
- II-51. Kidney shape of Anableps dowii (Anablepidae).
- II-52. Kidney shapes of cyprinodontids. A, Cyprinodon variegatus. B, Fundulus heteroclitus.
- II-53. Kidney shapes of goodeids and oryzias. A, Goodea
sp. B, Oryzias latipes.
- II-54. Kidney shapes of poeciliids. A, Belonesox belizanus.
B, Gambusia sp.
- II-55. Kidney shapes of atherinids and melanotaeniids. A,
Atherinops affinis. B, Chilatherina sp. C, Melanotaenia nigrans. D, Membras vagrans.
- II-56. Kidney shape of Polymixia sp. (Polymixiidae).
- II-57. Kidney shapes of holocentrids. A, Adioryx vexillarius. B, Holocentrus rufus. C, Myripristis jacobus.
D, Plectrypops retrospinis.
- II-58. Kidney shape of Xenolepidichthys dalgleishi (Grammicolepididae).
- II-59. Kidney shape of Zenion hololepis (Macruridae).
- II-60. Kidney shape of Zeus japonicus (Zeidae).
- II-61. Kidney shape of Velifer hypselopterus (Veliferidae).
- II-62. Kidney shape of Apeltes quadracus (Gasterosteidae).
- II-63. Kidney shape of Aulostomus maculatus (Aulostomidae).
- II-64. Kidney shape of Macrorhamphosus scolopax (Macrorhamphosidae).
- II-65. Kidney shapes of syngnathids. A, Corythoichthys sp.

- B, Hippocampus hudsonius. C, Syngnathus fuscus.
- II-66. Kidney shape of Ophicephalus argus (Channidae).
- II-67. Kidney shape of Synbranchus marmoratus (Synbranchidae).
- II-68. Kidney shapes of scorpaenids. A, Scorpaena sp. B, Scorpaenodes caribbaeus.
- II-69. Kidney shapes of triglids. A, Lepidotrigla stonuchii. B, Peristedion miniatum. C, Pterygotrigla hemisticta.
- II-70. Kidney shapes of Cottus cognatus (Cottidae).
- II-71. Kidney shape of Crinodus lophodon (Aplodactylidae).
- II-72. Kidney shapes of apogonids. A, Archamia lineolata. B, Cheilodipterus macrodon. C, Glossamia aprion.
- II-73. Kidney shape of Bathyclupea sp. (Bathyclupeidae).
- II-74. Kidney shape of branchiostegids. A, Branchiostegus japonicus. B, Caulolatilus princeps. C, Malacanthus plumieri.
- II-75. Kidney shape of Banjos typus (Banjosidae).
- II-76. Kidney shapes of carangids. A, Alectis ciliaris. B, Caranx crysos. C, Decapterus muroadsi. D, D. russelli. E, Megalaspis cordyla. F, Scomberoides tolooo. G, Selar sp.. H, Selene vomer. I, Seriola falcata. J, Seriola zonata. K, Trachinotus sp.. L, Trachurus japonicus. M, Vomer declivifrons.
- II-77. Kidney shapes of centrarchids. A, Acantharchus pomotis. B, Ambloplites cavifrons. C, Ambloplites rupestris. D, Archoplites interruptus. E, Centrarchus macropterus. F, Elassoma zonatum. G, Enneacanthus chaetodon. H, Enneacanthus gloriosus. I, E. obesus. J, Lepomis cyanellus. K, L. gibbosus. L, L. gulosus. M, L. humilis. N, L. macrochirus. O, L. marginatus. P, L. megalotis. Q, L. microlophus. R, L. punctatus. S, L. symmetricus. T, Micropterus coosae. U, M. salmoides. V, Pomoxis annularis. W, P. nigromaculatus.
- II-78. Kidney shapes of centropomids. A, Centropomus undecimalis. B, Chanda gymnocephalus. C, Lates calcarifer.

- II-79. Kidney shapes of cepolids. A, Acanthocepola krusensternii. B, Cepola rubescens.
- II-80. Kidney shapes of cheilodactylids. A, Goniistius zonatus. B, Nemadactylus macropterus.
- II-81. Kidney shape of Chironemus marmoratus (Chironemidae).
- II-82. Kidney shapes of cichlids. A, Ciclasoma champotonis. B, C. heterospilum. C, C. hyorhynchum. D, C. intermedium. E, C. motaguense. F, C. salvini. G, Haplochromis eucinostomus.
- II-83. Kidney shapes of cirrhitids. A, Amblycirrhitus pinos. B, Cirrhitichthys falco. C, Paracirrhites bimacula. D, Paracirrhites sp.
- II-84. Kidney shape of Coryphaena hippurus (Coryphaenidae).
- II-85. Kidney shapes of echeneids. A, Echeneis naucrates. B, Remora brachyptera. C, R. remora. D, Rhombochirus osteochir.
- II-86. Kidney shapes of embiotocids. A, Brachyvistius frenatus. B, Cymatogaster aggregata.
- II-87. Kidney shape of Dipterygonotus gruveli (Emmelichthyidae).
- II-88. Kidney shape of Enoplosus armatus (Enoplosidae).
- II-89. Kidney shape of Chaetodipterus faber (Ephippidae).
- II-90. Kidney shape of Gadopsis marmoratus (Gadopsidae).
- II-91. Kidney shapes of gerrids. A, Diapterus olisthostomus. B, Eucinostomus pseudogula. C, Gerres cinereus.
- II-92. Kidney shape of Rypticus saponaceus (Grammistidae).
- II-93. Kidney shapes of kuhlids. A, Kuhlia malo. B, K. marginata.
- II-94. Kidney shapes of kyphosids. A, Girella melanichthys. B, Girella mezina. C, Hermosilla azurea. D, Kyphosus vaigiensis. E, Sectator ocyurus. F, Scorpiis aequipinnis. G, S. georgianus.
- II-95. Kidney shape of Labracoglossa argentiventris (Labroglossidae).
- II-96. Kidney shape of Lactarius lactarius (Lactariidae).
- II-97. Kidney shape of Latridopsis forsteri (Latrididae).

- II-98. Kidney shapes of leiognathids. A, Gazza minuta. B, Leiognathus rivulatus. C, Parequula melbournensis.
- II-99. Kidney shapes of lethrinids. A, Lethrinus ornatus. B, L. rhodopterus. C, Monotaxis grandoculis.
- II-100. Kidneys shape of Lobotes sp. (Lobotidae).
- II-101. Kidney shapes of lutjanids. A, Lutjanus gibbus. B, L. griseus. C, Ocyurus chrysurus. D. Symphysandon typus.
- II-102. Kidney shape of Mene annocarolina (Menidae).
- II-103. Kidney shapes of mullids. A, Mullus barbatus. B, Parupeneus malabaricus. C, Pseudupeneus maculatus.
- II-104. Kidney shapes of nandids. A, Monocirrhus polyacanthus. B, Nandus nebulosus.
- II-105. Kidney shapes of nemipterids. A, Nemipterus sp.. B, Scolopsis bilineatus.
- II-106. Kidney shape of Oplegnathus sp. (Oplegnathidae).
- II-107. Kidney shape of Owstonia tosaensis (Owstoniidae).
- II-108. Kidney shapes of pempherids. A, Parapriacanthus sp. B, Pempheris sp.
- II-109. Kidney shapes of percids. A, Acerina schraetser. B, Ammocrypta vivax. C, Aspro streber. D, Etheostoma caeruleum. E, Etheostoma olmstedii. F, Perca flavescens. G, Percina caprodes.
- II-110. Kidney shape of Plesiops melas (Plesiopidae).
- II-111. Kidney shapes of pomacanthids. A, Centropyge bicolor. B, Holacanthus tricolor. C, Pomacanthus paru. D. Pomacanthus sp.
- II-112. Kidney shapes of pomacentrids. A, Abudefduf saxatilis. B, Amphiprion ocellaris. C, Chromis cyanea. D, C. multilineatus. E, Dascyllus trimaculatus. F, Eupomacentrus sp.. G, Eupomacentrus dorsopunicans. H, E. partitus. I, Microspathodon chrysurus.
- II-113. Kidney shapes of pomadasyids. A, Anisotremus virginicus. B, Bathystoma sp.. C, Haemulon chrysargyreum. D, H. melanurum. E, H. sciurus. F. Pomadasys jubelini.

- II-114. Kidney shape of Scombrops boops (Pomatomidae).
- II-115. Kidney shapes of priacanthids. A, Cookeolus boops. B, Priacanthus cruentatus. C, Pseudopriacanthus altus.
- II-116. Kidney shape of Gramma loreto (Pseudochromidae).
- II-117. Kidney shape of Rachycentron canadum (Rachycentridae).
- II-118. Kidney shape of Scatophagus argus (Scatophagidae).
- II-119. Kidney shapes of sciaenids. A, Aplodinotus grunniens. B, Bairdiella chrysura. C, Cynoscion regalis. D, Equetus acuminatus. E, Larimus fasciatus. F, Macrodon ancylodon. G, Menticirrhus americanus. H, Nebris microps. I, Odontoscion dentex. J, Paralenchurus sp. K, Plagioscion squamosissima. L, Stellifer rastri-fer.
- II-120. Kidney shapes of serranids. A, Liopropoma mowbrayi. B, Morone americana. C, Petrometopon cruentatum. D, Siniperca chuatsi.
- II-121. Kidney shape of Sillago bassensis (Sillaginidae).
- II-122. Kidney shape of Archosargus probatocephalus (Sparidae).
- II-123. Kidney shapes of teraponids. A, Amniataba percoides. B, Leiopotherapon unicolor. C, Pelates quadrilineatus. D, Terapon theraps.
- II-124. Kidney shape of Toxotes chatereus (Toxotidae).
- II-125. Kidney shapes of mugilids. A, Agonostomus monticola. B, Aldrichetta forsteri. C, Liza macrolepis. D, Mugil curema.
- II-126. Kidney shape of Sphyraena barracuda (Sphyraenidae).
- II-127. Kidney shapes of labrids. A, Bodianus rufus. B, Cirrhlabrus solorensis. C, Clepticus parrai. D, Doratonotus megalepis. E, Halichoeres bivittatus. F, Hemipteronotus splendens. G, Macropharyngodon meleagris. H, Pseudojulis notospilus. I, Stethojulis phekadopleura. J, Thalassoma bifasciatum. K, Tautoga onitis. L, Tautogolabrus adspersus.

- II-128. Kidney shape of Odax pullus (Odacidae).
- II-129. Kidney shapes of scarids. A, Scarus croicensis. B, Sparisoma radians. C, Sparisoma viride.
- II-130. Kidney shape of Bathymaster signatus (Bathymasteridae).
- II-131. Kidney shape of Champsodon sp. (Champsodontidae).
- II-132. Kidney shape of Cheimarrichthys forsteri (Cheimarrichthyidae).
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INTRODUCTION

Suyehiro's (1942) study on the digestive system of diverse teleostean fishes is the only systematic survey of the system within this group. His objective was to understand the nature of the feeding habits of fishes by studying the digestive organs. He discovered various types of intestinal patterns. In contrast to this ecologically orientated study, Harder (1960) used superficial gut morphology (of the stomach and pneumatic duct) as a basis for interpreting the phylogeny of the clupeoids. Greenwood (1968) described the gut and other viscera in Denticeps clupeoides in an attempt to resolve its systematic position among clupeiforms. Nelson (1972a) found evidence, from the intestinal pattern, for monophyly of osteoglossomorphs (including hiodontids). With similar (systematic) goals in mind, Mok (1975) surveyed the digestive system, swimbladder, and related tissues (e.g., the gas-gland) of tetraodontiforms. Results of that study suggested that intestinal pattern might be applicable to the reconstruction of phylogenetic relationships among other fishes. Accordingly, the scope of the present study included all main groups of actinopterygians but has the specific objective of answering the question: Do the intestinal patterns provide evidence of the phylogenetic interrelationships of perciforms?

Little has been written on the gross morphology of perciform kidneys. Hickman and Trump (1969) reviewed teleostean kidneys from a physiological point of view. Ogawa (1961) made

a detailed comparative study on the gross morphology of teleostean kidneys and found correlations between kidney types and some groups in the phylogeny of teleosts proposed by Gosline (1952). Ogawa's work concerns the kidney types of only a small sample of teleosts that occur in Japanese waters.

There are some questions relating to this subject which I explored : (1) How many types of fish kidneys are there? (2) How do fish kidneys change in shape during development? (3) How significant is the variation among individuals in kidney shape? (4) How much variation of kidney shape is there within a taxon such as a genus or family? (5) Is kidney type correlated with type of habitat? (6) When gross kidney morphology is applied to reconstruct phylogeny of certain taxa, does the phylogeny conflict with the conclusions reached by other authors using evidence from other systems?

During study of liver morphology of tetraodontiforms, I observed that tetraodontiforms possess two liver-lobes on the right and left sides of the esophagus and stomach, the left usually being much larger than the right (Mok, 1975). It is not known if this is the only character state of the relative size of the liver-lobes, nor, if there are some other character states, if they are limited to certain taxonomic group(s). It was, therefore, my intention to look into the phylogenetic implication of the relative sizes of the liver-lobes of actinopterygians.

The gas secreting complex (retia mirabilia and gas-gland) plays an important functional role in physoclistous

swimbladders. The anatomy of this structure in teleosts has been studied by Marshall (1960) and Fraser (1972). The gas-gland is part of the bladder epithelium, which may be one-layered, folded, or composed of stratified epithelium several cell layers thick (Lagler, et al., 1962). The rete mirabile is composed of numerous capillaries and venules. In teleosts, variations of the numbers and shapes of the gas-glands give rise to several forms of this structure. But no attempt has been made to study the variations in gas-glands of perciforms from a systematic point of view. Therefore, the present study examined the gas secreting complex of perciforms in search of evidence that will throw new light on their interrelationships.

MATERIALS AND METHODS

Specimens referred to in this study were drawn from the fish collection at the American Museum of Natural History (AMNH), Academy of Natural Sciences of Philadelphia (ANSP), Australian Museum in Sydney (AMS), Bernice P. Bishop Museum (BPBM), California Academy of Sciences (CAS), Field Museum of Natural History (FMNH), South Australian Museum (SAM), Scripps Institute of Oceanography (SIO), Institute of Animal Resource Ecology, University of British Columbia (BC), Western Australian Museum (WAM), Zoology Museum, National Taiwan University (ZMNTU), Zoology Museum, University of Michigan (ZMUM), and the personal collections of G. Dingerkus (GD),

M. Oliver (MO), P. Moller (PM). Catalogue number, standard length (measured in millimeters) of specimens examined are listed in Table 1.

Dissections were made on one or more individuals of each species studied. The fish was cut on the right side of the body cavity. Relative sizes of the left and right lobes of the liver and the shape of the left lobe were recorded. The digestive tract was removed and drawn. Intestinal pattern was recorded by tracing the coiling pathway with a continuous line. The swimbladder was cut open on its right side to display the gas secreting complex, which is generally found on the floor of the bladder. The kidney could be easily observed after the swimbladder was removed. Its shape and the position of the ureters relative to the first haemal spine were recorded. Illustrations of intestinal patterns and kidney configurations are shown in left side and ventral views, respectively; otherwise orientation of the illustrations will be specified in figure legends.

PHILOSOPHICAL BACKGROUND

To reconstruct evolutionary histories, I adopt the philosophy of phylogenetic systematics, as exemplified by the following concepts: (1) evolution is a complex temporal process of changes that results in a mosaic pattern of characters (primitive and advanced) in a taxon; (2) there is only one real pattern of relationships among taxa; (3) only synapomorphic characters provide evidence for monophyletic relation-

ships of taxa; (4) one may predict that whenever two taxa are found to share an advanced character or character state; the chance of their sharing additional advanced characters (or character states) is increased; (5) conflicts in synapomorphic characters or character states among taxa under consideration are the results of misinterpretations of the nature (advancement or primitiveness) of the characters (or character states); (6) the correct phylogeny should reflect perfect agreement of synapomorphies.

ABBREVIATIONS AND SYMBOLS USED IN ILLUSTRATIONS AND FIGURES.

- AD, archinephric duct.
 AF, anal-fin.
 b, presence of a small thin-membraned sac within the swim-bladder; when gas-gland is present, it is enclosed in this sac.
 BFHS (bfhs), base of first haemal spine.
 BHS (bhs), base of haemal spine.
 c, gas-gland curves to both lateral walls of the swimbladder.
 C, complex loop a.
 e, esophagus.
 EPK, extreme posterior kidney.
 f, fusion of the left and right kidneys.
 gg, gas-gland.
 h, hole.
 hs, haemal spine.
 i, intestine.
 j, the part of the swimbladder on both sides of the haemal spines is not separated by the spines.
 l, liver.
 lg, ligament.
 ll, left liver lobe.
 LPCV, left posterior cardinal vein.
 LSV, left side view.
 ML, muscle layer.
 PC, peritoneal cavity.
 PK, posterior kidney.
 rc, retial complex.
 rll, right liver lobe.
 rm, rete mirabile.
 RPCV, right posterior cardinal vein.
 RSV, right side view.
 s, swimbladder short or complete separation of the kidneys.
 S, simple loop a.
 sp, the part of the swimbladder on both sides of the haemal spines is separated by these spines.

st, septum.

TTL, thick tissue-layer.

U (u), urinary bladder.

UGP, uro-genital pore.

VC, vertebral column.

VV, ventral view.

+, presence of a structure or organ.

-, absence of a structure or organ.

— (Table 1), anterior tip of the swimbladder away from the front end of the peritoneal cavity.

→ (figures in Section II), fused area of the anterior kidneys.

→ (figures in Section I & V). Coiling direction of certain section of the intestine.

⇒, coiling direction of certain section of the intestine.

⇒, coiling direction of certain section of the intestine.

↔, posterior tip of the swimbladder away from the posterior end of the peritoneal cavity.

?, the concerned structure was not well reserved in the specimen dissected.

⋮, loop a or right liver-lobe.

—(—, junction of the stomach and intestine.

*** (Table 1), see text for detailed description.

** (Tables 3, 4), dominant type undistinguishable due to the equal occurring frequencies of the types.

* (figures in Section II), see text for detailed description.

* (Tables 3, 4), dominant type unknown due to the small sample size of the examined species.

++, dominant type of the group concerned.

RESULTS

Section I: Intestinal patterns.

Within the peritoneal cavity the positions of the various parts of the gastrointestinal tract form the intestinal pattern of the fish. The elements of the pattern are the relative positions of the parts.

Loop f and loop a:

In most actinopterygians, the anterior part of the intestine proceeds anterior and then displaces to the right of the stomach, which is, in most cases, either U-, V-, Y-, or T-shaped (Suyehiro, 1942; Greenwood, 1968; Nelson, 1972). The loop formed by the anterior section of the intestine at the front of the peritoneal cavity I term loop f (first loop; Fig. I-1, heavy line). According to this definition, this loop can only be found in the species in which the stomach is not I-shaped. The intestine in the rear of the peritoneal cavity commonly forms another loop, which I term loop a (Fig. I-1, stippled areas). Loop a may be recognized in most cases, because the length of the intestine between its beginning and the tip of the loop, and the length from the tip of the loop to the anus, are about the same. With this mid-intestinal position as a basic criterion, mistakes in recognizing this loop will be few. Sometimes, however, the intestine is long, and the pattern too complex, to recognize loop a. In such cases, comparisons may be limited to the overall winding tendencies of the intestine, not the exact numbers and shapes of loops.

Complexity of intestinal pattern.

Complexity of a pattern is dual in nature, namely, quantitative and directional. Complexity can be measured by the numbers of loops and/or by the directional changes that a loop displays. Therefore, the more loops a pattern is composed of, the more complex it is. If loop a is the only loop, a pattern with a dextral-winding loop a is more complex than a pattern with a straight loop a. Intestinal length is a factor determining the complexity of a pattern. With equal sizes of the peritoneal cavity, which is a determinant of intestinal growth (Montgomery, 1977), a species with a long intestine is likely to have a pattern more complex than a species with a short intestine. For example, the oval peritoneal cavity of chaetodontids, with their long intestine, generally leads to complex patterns (see section V). However, it is not true that a long intestine always gives rise to a complex pattern, because the size and shape of the peritoneal cavity also play a role in governing complexity. In most pleuronectiforms, for example, the peritoneal cavity ends in front of the first haemal spine, and a dextral-winding loop a occurs (Fig. I-2A). But in some soleid species (Achirus lineatus, Trinectes maculatus, and Zebrias zebra), the intestine is extraordinarily long, and the right secondary peritoneal cavity (the posterior extension of the cavity on the right side of the haemal spine) makes room for the intestine. Also, loop a of these species is straight and without the dextral winding tendency. The narrow secondary

peritoneal cavity provides space for the placement of the tip of loop a (Fig. I-2B). It seems generally true that fishes with a long peritoneal cavity tend to have a simple pattern. Besides the above-mentioned examples, other are demonstrated in other teleosts such as Ammodytes personatus (Ammodytidae), Atherina bleekeri (Atherinidae) and Trichiurus haumela (Trichiuridae) (Suyehiro, 1942).

Intestinal patterns.

Actinopterygian patterns can be classified into eleven basic types with reference to the variations of loop f and loop a. They are type B, D1, D2, SP, S, Z, HZ, LA, T, LF, ST (Fig. I-1A-K).

Type B.

Loop f is to the right of the esophagus, and loop a extends horizontally to the posterior part of the peritoneal cavity (Fig. I-1A). This is the basic and most widely distributed pattern in acanthopterygians, although it occurs also in some pre-acanthopterygian teleosts. Nelson (1972a) reported the same pattern in Acipenser oxyrhynchus and Lepisosteus platyrhincus. Among the perciforms I have studied, the vast majority (more than 80%) has this pattern (Table 1). It is, therefore, a primitive character state for acanthopterygians as a whole.

There are some perciforms with patterns that seem variants of type B. In Mene annocarolina and Lumpenus lumpretaeformis (figures I-23 and I-45E, respectively), the

patterns are similar in that the anterior section of the intestine bends downward (arrows in these figures show the bending direction of the heavy-line section of the intestine).

Loop f occurs in the great majority of actinopterygians, either to the right or the left of the stomach. The latter position occurs in osteoglossiforms and some atherinoids (Suyehiro, 1942; Nelson, 1972a). Nelson considered the left position of loop f as an apomorphic character of osteoglossomorphs (including hiodontids). As for atherinoids, Allantta harringtonensis, Atherinops affinis, Membras vagrans, and Menidia menidia (Atherinidae) and Chilatherina sp., Melanotaenia nigrans (Melanotaeniidae) (Fig. I-3) have this pattern (because specimens were lacking, I have not observed the patterns of the families Isonidae, Neostethidae, and Phallostethidae). A survey of these groups would be helpful for understanding the basic pattern of this suborder.

Loop a of type B generally does not bend. Exceptionally, loop a is distinctively tilted upward at a very steep angle (Fig. I-8D). Examples are Bostockia porosa (Serranidae), Glossamia aprion, Cheilodipterus macrodon, Astrapogon stellatus (Apogonidae), and Doratonotus megalepis (Labridae).

Type D1.

Loop a winds dextrally to the right of the rectum (Fig. I-1B). Loop a is not long enough to form a spiral pattern like that of type SP (see below). Type D1 has a broad distribution among perciforms. Some examples are Scomberoides

toloo, Vomer declivifrons (Carangidae), Cirrhitichthys falco (Cirrhitidae), Kuhlia taeniurus, K. malo (but not in K. marginata and Nantherina balstoni, Kuhliidae), Gnathodentex aurolineatus, Monotaxis grandoculis (Lethrinidae), Monodactylus falciformis (Monodactylidae), Oplegnathus sp. (Oplegnathidae), Pseudopriacanthus atlus (Priacanthidae), Dampiera cyclophthalma, Gramma sp. (Pseudochromidae), Stellifer rastri-fer (Sciaenidae), Amniataba percoides (Teraponidae), Trichodon trichodon (Trichonotidae). This type seems not to characterize a genus or family as a whole, but might be applied to the interpretation of species interrelationships.

Beyond perciforms, type D1 seldom appears. Among the non-perciforms I have worked with so far, I have seen this pattern only in Myoxocephalus quadricornis (Cottidae), Limanda sp. (Pleuronectidae), and Achirus lineatus (Soleidae).

Type D2.

Loop a winds dextrally to the left of the rectum and may extend anteriorly to the left of the stomach (Fig. I-1C). Type D2 is limited to Chironemus marmoratus (Chironemidae), Dentex japonicus (Sparidae), and Nomeus gronovii (Nomeidae) among the perciforms studied. Among non-perciforms, it is common in monacanthids (e.g., Alutera monoceros, Laputa sp. Monacanthus tuckeri, and Scobinichthys grannulatus, to name a few) and is also observed in Pterygotrigla hemisticta (Triglidae).

In two perciforms, Archosargus probatocephalus (Spar-

idae) and Bryostemma nigator (Stichaeidae), and also in some non-perciforms such as Holocentrus rufus (Holocentridae) and hexagrammids, loop a runs underneath the rectum and folds upward to the left of the rectum. These character states of the position of the tip of loop a are somewhat different and might be treated as apomorphic character states at various levels. A detail survey of the patterns of these families might be a fruitful study.

Type SP.

The long loop a winds dextrally to the right of the rectum, forming a spiral intestinal mass (Fig. I-1D). Type SP has a limited distribution within perciforms. Examples include most acanthurids (Fig. I-55), anabantoids (Colisa lalia, Macropodus opercularis, M. viridiauratus, Trichogaster trichopterus, Belontiidae ; Helostoma temminckii, Helostomidae ; Osphronemus goramy, Osphronemidae ; Fig. I-62), siganids (Lo vulpinus, Siganus rostratus; Fig. I-59), scatophagids (Scatophagus argus), and stromateids (Pampus argenteus). Among non-perciform actinopterygians, it has only been found in a few ostariophysians (Hypostomus sp. and Loricaria cataphracta) and cyprinodontoids (Goodea sp.)

The exact arrangement of the patterns differs to various degrees. Those of anabantoids, siganids, and scatophagids are more similar among themselves than to the others mentioned. Loop a of these three groups is the only major loop and is coiled in a spiral. The patterns of acanthurids,

and Pampus argenteus will be discussed below.

Type S.

The middle part of loop a is slightly depressed, and loop a is to the right of the rectum (Fig. I-1E). For adult individuals, this type occurs only in Dipterygonotus gruvelli (Emmelichthyidae), Psenopsis anomala (Centrolophidae) and Premnas biaculeatus (Pomacentridae).

Type Z.

The winding of loop a follows a Z-shaped pathway (Fig. I-1F; arrow indicates this winding route). It occurs widely in perciforms such as Crinodus lophodon (Aplodactylidae; Fig. I-7A), all kyphosids examined (Fig. I-21), most pomacentrids (Fig. I-29; Aoyagi, 1941), Agonostomus monticola (Mugilidae; Fig. I-35A), Psenes cyanophrys (Nomeidae; Fig. I-61D). Loop a of Cichlasoma heterospilum, C. spilurum, Haplochromis eucinostomus, and Melanochromis johanni (Cichlidae; Fig. I-15B, F, G, H) winds also in a Z-shaped pathway.

Type HZ.

Loop a turns at the rear of the peritoneal cavity and extends anteriorly such that the tip is located between the anterior and posterior section of loop a (Fig. I-1G; heavy lines represent these sections). This type can be distinguished from type Z in that the posterior section of loop a does not wind in a Z-shaped manner.

There are only a few examples found in perciforms: Leiognathus rivulatus (Leiognathidae), Abudefduf saxatilis, and

young A. taurus (Figs. I-19E, I-29A, B, respectively). The only other actinopterygians with this pattern are monacanthids (Mok, 1975).

Type LA.

Loop f occurs, and loop a is absent (Fig. I-1H). Type LA occurs in actinopterygians with a short intestine having only one loop. It is not limited to specific groups, but occurs in diverse actinopterygians. Examples are numerous, and they are listed in Table 1.

Type T.

The portion of the intestine corresponding to the convex section of loop f in type LA and type B (Fig. I-4A, C; heavy lines) is concave (Fig. I-4B; heavy line) and loop a is absent. Brachyistius frenatus (Embiotocidae) is the only examined perciform which has this pattern. However, type T consistently characterizes the patterns of some cyprinodontoids, such as Profundulus punctatus (Cyprinodontidae), Oryzias latifer (Oryziatidae), Belonesox belizanus, Gambusia sp. (Poeciliidae). This pattern has not been found among other actinopterygians.

Type LF.

Loop f is absent (Fig. I-1J). Type LF occurs at least in some species of the following perciform families: Carangidae, Cichlidae, Ehippidae, Serranidae, Gobioididae, Para-

gobioididae, Clinidae, Chaenopsidae, Gobioidae, Pholididae, and Ammodytidae. In non-perciform actinopterygians, type LF occurs in some species of the families Cyprinidae, Gastereosteidae, Macrorhamphosidae, and Triglidae. Loop f is absent also from all tetraodontids, diodontids, molids (Mok, 1975), and triodontids (Breder et al., 1942). Type LF is most widely distributed among gobioidids and blennioids of the families Chaenopsidae, Clinidae, and Eleotridae.

Type ST.

The simplest pattern is the straight gut (Fig. I-1K). In actinopterygians, it occurs in some species of the families Gobiesocidae, Belonidae, Exocoetidae, Aulostomidae, Syngnathidae, Synbranchidae, Echeneidae, Odacidae, Kraemeriidae, Microdesmidae, and Triacanthodidae (Table 1 and Mok, 1975).

Of species in the families Aulostomidae, Exocoetidae, Syngnathidae, and Synbranchidae, those that have a long peritoneal cavity generally have a straight gut. With a few exceptions, such as Hollardia hollardia (Triacanthodidae) (Mok, 1975), actinopterygians with an oval or short peritoneal cavity do not have a straight gut, regardless of their feeding habits.

Variation of intestinal patterns.

Individual variation

Individual variation was studied in Acanthurus bahianus,

Lepomis gibbosus, Nomeus gronovii, and Zanclus cornutus.

Individuals of about the same size are similar (A. bahianus, 4 specs., 48-52 mm; L. gibbosus, 7 specs., 34-36 mm; N. gronovii, 3 specs., 55-59 mm).

Developmental variation

Developmental change was studied in the same species (A. bahianus, 10 specs., 30-100 mm; L. gibbosus, 36 specs., 24-70 mm; N. gronovii, 6 specs., 19-70 mm). The pattern of A. bahianus and N. gronovii are shown in Figs. I-5 and I-6, respectively. The patterns of the individuals of L. gibbosus are similar.

Specimens of A. bahianus are similar in having two loops—loop a and loop b, which is located on the left of the stomach and is unique to acanthurids (also see below) (Fig. I-55; heavy and fine stipplings, respectively). The pattern develops early (prior to 30 mm), and no further change takes place beyond this stage.

Unlike A. bahianus, N. gronovii manifests developmental change in specimens between 19-70 mm. Loop a can be recognized in all specimens; a dextral winding tendency of loop a is found in these developmental stages (Fig. I-6A-F; heavy stippling indicate loop a; large arrows show the dextral developing tendency of loop a). A leftward folding appears at a standard length of 54 mm (Fig. I-6C; small leftward pointing arrows). This folding tends to increase in depth during development. The pattern typical of the species is formed

in specimens of 60 mm or longer in standard body length.

On the basis of these observations, it seems that patterns typical of adults develop early, and can be observed in specimens of small or larger adults as was shown also for pomacentrids (Fukusho, 1969).

Taxonomic variation

A. Perciformes

I. Percoidei

Aplodactylidae, 3 genera, about 5 species: Aplodactylus, Crinodus (1)*, Dactylosargus (Norman, 1957; Nelson, 1976).

Crinodus lophodon has a variant of type Z. The anterior section of the intestine bends downward (small arrow in Fig. I-7A points to this bending); this section is followed by a loop (fine stippling in Fig. I-7A) of which no homolog has been observed in other perciforms. The tip of loop a winds in a dextral pathway (large arrow in Fig. I-7A indicates this winding direction). Because of the special pattern of this species, further study on the species in the other genera of this family is recommended.

Comparison: Aplodactylids, with four other families (Cheilodactylidae, Chironemidae, Cirrhitidae, and Latridae) were classified as separate order Cirrhitiformes (Norman, 1957) or as a superfamily Cirrhitioidea (Nelson, 1976).

Nemadactylus macropterus (Cheilodactylidae) and Latri-

* Number in parenthesis is the number of species examined.

dopsis forsteri (Latridae) have type B; Chironemus marmoratus (Chironemidae) (Fig. I-7B), on the other hand, has type D2. The patterns of cirrhitids occur in various types: Amblycirrhitus pinos and Paracirrhites sp. have type B. However, loop f and loop a of the latter are placed horizontally (Fig. I-7C). Paracirrhites bimacula has type S, whereas Cirrhitichthys falco has type D1 (Fig. I-7D, E). Accordingly, there is no unique pattern shared only by these families.

Apogonidae, uncertain composition (Norman, 1957; Fraser, 1972; Nelson, 1976).

Six genera were studied. All have type B. Loop a of Astrapogon stellatus, Cheilodipterus macrodon (100 mm) and Glossamia aprion (Fig. I-8D, F, H) tilts upward so that it occupies the anterior part of the peritoneal cavity. Because smaller individuals of C. macrodon (85 mm) and also C. quinquelineatus have type B, I think that the tilted condition of loop a in the 100-mm individual of C. macrodon might be the result of developed gonads in larger specimens, which push the loop forward. It is necessary to study specimens of different sizes in order to see whether such is the case. If not, this character state of loop a might be phylogenetically significant. Other species studied have type B (Fig. I-8).

Interrelationships: Among these genera, the digestive tract of Apogon (A. cooki, A. cyanosoma, A. savagensis, A. taenio-

phorus), Archamia (A. lineolata), and Sphaeramia (S. nematoptera) is coated with a dark-brown layer of pigment, absent from Astrapogon (A. stellatus), Cheilodipterus (C. isotigma, C. macrodon, C. octovittatus, C. quinquelineatus), and Glossamia (G. aprion). A pigmented layer was not seen in other perciforms.

Bathyclupeidae, 1 genus, about 4 species: Bathyclupea (1) (Berg, 1940; Nelson, 1976).

Bathyclupea sp. has type B.

Branchiostegidae, 6 genera, about 24 species: Branchiostegus (1), Caulolatilus (1), Hoplolatilus, Lopholatilus, Malacanthus (1), and Prolatilus (Norman, 1957; Nelson, 1976).

Malacanthus plumieri has type B (Fig. I-9C). Branchiostegus japonicus and Caulolatilus princeps have variants of type B. Unlike the other two species, the posterior section of loop a of C. princeps bends upward (double lined arrow in Fig. I-9A shows this upward bending). In B. japonicus, the posterior section of loop a (near the tip of this loop) bends upward (single lined arrow in Fig. I-9B) instead of downward as in the other two branchiostegids.

Banjosidae, 1 genus, 1 species: Banjos (1) (Nelson, 1976).

Banjos banjos has type B.

Comparison: B. banjos is sometimes placed in the family Pomadasyidae (Norman, 1957), and sometimes in a monotypic

family in its own (e.g., Greenwood et al., 1966; Fowler, 1972). Pomadasyids also have type B.

Carangidae, 5 subfamilies, about 24 genera, about 200 species (Norman, 1957; Nelson, 1976).

Caranginae, 12 genera: Alectis (1), Atropus, Caranx (1), Decapterus (1), Hynniss, Megalaspis (1), Parastromateus, Trachurus (1), Selar (1), Selene (1), Ulua, Vomer (1).

Chloroscombrinae, 2 genera: Chloroscombrus, Orqueta.

Scomberoidinae, 2 genera: Oligoplites (1), Scomberoides (1).

Seriolinae, 4 genera: Elagatis, Nematistius, Seriola (2).

Trachinotinae, 4 genera: Campogramma, Hypacanthus, Parona, Trachinotus.

Within carangines, Alectis ciliaris has type LA (Fig. I-10A); Caranx crysos, Decapterus muroadsi, Megalaspis cordyla, Selar sp. and Trachurus japonicus have type B (Fig. I-10B-F). Interestingly, Selene vomer and Vomer declivifrons have type D1 (Fig. I-10G, H). Within scomberoidines, Scomberoides tolooo has type D1, whereas Oligoplites saurus has type B (Fig. I-11A, B). Within serioline, the patterns are characterized by the horizontal placement of loop f. Seriola zonata has type B and S. falcata has type LA (Fig. I-12A, B, respectively).

Centrarchidae, 9 genera, 30 species: Acantharchus (1), Ambloplites (1), Archoplites (1), Centrarchus (1), Elassoma (1),

Enneacanthus (1), Lepomis (1), Micropterus (1), Pomoxis (1) (Nelson, 1976).

Elassoma (E. zonatum) is the only genus lacking loop a (type LA). In addition, it lacks a pyloric caecum, in contrast to other centrarchids in which this structure is present. Type B is widely distributed in this family except for Archoplites, in which some variation of pattern was found (one 80-mm individual has type S and one 85-mm specimen has type B). The pattern of Pomoxis nigromaculatus is worth mentioning: among the three specimens dissected (144-150 mm) loop a varies significantly. In none does loop a follow its placement in type B (Fig. I-13; heavy stippling). The anterior section of the intestine in the 150-mm specimen bends downward (Fig. I-13C; arrow) instead of turning to the right of the stomach, as in the other two specimens (Fig. I-13A, B); loop a of this specimen is on the left side of the stomach. However, the right lobe of the liver of this specimen is much larger than the left, while the reverse condition of the liver lobes holds true for the other two specimens and also other centrarchids.

Centropomidae, 3 subfamilies, 8 genera, about 30 species

(Norman, 1957; Nelson, 1976).

Centropominae, 1 genus: Centropomus (1).

Chandinae, 3 genera: Chanda (1), Negambassis,

Synechopterus.

Latinae, 4 genera: Glaucosoma, Lates (1), Luciolates,

Psammoperca.

Centropomus nigrescens, Chanda gymnocephala and Lates calcarifer have type B.

Comparison: Fraser (1968) interpreted the interrelationships of species of the genus Centropomus and also the generic interrelationships of this family. He suggested that Lates might be closely related to Centropomus as supported by the character states of the sensory canals on the frontals, arrangement of the vertebrae, number of predorsal bones, ridge on the preopercle, spine on the lower border of the preopercle. This family has also been considered a possible relative of apogonids, as proposed by Fraser (1972). A detailed review of this family has recently been done by Greenwood (1976, 1977). As far as the intestinal pattern is concerned, no evidence supporting these proposals were found.

Cepolidae, 2 genera, about 7 species: Acanthocephala (1), Cepola (1) (Nelson, 1976).

The tip of loop a of Acanthocephala krusensternii and Cepola rubescens is to left of the rectum (Fig. I-14A, B).

Comparison: This family is classified as a member in the superfamily Cepoloidea which includes another family, the Owstoniidae (Nelson, 1976). The monophyly of these families is generally agreed (Okada and Suzuki, 1956; Springer, Smith and Fraser, 1977). Similar to the cepolid patterns, loop a coils sinistrally to the left of the rectum in Owstonia tosaensis (Fig. I-14C, arrow indicates the turning pathway

of loop a). Patterns of these species fall into type D2, which is considered as an advanced pattern among perciforms due to its limited distribution in this group. Intestinal pattern reflects the monophyly of these families as supported by other structural systems.

Chaetodontidae (see Section V).

Cheilodactylidae (see Aplodactylidae).

Chironemidae (see Aplodactylidae).

Cichlidae, about 95 genera, uncertain number of species (Fryer and Iles, 1972; Nelson, 1976).

The stomach of most cichlids has well developed diverticulum. The anterior section of the intestine extends posteriorly (heavy line in Fig. I-15) to the end of the peritoneal cavity before turning forward, to the right of the stomach. The coiling direction of loop a varies. Cichlasoma champotonis, C. hyorhynchum, C. motaguense, and C. salvini retain type B (Fig. I-15A, C, E). Loop a of C. heterospilum, C. spilurum, Haplochromis eucinostomus, and Melanochromis johanni follows a Z-shaped pathway (arrows in Fig. I-15B, F, G, H indicate this coiling direction). Loop a of C. intermedium uniquely coils dextrally (Fig. I-15D; arrow indicates this direction). The posterior section of the intestine of C. spilurum, H. eucinostomus, and M.

johanni bends posteriorly forming a loop (fine stippled areas in Fig. I-15F, G, H). The condition of this loop in M. johanni is special among perciforms examined: it is much larger than those of the other two species mentioned and extends anteriorly to the right side of the pyloric diverticulum of the stomach.

Cirrhitidae (see Aplodactylidae).

Echeneidae, 7 genera, about 8 species: Echeneis (1), Phtheinichthys, Reimlegia, Remora (2), Remorina, Remoropsis, Rhombochirus (1) (Nelson, 1976).

Species of Remora have different patterns— R. brachyptera has type ST (Fig. I-16B), whereas R. remora has type B (Fig. I-16C), as does Echeneis naucrates (Fig. I-16A). The posterior section of the intestine in E. naucrates and R. remora bends upward (arrows in Fig. I-16A, C). Rhombochirus osteochir (Fig. I-16D) differs from Remora species— loop a is not recognizable and an upward turning section in its pattern is characteristic (Fig. I-16D; arrow).

Embiotocidae, about 20 genera, about 23 species (Nelson, 1976).

Examined members of this family have simple patterns. Cymatogaster aggregatus has type LA, and the anterior section of the intestine is horizontal (Fig. I-17B). Brachyistius frenatus has type T (Fig. I-17A). Ditrema temmincki has

type B (Fig. I-17C).

Emmelichthyidae, uncertain composition (Norman, 1957;
Schultz, 1945).

Dipterygonotus gruveli and Merolepis sp. have type B.

Enoplosidae, 1 genus, 1 species: Enoplosus (1) (Scott, 1962).

Enoplosus armatus has type B.

Comparison: E. armatus was named as Chaetodon armatus by White. Its intestinal pattern is primitive in relation to the patterns of chaetodontids. E. armatus also differs from chaetodontids in having cycloid scales, whereas all chaetodontids have ctenoid scales (pers. obs. and Cockerell, 1915, 1916; Burgess, 1974).

Ephippidae, 2 subfamilies, 7 genera, 14 species (Nelson, 1976).

Drepaninae, 1 genus: Drepane (1).

Ephippinae, 6 genera: Chaetodipterus (1), Ephippus, Parapsettus, Platax (1), Tripterodon, Zabidius.

Chaetodipterus faber has the most complicated pattern among the ephippids studied. Loop a is difficult, if not impossible to recognize (Fig. I-18A). It seems possible that the tip of loop a (heavy stippling in Fig. I-18A) folds upward at the front part of the peritoneal cavity. The pattern of Drepane punctata is different from that of most perciforms in that the section of the intestine at the rear

part of the peritoneal cavity bends sharply downward (arrow in Fig. I-18B) and subsequently folds upward such that loop a is in a vertical position (heavy stippling in the figure). Interestingly, the tip of this loop in these two species is folded upward— an unusual condition of loop a. The pattern of Platax sp. is simple, but neither loop f nor loop a is recognizable (Fig. I-18C).

Gerridae, 7 genera, about 40 species: Diapterus, Eucinostomus (1), Gerres (1), Parequula, Pentaprion, Ulaema, Xystaema (Nelson, 1976).

Gerrids have type B (Fig. I-19 and Table 1).

Comparison: Ichthyologists differ in associating gerrids with leiognathids in one family or placing them in separate families. Gunther (1862), Jordan (1923), Montilla (1935), Schultz (1949) and Greenwood et al (1966) favored the idea of separating them. Gunther also associated Gazza (Gerridae) with carangids. Regan (1913), Weber and de Beaufort (1931), and Norman (1957), on the other hand, placed them in the family Leiognathidae. Regan (1913) also proposed that leiognathids are closely related to lutianids. The type B pattern of gerrids is also shared by most leiognathids (including Gazza, Leiognathus, Secutor) except for L. rivulatus in which loop a folds to the front and occupies a horizontal plane (type HZ) (Fig. I-19E). No special resemblance of leiognathids (especially Gazza) to carangids can be observed in the intestinal pattern.

Grammistidae, uncertain composition (Norman, 1957; Kendall, 1976).

Grammistes sexlineatus and Rypticus saponaceus have type B.

Comparison: Grammistids (as defined by Randall et al., 1971) were ranked as a subfamily, including Grammistes, Pogonoperca, and Rypticus, of the Serranidae (Norman, 1957).

Pseudogrammids were also classified as members of this subfamily by Kendall (1976). Affinity to pseudogrammids has also been suggested by Gosline (1960b, 1966a) and Schultz (1966). However, this hypothesis does not meet with the agreement of all ichthyologists, e.g., Smith and Atz (1969) and Randall et al. (1971). The primitive perciform type B pattern is shared not only by grammistids, pseudogrammids, but also most serranids.

Kuhliidae, 3 genera, about 12 species: Kuhlia (=Dules) (3), Nannatherina (1), Nannoperca (Nelson, 1976).

Kuhlia malo and K. taeniura have type D1 (Fig. I-20A, C), and K. marginata has type B (Fig. I-20B). Loop a of Nannatherina balstoni is not well developed (Fig. I-20D). Comparison: Gosline (1966a) thought that kuhliids are basal percoids. Kuhliid patterns are generalized among perciforms.

Kyphosidae, 3 subfamilies, 15 genera, 31 species (Nelson, 1976)

Girellinae, 6 genera: Dordyxodon, Girella, Girellops,
Melambaphes, Proteracanthus, Tephraeops.

Kyphosinae, 3 genera: Hermosilla (1), Kyphosus (2), Sectator (1).

Scorpinae, 6 genera: Atypichthys, Medialuna, Neatypus,
Neoscorpis, Parascorpis, Scorpis (2).

The intestine of species of Hermosilla, Kyphosus, and Sectator is much longer than that of other kyphosids (girellines and scorpines). Their type-Z intestinal patterns are complex but almost identical. In addition to the characteristic Z-shaped winding tendency of loop a, their patterns are unique also in having three loops, on the left side of the stomach, that are formed by the section of the intestine prior to and behind the tip of loop a (heavy lines in Fig. I-21A-D). Homologous loops have not been found in other perciforms. As such this advanced character state of the intestine supports the monophyly of these genera. The loops are either vertical (K. sectatrix) or tilted to the right (K. vaigiensis, Sectator ocyurus) or to the left (Hermosilla azurea). Juveniles of these species may provide necessary information for determining the nature of these three character states. The intestine of girellines and scorpines is much simpler in its arrangement than that of kyphosines, and loop a clearly shows the Z-shaped winding pathway (Fig. I-21E-H; arrows point out this pathway).

Interrelationships: In Norman's 1957 classification of the Kyphosidae, the family includes only three genera, Hermo-

silla, Kyphosus, and Sectator. However, some ichthyologists treat this family in a broader sense that includes the families Girellidae and Scorpidae (Greenwood et al., 1966; McAllister, 1968; Nelson, 1976). The type-Z pattern shared by girellines, kyphosines and scorpines is an advanced character state in perciform. Accordingly, the monophyly of these groups is supported. All kyphosines seem more closely related to each other than to either girellines or scorpines in sharing a unique pattern as mentioned.

Labracoglossidae, 3 genera, about 5 species: Bathystethus, Evistius, Labracoglossa (1) (Nelson, 1976).

Labracoglossa argentiventris has type B.

Lactariidae, 1 genus, 1 species: Lactarius (1) (Nelson, 1976).

Lactarius lactarius has type B.

Latridae (see Aplodactylidae).

Lethrinidae, 5 genera, about 21 species: Gnathodentex (1), Gymnochranius, Lethrinus (1), Monotaxis (1), Pentapodus (1) (Nelson, 1976).

In spite of the longer intestine of Gnathodentex auro-lineatus and Monotaxis grandocalis, as compared to Lethrinus rhodopterus and Pentapodus sp., their loop a is simple and similar to those of the latter two species (Fig. I-22A-D).

The extra intestine length of G. aurolineatus and M. grandocalis results in a condition that the intestine posterior to the tip of loop a folds in ripples (Fig. I-22A, C). Loop f is absent from G. aurolineatus. L. rhodopterus and Pentapodus sp. have type B.

Menidae, 1 genus, 1 species: Mene (1) (Nelson, 1976).

Mene annocarolina departs slightly from type B in that the anterior section of the intestine turns downward in a sharp angle (arrow in Fig. I-23).

Comparison: Menidae have been classified in the order Perciformes (Chen, 1969; Greenwood et al., 1966; Nelson, 1976; Norman, 1957; Weber et al., 1931). Weber and de Beaufort placed this family in the Carangi, a subgroup of Perciformes. Contrariwise, Montilla stated, "Menidae is closest to Lamprididae. The ventral fin has one spine and 5 soft rays, a character which separates Mene widely from Lampris, which is allied to it" (Montilla, 1935:281). The pattern of Mene is not duplicated in any carangids studied. No specimens of lampridids were available for study.

Monodactylidae, 3 genera, 5 species: Monodactylus (1),

Psettias, Schuettea (Nelson, 1976).

Monodactylus falciformis has a simple but special pattern: the tip of loop a, which is placed horizontally, folds dextrally (arrow in Fig. I-24); an extra loop is formed between loop a and the rectum (fine stippling in the figure).

Comparison: Schuettea has been ranked as a separate family of its own by Tominaga (1968). No specimen of this genus was available for comparison.

Mullidae, 6 genera, 55 species: Mulloidichthys, Mullus (1), Parupeneus, Pseudupeneus (1), Upeneichthys, Upeneus (Nelson, 1976).

Mullus barbatus and Pseudupeneus maculatus have type B.

Nandidae, 3 subfamilies, 7 genera, about 10 species (Nelson, 1976).

Badinae, 1 genus: Badius (1).

Nandinae, 5 genera: Afronandus, Monocirrhus (1), Nandus (1), Polycentropsis, Polycentrus.

Pristolepinae, 1 genus: Pristolepis (1).

The patterns of N. nebulosus, M. polyacanthus and Pristolepis fasciata are rather simple. M. polyacanthus has type B (Fig. I-25A). Loop a of N. nebulosus coils dextrally to such an extreme and, as a result, lies horizontally at the anterior part of the peritoneal cavity (Fig. I-25B; heavy stippling). P. fasciata differs remarkably from the other two nandids in that there is an extra loop (Fig. I-25C; fine stippling indicates this loop) located between the dextral loop a and the rectum.

Comparison: The systematic position of this family does not seem to be generally agreed upon. Badines, nandines and pristolepines are sometimes lumped into the family Nandidae

(e.g., Nelson, 1976). Gosline (1972) ranked them as separate families and expressed the idea that they are related to anabantoids. Barlow, Liem and Wickler (1968) also treated them as separate families and, by behavioral and structural evidence, favored the idea of close relationship of badids and anabantoids. Liem (1970) argued that nandids and anabantoids show no phylogenetic affinity and considered nandids to resemble relatively advanced percoids. Unlike the simple patterns of nandines, pristolepines and badines, the complex type SP dominates anabantoids(see below).

Nemipteridae, 3 genera, numerous species: Nemipterus (1),

Parasclopsis, Scolopsis (Nelson, 1976).

Nemipterus sp. has type LA.

Comparison: Not much has been proposed with respect to the phylogenetic position of the family. Smith (1941) classified the family Denticidae, Lethrinidae, Lujanidae, Nemipteridae and Sparidae to the group Spariform (a subgroup of the Perciformes). Type LA of Nemipterus sp. is not duplicated by any of the species in the other four families mentioned (Table 1).

Oplegnathidae, 1 genus, about 4 species: Oplegnathus (1)
(Nelson, 1976).

Oplegnathus sp. has type D1 (Fig. I-27).

Owstoniidae (see Cepolidae).

Pempheridae, 2 genera, 5 species: Parapriacanthus (1),

Pempheris (1) (Tominaga, 1968).

Parapriacanthus sp. and Pempheris sp. have type B.

Percidae, 2 subfamilies, 9 genera, 126 species (Collette, 1963).

Percinae, 2 tribes, 6 genera:

Etheostomatini: Ammocrypta (1), Etheostoma (2), Percina (1).

Percini: Gymnocephalus (= Acerina) (1), Perca (1), Percarina.

Luciopercinae: 2 tribes, 3 genera:

Romanichthyini: Zingel (= Aspro) (1), Romanichthys.

Luciopercini: Stizostedion (= Lucioperca).

Type LA dominates the tribe Etheostomatini (Ammocrypta vivax, Etheostoma caeruleum, E. olmstedii, and Percina caprodes). Species in the Percini (Gymnocephalus schraetzer, Perca flavescens) have type B. Within the Luciopercinae, Zingel streber has type B. It seems clearly that type LA characterizes the Etheostomatini.

Plesiopidae, 2 subfamilies, 4 genera, about 14 species (Norman, 1957).

Plesiopinae: 3 genus: Assessor, Plesiops (1), Paraplesiops.

Pseudoplesiopinae: 1 genera: Pseudoplesiops.

Plesiops melas has type B.

Comparison: Weber and de Beaufort (1929), Bohlke (1960), Nelson (1976) ranked both subfamilies of Norman (1957) as families. Smith (1954a), on the other hand, assigned the pseudoplesiopines in which he put the Chilidichthys, Nematochromis, and Wamizichthys as well, as a subfamily of Pseudochromidae. Pseudoplesiopines are considered the closest relatives of anisochromids (Springer, et al., 1977) and the affinity of anisochromids plus pseudoplesiopids to pseudochromids was also proposed by these authors. Some pseudochromids examined (Dampiera cyclophthalma and Gramma loreto) possess type D1 and type B, respectively.

Pomacanthidae, 7 genera, about 30 species: Arusetta, Chaetodontoplus, Centropyge (2), Holacanthus (1), Geniocanthus, Pomacanthus (1), and Pygoplites (Norman, 1957).

In Centropyge bicolor, C. flavissimus and Pomacanthus sp. the section anterior to the tip of loop a coils in a Z-shaped manner (Fig. I-28A,B,D; heavy lines), while the posterior section does not follow the same pathway. Pomacanthus sp. is the most simple. The loop anterior to loop a in this species (Fig. I-28D; single line circle) is also found in Centropyge. In the case of Centropyge, this loop is prominent and is bent downward (Fig. I-28A, B; single line circle). Holacanthus tricolor has a much longer intestine, and its pattern is complex, characterized by a group of loops at the anterior part of the peritoneal cavity above the stomach (heavy line in Fig. I-28C). Among them, an anteriorly pointed loop is prominent (double line circle in Fig. I-28C). Another group of loops is placed horizontally at the posterior part of the

peritoneal cavity.

Interrelationships: Centropyge and Holacanthus are unusual in perciforms. A detailed comparison of the intestinal pattern of representative species in each genus might bear evidence for the generic relationships of this group.

Comparison: Fraser-Brunner (1933) revised the group Pomacanthinae, which has been treated as a subfamily of Chaetodontidae. The subfamily status of angelfishes is adopted by some ichthyologists such as Norman (1957), and Nelson (1976). Burgess (1974) preferred the idea of elevating this group to family status. Comparison of their patterns and those of chaetodontids will be made in Section V.

Pomacentridae, 4 subfamilies, about 23 genera, about 230 species (Norman, 1957; Nelson, 1976).

Amphiprioninae, 1 genus: Amphiprion (1).

Chrominae, 5 genera: Acanthochromis, Azurina, Chromis (3), Dascyllus (1), Lepidozygus.

Pomacentrinae, 12 genera: Abudefduf (2), Actinochromis, Cheiloprion, Daya, Glyphisodon, Hemiglyphidodon, Hypsypops, Microspathodon (1), Nexilarius, Nexilosus, Parma, Plectroglyphidodon, Pomacentrus (1).

Premninae, 1 genus: Premnas (1).

Aoyagi (1941) studied this group in great detail. The intestinal patterns of many pomacentrid species were reported in his paper, and type Z is dominant in this family. Among chromines, Chromis caeruleus (Aoyagi, 1941), C. cyanea,

and C. multilineatus (Chrominae) have simple type B (Fig. I-19D, E). However, loop a of C. multilineatus differs slightly from typical type B in having some foldings along the whole length (arrows in Fig. I-29E show these foldings). The pattern of Dascyllus trimaculatus (Chrominae) is unique, and can be evolved only from type B but not from type Z. Loop a is obliquely pointed anteriorly (Fig. I-29F; arrow shows the pointing direction). Premnas biaculeatus (Premninae) has type S, and the mid-section of loop a bends slightly downward (Fig. I-29I). This type seems to be the precursor of type Z, which characterizes Amphiprion ocellaris (Amphiprioninae) and Eupomacentrus sp. (Pomacentrinae) (Fig. I-29C, G). Some Abudefduf species (Pomacentrinae), Chrysiptera, Parapomacentrus, and Pomacentrus also have this pattern (Aoyagi, 1941). However, not all pomacentrines have type Z. Conversely, Cheiloprion labiatus has a unique coiling pattern (Aoyagi, 1941: Fig. 9, Plate 22), which does not fall into any of the categories I propose; Microspathodon chrysurus has a long intestine, and its pattern is slightly more complicated than typical type Z. The section of the intestine anterior to the tip of loop a bends distinctively downward, forming an extra loop (single line circle in Fig. I-29H). The folding tendency is similar to that of Centropyge (Pomacanthidae). The herbivorous Abudefduf taurus has an intestine longer than that of the omnivorous A. saxatilis, which has type HZ in 66-mm and 116-mm specimens. In a 135-mm specimen, A. taurus has type Z, similar to a 42-mm specimen

Eupomacentrus sp. (an omnivorore). Smaller specimens of A. taurus (55 mm) have type HZ. The section of the intestine anterior to the rectum in the larger specimen of A. taurus, which is developed at a standard length of 55-mm, and which bends to the right, following the winding pattern of the other section of the intestine, determines this pattern as type Z (Fig. I-29G, for instance; heavy line). The type-Z pattern of the larger specimen of A. taurus is therefore developed from type HZ, whereas the type-Z pattern of Amphiprion ocellaris (42-mm) is developed from type S, present in the 17-mm specimen. Ontogenetic change of A. taurus indicates that type HZ is the primitive character state. Since this type is also shared by A. saxatilis, I postulate that type HZ is characteristic of the genus Abudefduf.

Interrelationships: Because the sister-group of pomacentrids is not known, out group comparison cannot be made at this point. If type B is primitive for this family, types S, HZ Z, and the patterns of Dascyllus trimaculatus, Cheiloprion labiatus, and Microspathodon chrysurus become advanced character states at different levels in pomacentrid phylogeny. Chromines, which possess type B, may be the plesiomorphic group of the other pomacentrids, in which the pattern are either type S, HZ, or Z. Type Z is treated as a synapomorphic character state of pomacentrines and amphiprionines. Premnines, which have type S, may be the plesiomorphic sister-group of pomacentrines plus amphiprionines.

We may alternatively hypothesize that pomacentrids primitively have long intestines in which loop a follow a Z-shaped coiling pathway. The relatively short intestines and simple patterns (types B and S) of chromines and premnines are secondary evolved and indicative of close affinity. Under this hypothesis, the systematic positions of pomacentrines and amphirpionines are unsolved.

Within these subfamilies, some species possess unique patterns, which may be shared by other species. Examples are: Dascyllus trimaculatus, Microspathodon chrysurus, Cheiloprion labiatus, and Chrysiptera parasema

Comparison: The similarity between pomacentrids and cichlids in the number of nostrils and the attachment of the lower pharyngeals is interesting and may be significant (synapomorphic character states) regarding their systematic positions. If we adopt the hypothesis that type-Z intestinal pattern is primitive for pomacentrids, pomacentrids and cichlids share another character state in common, namely, loop a coils in a Z-shaped pathway. This pattern, which is shared also by kyphosids, is unusual in perciforms and may be apomorphic at a level in the perciform phylogeny where pomacentrids and cichlids are monophyletic.

Pomadasyidae, 22 genera, about 175 species (Norman, 1957; Nelson, 1976).

Anistotremus virginicus, Bathystoma sp., Haemulon chrysargyens, H. melanurum, H. sciurus, and Pomadasy jubelini have type B.

Pomatomidae, 2 genera, about 3 species: Pomatomus (1) Scombrops (1) (Nelson, 1976).

Pomatomus saltatrix and S. boops have type B.

Priacanthidae, 3 genera, about 18 species: Cookeolus (1) Priacanthus (1), Pseudopriacanthus (1) (Caldwell, 1962).

Priacanthus cruentatus has type B (Fig. I-30B); loop a of Pseudopriacanthus altus follows a dextral winding pathway (Fig. I-30C); Cookeolus boops, on the other hand, shows a unique pattern in that its loop a winds sinistrally (Fig. I-30A). Study of the other priacanthids is recommended.

Pseudochromidae, uncertain composition (Norman, 1976)

Gramma loreto, G. melacara, and Pseudogramma polyacan-

tha have type B, whereas Dampieria cyclophthalma, and Gramma sp. have type D1.

Comparison: Springer, Smith and Fraser (1977) believed that pseudochromids (including anisochromids and pseudoplesiopids) are monophyletic. However, the sister-group of pseudochromids is not known at the present time. The primitive percid form intestinal pattern (type B) is broadly distributed in these groups.

Rachycentridae, 1 genus, 1 species: Rachycentron (1) (Nelson, 1976).

Rachycentron canadum has type B.

Comparison: The primitive type-B pattern of R. canadum does not support a relationship between this family and echeneids.

Rhinopreidae, 1 genus, 1 species: Rhinoprenes (1) (Munro, 1964)

Rhinoprenes pentanemus has type HZ (Fig. I-31; heavy stippling shows loop a).

Sciaenidae, uncertain composition (about 25-28 genera with about 130 species) (Norman, 1957; Nelson, 1976).

Species of 12 genera were examined. Except for Cynoscion regalis, Nebris microps, and Stellifer rastrifer, other species (Aplodinotus grunniens, Bairdiella chrysura, Equetus acuminatus, Larimus fasciatus, Macrodon ancylodon, Paralochurus brasiliensis, and Plagioscion squamosissimus)

have type B. Stellifer rastrifer has type D1, whereas Cynoscion regalis and Nebris microps have type LA, a pattern unique to these two species within this family.

Serranidae, about 81 genera, about 370 species (Norman, 1957; Nelson, 1976).

Except for Petrometopon cruentatum, other serranids examined have type B. The former lacks loop f, and the section of the intestine anterior to the rectum (heavy line in Fig. I-32B) occupies the left side of the anterior section of the intestine. The tip of loop a of a 72-mm specimen of Bostockia borosa tilts upward (Fig. I-32A), and an 80-mm specimen has exhibits type B.

Comparison: Norman (1957) assigned four groups which have one pelvic spine and 5 soft rays and lack a scaly axillary pelvic process to the family Serranidae. These groups are the Grammistinae, Pseudochrominae, Serraninae, and Theraponinae. The limitation of the Serranidae was later discussed by Gosline (1966b) who suggested that Serranidae should be restricted to the subfamilies Serraninae, Epinephelinae, and Anthiinae of Jordan and Eigenmann (1890) and excluded the Acropomatinae, Doderleiniinae, Malakichthyinae, Polyprioninae, Ostracoberycinae, Callanthiinae, and Symphysanodoninae. Teraponids and pseudochromids were not mentioned by Gosline in that paper. These two groups and also Grammistinae have been ranked as independent families by most ichthyologists. Most members of these groups have type B (Table 1).

Sillaginidae, 3 genera, about 6 species; Sillago (2), Sillaginodes, Sillaginopsis (Gill, 1861; Norman, 1957; Nelson, 1976).

Sillago bassensis and S. maculatus have type B.

Interrelationships: Weber and de Beaufort (1931:169) argued that Sillagonodes is not worthy of generic rank. No specimen of this genus was available for comparative study.

Sparidae, 3 subfamilies, 29 genera, about 100 species (Jordan et al., 1893; Nelson, 1976).

Dentex dentex (Denticinae) has type B. Dentex sp. has type D2. Calamus pennatula, Lagodon rhomboides, and Stenotomus chrysops (Sparinae) have type B. Archosargus probatocephalus (Sparinae) and L. rhomboides deserve special attention. In the former species, the tip of loop a coils sinistrally to the left side of the rectum (Fig. I-33A) — an advanced character state within this family. In L. rhomboides, a loop (fine stippling in Fig. I-33B) is found after loop a. This is a specialized character for perciforms; it resembles the patterns of Gnathodentex aurolineatus and Monotaxis grandoculis (Lethrinidae).

Teraponidae, 15 genera, 37 species: Amniataba (1), Bidyanus, Hannia, Hephaestus, Lagusia, Leiopotherapon (1), Mesopristes, Pelates (1), Pelsartia, Pingalla, Rhyncopelates, Scortum, Syncomistes, Terapon (1), "Terapon" (Vari, 1978).

Amniataba percoides (72-mm), Leiopotherapon unicolor, Pelates quadrilineatus and Terapon theraps have type B. A 64-mm specimen of A. percoides has type D1.

Toxotidae, 1 genus, 5 species: Toxotes (1) (Weber et al., 1963).

The intestine of T. chaetereus is short. As a consequence, its pattern is simple and loop a is not well developed (Fig. I-34). However, its pattern is type B.

II. Mugiloidei, 1 family (Greenwood et al., 1966).

Mugilidae, uncertain composition (Thomson, 1954; Nelson, 1976).

The freshwater species, Aldrichetta forsteri has type B (Fig. I-35B). Agonostomus monticola, which is a member of the subfamily Cestraeinae (Norman, 1957) has type B but it is unique in that the mid-portion of loop a folds distinctively upward (arrow in Fig. I-35A) and lies on the left side of the rectum. This is an advanced character within this family. Further winding of this loop, following a counter-clockwise pathway, can give rise to the patterns of the species of Mugil (see below).

The intestine of Mugil spp. is much longer than that of the two species just mentioned. Their patterns are basically similar. In Liza macrolepis, for example, the anterior section of the intestine (heavy line in Fig. I-35C) follows a Z-shaped pathway and then coils sinistrally. This winding

tendency gives rise to an anteriorly directed loop a (heavy stippling in Fig. I-35D). The same condition of loop a occurs also in M. curema and M. trichodon. However, in these two species, an extra loop (loop c; fine stippling in Fig. I-35D, E) is formed anterior to the tip of loop a.

Interrelationships: Because Sphyraena and Polydactylus, which are believed to be close relatives of mugilids (Gosline, 1968, 1971; McAllister, 1968), have short intestines and simple patterns (see below), it is assumed that the hypothetical common ancestor or mugilids has a short intestine. Mugil and Liza, therefore, may form a monophyletic group in sharing the advanced character state of an extraordinarily long intestine. Within this groups, M. curema and M. trichodon may be more closely related to each other than either of them is to L. macrolepis, in sharing the synapomorphic character of loop c. Further study of the intestinal patterns of other mugilids is suggested.

Comparison: Nelson (1976) reviewed in detail the classifications of Mugilidae as proposed by various authors. Mugilids have been grouped with atherinids and sphyraenids (Berg, 1940), with polynemids, sphyraenids, melanotaenids, atherinids, isonids, neostethids and phallostethids (Gosline, 1968, 1971; Scott, 1962), with sphyraenids (McAllister, 1968). Greenwood et al (1966) gave subordinal status to mugilids. Sphyraenids and polynemids have rather simple patterns, and no evidence supporting relationship of mugilids, sphyraenids, and polynemids is available from the present set of data.

III. Sphyraenoidei, 1 family (Greenwood et al., 1966).

Sphyraenidae, 1 genus, 18 species: Sphyraena (s) (Nelson, 1976).

Sphyraena spp. examined are similar and have type LA (Fig. I-36). The pyloric diverticulum of the stomach is long; loop f is insignificant.

IV. Polynemoidei, 1 family (Greenwood et al., 1966).

Polynemidae, 7 genera, about 35 species: Eleutheronema, Filimanus, Galeoides, Pentanemus, Polistonemus, Polydactylus (1), Polynemus (Myers, 1936).

Polydactylus sp. has type B. The pyloric diverticulum of the stomach is rather long in this species (Fig. I-37).

V. Labroidei, 3 families (Greenwood et al., 1966).

Labridae, 58 genera, about 400 species (Nelson, 1976).

There are some general similarities between labrids and other labroids (odacids and scarids) in their digestive tract. Pyloric caeca are absent from labroids. The anterior section of the intestine runs posteriorly to different degrees before it is displaced anteriorly to the right of the esophagus - in contrast to the patterns of perciforms that possess pyloric caeca. In the latter, this part of the intestine is displaced to the right (or left) of the U- or V-shaped stomach, not faraway from the end of the stomach, and gives rise to loop f. The character state of the intestinal pattern of labrids has been observed in other actinopterygians,

such as Pholidichthys leucotaenia (Microdesmidae) and Scytalina cerdale (Scytalinidae) and gobiids (see below). Labrids, except for Doratonotus megalepis, Iniistius sp., Thalassoma bifasciatum, Tautoga onitis, Tautogolabrus adspersus, have type B (Table 1). Iniistius sp. has a straight gut; Thalassoma bifasciatum, Tautoga onitis, and Tautogolabrus adspersus have type LA (Fig. I-38D, E). Doratonotus megalepis, interestingly, has type T (Fig. I-38C). In Chirrhilabrus solorensis, a long section of the intestine immediately after the insignificant stomach runs posteriorly to the end of the peritoneal cavity, where it is displaced to the right (Fig. I-38A; heavy line). Loop a can be recognized in this species. For other labrids, the anterior part of the intestine occupies the anterior section of the peritoneal cavity (heavy lines in Fig. I-38B-E). In Clepticus parrai, although its pattern is type B, loop a is on the left of the rectum instead of on the right as in typical type B (Fig. I-38B).

Odacidae, 5 genera, about 8 species: Coridodax, Haletta (1), Neoodax, Odax (1), Siphonognathus (Nelson, 1976).

The pattern of Odax pullus is special - loop a is absent (Fig. I-39); the section of the intestine anterior to the tip of loop f (heavy line in the figure; fine stippling represents loop f) does not reach the posterior end of the peritoneal cavity. Loop f is placed horizontally. Haletta semifasciata, on the other hand, has a straight gut.

Scaridae, 10 genera, about 68 species: Calotomus, Chlorurus, Cryptotomus, Euscarus, Leptoscarus, Nicholsina, Scarus (1), Scaridea (1), Scarops, Sparisoma (3) (Schultz, 1958).

The stomach of scarids is insignificant and cannot be distinguished from the intestine. The anterior section of the intestine extends posteriorly to the end of the peritoneal cavity, then turns and extends anteriorly to the front part of the cavity, where it is displaced to the right of the esophagus. Loop a in scarids is recognizable. Except for Sparisoma viride, other scarids have type LF (Fig. I-40 A-D). S. viride is special in its morphology of the coelomic organs, e.g., the intestinal pattern and the liver-lobe morphology (see Section IV). In contrast to other scarids, the intestine of this species is displaced to the left of the anterior section of the intestine (Fig. I-40E, heavy line).

VI. Trachinoidei, 16 families (Greenwood et al., 1966).

Champsodontidae, 1 genus, uncertain number of species: Champsodon (1) (Norman, 1957).

Loop a of Champsodon sp. is short. The pattern is type B (Fig. I-41B).

Limnichthyidae, 3 genera, 3 species: Limnichthys (1), Schizochirus, Tewara (Norman, 1957).

Loop f of L. fasciatus is placed horizontally (Fig. I-41E). The pattern is type B.

Opisthognathidae, 3 genera, about 30 species: Lonchopisthus,
Lonchistium, Opisthognathus (1) (Nelson, 1976).

Loop f is present in Opisthognathus sp. but it is
absent in O. whitehursti (Fig. I-41G, H).

Bathymasteridae, 3 genera, 7 species: Bathymaster (1), Rath-
bunella, Ronquilus (Nelson, 1976).

Differing from the primitive type B pattern, B. signatus
has type S (Fig. I-41A).

Dactyloscopidae, 5 genera, about 20 species: Dactylagnus,
Dactyloscopus (1), Gillellus, Leurochilus, Myxodagnus
(Nelson, 1976).

Dactyloscopus sp. has type LA, and its loop f is hor-
izontal (Fig. I-41D).

Trichonotidae, uncertain composition (Nelson, 1976).

Loop a of Trichodon trichodon winds dextrally such that
its pattern is type D1 (Fig. I-41J). Interestingly, the py-
loric diverticulum of its stomach is inserted between the
sides of loop a (Fig. I-41J; heavy line).

VII. Notothenioidei, 4 families (Greenwood et al., 1966).

Bovichthyidae, 4 genera, about 6 species: Aurion, Bovichthys
(1), Cottoperca, Pseudaphritis (Nelson, 1976).

Bovichthys sp. has type B.

Notothenidae, 10 genera, about 58 species: Harpagifer (1),
Notothenia (1), Trematomus (1) (Nelson, 1976).

Harpagifer bispinis and Notothenia sp. have type B. In a 179-mm specimen of Trematomus sp. the anterior section of the intestine turns downward, instead of upward, and is displaced to the right of the stomach (Fig. I-42). Another specimen of this species has normal type B.

VIII. Blennioidei, 15 families (Greenwood et al., 1976).

Blenniidae, 3 subfamilies.

Blenniinae: As a broad generalization, most blenniines have short guts and simple patterns (Fig. I-43A-E). Loop f of Blennius tentacularis is in a horizontal position (Fig. I-43B; fine stippling). In the intestinal pattern of Blennius cristatus, loop a folds underneath the rectum and bends upward to the left side of the rectum (Fig. I-43A).

Ophioblenniinae: Unlike blenniines, the intestine of ophioblenniines and salariines is long. The anterior section of the intestine extends posteriorly beyond the midpoint of the peritoneal cavity and turns upward to the right of the anterior section of the intestine (e.g., Fig. I-43H; heavy line). A sinistral loop (fine stippling in Fig. I-43H) is on the right side of the anteriormost section of the intestine. Another sinistral loop (stipes represent this loop in the figures), posterior to loop a is also found. In short, the patterns of Ophioblennius and Alticus (Salariinae) are characterized by (1) the upward turning of the anterior

section of the intestine, (2) a sinistral loop anterior to loop a (Fig. I-43F-H).

Salariinae: The pattern of Entomacrodus nigricans is slightly different from that of the other species of ophi-blenniines and salariines. The anterior section of the intestine turns downward and displaces to the right; the homolog of the first sinistral loop of Alticus and Ophioblennius is absent. However, loop a and the second sinistral loop a are recognizable in this species (Fig. I-43I). Salarias enosinae and Salarias sp. are similar and resemble Ophioblennius and Alticus except that the first sinistral loop in S. enosinae is replaced by a dextral loop (stippled area in Fig. I-43J; arrow indicates the turning direction) and the front section of the intestine, like that of Entomacrodus nigricans, bends downward or is placed horizontally.

Zaproridae, 1 genus, 1 species: Zaprora (1) (McAllister et al., 1961).

Zaprora silensus is unique in that the anterior section of its intestine displaces to the left of the esophagus (Fig. I-44; heavy line). Homologs of loop a and the second sinistral loop of ophioblenniines and salariines are present.

Stichaeidae, 31 genera, about 57 species (Nelson, 1976).

The digestive tract of stichaeids is percoid-like. The stomach, unlike that of other blennioids, is not straight; pyloric caeca are present (except for Epigeichthys rupestris).

Anoplarchus purpurescens shows the typical type-B pattern (Fig. I-45A), whereas Lumpenus lampretaeformis seems to have a variant of type B, and the anterior section of the intestine bends downward distinctively (Fig. I-45E; heavy line). In Bryostemma nugator, loop a folds underneath the rectum and bends upward to the left side (Fig. I-45B). In Cebidichthys violaceus and Epigeichthys rupestris loop a is difficult to recognize. An upward folding characterizes these patterns (Fig. I-45C, D; arrows point out this folding).

Other blennioid families:

Except for blenniids and zaprorids, species in the other blennioid families examined (Chaenopsidae, Clinidae, Pholididae, Scytalinidae, and Tripterygiidae) have a short intestine and a simple intestinal pattern. Chaenopsids (Fig. I-46), clinids (Fig. I-47), pholidids (Fig. I-48A), scytalinids (Fig. I-49), and tripterygiids (Fig. I-48B) are simple and similar. For most of these species, the stomach is indistinguishable; the intestine extends posteriorly to the rear part of the peritoneal cavity and turns to the right; loop a and loop f are absent. In Scytalina cerdale, the posterior section of the intestine turns to the left (Fig. I-49, heavy line).

Most clinids have an enlarged stomach. Except for Acanthemblemaria mari and possibly Starksia lepicoelia (Fig. I-47A, J), loop f of other clinids is absent. Like other blennioids with a simple pattern, their intestine

extends posteriorly and turns to the right. Two individuals of Springeratus xanthosoma (63 and 65 mm) are different. In the small specimen, the posterior section of the intestine folds to the left, whereas in the large specimen, it is to the right (Fig. I-47H, I).

Among pholidids, Opisthocentrus sp. (Fig. I-48A) has a well developed stomach and a pattern similar to that of Cristiceps australis (Fig. I-47B), whereas Pholis gunnellus has a straight gut.

Tripterygion etheostoma has type LA but its stomach is insignificant (Fig. I-48B).

Interrelationships: Blennioids form three groups on the basis of the complexity and type of intestinal patterns. In one group, the pattern is percoid-like and it includes only the Stichaeidae. In the second group, the intestine is extraordinarily long and the patterns are complex. It includes the Ophioblenniinae and Salariinae of Norman's Blenniidae and the Zaproridae. In the third group, the intestine is short and the patterns are simple. It includes the Blenniinae (Blenniidae) and the rest of the blennioid families (except Stichaeidae) examined.

IX. Icosteoides, 1 family (Nelson, 1976).

Icosteidae, 2 genera, 2 species: Acrotus, Icosteus (1)
(Regan, 1923b).

The stomach of Icosteus aenigmaticus is U-shaped, and the intestinal pattern is unique in possessing (1) two hori-

zontal loops (double line hemicircles in Fig. I-50), which are followed by (2) two sinistral loops (fine stippling in Fig. I-50). This pattern has never been observed in other perciforms. The pattern of Acrotus willoughbyi remains to be investigated.

Comparison: Icosteids were classified with tetragonurids in the suborder Tetragonuroidei (Berg, 1940). Tetragonurids were later assigned to the suborder Stromateoidei and icosteids to a separate suborder of Perciforms (e.g., Greenwood et al., 1966). Tetragonurids have simple intestinal patterns (see below).

X. Ammodytoidei, 2 families (Greenwood et al., 1966).

Ammodytidae, 3 genera, about 12 species: Ammodytes (2), Bleekeria, Embolichthys (Nelson, 1976).

Ammodytids have type LA. The pyloric diverticulum of the stomach of A. americanus is shorter than that of A. hexapterus. The intestine of the latter species, but not the former, turns to the right of the stomach (Fig. I-51A, B). Interestingly, the anterior section of the intestine of these species has an anteriorly pointed blind section (heavy line in these figures).

Comparison: Gosline (1963:100) made comparisons of the osteology of ammodytids with other elongated perciforms such as trichonotids, and tripterygiids, and stated, "The problem of ammodytoid origin remains obscure. The majority of features point to a percoid origin of some sort, but none

of the percoid family known to the author would seem to provide a suitable ancestor." No specialized characters of the intestinal pattern common only in ammodytids, trichonotids, and tripterygiids or other perciforms were found. A pyloric diverticulum similar to that of ammodytids occurs also in echeneids, pomadasyids, sphyraenids, scombroids, and a few sciaenids.

XI. Callionymoidei, 2 families (Berg, 1947; Briggs et al., 1959).

Callionymidae, 8 genera, about 40 species: Brachycallionymus, Callionymus (3), Dactylopus, Diplogrammus, Draculo, Paracallionymus, Synchiropus, Yerutius.

The intestine of species of Callionymus is placed horizontally in the peritoneal cavity, because of the dorsoventrally depressed body-form. Loop a, which is pointed to the right side of the body, is rather simple in Callionymus sp. and C. richardsoni (Fig. I-52A, D). Loop a of C. lunatus and C. japonicus is more complex. In the former species, the mid-section of this loop seems to be pushed to the left (arrow in Fig. I-52C). An extreme condition of the leftward pushing might give rise to the pattern of C. japonicus, in which loop a is located close to the anterior section of the intestine. Two extra loops are developed in the latter species (Fig. I-52B, fine stippling). In C. richardsoni, small loops appear at the anterior section of the intestine. Interestingly, the rectum of Callionymus sp. and C. richard-

soni is almost in line with the anterior section of the intestine. The rectum is far away to the right of the anterior section of the intestine in the other two species.

XII. Gobioidi, 6 families (Greenwood et al., 1966).

Intestinal patterns of gobioids are listed in Table 1. In contrast to the general pattern of most gobioids (see below), Plagiogrammus sp. (Gobiidae), Gobioides sp. (Gobioididae), Kraemeria samoensis (Kraemeriidae), Gunnellichthys pleurotaenia (Microdesmidae) possess other types. Plagiogrammus sp. has type B (Fig. I-53G), and it is the only gobioid examined that has pyloric caeca. Kraemeria samoensis and Gunnellichthys pleurotaenia have type ST. Gobioides sp. is the most interesting species. It has an extremely long intestine that is coiled in a horizontal plane, following a counter-clockwise winding pathway (Fig. I-53H). The pattern of Sericagobioides lighti (Fig. I-53I) is extremely simple; loop f and loop a are absent. The general pattern of other gobioids is characterized by the short and insignificant "stomach"; the intestine is displaced to the right, at the rear part of the peritoneal cavity (Fig. I-53; heavy line). Interestingly, the pattern of Trypauchenichthys sp. resembles type LA of some perciforms (Fig. I-53L).

XIII. Kurtoidei, 1 family (Weber et al., 1951).

Kurtidae, 1 genus, 2 species: Kurtus (2) (Weber et al., 1952).

Kurtus indicus and K. gulliveri have type B and type IA, respectively (Fig. 54A, B).

XIV. Acanthuroidei, 2 families (Nelson, 1976).

Acanthuridae, 2 subfamilies, 10 genera, about 87 species:

Acanthurinae, 7 genera: Acanthurus (3), Ctenochaetus (1), Naso (2), Paracanthurus (1), Zebrasoma (4).

Zanclinae, 1 genus: Zanclus (1).

A feature unique to acanthurids among all acanthopterygian groups I have studied, is the placement of a loop on the left side of the stomach (I term this loop, loop b; fine stippling in figures I-55, I-56). Loop a shows different degrees of winding complexity among acanthurids. In Zanclus cornutus and Zebrasoma flavescens, loop a is simple (Figs. I-56, I-55A, respectively). Naso hexacanthus, at the other extreme, has a very complex loop a (Fig. I-55F). However, there is no trend of progressive development of complexity of this loop that can be traced within acanthurids. The patterns of the four species of Zebrasoma dissected in this study are basically similar. Except for Z. flavescens, loop a of the other three species (Z. rostratum, Z. scopas, and Z. veliferum) winds antero-dextrally to the right side of the rectum (Fig. I-55B, C, D). Barlow (1974) equated Z. scopas with Z. flavescens without explanation. At Enewetak, Z. flavescens is rare and Z. scopas is common and

the species hybridize. It is likely that the establishment of a hybrid population at this locality has led Barlow to this conclusion (Randall, pers. comm.). The difference in complexity of loop a in the gut pattern of these two species suggests that Z. flavescens and Z. scopas are best retained as separate species. The gross morphology of the stomach of Zebrasoma and Naso is similar, giving the anterior section of the winding pattern an easily recognizable W-shaped (Fig. I-57) as seen in lateral view. In Paracanthurus hepatus, the stomach is more elongate than in other acanthurids, extending to the rear part of the abdominal cavity.

Interrelationships: Zaclines are traditionally considered as the sister group of acanthurines (e.g., Greenwood et al., 1966; Herald, 1961:208; McAllister, 1968:143). The synapomorphy of loop b supports their close affinity. Zebrasoma has two character states of loop a; the simple state as found in Z. flavescens and the complex state seen in all other species of this genus. The similarity in the unusually simplified state of loop a in Z. flavescens and Zanclus cornutus is of particular interest. This shared character state might be the result of "convergence", or it might be synapomorphic, and hence evidence for the relationship of these two genera because other possibly related fishes have a complex loop a, for example, siganids (Fig. I-59). Two phylogenetic hypotheses can be proposed, as outlined (Fig. I-58). There are eight possible evolutionary changes of loop a in either one of these two hypotheses. When the

possible sister-group, such as Siganidae (Greenwood et al., 1966), is taken into account, sixteen possible evolutionary changes can be assumed for each of these hypotheses. However, there is no minimum evolutionary change unique to only one of these hypothetical events in both cases. It is, therefore, not possible to ascertain whether the simple character state of loop a is primitive or advanced by the criterion of parsimony.

A final observation involves the number of pyloric caeca. All acanthurines dissected except Naso annulatus, have five pyloric caeca. In Naso annulatus, a juvenile specimen (55 mm) has six pyloric caeca, while adult specimens (124-137 mm) have only five. Because of the limited number of specimens available, the significance of this variability in number of pyloric caeca is not known. It is possible that the number becomes reduced during ontogeny. A low number of pyloric caeca may be evidence of specialization and hence close interrelationship of acanthurines. In contrast to the acanthurines, Zanclus cornutus has seven to ten pyloric caeca. Consideration of a low number of pyloric caeca as an advanced character state is based on the assumption that a primitive feature is to be found early in ontogeny and an advanced feature late (Nelson, 1972b).

Siganidae, 2 genera, about 10 species: Lo (1), Siganus (1) (Norman, 1957).

The intestinal patterns of siganids (L. vulpinus and

S. rostratus) are complex as a result of their long intestine. Their patterns are type SP (Fig. I-59).

Comparison: Acanthurids and siganids have been considered members of the suborder Acanthuroidei (Gosline, 1968:16; Weber et al., 1951). The type SP pattern of siganids and the unique acanthurines and zancines patterns are uncommon in perciforms. No synapomorphies of the pattern was revealed indicating the monophyly of these two families.

XV. Scombroidei, 6 families (Greenwood et al., 1966).

Type LA is common among gempylids (Epinnula sp. and Gempylus serpens), trichiurids (Benthodesmus atlanticus, Trichiurus lepturus; Fig. I-60A, B, I, J), scombrids (Auxis sp., Sarda sarda; Fig. I-60C, H), and xiphiids (Xiphias gladius; Fig. I-60K). The remaining species of scombrids I have examined (Scomber colias, Scomber japonicus, Scomberomorus commersonianus, Scomberomorus sp.; Fig. I-60D-G) have type B.

Interrelationships: Primitively, the anterior section of the intestine of scombroids runs forward and turns to the right of the stomach, as occurs in most ammodytids in which the digestive tract is similar to that of scombroids. Interestingly, this part of the intestine in Auxis sp., Scomberomorus commersonianus, Scomberomorus sp., and Sarda sarda runs backward (heavy line in Fig. I-60C, F, G, H), whereas Xiphias gladius shows the intermediate state— being almost perpendicular to the stomach (Fig. I-60K). The lat-

ter two states can be treated as apomorphic and as a consequence, Auxis, Sarda and Scomberomorus may be more closely related to each other than to other genera in the Scombridae. This conclusion does not conflict with that proposed by Starks (1910) who suggested that Auxis, Acanthocybium, Gymnosarda, Sarda, Scomberomorus and Thunnus are more closely related to each other than to Rastrelliger and Scomber. The close affinity of Auxis and Sarda is also supported by kidney characters (see Section II). Regan (1909) put gempylids and trichiurids in the Trichiuroidei and left the remaining families in the Scombroidei. No unique characters were found that defined the two groups that Regan proposed.

XVI. Stromateoidei, 5 families (Haedrich, 1967).

Centrolophidae, 6 genera, 22 species: Centrolophus, Hyperoglyphe, Icichthys, Psenopsis (1), Schedophilus, Seriolella.

Psenopsis anomala has type S (Fig. I-61A).

Nomeidae, 3 genera, about 15 species: Cubiceps (1), Nomeus (1), Psenes (1).

Cubiceps sp. has type Z (Fig. I-61B). This pattern is also shared by Psenes cyanophrys (Fig. I-61D) although the tip of loop a coils dextrally. Loop a of smaller specimens of Nomeus gronovii winds dextrally to the left of the rectum; a leftward folding appears at the section of the intestine anterior to the tip of loop a (large arrow in Fig.

I-61C). This folding becomes significant during development. As such, this pattern is classified as type D2 and is treated as an autapomorphic character state within this family.

Stromateidae, 3 genera, 13 species: Pampus (1), Peprilus (1), Stromateus (1).

The pattern of Pampus argenteus is different from those of the other stromateids. Loop a of this species follows a special pathway: the anterior section and the tip of this loop remain dextral in direction (Fig. I-61E, F; large and fine arrows show the directions of the anterior section and the tip of this loop). Peprilus sp. and Stromateus fiatola share a similar pattern in which loop a does not remain in a strictly spiral (dextral) pathway along its whole length. The anterior section of this loop is dextral in its winding direction (large arrows in Fig. I-G, H, I). However, this direction is changed to a sinistral one at the mid-section and the tip of loop a (fine single-line arrows indicate this direction). This might be a variant of type Z that is formed as a result of an extreme leftward and upward folding tendency acting on the mid-section of loop a as indicated by the double-line arrows in these figures. Or it can be considered to be similar to that of Pampus argenteus in lacking folds at specific section of the loop. The coiling pathway represents the growing pathway of loop a (in other word, the migrating pathway of the tip of loop a

during development). Small adult and juvenile specimens will prove necessary to decide which is the real situation of the development of this pattern. Even though specimens were unavailable, I would think that the first situation is true. If this prediction turns out to be correct, then the pattern of Pampus argenteus becomes an autapomorphic character state. This leads me to a conclusion that type S and Z, which are closely related forms as far as development is concerned, are the main patterns in this suborder.

Tetragonuridae, 1 genus, 3 species: Tetragonurus (1).

Tetragonurus cuvieri has type B (Fig. I-61J).

Interrelationships: Nomeids and stromateids are most similar in their patterns; centrolophids have simpler but similar patterns. The pattern of tetragonurids seems to be autapomorphic in this suborder: loop f of T. cuvieri is horizontally placed— a condition not equivalent to the typical type B pattern.

With regard to the interrelationships of stromateoids, Haedrich (1967:51) stated, "Within the suborder Stromateoidei, there are three distinct groups, the primitive centrolophids, the intermediate nomeids with their specialize offshoots the tetragonurids and the ariommids, and the advanced stromateids. The stromateids are an obvious derivative of the centrolophid line. The nomeids, an evolutionary grade above the centrolophids have evolved parallel to the centrolophids but from an earlier common ancestor."

Further detailed study of the patterns of other stromateoids is strongly recommended.

XVII. Anabantoidei, 4 families (Nelson, 1976; Liem, 1963).
Anabantidae, 3 genera, about 40 species: Anabas (1), Ctenopoma (2), Sandelia.

The patterns of some anabantids (Anabas testudineus, Ctenopoma nanus, C. congicus; Fig. I-62A-C) are type B.

Belontiidae, 3 subfamilies, 10 genera, about 28 species.

Belontiinae, 1 genus, about 2 species: Belontia (1).

Macropodinae, 5 genera, about 14 species: Betta (1),
Macropodus (1), Malpulutta, Parosphronemus.

Trichogasterinae, 4 genera, about 12 species: Colisa (1),
Parasphaerichthys, Sphaerichthys, Trichogaster (1).

Except for Belontia sp. and Betta splendens, which have simply type-B patterns (Fig. I-62D, E), other belontiids (trichogasterines, and most macropodines) (Table 1) have type SP.

Helostomatidae, 1 genus, 1 species: Helostoma (1).

Helostoma temmincki is unique in that the intestine is arranged in two spiral masses (arrows in Fig. I-62I point to these masses). I suggest investigation of other belontiids, especially trichogasterines, which also have a long intestine.

Osphronemidae, 1 genus, 1 species: Osphronemus (1).

Osphronemus goramy has type SP (Fig. I-62J).

Comparison: The anus of Anabas testudineus, Ctenopoma spp. (Anabantidae) and Belontia sp. (Belontiinae, Belontiidae) is abdominal (primitive state), whereas it migrates to the thoracic area in other anabantoids. A general review of the taxonomic and systematic treatments by previous authors was made by Nelson (1976). Anabantoids have been considered somewhat related to luciocephaloids, channoids (Jordan, 1923); to luciocephaloids (Berg, 1940; Greenwood et al., 1966), to luciocephaloids, channoids forming a group which relates to nandids (Gosline, 1971) and to the badids (Barlow et al., 1968). The latter authors strongly opposed the close relationships of anabantoids, luciocephaloids and channoids. Luciocephalus pulcher has type B. No evidence supporting the monophyly of luciocephaloids and anabantoids was revealed from this study.

XVIII. Luciocephaloidei, 1 family (Greenwood et al., 1966).

Luciocephalidae, 1 genus, 1 species: Luciocephalus (1)

(see Anabantoidei).

XIX. Mastacembeloidei, 2 families (Greenwood et al., 1966).

Mastacembelidae, 2 genera, about 50 species: Macrognathus,

Mastacembelus (2).

Mastacembelus congicus and M. sinensis have type LA.

B. Non-perciform actinopterygians

Type B turns out to be not the dominant pattern in non-perciform actinopterygians. Type LA appears very often in these fishes, indicating that for a majority of these fishes, the intestine is rather short. Besides some herbivorous species, which possess an extremely long intestine with a complicated pattern, other species usually have type B, and type ST. Types S and Z have never been observed in these fishes. Except for the unusual character state of the leftward displacement of the anterior section of the intestine in relation to the stomach (Osteoglossomorpha and possibly also in Atherinoidei), other variation seems to be limited to certain lower taxonomic levels (e.g., genus or family). Therefore, I will point out some of these variations that will provide baseline information for further studies.

I. Pre-euteleostean actinopterygians

Chondrosteans have either type LA or type B (Table 1).

Interestingly, the stomach of Lepisosteus oculatus extends to the rear part of the peritoneal cavity and folds to the right; the intestine of this species is extremely short (Fig. I-64).

Type B appears in Amia calva, but the pattern is specialized in that the rectum is on the right of the intestine (heavy line in Fig. I-65).

Loop a is absent from elopids, megalopids, albulids (and also Anguilla rostrata) (Figs. I-66 to I-69A). The

pyloric diverticulum of their stomach is usually long. The same condition is true also for *Anguilla rostrata* and *Gymnothorax moringa*. However, the patterns of the latter two species are type LA and type B, respectively (Fig. I-69A, B).

In clupeoids, *Dorosoma* sp. has very long intestine, which gives rise to a complex pattern. The section of the intestine anterior to the tip of loop a coils in a W-shaped pathway (Fig. I-70C; heavy stippling). In addition to this specialization, the stomach is gizzard-like. For the other clupeoids, loop a is usually absent (Table 1) except for *Clupea* sp. (Fig. I-70B), which has a type-B pattern.

II. Ostariophysi

Ostariophysan intestinal patterns are diverse. Among those groups in which the stomach is horizontal, three types of stomach can be discriminated: in type 1, the pyloric region of the stomach is on the right of the esophagus; in type 2, the pyloric region of the stomach is on the left of the esophagus; type 3 has a straight stomach. The distribution of these types is interesting as it bears on the question on relationships within the Ostariophysi. Type 1 occurs in gymnotoids (Fig. I-73) and some cyprinoids (gyrinocheilids, homalopterids, and cobitids; Figs. I-76, 77) and is rare in gnathostomes. Type 2 occurs in siluriforms (Figs. 78-83) and outside the Ostariophysi, in *Polypterus* sp., *Polyodon* sp., and *Acipenser stellatus* (Fig. I-63). Type 3 occurs in catostomids, cyprinids, and psilorhynchids (Fig. I-75). If type 1 is apomorphic in ostariophysans, gymnotoids and cyprinoids would

seem to be related. Within cyprinoids, a straight stomach is apparently apomorphic.

For comparison, the intestinal patterns of catostomids-cyprinids-psilorhynchids and gyrinocheilids-homalopterids-cobitids can be simplified (Fig. I-74A, B, respectively). The intestine can be divided into three sections, 1, 2, and 3. Between these sections, two loops are formed (loop a: heavy stippling; loop e: fine stippling; Fig. I-74). Among other groups in which the intestine is horizontal, loop a tends to coil sinistrally and spirally (e.g., Ogcocephalus nasutus, Hypostomus sp., and Loricaria cataphracta). The patterns of both catostomids-cyprinids-psilorhynchids and gyrinocheilids-homalopterids contradict this generalization. The cyprinid and catostomid patterns are alike - section 1 remains straight while the mid portion of sections 2 and 3 bend to the right as the fish increases in length (Fig. I-75, small arrows). As the intestine lengthens further, the anterior portion of these sections then bends to the left (large arrows in Fig. I-75C, H). In most cases, except for two species of Notropis (N. rubellus and N. mekistocholas), the tip of loop a points to the left (double-line arrows in Fig. I-75C, F, I, J, L). However, this part of loop a turns to the right in N. rubellus (Fig. I-75H, double-line arrow) and N. mekistocholas (Balderas et al., 1977). The pattern of these two species is thus considered an advanced character state. In Psilorhynchus balitora, this loop bends over to

the anterior section of the intestine and extends posteriorly (Fig. I-75M). This pattern is not shared by any catostomids and cyprinids I have examined and is probably apomorphic.

Because of the straight stomach, loop f which generally appears in perciform patterns, is absent in catostomid-cyprinid-psilorhynchid patterns. Accordingly, they are type LF. Interestingly, in those perciforms with this type of pattern, the major loop (loop a) is either pointed anteriorly (e.g., Macrorhamphosus scolopax; Fig. I-105), coiled sinistrally (e.g., Gobioides sp.; Fig. I-53H), or pointed posteriorly (e.g. cichlids; Fig. I-15) just like in most perciforms. For M. scolopax, loop a is straight. The patterns of catostomids-cyprinids-psilorhynchids are comparable to that of M. scolopax. However, this anteriorly directed coiling of loop a has not been observed in any other fishes. Within the monophyletic group formed by catostomids-cyprinids-psilorhynchids united by the stomach character, intestinal patterns appear autapomorphic for their possessors. However, ontogenetic information supporting the monophyly of catostomids and cyprinids is difficult to obtain since early in ontogeny (20 mm SL) P. balitora has an adult intestinal pattern.

In homalopterids and gyrinocheilids, section 1, 2 and 3 are bent. Loop e coils sinistrally in these groups (Fig. I-76A, B, C; large arrows) in contrast to cyprinids, catostomids which lack this coiling. An autapomorphic character

state of the position of loop a characterizes all homalopterids in which the tip of this loop coils around the stomach (small arrows in Fig. I-76B, C). Loop f cannot be distinguished in gyrinocheilids and homalopterids. Loop e which is unique to the type-LF pattern, is formed by the anterior section of the intestine and is located at the rear end of the peritoneal cavity. In contrast to the straight loop e of all perciforms with a type-LF pattern, the loop e of gyrinocheilids and homalopterids coils sinistrally, a special condition that has not been found in any other group.

Most cobitids have a short intestine. However, Barbatula posteroventralis has a very long intestine in which all sections of the intestine coil in a zigzag manner (Fig. I-77A).

The intestinal patterns of gymnotoids are simple (Fig. I-73). The urogenital orifice is jugular. Accordingly, the rectum runs postero-anteriorly. Gymnotoids all have type B (Fig. I-73).

For most siluriforms examined, the intestinal patterns are type LA (Fig. I-78A-E). Hypostomus sp. and Loricaria cataphracta (Loricariidae), however, show a strictly spiral, sinistral loop a (Fig. I-82A, B).

In characoids, the stomach is dorso-ventral. The same character state of the stomach occurs also in Gonorynchus greyi, a member of Gonorynchiiformes, which have been considered the sister-group of Otophysi (Rosen & Greenwood, 1970). The patterns of carnivorous characoids are type B (Fig. I-

72A-C). In herbivorous species, such as Citharinus citharus and Distichodus maculatus, the patterns are complex. They share some characteristics in common— loop a occupies the left side of the stomach; the rectum runs dorsal to the other parts of the intestine and is close to the swimbladder (Fig. I- 72D, E).

In summary, on the basis of intestinal pattern character, cyprinoids and gymnotoids are hypothesized to be related. Within the former, gyrinocheilids-homalopterids and catostomids-cyprinids-psilorhynchids form two monophyletic groups. The interrelationships of the members of the latter group are still obscure as is the phylogenetic position of cobitids, siluriforms and characoids.

III. Protacanthopterygii

The type B intestinal pattern has not been found in protacanthopterygians. Type LA is widely distributed in this group (Table 1). The patterns of Salmo gairdneri and Esox americanus should be mentioned. In the former, a concave section (arrow in Fig. I-84) appears in the anterior part of the intestine. The stomach of E. americanus is long and the intestine turns to the right part of the stomach and then extends anteriorly to the front part of the peritoneal cavity before turning backward (Fig. I-85).

The extra length of the intestine in Talismania sp. (Alepocephalidae) gives rise to numerous small coils arranged in a spring-like fashion between the stomach and the

rectum (Fig. I-86). Myctophum sp. (Myctophidae) has type LA. It is peculiar in that (1) the anterior section of the intestine bends downward, (2) a small folding appears at the distal part of the intestine (Fig. I-87).

IV. Paracanthopterygii

In paracanthopterygians, type ST, LA, and B are the three main patterns. Percopsiforms and gobiesociforms have a short intestine. In the former group, Percopsis omiomiscomaycus and P. transmontana have type LA. Amblyopsis spelaea has the same pattern, but the intestine is horizontally placed and, because of the jugular position of the anus, the rectum runs postero-anteriorly (Fig. I-88). Two gobiesociforms examined, Gobiesox strumosus and Tomicodon sp. have straight guts.

For lophiiforms and gadiforms, type B is the main pattern. Suyehiro (1942:245) depicted the digestive tract of Antennarius tridens in which the major loop is directed downward at the front end of the peritoneal cavity; loop f is not formed (Fig. I-93; stippled area). Another antennariid species, Histrio histrio has type B. Unlike antennariids, the intestine of chauncacids and ogcocephalids is horizontal. Loop a of Chaunax sp. and Ogcocephalus nasutus coils sinistrally (Figs. I-89, I-90).

Except for Zoarces viviparus, gadiforms are similar to antennariids in that the intestine is dorso-ventral and the patterns are type B. Loop f of Z. viviparus is absent (Fig.

(Fig. I-92).

V. Atherinomorpha

Among exocoetoids, all belonids and exocoetids examined (Table 1) and scomberesocids (e.g., Cololabis saira) (Suyehiro, 1942) have a straight gut. The patterns of cyprinodontoids are much more variable. Type LF appears in Anableps dovii (Fig. I-94). Type LA dominates the patterns of cyprinodontids, e.g., Fundulus heteroclitus, F. majalis, and Profundulus punctatus. The intestine of Cyprinodon variegatus is long; the major loop occupies the posterior part of the body cavity (stippled area in Fig. I-95A). A small sinistral loop occurs anterior to the rectum (heavy line in the figure). A similar loop occurs also in Poecilia vivipara. However, this is the major coiling of the intestine in this species (heavy line in Fig. I-98)— a character different from that of C. variegatus. The pattern of P. vivipara has not been found in other groups. Belonesox belizanus and Gambusia sp. have type T (Fig. I-97)— a character state seldom found in actinopterygians.

The pattern of Oryzias latipes is more complex than most other cyprinodontoids. Loop a is difficult, if not impossible, to recognize (Fig. I-96). There is a distinctive downward section at the anterior part of the intestine (Fig. I-96; arrow). The same condition appears also in Profundulus punctatus (arrow in Fig. I-95B).

VI. Acanthopterygii

Some representative species of Beryciformes, Zeiformes, Lampridiformes, Gasterosteiformes, Channiformes, Synbranchiiformes, Scorpaeniformes, and Pleuronectiformes were examined. Bercyciformes:

Polymixia sp. (Polymixioidei) has type LA. A group of small coils occur before the rectum (Fig. I-99, fine arrows). Like the pattern of Oryzias latifer (Cyprinodontoidei), the anterior section of the intestine bends downward (Fig. I-99, large arrow).

Type B is the general pattern for holocentrids (Berycoidei). Myripristis jacobus and Plectrypops retrospinis have this pattern. Interestingly, in Holacetrus rufus, loop a folds ventrally from the right to the left side of the rectum (Fig. I-100). A similar pattern is found also in some hexagrammids (Scorpaeniformes; see below) and Oplegnathus fasciatus (Oplegnathidae, Perciformes; Suyehiro, 1942).

Channiformes, 1 family (Greenwood et al., 1966).

The species examined in the Channiformes, e.g., Ophicephalus argus (Ophicephalidae; see also Table 1) have type B.

Gasterosteiformes, 9 families (Greenwood et al., 1966).

The intestinal patterns of most gasterosteiforms are simple but unique in a certain way. The stomach is straight and tube-like. The intestine of Apeletes quadracus (Gasterosteidae) extends posteriorly to the rear part of the per-

itoneal cavity and bends upward forming a loop (Fig. I-104; heavy line) before reaching the rectum. Loop f is absent from the pattern. It seems to be a general condition for those gasterosteiforms with long intestine that the part at the posterior section of the peritoneal cavity bends upward forming a loop. The position of this loop in relation to the rectum is different in two occasions— it locates on the right of the rectum in Hippocampus hudsonius (Syngnathidae), but on the left in Macrorhamphosus scolopax (Macrorhamphosidae) (Figs. I-106, I-105, respectively).

Lampridiformes, 6 families (Greenwood et al., 1966).

The stomach of Velifer hypselopterus (Veliferidae) is straight. The anterior section of the intestine extends to the posterior end of the peritoneal cavity; loop a is insignificant (Fig. I-103).

Scorpaeniformes, 21 families (Greenwood et al., 1966).

Scorpaenodes caribbaeus (Scorpaenidae) has type LA. Type B is found in Lepidotrigla stonuchii, Peristedion minutum (Triglidae) and Cottus cognatus (Cottidae). The pattern of Pterygotrigla hemisticta (Triglidae) is a special condition in scorpaeniforms: loop a occupies the anterior part of the peritoneal cavity and is placed on the left of the stomach and other parts of the intestine (Fig. I-107A).

The intestinal patterns of hexagrammids deserved special attention. According to Rutenberg's work, Nelson (1976)

listed four subfamilies, five genera and eleven species in this family. These subfamilies are: Hexagramminae (including Agrammus and Hexagrammos), Pleurogramminae (including Plurogrammus), Ophiodontinae (including Ophiodon), and Oxylebinae (including Oxylebius).

The intestinal patterns of piscivorous hexagrammids are not complex and are basically type B. However, the tip of loop a in Agrammus agrammus and Hexagrammos otakii runs underneath the rectum and bends upward to the left side of the rectum. Their patterns were reported by Suyehiro (1942:202, 204) but he did not notice this specialization. My observations on the patterns of several other species of Hexagrammos (H. decagrammus, 128 mm, H. lagocephalus, 108 mm, and H. stelleri, 218 mm) show also the same pattern (Fig. I-107B). Smaller individuals (the 83-mm individual of H. stelleri) do not clearly show this pattern. The specimens that Suyehiro examined are large (201-234 mm for the A. agrammus specimens; 102-291 mm for the H. otakii specimen). This unique pattern (although it is also possessed by Holocentrus fuscus and Bryostemma nugator, for instance, their patterns were considered as derived independently) does not appear in Pleurogrammus antarcticum and Ophiodon elongatus (Fig. I-107 C, D). The present data suggest that Hexagrammos and Agrammus are monophyletic groups.

Synbranchiiformes, 3 families (Greenwood et al., 1966).

Synbranchus marmoratus (Synbranchidae) has a straight

gut.

Zeiformes, 6 families (Greenwood et al., 1966)

The pattern of Xenolepidichthys dogleishi (Grammicolepididae) (Fig. I-101) is similar to that of Oryzias latifer (Atheriniformes) in that the anterior section of the intestine bends downward distinctively. Other zeiforms, such as Zeus japonicus (Zeidae) have type B. Zenion hololepis (Macruricyttidae) has a unique condition in that loop a is to the left of the rectum (Fig. I-102).

Pleuronectiformes, 7 families (Greenwood et al., 1966).

Psettodidae

The stomach of Psettodes erumeri has a long pyloric diverticulum, a unique feature among pleuronectiforms. Other than this, its pattern is general (type B), and the rectum runs postero-anteriorly to the anus.

Bothidae

Type B dominates the patterns of bothids. Because of the anterior position of the anus, the rectum of Rhombosolea tapirina, Synacium papillosum, Taeniopsetta radula, and Tephrineches sinensis is directed forward (Fig. I-109E-H). As such, their patterns also derivate from the general one. T. radula has a very simple pattern amongst these species; the patterns of R. tapirina, S. papillosum and T. sinensis are copies of the same mold having a loop pointing downward

(heavy stippling in the figures). This is considered as a synapomorphic character indicating the close affinity of these genera.

Pleuronectidae

Intestinal patterns of pleuronectids are simple and are classified as type LA (Citharichthys spilopterus, Glypterocephalus zachirus), type B (Ammotretis elongatus, Liopsetta exilis) and type D1 (Limanda sp., Pseudopleuronectes americanus) (Fig. I-110E, I). The patterns of Platyichthys stellatus and Pleuronichthys cornutus are specialized in that two loops beside loop f can be recognized. The loop underneath the stomach is significantly dextral in its coiling direction (fine stippling in Fig. I-110G, H). The other loop is formed by the section of the intestine between the first loop and the rectum (heavy stippling in the figure). Loop a is not recognized in these species. These species are more closely related to each other than to the other pleuronectids I have mentioned.

The anus of C. spilopterus, Eopsetta grigorjewi, G. zachirus, and L. exilis is posterior (Fig. I-110B-E, F). The anus is anterior in some pleuronectids, e.g., Ammotretis elongatus, Limanda sp., Platyichthys stellatus, Pleuronichthys cornutus, and P. americanus, in which the rectum either runs postero-anteriorly or dorso-ventrally toward the anus (Fig. I-109A, E, G, H, I).

Scophthalmidae

Scophthalmids (Lophopsetta maculata and Scophthalmus aquosus) are type B (Fig. I-111A, B).

Soleidae, 2 subfamilies: Achirinae, Soleinae (e.g., Norman, 1957; Hubbs, 1945).

Trinectes maculatus (Achirinae) and Heteromycteris japonicus (Soleinae) have type B, and loop a occupies the right secondary body cavity (the part of the peritoneal cavity formed between the body wall and the caudal haemal spines; Fig. I-113B, D). Several small coils occur along loop a in the former species. In these subfamilies, the other species with a long intestine do not share the same pattern of H. japonicus. Loop a in Archirus lineatus (Achirinae) coils dextrally (Fig. I-113A), whereas the pattern of Synaptura marginata (Soleinae), as reported by Matsubara (1963) (Fig. I-113C), has a sinistrally coiled loop a. A similar condition of loop a was observed also in Zebrias zebra (Soleinae; Fig. I-113E). Study of other soleoids is recommended.

Archirus lineatus and Trinectes maculatus lack melanophores from both side walls of the peritoneal cavity, as do Psettodes and Bothus lunatus. For the majority of pleuronectiforms, the wall of the peritoneal cavity on the blind-side lacks melanophores, whereas they are present on the ocular-side. It seems likely that this character state of lacking melanophores from both side-walls developed independently in this order. If this is an apomorphic character

state, achirines would be closely related.

Cynoglossidae

Cynoglossus monopus and Paraplagusia bilineata have a peculiar feature not shared by Symphurus spp., Areliscus interruptus and any soleids: two small loops are formed by the anterior and mid-sections of the intestine (fine stippled areas in Fig. I-112B, C); loop a cannot be distinguished in these patterns; the rectum runs postero-anteriorly to the anus. This character is treated as a synapomorphic condition implying the close relationships of these two species while other cynoglossid patterns show a dextral loop a (Fig. I-112).

In summary, pleuronectiform intestinal patterns are simple, without much variation. They are classified as types LA, B, D1, D2, and a type in which the tip of the dextrally coiling loop a does not reach the rectum. There are other variations within the pleuronectiform families that are applicable to the elucidation of the generic inter-relationships to a certain degree.

Comparison: Ichthyologists have generally agreed upon the close relationship of Soleidae and Cynoglossidae (e.g., Hubbs, 1945; Regan, 1910) and have put them in the suborder Soleoidei (Greenwood et al., 1966).

Ochiai (1966) studied the differentiation of the alimentary canal of Japanese soleoids (including soleids and cynoglossids) and proposed a transformation series of the

ten types of intestinal patterns he found. He assumed that the hypothetical ancestor of soleoids should have a short intestine and its major loop (loop a) should be horizontal. To the present author, these ten types can be divided into two groups: in Group 1, loop a does not extend beyond the posterior limit of the stomach or the main body cavity regardless of the intestinal length; in Group 2, loop a extends beyond the stomach and occupies the right secondary body cavity (left and/or right secondary body cavities, which are posterior extensions of the main body cavity beyond the first haemal spine, develop in most pleuronectiforms; these cavities are occupied by the gonads and seldom by the intestine). Soleids have the intestinal pattern of Group 2, but cynoglossids with their long intestine belong to Group 1. This condition in soleids is apparently synapomorphic for soleoids indicating the monophyletic origin of soleids. In species with a very long intestine, such as Heteromycteris japonicus (Soleidae), loop a reaches the distal end of the right secondary body cavity (Fig. I-113B), and does not bend forward again. Ochiai considered a member of Group 2, in which loop a does not coil within the right secondary body cavity, as an off-shoot of the ancestral pattern of Soleoidei, and he treated the remaining types in both groups as one evolutionary stream which terminated in a type in which loop a coils within the right secondary body cavity. If this judgement is correct, the implication is that Cynoglossus itinus and Paraplagusia blochi (Cynogloss-

idae), in which loop a coils dextrally, are more closely related to soleids than Heteromycteris japonicus which has a straight loop a in the secondary body cavity, is to other soleids.

The position of the anus and of the urogenital opening in pleuronectiforms varies remarkably. These variations have been applied to the interpretations of the generic interrelationships of bothids (Hensley, 1977). At least six character states have been found: (1) anus and urogenital papilla on the mid-ventral line of the abdomen; (2) anus and urogenital papilla on the blind-side; (3) anus medial, urogenital papilla on the blind-side; (4) both openings on the ocular -side; (5) anus on the blind-side, urogenital papilla on the ocular-side; (6) both openings on the blind-side. The distribution of these character states among the pleuronectiforms examined is listed in Table 2.

It is clear that the primitive condition is that both openings are on the mid-ventral line of the abdomen, as in Psettodes and other gnathostomes. The evolutionary relationships of the other conditions are difficult, if not impossible, to resolve unless evidence from ontogenetic changes is revealed. It would seem that these states (except the most primitive one) have been repeatedly developed in the families of this group. However, since I have postulated the most primitive state, it is still logically sound to assume that the genera within any of these families sharing the same advanced character state are more closely re-

lated to each other than to other genera.

In the majority of pleuronectiforms examined, the anus is on the blind-side and the urogenital papilla is on the ocular-side. In citharids, these openings are on the ocular-side (Hubbs, 1954), indicating monophyly for the genera in this family.

As already noticed, bothids, pleuronectids, citharids, and scophthalmids probably form a monophyletic group. All scophthalmids examined have their anus and urogenital papilla on the blind-side and ocular side, respectively. This character state is also common in Bothus, Paralichthys (Bothidae), Liopsetta, Platyichthys, Pleuronichthys, Pseudopleuronectes (Pleuronectidae). On the basis of the locations of these openings among these families, Ammotret s, Glypterocephalus, Limanda (Pleuronectidae); Cyclopsetta, Tephrinches (Bothidae); Etropus, Synacium, and Taeniopsetta (Bothidae); all species of Citharidae, perhaps form four monophyletic groups (also see Table 2).

Heteromycterus (Soleidae) and Cynoglossus (Cynoglossidae) are similar in the position of these opening (Table 2); the medial position of these openings in Zebrias (Soleidae) and the placement of both openings on the blind-side in Symphus (Cynoglossidae) present a complex distribution pattern of these character states within soleoids. More work has to be done to survey this character in this suborder.

Interrelationships of the basic actinopterygian intestinal patterns

Information of the ontogenetic change of intestinal patterns and also the frequency of association of various types of patterns in the members of monophyletic or hypothetical monophyletic groups should help elucidate the interrelationships of the types.

The former source of information is limited in this study because (1) specimens of different sizes were usually not available; (2) no developmental change was observed in the examined specimens. However, the developmental changes of the intestinal patterns of the pomacentrids Abudefduf taurus and Amphiprion ocellaris suggest that type Z can be developed from type HZ (as in the case of A. taurus) or from type S (as exemplified by A. ocellaris). These observations provide direct indication of the close relationship of these types (Fig. I-114).

In 48 cases of association between two types of patterns found in the 31 monophyletic groups (Acipenseridae, Clupeidae, Cobitidae, Cyprinodontidae, Gasterosteiformes, Scorpaeniformes, Cottidae, Carangidae, Centrarchidae, Cirrhitidae, Echeineidae, Embiotocidae, Kuhlidae, Leiognathidae, Nemipteridae, Percidae, Pomacentridae, Pseudochromidae, Sciaenidae, Sparidae, Teraponidae, Labridae, Odacidae, Pholididae, Gobiidae, Kurtidae, Scombridae, Belontiidae, Pleuronectidae, and Soleidae), the frequencies of 15 kinds of as-

sociation (or frequencies of co-occurrence) of the types were obtained and they are listed in decreasing order as follows: B-LA, 17; B-D1, 9; B-ST, 3; D1-LA, 3; B-S, 2; LA-ST, 2; B-D2, 1; B-HZ, 1; B-Z, 1; B-SP, 1; B-T, 1; S-Z, 1; D1-S, 1; LA-T, 1; LF-ST, 1.

Chi-square test of these data ($\chi^2=27.8796$, $df=10$, $P<0.05$) leads to the conclusion that the appearance of the types of intestinal patterns in a monophyletic group is not an independent event. This conclusion suggests that certain types tend to associate. Only 15 kinds of the 55 possible ways of association between two of the eleven types appear in this sample. The extraordinarily high frequency of association between type B and types LA, D1 suggests the close relationship between them (Fig. I-114). A close relationship exists between types B, HZ, S, and Z (Fig. I-114). This hypothesis is grounded on the occurrence of their associations within monophyletic groups and also on ontogenetic evidence. Type B is also related to types D2, T, and ST. The multiple association of type B to the other types suggests that it is the most generalized type, at least for acanthopterygians, which may change into the other forms (Fig. I-114).

Although no example of the association between types D1 and SP has been found, they might be related forms, and the former seems to represent the plesiomorphic character state (Fig. I-114).

The problem with other simple patterns, types T, LF,

and ST are more complicated because they may be independently evolved from various types by significant or mild reduction of intestinal length. But on the basis of these data, type T is related to type B and type LA; type ST is related to types B, LA, and LF (Fig. I-114). No association between types B and LF was found.

The distribution of the types of pattern in actinopterygians is summarized in Table 3. Type LA dominates the patterns of lower actinopterygians, such as elopomorphs, clupeomorphs, protacanthopterygians. Type B becomes the dominant one in some actinopterygians including channiforms, scorpaeniforms, perciforms, and pleuronectiforms. Several of the basic patterns are "unique" to perciforms: types S, Z, D2, HZ, and SP (a few exceptions were found in ostariophysans and atherinomorphs). Type HZ, which is limited to a few perciforms, becomes the dominant type in monacanthids and balistids. Its synapomorphic nature in Tetraodontiformes is unquestionable.

Section II. Gross morphology of gnathostome kidneys.

Ogawa (1961) classified the external shapes of teleostean kidneys into five types on the basis of the degree of fusion of the left and right kidneys and of the development of specific parts of the kidneys. My observations provide additional information such that a classification of gnathostome kidneys can be made in which only the extent of their fusion is the major criterion.

For comparative purposes, as shown in Fig. II-1, certain terms are applied to specific parts of the kidneys. The extreme anterior kidney is that part lying lateral to the pharyngeal retractor muscles (m. retractor branchialium arcuum dorsalis). This part has frequently been called the head or cranial kidney. The terms anterior and posterior kidneys refer to the anterior and posterior parts from the rear of the extreme anterior kidney to the point directly in front of the base of the first haemal spine. These parts have often been referred to as the trunk or posterior kidney. The extreme posterior kidney is that part adjacent to the base of the basal anal pterygiophore.

The following key defines 24 types of kidneys. Even so, some kidneys, as indicated by asterisk in the figure, do not fall into these categories, and they will be described separately in the text.

Key to the kidney types (Fig. II-1B).

- 1A. Fusion of the left and right kidneys is complete.
 - 2A. Posterior kidney does not extend posteriorly beyond the base of the first haemal spine..... type 1A
 - 2B. Posterior kidney extends posteriorly to the base of the basal anal pterygiophore..... type 1B
- 1B. Fusion of the left and right kidneys is incomplete.
 - 3A. Left and right extreme anterior kidneys are fused; the anterior kidneys are separate , at least in part.
 - 4A. Part of the anterior and (or) the posterior kidneys is extraordinarily developed laterally... type 2A
 - 4B. No extraordinarily developed areas in the anterior and (or) the posterior kidneys.
 - 5A. Extreme posterior kidney absent; posterior kidney does not extend beyond the base of the first haemal spine..... type 2B
 - 5B. Extreme posterior kidney present.
 - 6A. Extreme posterior kidney fused with the posterior kidney.
 - 7A. Posterior kidney extends laterally along the sides of the first haemal spine and fuses at the base of the basal anal pterygiophore..... type 2C
 - 7B. Posterior kidney extends continuously (ventral to the first haemal spine) to the base of the basal anal pterygiophore type 2D

- 6B. Extreme posterior kidney does not directly fuse to the posterior kidney; they are joined by the ureters..... type 2E
- 3B. Extreme anterior kidneys separate; anterior kidneys do not fuse completely.
- 8A. Extreme posterior kidney absent.
- 9A. Part of the kidney degenerated.
 - 10A. Posterior kidney degenerated....type 3A
 - 10B. Anterior and (or) extreme anterior kidneys degenerated..... type 3B
- 9B. No degeneration.
 - 11A. Posterior kidney extends posteriorly on both sides of the first haemal spine type 3C
 - 11B. Posterior kidney does not extend posteriorly beyond the base of the first haemal spine.
 - 12A. Separate part of the kidney does not extend posteriorly beyond the point of origin of the pharyngeal retractor muscles..... type 3D
 - 12B. Separate part of the kidney extends posteriorly beyond the point of origin of the pharyngeal retractor muscles.
 - 13A. Anterior kidneys separate type 3E

- 13B. Anterior and part of the posterior
kidneys separated laterally
..... type 3F
- 13C. Only a small portion of the rear
part of the posterior kidney is
fused..... type 3G
- 8B. Extreme posterior kidney present.
 - 14A. Extreme posterior kidney does not directly
fuse to the posterior kidney; they are join-
ed to the ureters..... type 4A
 - 14B. Extreme posterior kidney fuses with the
posterior kidney (or kidneys).
 - 15A. Left and right posterior kidneys fuse in
front of the base of the first haemal
spine.
 - 16A. Posterior kidney extends postero-ven-
trally relative to the first haemal
spine to the base of the basal anal
paterygiophore.
 - 17A. Extreme posterior kidney extends
to the caudal region.. type 4B
 - 17B. Extreme posterior kidney does not
extend to the caudal region
..... type 4C
 - 16B. Posterior kidney extends posteriorly
along the sides of the first haemal
spine to the base of the basal anal

- pterygiophore where it is fused to
give rise to the extreme posterior
kidney..... type 4D
- 15B. Left and right posterior kidneys are
separate anterior to the base of the
first haemal spine. They extend inde-
pendently to the base of the first haemal
spine where they fuse and give rise to
the extreme posterior kidney.
- 18A. Extreme posterior kidney is rather
large..... type 4E.
- 18B. Extreme posterior kidney is narrow
(small)..... type 4F
- 1C. Left and right kidneys completely separated.
- 19A. Only the extreme anterior kidneys are present
..... type 5A
- 19B. Extreme anterior and anterior kidneys are present
..... type 5B
- 19C. Extreme anterior, anterior and posterior kidneys
are present..... type 5C
- 19D. Extreme anterior, anterior and posterior kidneys
are present. The latter extend posteriorly to the
base of the basal anal pterygiophore..... type 5D

Variation of kidney morphology

Variation of kidney morphology is low in individuals of
about the same body length. This is also true for the de-

velopmental changes. These conclusions are reached based on the individual similarities of Nomeus gronovii (Stromateidae) (19, 42, 50, 54, 60, 62, 70 mm), Acanthurus bahianus (Acanthuridae) (30, 32, 50, 59, 75, 100 mm), Archoplites interruptes (Centrarchidae) (75, 79, 80, 85 mm), Lepomis gibbosus (Centrarchidae) (36 specimens, 24-70 mm). Therefore, I make the practical assumptions that (1) most of the differentiations of the gross kidney morphology amongst species are : mainly caused by the processes of speciation, (2) one can examine a few specimens of any length to obtain the kidney type of the species.

Distribution of kidney types

Type 1

Due to the occurrence of the pharyngeal retractor muscles in most teleosts, the extreme anterior kidneys are prevented from fusing completely. Accordingly, kidneys of type 1 seldom appear in teleosts. In other non-teleostean actinopterygians, this type is found mainly in those species from which these muscles are absent. Among teleosts, examples include clupeiforms, Coilia sp., Clupea sp., Dorosoma sp., Pomolobus pseudoharengus, Sardinops sp. (Fig. II-16A-E), Anchoa mitchilli, and Chirocentrus dorab (Figs. II-17, II-18), some salmoniforms, e.g., osmerids and plecoglossids (Ogawa, 1962), Mallotus villosus, Salmo gairdnei, Osmerus sp. (Figs. II-33A, B; II-34). However, it is not true that there is an absolute correlation between the absence of the

pharyngeal retractor muscles and the occurrence of type-1 kidneys. Galaxias sp. (Galaxiidae), Dallia pectoralis and Umbra limi (Umbriidae), which lack the pharyngeal retractor muscles but possess kidneys of type 3, are examples to support this statement. In perciforms there are also exceptional species that have the pharyngeal retractor muscles but their extreme anterior kidneys are either fused on top of the muscles or the fused kidneys do not extend beyond the origin of these muscles. Examples are Sparisoma viride (Fig. II-129C), Auxis sp. (Fig. II-155A), Helostoma temmincki (Fig. II-162), Trichogaster trichopterus (Fig. II-161E), and Cubiceps sp. (Fig. II-157A).

Type 1 has also been developed independently in a number of ostariophysians, e.g., Clarias fuscus (Fig. II-28) and Loricaria cataphracta (Fig. II-30), and pleuronectiforms, e.g., Bothus ocellatus, B. lunatus, Rhombosolea tapirina (Fig. II-167B, C, F), Ammotretis elongatus, Limanda sp. (Fig. II-168A, D), Lophosetta maculata (Fig. II-169A), Cynoglossus monopus, Paraplagusia bilineata (Fig. II-170B, C), Archirus lineatus, Heteromycteris japonicus, Trinectes maculatus, Zebrias zebra (Fig. II-171A-D).

Because the kidneys of most of the gnathostomes examined belong to type 3, it is logical to hypothesize that type 1 is an advanced character state at various taxonomic levels. If so, the similarity found in some higher taxa (e.g., clupeiforms and pleuronectiforms) is likely the result of convergence. But at lower levels, the character state may

by synapomorphic, e.g., in salmonoids (Osmeridae, Plecoglossidae, and Salmonidae).

Type 2

In his classification, Ogawa (1961) defined a kidney type as, "the fusion of the two sides of the kidney is incomplete; the middle and posterior parts are fused. The middle part expands and fully develops. The distinction between the head kidney and the kidney is clear." Some ostariophysans are given as examples. The characteristic that the middle part expands and fully develops is unusual in ostariophysans and even among teleostomes (found in teraponids). However, there is a disadvantage in using this character for the purpose of studying phylogeny because of the correlation of this character with the size and shape of the two-chambered swimbladder. In those ostariophysans in which the swimbladders are similar to the usual teleostean type, this characteristic becomes difficult to distinguish. Pseudogobio esocinus, the kidney of which Ogawa has classified in this category, is an example (Fig. II-21D).

Fusion of the extreme anterior kidneys is generally associated with expansion of the middle part of the kidneys of ostariophysans. Ogawa made no mention of this fusion. Since this fusion is unusual in teleostomes, I define a kidney type (type 2) as that in which the extreme anterior kidneys are fused while at least part of the anterior kidneys are separate. Further subdivision can be made on the basis of the degree of development of the posterior kidneys.

This type occurs in Polyodon spathula (type 2D; Fig. II-8B), some ostariophysans, such as Acheilognathus moriokae, Pseudoperilampus typus, Hemibarbus barbus, Pseudorasbora parva, Sarcocheilichthys variegatus, Moroco steindachneri, Zacco platypus, Cyprinus carpio, Parasilurus asotus, Pelteobagrus undiceps, Carassius auratus (Ogawa, 1961), Ephippicharax sp., Micralestes sp. (Characoidei; Fig. II-19B, C), Hemiculter kneri (Cyprinidae; Fig. II-21C), Botia citraurata (Cobitidae; Fig. II-24A) and some siluriforms, e.g., Arius felis (Fig. II-25), Bagrus sp., Leiocassis sp. (Fig. II-26A, B), Ictalurus melas (Fig. II-29), Rhamdia sp. (Fig. II-31), and Plotosus linneatus (Fig. II-32). Among other teleosts, it occurs also in Esox americanus (type 2D; Fig. II-37), Talismania sp. (type 2D; Fig. II-39), Velifer hyselopterus (type 2B; Fig. II-61), Goodea sp (type 2B; Fig. II-53A). There are also some examples in perciforms, e.g., Decapterus muroadsi (type 2B), Megalaspis cordyla (type 2B), Selar sp. (type 2B) (Fig. II-76C, E, G), some centrarchids (see below; Fig. II-77 and Table 1), Ammocrypta vivax (type 2B), Acerina schraetser (type 2B), Perca flavescens (type 2B), Percina capiodes (type 2B) (Fig. II-109A, B, F, G), Cookeolus boops, Pseudopriacanthus altus (type 2C; Fig. II-115A, C), Sphyræna barracuda (type 2B; Fig. II-126), Odax pullus (type 2C; Fig. II-128), and Notothenia elegans (type 2B; Fig. II-142B). Different from the others, the posterior extensions of the posterior kidney of Cookeolus boops do not fuse at the base of

the basal anal pterygiophore.

Type 3

Type 3 E and 3F make their first appearance in osteoglossomorphs during the evolution of teleostomes. They become widely distributed in the groups beyond this point of the teleostome phylogeny. For the rest of the types classified in this large category (types 3A, 3B, 3C, 3D, and 3G), examples in teleostomes are limited and can be treated as advanced character states at various levels in the phylogeny. Type 3 has not been found in elasmobranchimorphs.

Distributions of type 3A, 3B, 3C, 3D, and 3G are listed as follows:

Type 3A: Eigenmannia virescens (Fig. II-20C), Tripterygion ethostoma (Fig. II-143-26), Acanthurus bahianus, Ctenochaetus striatus, Paracanthurus hepatus (Fig. II-153A,B, D), Kurtus indicus (Fig. II-152B), and Paratriacanthus retrospinis (Fig. II-172A).

Type 3B: Pantodon buchholzi (Fig. II-11B), Adioryx vexillarius (Fig. II-57A), Electris fusca, Awaous sp. (Fig. II-147C, G).

Type 3C: Holocentrus rufus (Fig. II-57B), some chaetodontids (see Section V), Cichlasoma champotonis, C. heterospilum, C. salvini, and Haplochromis eucinostomus (Fig. II-82A, B, F, G), Scorpiis aequipinnis (Fig. II-94F), Aplodinotus grunniens (Fig. II-119A), Bodianus rufus, Clepticus parrai (Fig. II-127A, C).

Type 3D: Hiodon alosoides (Fig. II-11C), Hypentalium nigricans (Fig. II-22B), Leptobotia elongata (Fig. II-24B), Opsanus tau (Fig. II-43), Membras vagrans (Fig. II-55D), Xenolepidichthys dolgleshii (Fig. II-58), Crinodus lophodon (Fig. II-71), Alectis ciliaris, Selene vomer, Seriola falcata (Fig. II-76A, H, I), Lates calcarifer (Fig. II-78C), Microcanthus strigatus, Vinculum sexfasciatus (Fig. V-1A, B), Goniistius zonatus, Nemadactylus macropterus (Fig. II-80A, B), Chironemus marmoratus (Fig. II-81), Amblycirrhitus pinos, Cirrhitichthys falco, Paracirrhites bimaculatus, and Paracirrhites sp. (Fig. II-83A-D), Dipterygonotus gruveli (Fig. II-87), Diapterus olisthostomus (Fig. II-91A), all kyphosids examined (Fig. II-94A-G), Latridopsis forsteri (Fig. II-97), Parequula melbournensis (Fig. II-98C), Mullus barbatus, Parupeneus malabaricus, Pseudupeneus maculatus (Fig. II-103A-C), Etheostoma caeruleum (Fig. II-109D), Pomacanthus paru (Fig. II-111C), all teraponids examined (Fig. II-123A-D), some labrids (Fig. II-127), most scarids examined (Fig. II-129A, B), Blennius cristatus, B. tentacularis, Homoesthes caulopus, Ophioblennius steindachneri (Fig. II-143-a, 2, 3, 7), some clinids (Fig. II-143-15-18), Icosteus aenigmaticus (Fig. II-144), Plagiogrammus sp. (Fig. II-147I), Zanclus cornutus (Fig. II-153G), Siganus sp. (Fig. II-154B), Sarda sarda (Fig. II-155D), Osphronemus goramy (Fig. II-163), most pleuronectiforms (Figs. II-116-171).

Type 3G: Liopropoma mowbrayi (Fig. II-120A), Chromis cyanea,

C. multilineatus (Fig. II-112C, D), Toxotes chaterius (Fig. II-124).

Extreme anterior kidneys of Myctophum sp. (Fig. II-40) are worth mentioning. They expand medially underneath the pharyngeal retractor muscles - a unique feature that has not been seen in any other group of gnathostomes.

Type 4

Type 4A: This group has only been observed among perciforms. Examples are Banjosidae, Banjos typus (Fig. II-75), Centrarchidae, e.g., Ambloplites rupestris, Enneacanthus chaetodon, Lepomis marginatus, L. punctatus (Fig. II-77C, G, O, R), Embiotocidae, e.g., Brachyiotus frenatus, Cymatogaster aggregatus, and probably Ditrema temmincki (Fig. II-86A, B, C), Enploidae, e.g., Enoplosus armatus (Fig. II-88), Ephippidae, e.g., Chaetodipterus faber (Fig. II-89), Pomacentridae, e.g., Dascyllus trimaculatus, Microspathodon chrysurus, Eupomacentrus sp., E. dorsopuncians, E. partitus (Fig. II-112E-I), Serranidae, e.g., Petrometopon cruentatum (Fig. II-120C), Labridae, e.g., Cirrhilabrus solorensis (Fig. II-127B), and Nomeidae, e.g., Cubiceps sp. (Fig. II-157A). This type is treated as an advanced state at the generic level in the family Centrarchidae. It should be considered as advanced state at the generic or species levels in the remaining families as mentioned. It is an autapomorphic character state for the families Serran-

idae , Labridae, and Nomeidae.

Type 4B: Only two examples have been revealed from quite a large number of perciforms I have studied. They are in Limnichthys fasciatus (Fig. II-135) and the Ammodytes americanus (Fig. II-145). However, it is more frequently found in non-perciform teleosts such as Dallia pectoralis (Fig. II-38A), Microgadus tomcod (Fig. II-47), Hemiramphus brasiliensis (Fig. II-50B), Chilatherina sp. (Fig. II-55B), Corythoichthys sp., Syngnathus fuscus (Fig. II-65A, C), and Synbranchus marmoratus (Fig. II-67).

Type 4C: This type occurs more frequently among non-perciforms. It is possessed by Acipenser stellatus (Fig. II-8A), Megalops cyprinoides (Fig. II-13), Electrophorus electricus, Gymnotus sp. (Fig. II-20A, B), Synodus synodus (Fig. II-41), Lepophidium sp. (Fig. II-48), Zoarces viviparus (Fig. II-49), Gobiesox strumosus (Fig. II-44A), Halocypselus evolans (Fig. II-50A), Ophicephalus argus (Fig. II-66), Lepidotrigla stonuchii, Pterygotrigla hemisticta (Fig. II-69A,C), Cottus cognatus (Fig. II-70).

There are also some examples in perciforms, e.g., Acantharchus pomotis (Fig. II-77A), Cichlasoma intermedium, C. motaguense (Fig. II-82D, E), Remora remora (Fig. II-85 C), Nemipterus sp. (Fig. II-105A), Creedia haswelli (Fig. II-133), pholidids (Fig. II-143-19, 20), Anoplarchus purpurescens (Fig. II-143-22), Kraemeria samoensis (Fig. II-449), Gunnellichthys pleurotaenia, Paragobiodon echinocephalus (Fig. II-150A, B), Scomberomorus spp. (Fig. II-155C,D), Trichiurus lepturus (Fig. II-155G), Psenopsis

anomala (Fig. II-156), Tetragonurus cuvieri (Fig. II-159), Luciocephalus pulcher (Fig. II-64), Mastacembelus sinensis (Fig. II-165B).

Type 4D: It is most commonly distributed in Chaetodontidae (see Section V). Besides this group, it has only been observed in two perciform species among all other fishes I have examined. They are Ambloplites rupestris (Fig. II-77C) and Opleganthus sp. (Fig. II-106). The nature of this character state of the posterior kidney within the Chaetodontidae will be discussed in Section V and it is considered as an advanced state at the generic level in Centrarchidae (see below). As for the Oplegnathidae, because I have only examined one species, more work should be done before a sound assumption is made.

Type 4E: This type seems to be more generally appeared among lower gnathostomes. Examples are numerous: Scoliodon terraenovae, Squalus acanthias (Fig. II-3A, B), Urogymnus africanus (Fig. II-4B), Lepisosteus platyrhincus (Fig. II-9B), Albula vulpes (Fig. II-14), Anguilla rostrata, Gymnothorax moringa (Fig. II-15A, B), Argentina sp. (Fig. II-35), Umbra pygmaea, U. limi (Fig. II-38B, C), Fundulus heteroclitus (Fig. II-52B). Only a few examples have so far been found in perciforms. Branchiostegus japonicus, Malacanthus plumieri (Fig. II-74A, C), Enneacanthus chaetodon (Fig. II-77G), Gadopsis marmoratus (Fig. II-90), Lobotes sp. (Fig. II-100), and Acanthogobius flavimanus (Fig. II-147A) share this kidney type.

Type 4F: This type is strictly limited to lower gnathostome.

Examples are plentiful as listed below: Chimaera phantasma (Fig. II-2), Lepisosteus oculatus (Fig. II-9A), Amia calva (Fig. II-10), Gymnarchus niloticus (Fig. II-11E), Anableps dovii (Fig. II-51). The kidney of Rhombochirus osteochir (Echeneidae; Fig. II-85D) resembles this type except that there is a small fused section at the left and right anterior kidneys.

Except for types 4A and 4D which are strictly distributed among perciforms, other types in this category (type 4) are mainly possessed by non-perciform gnathostomes. This distribution pattern seems to indicate that non-perciform gnathostomes, especially lower gnathostomes, generally have long kidneys in which the left and right kidneys fuse to various degrees.

Type 5

Complete separation of the left and right kidneys appeared early in the evolution of gnathostomes and it also repeatedly characterizes various groups of higher gnathostomes. Interestingly, this character state occurs in several taxa at the suprageneric level among perciforms (see below). I have also found examples in dipnoans and polypterids (see below) among non-actinopterygian teleostomes examined.

Among elasmobranchiomorphs examined, only some batoidimorphs (e.g., Taeniura meyeri; type 5D; Fig. II-4A) possess this character state.

No examples of this kidney type have been found in paleopterygians, ginglymods, and amiids. Among teleosts, it makes its first appearance in paracanthopterygians, e.g., Amblyopsis spelaea (Amblyopsidae; type 5A), Percopsis omiscomaycus (type 5D), P. transmontana (type 5B) (Fig. II-42A-C), Histrio histrio (Antennariidae; type 5A; Fig. II-45), Chaunax sp. (type 5B) and Ogcocephalus nasutus (type 5A) (Chaunacidae and Ogcocephalidae, respectively; Fig. II-46A, B). For the species of other paracanthopterygian families studied, e.g., Microgadus tomcod (Gadidae), Lepophidium sp. (Ophidiidae), Zoarces viviparus (Zoaridae), however, the kidneys are fused posteriorly.

Among atherinomorpha, I have examined species of Exocoetidae, Belonidae, Oryziatidae, Cyprinodontidae, Anablepidae, Poeciliidae, Melantaeniidae, and Atherinidae. Kidneys of type 5 were observed only in Oryzias latipes (type 5B; Fig. II-53B), Belonesox belizanus and Gambusia sp. (type 5C; Fig. II-54A, B). In the second species the left kidney is much shorter than the right kidney— a special condition.

Among acanthopterygians, there are species scattered in the orders I studied, such as the Zeiformes, Scorpaeniformes, Perciformes, and Tetraodontiformes, that develop this kidney type. In Zeiformes, only Zenion hololepis (Macruricyttidae; Fig. II-59) has this character state (type 5A). In Scorpaeniformes, Peristedion miniatum (Triglidae) has this character state (type 5C; Fig. II-69B). The fused area of the posterior kidneys of Scorpaenodes caribbaeus is very narrow

(Fig. II-68B). Among perciforms, some examples were found: Enneacanthus obesus (type 5D; Centrarchidae; Fig. II-77I), all callionymids studied, e.g., Callionymus sp. (type 5C), C. japonicus (type 5C), C. lunatus (type 5C), and C. lunatus (type 5C; Fig. II-146A-D), Kurtus gulliveri (type 5A; Kurtidae; Fig. II-152A), Prionurus microlepidotus (type 5B), Zebrasoma flavescens (type 5B; Acanthuridae; Fig. II-153E, F). In Lo vulpinus (Siganidae; Fig. II-154A), there is an isolated extreme posterior kidney, which is specialized among perciforms.

All kidneys of tetraodontiforms observed except for Paratriacanthodes retrospinis, are separate completely and their kidneys also show certain degrees of degeneration in length (Fig. II-172A-M; Also see Ogawa, 1961).

Taxonomic variation of kidney type

Sarcopterygii

The interrelationships of sarcopterygians have been widely discussed, but are not agreed upon. Dipnoans, for example, are of uncertain relationships (Moy-Thomas et al., 1971) although it has been hypothesized that they are closely related to Crossopterygii (e.g., Westoll, 1949; McAllister, 1968; and Gardiner, 1973); to Actinopterygii (Bertmar, 1966); or that they are a separate group related to the common stock of crossopterygians and actinopterygians. As for the systematic position of crossopterygians, the problem seems to become more complicated with time. Bjerring (1973) argu-

ed against the monophyly of the crossopterygians and suggested that coelacanthiforms are not member of this group on the basis of the differences in their cranial subdivisions. However, he did not make further suggestion concerning the relationship of coelacanthiforms.

The systematic position of polypteriforms is also equivocal. Pehrson (1947), Stensio (1947), De Bont and Paulus (1964), McAllister (1968), and Gardiner (1973) agreed upon the actinopterygian affinity of polypteriforms. Nelson (1969, 1973), on the other hand, placed them in the subclass Sarcopterygii on the basis of the evidence of gill arch and jaw structures. Jessen (1973) remarked that the shoulder-girdle and pectoral fin of Polypterus show no similarities at all with those of actinopterygians, which are clearly distinguishable from polypteriforms and occupy a position of their own among fishes in general.

Interestingly, a character state of the kidney— complete separation of the left and right kidneys, is shared by the two genera of polypteriforms (pers. obs.; Budgett, 1901). Further survey on the distribution of this character state reveals that it is possessed by some batoidimorphs e. g., Taeniura meyeni (Fig. II-4A) and Rhinobatos sp., dipnoans, such as Protopterus annectens (Parker, 1892:plate 45; Fig.II-6) , Lepidosiren paradoxa (Kerr, 1901b: Fig. 49B; pers. obs.) and some euteleosts among the large number of species I have examined.

Whether all dipnoans have the same kidney morphology,

namely, complete separation of the left and right components is not certain. About this organ of Ceratodus forsteri, Ballantyne (1928) wrote, "The two kidneys are fused for a short distance at the level where the most anterior vasa efferentia open into the kidney tissue." Since there is no illustration in his paper, the exact position of fusion is not known. Whether the kidneys are really fused in this species is doubtful to me. It might be the same condition as occurs in Protopterus annectens, wherein the posterior parts of the kidneys near the urinary bladder are "fused" superficially. But they are, in fact, separate and are only connected by the lympho-adenoid tissue that coats these organs (Parker, 1892)

For the other living gnathostomes (including chimaerids, selachimorphs, some batoidimorphs, coelacanthiforms, actinopterygians), the posterior kidneys or the extreme posterior kidneys are fused to various degrees. The kidney of Lati-mera chaulumnae is specialized in that only the extreme posterior kidneys are present. They are fused medially, placed on the floor at the posterior end of the peritoneal cavity (Fig. II-5). For cyclostomes, the kidney structure is strikingly different from that of gnathostomes (Frang, 1963). Comparison between these kidneys at the structural level of my concern is not practical for the purpose of providing information for determining the nature of the two character states (complete separation versus partly fused) of gnathostome kidneys.

With regard to the distribution of these character states among gnathostomes, a hypothesis concerning the interrelationships of the members of Sarcopterygii can be reached. This hypothesis is the most parsimonious one that involves a minimum number of reversals of character state of the kidney (Fig. II-173). Coelacanthiiformes are considered as the plesiomorphic sister-group of a monophyletic assemblage that includes the Dipnoi, Brachiopterygii, and Tetrapoda. The monophyly of the latter group is supported by the synapomorphic character state of the kidney (complete separation.) The occurrence of this state in some batoidimorphs is considered as independently evolved. Miles (1977) also reached to the conclusion of the choanates affinity of dipnoans supported by several advanced characters, including the presence of cosmine, submandibular bones and a highly-differentiated supraotic cavity.

Paleopterygii

In Acipenser stellatus, the kidney morphology is not peculiar (type 4C; Fig. II-8A). On the other hand, Polyodon spathula (Fig. II-8B) has an autapomorphic condition in that its fused extreme anterior kidney extends anteriorly to the anterior part of the parasphenoid.

Ginglymodi and Halecostomi

Kidneys of lepisosteids, e.g., Lepisosteus oculatus, L. platyrhynchus (Fig. II-9A, B) and amiids, Amia calva

(Fig. II-10) are long and deeply separate, and reach the base of the basal anal pterygiophore.

Osteoglossomorpha

Degree of development and fusion of the anterior kidneys vary among osteoglossomorphs. Unlike other osteoglossomorphs, kidneys of Gymnarchus niloticus and Mormyrops deliciosus (Fig. II-11F, H) are deeply separate (type 4F). Among other mormyrid species, only the anterior parts of the anterior kidneys are separate in Petrocephalus sp. (Fig. II-11I), whereas complete fusion of the kidneys occurs in Gnathonemus sp. (Fig. II-11G). Complete fusion occurs also in Xenomystus nigri (Fig. II-11E), in which the kidney is the most fully developed of all osteoglossomorphs examined. This character state, however, is not shared by Notopterus sp., which possesses a type-3E kidney. In Hiodon alosoides, the kidneys are fused except for the extreme anterior sections. The anterior and extreme anterior kidneys in this species are well developed.

Interestingly, there seems to be a common character in the kidneys of Osteoglossum bicirrhosum and Pantodon buchholzi. Anterior kidneys of the former species are degenerated (Fig. II-11A), but the extreme anterior kidneys remain. In Pantodon buchholzi, only the posterior kidney is retained (Fig. II-11B).

Elopocephala

Elopiiformes and Megalopoiformes

Elops saurus has a peculiar kidney (Fig. II-12). Basically, it belongs to type 3E. However, the anteriorly extended left and right extreme anterior kidneys are joined through a bridge-like connection. This kidney structure is not duplicated in Megalops cyprinodes in which the kidney has a type-4C configuration (Fig. II-13).

Anguilliformes (Elopomorpha)

Albula vulpus has a type-4E kidney. Its common ureter passes to the right of the swimbladder (Fig. II-14) on its way to the urogenital pore.

Kidneys of Gymnothorax moringa are fused only at the extreme posterior portion, which is more developed than the separate anterior kidneys (Fig. II-15B). There is a unique character state of the ureter, namely, numerous (about 13) ureters from the fused extreme posterior kidney drain into the elongate urinary bladder. This character state is also observed in G. vicinus. However, it is not duplicated in Anguilla rostrata and other eels, such as Kaupichthys hyoproroides. Kidneys of A. rostrata belongs to type 4E (Fig. II-15A). Although its fused extreme posterior kidney is well developed, the division between the extreme posterior kidney and the separate posterior kidneys is not as apparent as that of Gymnothorax moringa. As for the nature of the character state of the ureter of Gymnothorax, more observa-

tions on other eels have to be done in order to decide at what level it might become an advanced character state.

Clupeocephala .

Clupeiformes

Kidney morphology of Clupea sp. (type 1A), Dorosoma sp. (type 1A), Pomolobus pseudoharengus (type 1B), Sardinops sp. (type 1B; Fig. II-16B-E; Clupeidae) and Anchoa mitchilli (type 1A; Fig. II-17; Engraulidae) are similar. The kidney of Coilia sp. (Fig. II-16A; Clupeidae) resembles that of Elops saurus in having the bridge-like connection between the two sides of the fused extreme anterior kidney. In Clupea sp. and Dorosoma sp., there are numerous bands of ligaments that lie transversely on the ventral surface of the kidney, and connect the two sides of the peritoneal cavity. No such structures were seen in other genera of clupeiforms I examined. Kidney of Chirocentrus dorab (Chirocentridae) belongs to type 3E (Fig. II-18).

Euteleostei

Ostariophysi

For those ostariophysans with a swimbladder, the kidney size and morphology are highly correlated with the position and morphology of the swimbladder. For most of those with a two-chamber swimbladder, there is a fused and rather well developed area at the anterior kidneys upon which the junction of the two chambers of the swimbladder rests, e.g.,

Astyanax sp., Ephippicharax sp. and Micralestes sp. (Fig. II-19A-C; arrow indicates this fused area); Catostomus latipinnis, Hypentelium nigricans (Fig. II-22A, B). However, such fusion does not appear in Cyprinus carpio and Carassius auratus. The anterior kidneys of these species are separate, and the posterior kidneys are extremely well developed. A similar character state of the development of the posterior kidney also characterizes most siluriforms examined except for Callichthys sp., Clarias fuscus and Loricaria cataphracta (Figs. II-27, 28, and 30). This character state of the posterior kidney is associated with the occurrence of the huge posterior chamber of the swimbladder in some cyprinids and the huge one-chambered swimbladder of most siluriforms.

Characoids: Besides the kidney characters of the three representative species of characoids as already noticed, the extreme anterior kidneys of Ephippicharax sp. and Micralestes sp. are fused (Fig. II-19B, C).

Gymnotoids: Swimbladders of gymnotoids are single-chambered. They are located anteriorly in the peritoneal cavity in Electrophorus electricus and Gymnotus sp. and are smaller in size compared with that of Eigenmanina virescens, in which the long swimbladder is placed at the posterior half of the cavity, leaving the anterior half occupied by other visceral organs. Due to these differences, there appear some variations of the kidney morphology between these species. The first two species are very

similar in their kidney morphology. Kidneys are well developed and occupy the whole length of the body cavity; the extreme anterior kidneys are separate, and the swimbladder is placed between the extreme anterior kidneys (Fig. II-20A, B). E. virescens degenerates its size and length of the posterior kidney. In the 178-mm individual, only the anterior part of the anterior kidneys and the extreme anterior kidneys remain.

Cyprinids: As already mentioned, the kidneys of Cyprinus carpio and Carassius auratus are similar. Hemiculter kneri differs from these species in the kidney morphology. Conversely, its kidney is more similar to that of the characoids I have examined (Fig. II-21C). Kidneys of Pseudogobio esocinus are completely fused (Fig. II-21D).

Catostomids: Catostomus latipinnis and Hypentelium nigricans (Fig. II-22A, B) have two-chambered swimbladders. Unlike Cyprinus carpio, for instance, their kidney morphology does not diverge much from that of characoids, especially that of Astyanax sp.. The extreme anterior kidneys remain separate.

Homalopterids: The swimbladder being absent in this group, the kidney morphology seems inevitably different from the other ostariophysans so far mentioned. Kidneys of Gastromyzon punctulatus and Hemimyzon zebroidus are thin and not well developed compared with those of other ostariophysans. Anterior kidneys of these two species

are separate (Fig. II-23A, B).

Cobitids: Cobitid swimbladders are small and occupy the anterior part of the peritoneal cavity. Anterior kidneys are separate in Botia citraurata and Leptobotis elongata (Fig. II-24A, B). Extreme anterior kidneys of B. citraurata are fused; they are separate in L. elongata.

Siluriforms: Arius felis, Bagrus sp., Leiocassis sp., Ictalurus melas, Rhamdia sp., Plotosus lineatus have a common kidney morphology: fused extreme anterior kidneys, degenerated anterior kidneys (especially for Rhamdia sp.) and extremely well developed anterior part of the posterior kidney. The large swimbladders of these species are embraced by the fused extreme anterior kidneys and the posterior kidney. The swimbladder of Loricaria sp. is absent and the kidneys are completely fused (Fig. II-26B); complete fusion of the kidneys also occurs in Clarias fuscus (Fig. II-28). The swimbladder of Callichthys sp. is most interesting. It divides into three branches in its front part; the posterior part of the swimbladder is elongate and bag-like. The swimbladder occupies the posterior two-third of the peritoneal cavity. The kidneys are fused and rather short but well developed. They do not extend posteriorly to the posterior half of the swimbladder (Fig. II-27).

Salmoniformes

Salmonoidei: Salmo gairdneri (Salmonidae) and Mallotus villosus, Osmerus sp. (Osmeridae; Figs. II-33 and II-34A, B) share the same kidney type (type 1B). This type is not shared by any species in the other suborders of the Salmoniformes and may be an advanced character state within this order.

Argentinoidei: Argentina sp. (Argentinidae) has an autapomorphic kidney character state in that the two anterior kidneys are widely separate (Fig. II-35).

Esocoidei: Esox americanus (Fig. II-37) has type-2D kidneys (extreme anterior kidneys fused). A similar type has also been found in Talismania sp. (Alepocephalidae; Alepocephaloidei; Fig. II-39). Among umbrids, Dallia pectoralis has type 4B (Fig. II-38A). Umbra limi and U. pygmaea, on the other hand, share unique character states of the kidneys: the separate, extreme anterior kidneys are well developed; anterior and posterior kidneys degenerate; extremely well developed posterior kidney (Fig. II-38B, C). Umbra seems, therefore, a monophyletic group.

Myctophoidei: The autapomorphic condition of the extreme anterior kidneys of Myctophum sp. is worth mentioning. The anterior section of this part of the kidneys extends medially underneath the pharyngeal retractor muscles (Fig. II-40).

Except for salmonoids, the kidneys of other salmoniforms are at least partly separate. There are different de-

degrees of development of each section of the kidney: laterally developed extreme anterior kidneys of umbrids; medially developed extreme anterior kidneys of Esox americanus and alepocephalids, causing fusion of this part of the kidney; extremely degenerated anterior and posterior kidneys of umbrids; well developed extreme posterior kidneys of Esox americanus, Dallia pectoralis and Umbra spp. The extreme posterior kidney of E. americanus and D. pectoralis extends posteriorly beyond the urogenital pore. In D. pectoralis and synodus synodus (Fig. II-41), only the extreme anterior and anterior kidneys are separate; in Galaxias sp., on the other hand, the kidneys are deeply separate (Fig. II-36).

Paracanthopterygii

Batrachoidiformes: Only one species of this order was studied. The kidneys of Opsanus tau (Batrachoididae) are fused posteriorly; anterior kidneys are separate and well developed (type 3D; Fig. II-43).

Gadiformes:

Gadoidei: Microgadus tomcod (Gadidae) has type 4B; the ureters is attached to the left body wall (Fig. II-47).

Ophidoidei: Lepophidium sp. (Ophidiidae) has type 4C (Fig. II-48).

Zoarcoidei: Zoarces viviparus (Zoaridae) has type 4C (Fig. II-49).

Gobiesociformes: Gobiesox strumosus (type 3E) and Tomicodon sp. (type 3F) were studied (Fig. II-44A, B). The common

ureter of the latter is extraordinarily large in its diameter.

Lophiiformes: Three species of this order were examined.

The kidneys of Histrio histrio (Antennariidae), Chaunax sp. (Chaunacidae) and Ogcocephalus nasutus (Ogcocephalidae) are degenerated (only the extreme anterior kidneys are retained; Figs. II-45, 46A, B). Complete separation of the two kidneys occurs.

Percopsiformes:

Amblyopsoidei: Only the extreme anterior kidneys are retained in Amblyopsis spelaea. They are separate. The urinary bladder of this species is huge (Fig. II-42A).

Percopsoidei: Kidneys are completely separate in this group. Percopsis omiscomaycus and P. transmontana differ in the length of their kidneys. Only the extreme anterior and the anterior kidneys are retained in the latter species; in the former species, the two separate kidneys are long; the right one ends close to the urinary bladder (Fig. II-42B, C).

Complete separation of the kidneys is the advanced character state within this group. If this hypothesis is correct, Lophiiformes and Percopsiformes are closely related groups.

Atherinomorpha

Exocoetoidei: Fusion occurs along most part of the kidneys of Halocypselus evolans and Hyporhamphus unifasciatus

(Exocoetidae; Fig. II-50A, B). The extreme anterior kidneys are separate. The kidneys are narrow.

Cyprinodontoidei: Anableps doyii (Anablepidae; Fig. II-51), Fundulus heteroclitus and Profundulus punctatus (Cyprinodontidae; Fig. II-52B) are similar in their kidney morphology— only the posterior part of the posterior kidneys is fused. The kidneys of Cyprinodon variegatus (Cyprinodontidae; Fig. II-52A), Oryzias latipes (Oryziatidae; Fig. II-53B), and Goodea sp. (Goodeidae; Fig. II-53A) are worth mentioning. Only the extreme anterior kidneys are retained in these species. Except for Oryzias latipes, the extreme anterior kidneys of the other species fuse medially. Kidneys of O. latipes are completely separate. The same character state of the kidney (separation) occurs also in Belonesox belizanus and Gambusia sp. (Poeciliidae; Fig. II-54A, B) but degeneration in length of the kidneys does not happen in these species. Cyprinodon variegatus is unique among cyprinodontids not only because of the fusion of the extreme anterior kidneys but also because the extreme anterior kidneys are vertically placed.

Atherinoidei: Kidneys of atherinoids are fused along their lengths except the areas occupied by the interjunctions of the vertebrae. Extreme anterior kidneys of Chilatherina sp. and Membras vegrans (Fig. II-55B, D) are

separate, whereas those of Atherinops affinis and Allantetta harringtonensis (Fig. II-55A, C) are fused. The common ureter of A. affinis attaches to the left body wall; it attaches to the right body wall in Chilatherina sp.. Atherinoid kidneys can be distinguished from those of exocoetoid and cyprinodontoid kidneys because they are wide and fused.

Rosen (1977) suggested the affinity of exocoetoids and cyprinodontoids as supported by character of the gill arches. As far as the present kidney evidence, the interrelationships of these three suborders cannot be resolved. More knowledge is needed about the kidney morphology of other atherinomorphs.

Acanthopterygii

Berciformes

Polymixioidei: Polymixia sp. (Polymixiidae) has a unique character state of the width of the kidneys. They are especially wide and also long; only the posterior kidneys are fused (Fig. II-56). No other fishes have been observed with this kidney structure.

Berycoidei: Only four species representing the family Holocentridae were studied. Myripristis jacobus and Plectrypops retrospinis share a synapomorphic condition of the posterior kidney: it develops laterally to an extraordinarily size (Fig. II-57C, D). Extreme anterior kidneys of Adioryx vexillarius are absent, and

accordingly, the kidney is shortened anteriorly (Fig. II-57A). The posterior kidneys of Holocentrus rufus and A. vexillarius is not well developed. In the former species, it extends posteriorly on both sides of the first haemal spine (Fig. II-57B).

Zeiformes: Kidneys of three zeiform species, Xenolepidichthys dalgleishi (Grammicolepidoidae), Zenion hololepis (Macrurocyttidae), and Zeus japonicus (Zeidae) were examined. Zeus has type 3E (Fig. II-60) and is similar to the general perciform type (see below). Zenion has type 5A (Fig. II-59)— only the extreme anterior kidneys are present and they are separate. Extreme anterior kidneys of Xenolepidichthys are separate and are much more developed than the fused anterior and posterior kidneys (Fig. II-58). Total length of the kidney is least in Zeus.

Lampridiformes: Extreme anterior kidneys of Velifer hypselopterus (Veliferoidei) are well developed and fused (type 2B; Fig. II-61).

Gasterosteiformes: Kidneys of Apeltes quadracus (Gasterosteidae) degenerate in length anteriorly. The anterior part of the anterior kidneys is separate from each other; the posterior kidneys are fused (Fig. II-62). This is a specialized kidney type. Extreme anterior kidneys of Aulostomus maculatus (Aulostomidae) are fused; anterior

and posterior kidneys are separate and only a small area at the extreme posterior kidneys is fused (Fig. II-63). Interestingly, part of the left anterior kidney is isolated from the left extreme anterior and left posterior kidneys. This may be a condition reflecting individual variation. Macrorhamphosus sp. (Macrorhamphosidae) has type 3F, which is also widely distributed among perciforms (see below). The posterior kidney is well developed (Fig. II-64). Some species of Syngnathidae were examined. Corythoichthys sp. and Syngnathus fuscus are similar in that the extreme posterior kidney extends to the caudal region (Fig. II-65A, C). In Hippocampus hudsonius the posterior kidney does not extend posteriorly (Fig. II-65B).

Channiformes: Ophicephalus argus has type 4C. Because the swimbladder extends posteriorly beyond the urogenital orifice, the two ureters have to pass either independently on both sides of the swimbladder or on one side of the swimbladder (to the left or right). The latter conditions are both found in ophicephalids. In O. argus, O. micropeltes, and O. obscurus, they pass to the right; they pass to the left in other species examined. One may hypothesize that (1) either one of these character states is the advanced state, or (2) both of them are advanced states that are evolved independently from a third state. Due to the fact that the closely attached ureters in most

perciforms pass to the left side of the first haemal spine on their way to the urogenital orifice, perhaps the condition of O. argus, O. micropeltes, and O. obscurus is the advanced state.

Scorpaeniformes

Scorpaenoidei: Degeneration of the posterior kidney and (or) the posterior part of the anterior kidneys occurs in the two scorpaenids (Scorpaena sp. and Scorpaenodes caribbaeus). Extreme anterior and anterior kidneys of the former species are completely fused, whereas in the latter species, they are deeply separate (Fig. II-68A, B). No degeneration of any part of the kidneys was seen in the three triglid species examined. The fused posterior kidney of Lepidotrigla stonuchii and Pterygotrigla hemisticta is extraordinarily well developed (Fig. II-69A, C); their anterior and extreme anterior kidneys are separate. Complete separation of the two kidneys characterizes Peristedion miniatum (Fig. II-69 B).

Cottoidei: The kidney of Cottus cognatus is well developed and its form is classified as type 4C. The left side of the posterior kidney is laterally expanded (Fig. II-70).

Synbranchiiformes: The kidney of Synbranchus marmoratus is long and subdivided into four parts: two small pieces

(the extreme anterior kidneys) lie beside each other ventral to the first few vertebrae; the third and fourth pieces are placed antero-posteriorly. The fourth piece is longest among them (Fig. II-67).

Perciformes: Types 3E and 3F configurations most commonly occur among perciform fishes. These configurations have some characteristics in common. Parts of the posterior kidneys are fused anterior to the base of the first haemal spine; medial separation of the left and right kidneys develops to various degrees. I will concentrate only on those families with certain variations that may be applicable to the elucidation of phylogenetic relationships and on others in which the diversity of kidney form within the group should be pointed out as base-line information that may prove to be helpful for further studies. As for those groups in which variation of kidney form is confined to types 3D, 3E, and 3F, they will be omitted in this section. However, their kidney configurations are shown in the figures (also see Table 1).

Brachioistegidae

Kidney morphology of Brachioistegus japonicus and Malacanthus plumieri (Fig. II-74A, C) are similar in certain aspects— only the extreme posterior kidneys are fused. For M. plumieri the extreme posterior kidney is fully developed. Unlike these species, there are several fused areas along

the anterior and posterior sections of the kidney of Caulo-latulus princeps (Fig. II-74B). The extreme posterior kidneys of these species are placed at the posterior end of the peritoneal cavity. Unlike B. japonicus and C. princeps, in which the urogenital pore is close to the posterior end of the peritoneal cavity, this pore of M. plumieri is relatively anterior in the abdomen. As a consequence, the ureters from the extreme posterior kidney to the urinary bladder of M. plumieri are much longer than those of the other two species. The urinary bladder of B. japonicus and C. princeps is next to the extreme posterior kidney. The character state of M. plumieri is very unusual and probably is an autapomorphic state within this family.

Centrarchidae

The various configurations of centrarchid kidneys are depicted in figure II-77. Elassoma zonatum and Micropterus spp. have type 3E (Fig. II-77F, U, V). Out-group comparison suggests that this is the type of the hypothetical ancestor of centrarchids.

In other centrarchids, kidney morphology varies from this primitive type. The extreme anterior kidneys fuse in Archoplites, Centrarchus, Pomoxis annularis, P. nigromaculatus, and Lepomis spp. (including L. gulosus, which had been placed in the abandoned genus Chaenobryttus), but not in L. marginatus and L. punctatus (Fig. II-770, R; arrow points to the area of fusion). This character state of the

extreme anterior kidneys, which among perciforms is limited to these genera, is hypothesized as an apomorphic character state within the centrarchids.

It is possible to set up a transformation series of the various forms of the extreme anterior kidneys within the genus Lepomis. L. marginatus and L. punctatus have separate extreme anterior kidneys, whereas they are fused in other species of Lepomis. We may hypothesize that either the separate extreme anterior kidneys or fused extreme anterior kidneys is primitive in this genus. Under the former hypothesis, a situation of "convergence" must be postulated, while the latter requires a secondary loss of connection of the extreme anterior kidneys. At the present time, no other evidence (both ontogenetic and out-group comparison) from kidney morphology leads me to prefer either one of these alternative hypotheses.

The posterior kidneys of most centrarchids are fused in front of the base of the first haemal spine (Fig. II-77; a small circle represents the base of this spine). In Centrarchus and Pomoxis, the posterior kidneys fuse behind the base of the first haemal spine (Fig. II-77E, W, X)— a hypothesized advanced character state.

In Enneacanthus chaetodon, the posterior kidneys are separate and extend to the third haemal spine before descending toward the urogenital pore near which they fuse to form the extreme posterior kidney (Fig. II-77G). In Enneacanthus obesus, the kidneys extend to the base of the basal anal

pterygiophore as separate units (Fig. II-77I). These are postulated as autapomorphic character states.

The posterior kidneys of Acantharchus, Ambloplites cavifrons (but not Ambloplites rupestris), and Archoplites fuse anterior to the first haemal spine, extend posterior on both sides of this spine towards the base of the basal anal pterygiophore and then fuse to give rise to the extreme posterior kidney (Fig. II-77A, B, D). In Acantharchus pomotis, the kidney tissue adjacent to the first haemal spine has a highly developed and apomorphic condition; it is fused medially and covers the first haemal spine ventrally (Fig. II-77A). In contrast to Acantharchus, Ambloplites cavifrons, Archoplites, and Enneacanthus chaetodon, the extreme posterior kidneys of Ambloplites rupestris, Centrarchus macropterus, Enneacanthus gloriosus, Pomoxis annularis, P. nigromaculatus and all species of Lepomis except L. humilis, "connect" to the posterior kidneys only through the ureters (Fig. II-77). These two character states are apomorphous in relation to that of Micropterus.

Without ontogenetic evidence or knowledge of the sister-group of Enneacanthus, it becomes difficult, if not impossible, to determine the character state of the hypothetical ancestor of Enneacanthus. Because the character states of Enneacanthus chaetodon and E. obesus are unusual not only in centrarchids but also in perciforms, and because the kidney form of E. gloriosus has a wide distribution within centrarchids, I assume that the form of the latter species char-

acterizes the genus Enneacanthus. If Acantharchus is the sister-genus of Ambloplites (see below), out-group comparison leads to the conclusion that the hypothetical ancestral character state of the kidney of Ambloplites is like that of Acantharchus pomotis (having the posterior extensions of the posterior kidney fused medially). When applied to the postulated phylogeny of the species of Acantharchus and Ambloplites, the above hypothesis reveals a sequence of character states that require minimal evolutionary change.

The extreme posterior kidney of most centrarchids that possess this structure is overlain by a thin layer of membranous tissue. In Lepomis species (including L. humilis), however, this tissue layer increases in thickness (Fig. II-174). This is treated as an advanced character state uniting Lepomis species as a monophyletic group.

The shape of the extreme posterior kidney varies. The deep V-shaped configuration of Pomoxis (Fig. II-77W, X) differs from the oval-shaped, which generally appears in other centrarchids. This can be treated as an advanced character state supporting the monophyly of Pomoxis species.

The distribution of the character states of the kidney characters are summarized in figure II-175. Conflict in the distribution of apomorphic character states leaves unsolved the phylogenetic position of Archoplites.

On the basis of kidney morphology, the following hypotheses concerning the phylogeny of centrarchid genera may be reached (Figs. II-176, 177). The monophyly of the group

including Lepomis, Enneacanthus, Ambloplites, Acantharchus, Archoplites, Centrarchus, and Pomoxis is supported by the possession of the extreme posterior kidney. Centrarchus and Pomoxis form a monophyletic group (Archoplites and Lepomis may be also included) by sharing the synapomorphic character state of the fused extreme anterior kidneys. Centrarchus and Pomoxis are sister genera, as suggested by the fusion of the posterior kidneys behind the base of the first haemal spine. The monophyly of Lepomis is indicated by the thick tissue layer over the extreme posterior kidney. Pomoxis is a monophyletic group as shown by the V-shaped extreme posterior kidney. The phylogenetic position of Archoplites and Lepomis is obscure.

The study of Smith and Bailey (1961) on the dorsal-fin supports of percoid fishes shows there is some evidence for considering Acantharchus, Ambloplites, Archoplites, Centrarchus, and Pomoxis a monophyletic group since they share the advanced character state of a high number of anal spines (5 to 9 versus 3). Branson and Moore (1962), however, argued that a low number of anal spines is the advanced character state in this family. Acantharchus and Ambloplites form a monophyletic group as indicated by the possession of one additional dorsal spine and pterygiophore (Smith and Bailey, 1961).

Eaton's (1956) study on the olfactory organs of centrarchids throws light on the monophyly of Archoplites, Pomoxis, and Centrarchus. Two possible synapomorphies of

the olfactory organs were discovered by Eaton. In Archo-
plites, Centrarchus, and Pomoxis the olfactory epithelium in
the floor of the olfactory sac has paired folds; alternate
folds are swollen. In other centrarchids (e.g., Elassoma,
Lepomis, and Micropterus), this pairing has not been found,
and either the more posterior, or all of the folds may be
swollen. Enneacanthus and Elassoma show a reduction in the
number of folds.

The monophyletic status of Pomoxis is indicated by a
lower number of dorsal spines and predorsal bones (Smith and
Bailey, 1961). However, the dorsal-fin supports offer no evi-
dence for the systematic position of this genus.

Bailey (1938) and Branson and Moore (1962) agreed that
Chaenobryttus (=part of Lepomis), Lepomis, and Micropterus
shared a common ancestor although they disagreed in how
these genera are related. Avise, Straney and Smith (1977),
by evidence of genetic similarity among centrarchid genera,
have reached a similar conclusion. On the basis of the fin
structures, Enneacanthus, Lepomis, and Micropterus share
only primitive character states for the dorsal-fin supports
(the formula of the predorsal bones and fin supports is 0-0-
0-1) and in the number of dorsal and anal spines (10 and 3,
respectively; Smith & Bailey, 1961). The hypothesis of Bran-
son and Moore with respect to the monophyly of the unit
formed by Lepomis and Micropterus is founded on the apparent
misinterpretation that a low number of anal spines is the
advanced character state in Centrarchidae. Since a low

anal-spine count is so widely distributed among perciforms, I cannot accept their hypothesis that it is an apomorphic character state within centrarchids. My judgement on the characters of the acoustico-lateralis system (lachrymal with two anterior directed branches, two openings on posttemporal canal, infra-orbital canal not greatly interrupted, and five mandibular openings, common in Lepomis and Micropterus) is that they are not synapomorphic character states for Lepomis and Micropterus, because these character states occur also in other centrarchid genera. These interpretations point to the idea that there is no evidence to support the monophyly of Lepomis and Micropterus.

The autapomorphic character states of Enneacanthus (lachrymal with a single anteriorly directed branch, loss of 0-2 dorsal spines and one predorsal, and probably 4 mandibular openings, a character shared only by Elassoma) and its plesiomorphic character states (e.g., 3 anal spines) do not lead to a satisfactory conclusion with respect to its systematic position.

Lepomis humilis and Elassoma are controversial taxa. The former possesses many autapomorphic character states, such as the absence of the extreme posterior kidney and the presence of a very large and slit-like lateral line pore (except in the lachrymal component); other species of Lepomis have rounded pores (Branson et al., 1962). Ortenburger and Hubbs (1927) erected a separate genus (Allotis) for this species. L. humilis seems more closely related to

other Lepomis species than to other centrarchids since it shares an advanced character state with the members of that genus (extreme posterior kidney covered by a thick layer of tissue).

Jordan and Evermann (1896) ranked the genus Elassoma as a separate family, Elassomidae. Branson and Moore (1962) echoed this classification. Avise, Straney and Smith (1977: 255) stated, "Most workers feel that elassomids either diverged very early from primitive centrarchid stock or else have completely different affinities." As far as its kidney morphology is concerned, Elassoma zonatum possess plesiomorphic kidney character states except the autapomorphic (elongate) urinary bladder. Although the systematic position of Elassoma cannot at the present time be resolved, its kidney character states lead me to agree with the general opinion of most ichthyologists (e.g., Avise, Straney and Smith) regarding this genus.

The hypotheses reached on the basis of my interpretations of the data of Eaton (1956; monophyly of Archoplites, Pomoxis, and Centrarchus), and those of Smith and Bailey (1961; monophyly of Pomoxis, Acantharchus, Ambloplites, Archoplites, Centrarchus as summarized in figure II-176) show some agreement with the phylogeny derived from kidney morphology (Fig. II-175). If these hypotheses are correct, then (1) the fusion of the extreme anterior kidney has appeared at the level of the hypothetical ancestor that would give rise to Pomoxis, Centrarchus, and Archoplites. The

occurrence of a similar character state in most Lepomis would be a result of "convergence," and (2) the similarity of Archoplites, Acantharchus, and Ambloplites in the direct connection of the posterior and extreme posterior kidneys is "parallelism."

It seems clear that the disagreements in the hypotheses made by various authors are the outcome of differing philosophies about the concept of phylogenetic relationships, namely, phenetic versus cladistic concepts. Agreement may never be reached as long as this separation of basic concepts exists.

Centropomidae

No synapomorphic kidney character is shared by Centropomus undecimalis, Chanda gymnocephala, and Lates calcarifer. The kidneys of the first two species are types 3F and 3E, respectively (Fig. II-78A, B). Lates calcarifer has type 3D: only the extreme anterior kidneys are separate and the common ureter is large in diameter. The position of the ureters of C. undecimalis in relation to the first haemal spine varies. They lie on the ventral surface of the first haemal spine (45- and 85-mm individuals), or on the left (70- and 100-mm individuals), or on the right (94-mm individual) of the spine.

Cepolidae

The elongate swimbladder of Acanthocepola krusensterni

occupies the areas beyond the first haemal spine and, as a consequence, the ureters pass to the left of this spine toward the urogenital pore. The swimbladder of Cepola rubescens is limited to the front of this spine. Anterior and extreme anterior parts of the left kidney of C. rubescens are degenerate and the kidney is classified as type 3F (Fig. II-79B). A. krusensterni, on the other hand, has type 3E (Fig. II-79A).

Owstoniids and cepolids have been placed in a superfamily Cepoloidae by some ichthyologists. A specimen of Owstonia tosaensis was examined. The anterior kidneys of this specimen were badly preserved. The posterior kidneys are fused in front of the first haemal spine (Fig. II-107). Therefore, no synapomorphic kidney character is present in these families.

Cheilodactylidae

Greenwood et al. (1966) put Gadopsidae, Cirrhitidae, Chironemidae, Aplodactylidae, Cheilodactylidae, and Latridae in sequence in their classification of the perciform families. Nelson (1976) placed the Gadopsidae in the superfamily Gadopsoidea and the other families as mentioned in the superfamily Cirrhitioidea. Interestingly, kidneys of aplodactylids (Crinodus lophodon; Fig. II-71), cheilodactylids (Goniistius zonata, Nemadactylus macropterus; Fig. II-80A, B), chironemids (Chironemus marmoratus; Fig. II-81), cirrhitids (Amblycirrhitus pinos, Cirrhitichthys falco,

Paracirrhites bimacula, Paracirrhites sp.; Fig. II-83A-D) are well developed and belong to type 3D. Cirrhitids have well developed anterior and posterior kidneys with a narrow mid-section. Gadopsis marmoratus (Gadopsidae), on the other hand, has type 4E (Fig. II-90), which is infrequent in perciforms. Type 3D is also rare in perciforms. I am treating types 3D and 4E as apomorphic character states. These hypotheses lead to the conclusions that (1) Aplodactylidae, Cheilodactylidae, Chironemidae, and Cirrhitidae form a monophyletic group, (2) the autapomorphic kidney character of Gadopsis marmoratus (type 4E) does not allow me to come to any meaningful proposal concerning the systematic position of Gadopsidae.

Cichlidae

Two kidney types were found in Cichlasoma and Haplochromis. Type 3C is most commonly distributed in these genera, e.g., C. champotonis, C. heterospilum, C. salvini, H. eucinostomus (Fig. II-82A, B, F, G) and probably also in C. hyorhynchum (Fig. II-82C). The posterior kidney of C. intermedium and C. motaguense extends continuously to the anal region (Fig. II-82D, E). This character state is apomorphic in the genus Cichlasoma. C. intermedium and C. motaguense are indicated as sister-groups.

The infrequent occurrence of type 3C in perciforms makes further study of the kidney morphology of other cichlid genera interesting. Whether this character state is

a synapomorphic one at the familial or generic level remains to be investigated.

Embiotocidae

I have examined only three genera of 20 genera in this family. Two types of kidney were revealed. An "isolated" extreme posterior kidney was clearly seen in Brachyiotius frenatus and Cymatogaster aggregata (Fig. II-86A, B). A piece of tissue is attached to the anterior tip of the urinary bladder in Ditrema temmincki (Fig. II-86C). This might be the homolog of the extreme posterior kidney of the other two species. Embiotocid kidneys are therefore characterized by the isolated extreme posterior kidney (type 4A).

Only the rear part of the posterior kidneys of B. frenatus and C. aggregatus are fused; in D. temmincki, anterior and extreme anterior kidneys are fused and the kidney is well developed.

An isolated extreme posterior kidney occurs also in enoplosids (Enoplosus armatus), which is listed as being close to the Embiotocidae by Greenwood et al. (1966).

Kyphosidae

A character common to the members of this family is the complete fusion of the anterior and posterior kidneys; only the extreme anterior kidneys are separate (type 3D; Fig. II-94A, B, C, D, E, G). The kidneys of Scorpius aequipinnis differ from other kyphosids (including Scorpius georgianus)

in that posterior extensions of the posterior kidney appear (Fig. II-94F).

Nandidae

No synapomorphic character was revealed in the two nandid species I examined. Nandus nebulosus has a general perciform kidney type (type 3E; Fig. II-104B); Monocirrhus polycentrus uniquely has type 5D (complete separation of the left and right kidneys; Fig. II-104A). Comparison of the kidney morphology of other nandids should be made.

Owstoniidae (see Cepolidae).

Percidae

Unlike other percids, only a narrow section of the extreme posterior kidneys is fused in Aspro streber (Luciopercinae; Fig. II-109C).

Kidneys of Acerina schraetser and Perca flavescens (Percini; Fig. II-109A, F) are similar in that their well developed extreme anterior kidneys are fused.

Two kidney types occur in Etheostomatini. In one, the extreme anterior kidney and part of the anterior section of the anterior kidneys are fused (Ammocrypta vivax and Percina caprodes; Fig. II-109B, G). These parts in P. caprodes are well developed. In the other type, as represented by Etheostoma (E. caeruleum and E. olmstedii; Fig. II-109D, E), the extreme anterior kidneys are separate; other parts are fused.

In order to interpret the relationships of these subfamilies, other luciopercines must be examined. Asprostreber, except for the separate extreme anterior kidneys, is similar to Acerina schraetser, Perca flavescens (Percinae) and Percina caprodes (Etheostomatini) in that only a narrow part of the extreme posterior kidney is fused. If the extreme anterior kidneys of other luciopercines are separate, and if we assume that each of these subfamilies is a monophyletic group, then percines and etheostomatines may be sister-groups, as indicated by the synapomorphic character state of the extreme anterior kidney (fusion). Within the latter subfamily, Etheostoma seems to be a natural group as indicated by the advanced character state of fusion of most parts of the kidneys.

Pomacanthidae

Kidneys of Centropyge bicolor and Holacanthus tricolor are completely fused except for some small areas occupied by the interjunctions of the vertebrae (Fig. II-111A, B). Extreme anterior kidneys of Pomacanthus paru are separate, but most other areas are fused (Fig. II-111C). Pomacanthus sp. differs from the latter species in that only the rear parts of the posterior kidneys are fused (Fig. II-111D). The character state shared by C. bicolor and H. tricolor seems synapomorphic, indicating that these species are more closely related to each other than to Pomacanthus species.

Pomacentridae

The extreme posterior kidney appears in Dascyllus tri-
maculatus, Eupomacentrus sp., E. dorsopunicans, E. partitus
 (Fig. II-112E-H) and probably also in Microspathodon chry-
surus (Fig. II-112I), in which a piece of tissue is develop-
 ed between the proximal ends of the ureters next to the pos-
 terior kidney. These genera might be related. Chromis
cyanea and C. multilineatus are alike in that their anterior
 kidneys and the anterior sections of the posterior kidneys
 are narrow; only the rear parts of the posterior kidneys are
 fused (Fig. II-112C, D). A similar condition occurs in
Abudefduf saxatilis (Fig. II-112A). The kidney of Amphi-
prion ocellatis is a general perciform type (type 3E; Fig.
 II-112B).

Priacanthidae

Extreme anterior kidneys of Cookeolus boops and Pseudo-
priacanthus altus are fused (Fig. II-115A, C). The poster-
 ior kidneys of these species extend posteriorly along the
 sides of the first haemal spine. No fusion of these parts
 of the posterior kidney occurs in C. boops, whereas an ex-
 traordinarily well developed fused area (the extreme poster-
 ior kidney) appears in P. altus. For Priacanthus cruentatus,
 the kidney is a general perciform type (type 3F; Fig. II-115
 B).

Serranidae

Kidneys of species of four genera were examined. The kidney of Petrometopon cruentatu, which is autapomorphic within the family, resembles that of Microspathodon chrysurus (Pomacentridae). Two pieces of tissues lie close to the posterior kidney between the ureters (Fig. II-120A). Morone americana is primitive in its kidney morphology (type 3F; Fig. II-120B). The posterior kidneys of Liopropoma mowbrayi and Siniperca chuatsi are slightly enlarged laterally (Fig. II-120A, D) to which a huge urinary bladder is directly connected. This character state does not occur often in perciforms. I propose a close relationships between these two species.

Teraponidae

Swimbladders of teraponid are composed of two chambers. Their kidneys are type 3D, with the enlarged mid-portion of the kidney (Fig. II-123A-D). A similar kidney occurs in ostariophysans with two-chambered swimbladders.

Labroidae

Labrid kidneys are fully developed and most of them are type 3D. However, there are some variations: (1) posterior extensions of the posterior kidneys are present in Bodianus rufus and Clepticus parrai (Fig. II-127A, C); (2) an isolated extreme posterior kidney occurs in Cirrhitilabrus solorensis (Fig. II-127B); (3) the distal end of the extreme posterior

kidneys of Tautoga onitis and Tautogolabrus adspersus expands laterally giving rise in a rectangular shape (Fig. II-127K, L). These character states are probably apomorphic within this family.

Unlike labrid and scarid kidneys in which the anterior, posterior, and extreme posterior kidneys, if they occur, are fused medially, Odax pullus has type 2C, and only the extreme anterior and extreme posterior kidneys are fused medially (Fig. II-128). This is autapomorphic in the suborder.

In relation to other scarids, Sparisoma viride has not only a special intestinal pattern and liver shape (see Section IV), but also kidney configuration. As already mentioned, the kidneys of most scarids examined (Scarus croicensis and Sparisoma radians) are type 3D and their extreme anterior kidneys are separate by the pharyngeal retractor muscles. The extreme anterior kidneys of S. viride are fused and lay on the ventral surface of the muscles, which are uniquely fused at their attachments on the vertebrae (Fig. II-129C).

Trachinoidei

No unique kidney character for trachinoids was found. However, there are some variations within this group. Kidneys of Champsodon sp. are deeply separate and only the rear parts of the extreme posterior kidneys are fused; the ureters leave at the left posterior kidney and attach to the

left body wall (Fig. II-131). The extreme posterior kidney of Limnichthys fasciatus (Limnichthyidae) extends to the caudal region (Fig. II-135). Parapercis ommatura, P. sexfasciatus (Mugiloididae) and Uranoscopus oligolepis (Uranoscopidae) are similar. Their anterior kidneys and the anterior parts of the posterior kidneys are widely separate (Figs. II-136A, B and II-140, respectively). The common ureter of Trichodon trichodon is extraordinarily wide in diameter (Fig. II-139). These variations are probably advanced character states within the suborder. The primitive type may be 3E, as in opisthognathids (Fig. II-137) and trachinids (Fig. II-138).

Notothenioidei

The primitive kidney type of this suborder is probably 3E, as in Harpagifer bispinis and Bovichthys sp. (Figs. II-142A and II-141, respectively). The extreme anterior kidneys of the latter species are especially large. Two unique kidney forms were found in other notothenioids. The extreme posterior kidney of Notothenia sp. is enlarged laterally; its extreme anterior kidneys are fused (Fig. II-142B). This character state of the extreme anterior kidneys is autapomorphic in this suborder. The character state of the extreme posterior kidney is shared also by Trematomus sp. (Fig. II-142C). The extreme anterior kidneys and the anterior kidneys of Trematomus sp. are separate— a specialized character state in this suborder. On a basis of the

kidney morphology, Notothenia sp. and Trematomus sp. seem more closely related than to other notothenioids examined.

Blennioidei

Variation of kidney morphology is low among blennioids (Figs. II-143-1 to II-143-10). Kidneys are types 3D or 3E.

Kidneys of Chaenopsis alepidotus (Chaenopsidae) are deeply separate (Fig. II-143-11), of type 4E, shared by Scytalina cerdale (Fig. II-143-21) and Lumpenus lumpretaeformis (Fig. II-143-25).

Among clinids, Lepidoblennius marmoratus is most interesting, and different from other clinids, the extreme anterior kidneys are thin and widely separate; a small fused area exists at the posterior end (Fig. II-143-14). Other clinids (Acanthemblemaria maria, Labrisomus nuchipinnis, Malaccoctenus boehlkei, Paraclinus nigripinnis, Springeratus xanthosoma, Starksia lepicoelia) have either types 3E or 3D (Fig. II-143-12, 13, 15, 16, 17, 18).

Pholis gunnellus (Pholididae) is unique among fishes in that its kidney is overlain by a thick muscle layer. This special condition does not occur in Opisthocentrus ocellatus. Their kidney types are 4C, except that the anterior and posterior kidneys of P. gunnellus are very narrow (Fig. II-143-20), whereas these parts in O. ocellatus are well developed (Fig. II-143-19).

Lumpenus lumpretaeformis is the only stichaeid examined in which the kidneys are deeply separate. In Cebidichthys

violaceus and Epigeichthys rupestris, the kidneys are completely fused (Fig. II-143-23, 24). The anterior section of the kidney of E. rupestris bends to the right side of the vertebrae column. Anoplarchus purpurescens differs from other stichaeids. Extreme anterior kidneys and the mid-section of the kidney are separate medially (Fig. II-143-22).

Kidney of Tripterygion etheostoma (Tripterygiidae) is short and belongs to type 3A (Fig. II-143-26).

Complete fusion characterizes the kidney form of Zeprora silenus (Fig. II-143-27)

Icosteoidei

In Icosteus enigmaticus, except for a small section of the extreme anterior kidneys, the kidneys are fused (type 3D; Fig. II-144).

Ammodytoidei

Ammodytes americanus has type 4B (Fig. II-145). The extreme posterior kidney extends to the caudal region.

Callionymoidei

Complete separation of the kidneys (type 5C; Fig. II-146A-D) characterizes all callionymids (also see Table 1). No degeneration of any part of the kidneys occurs in this group; the extreme posterior kidney is absent from all callionymids.

Gobioidei

At least part of the anterior kidney in Eleotus fusca and Awaous sp. is degenerate so that the total kidney length of these species is shorter than in other gobiids (Fig. II-147C, G). Interestingly, only the extreme posterior kidney is retained in E. fusca. For Gobius hadropterus and Plagiogrammus sp. (Fig. II-147D, I), only the anterior sections of the kidneys are separate. Small sections of the anterior kidneys of Acanthogobius flavimanus and Lophogobius cyprinoides (Fig. II-147A, E) are fused, whereas the rest of the anterior kidneys and the anterior section of the posterior kidneys of these species are separate. For Ophiocara aporos and Periophthalmus koelreuteri the kidneys are deeply separate (Fig. II-147F, H).

Like those of Ophiocara aporos (Gobiidae), the kidneys of Gobioides sp. (Gobioididae) are deeply separate (type 4E; Fig. II-148).

Kraemeria samoensis has type 4C (Kraemeridae; Fig. II-149), as do some microdesmids, e.g., Gunnellichthys pleurotaenia and Paragobiodon echinocephalus (Fig. II-150A, B), but not in Pholidoichthys leucotaenia, which has type 4F. The extreme posterior kidney of Trypauchenichthys sp. (Trypauchenichthyidae) extends to the caudal region (type 4B; Fig. II-151).

Kurtoidei, Acanthuroidei, and Tetraodontiformes

Kurtids are familiar to ichthyologists for their exotic

occipital hook. They are peculiar also because of their expanded ribs, which form a bony case enclosing most of the air bladder (Weber et al., 1951). De Beaufort (cf. Weber et al., 1951:82) placed them in an order of their own and related it to the Berycoidea based on the assumption that an orbitosphenoid is present in Kurtus. De Beaufort later changed his mind and agreed with Regan's classification, wherein kurtids are ranked a suborder in the Percomorpha (Weber et al., 1951). The change was due to his reinterpretation of the orbitosphenoid as the ossified interorbital membrane.

In Kurtus gulliveri, the anterior and posterior kidneys are absent. There are well developed, and separate extreme anterior kidneys (Fig. II-152A). The ureters leave these parts and extend posteriorly along the surface of the vertebral column toward the anal region. K. indicus resembles K. gulliveri in its kidney size; the extreme anterior kidneys, however, fuse at their rear portions (Fig. II-152B).

Degeneration of the anterior and posterior kidneys occurs also in acanthurids. Naso annulatus is an exception, for rudimentary posterior kidneys are retained (Fig. II-153C). For the remaining acanthurid genera the posterior kidneys, and in some cases the rear part of the anterior kidneys, are absent. The front part of the anterior kidneys and the extreme anterior kidneys are well developed. The left and right kidneys may be fused, e.g., Acanthurus bahianus, Ctenochaetus striatus, Naso annulatus, and

Paracanthurus hepatus (Fig. II-153A-D) or separate, e.g., Acanthurus coeruleus, Prionurus microlepidotus, and Zebra-soma flavescens (Fig. II-153E, F). In short, acanthurids have well developed extreme anterior kidneys, front part of the anterior kidneys, degenerate posterior kidneys (in some cases, even the rear part of the anterior kidneys are degenerate), and a short total length of the kidneys.

In Zanclus cornutus, total kidney-length is as short as that of most acanthurids (Fig. II-153G). The kidney nevertheless is fully developed and occupies the dorsal part of the peritoneal cavity, between the base of the first haemal spine and the anterior limit of the peritoneal cavity. The distance between these two reference points is shorter than in acanthurids and siganids, because of the shape of the cavity in Z. cornutus, which is dorso-ventrally elongate. It seems that the kidney of Z. cornutus is homologous to the extreme anterior and anterior kidneys of acanthurids. Zanclus and acanthurids seem closely related, as indicated, for example, by intestinal pattern. The shape of the peritoneal cavity of Zanclus is not found in any other families that have been considered as possible close relatives. The primitive state of kidney morphology of acanthuroids (including Zanclus), therefore, should be similar to the acanthurine kidneys described.

Siganus sp. has type 3D (Fig. II-154B), which is generalized for perciforms. Lo vulpinus is autapomorphic: the left and right anterior and posterior kidneys are completely

separate; the extreme posterior kidney is connected to the posterior kidneys by the ureters (Fig. II-154B).

Without exception in tetraodontiforms, the posterior kidneys are absent; the anterior parts of the anterior kidneys and the extreme anterior kidneys are well developed (Fig. II-172). Except for Paratriacanthodes retrospinis, in which the kidneys fuse posteriorly (Fig. II-172A), the left and right kidneys are widely separate (Fig. II-172B-M).

Among perciforms so far examined, few have the posterior section degenerated. Only in kurtoids, acanthuroids, and tetraodontiforms among other teleosteans is this character state dominant. Of course, this kidney type is not unique to these perciform groups, for it appears also in Cyprinodon variegatus (Cyprinodontidae) and Percopsis transmontana (Percopsidae). However, it is not characteristic of the families Cyprinodontidae and Percopsidae; Profundulus punctatus (Cyprinodontidae) and Percopsis omiscomaycus (Percopsidae) have the general kidney type. The distribution pattern of this kidney type seems random at this high taxonomic level. As for acanthopterygians, we may consider the following propositions with regard to kurtoids, acanthurids, and tetraodontiforms: (1) the similarity in kidney type is only an artifact of the evolutionary processes; (2) the similarity is synapomorphic, reflecting monophyly of these taxa; (3) the similarity of tetraodontiforms to kurtoids and acanthurids is an example of parallelism, and the latter two taxa may be closely related in sharing this character

state. Siganiids have a general kidney type (type 3D). Their affinity with acanthurids is not supported by kidney morphology.

Scombroidei

Most scombroid kidneys are narrow. The anterior kidneys are separate to various degrees. In Auxis sp. and Sarda sarda, which are placed in the Tribe Thunnini of Scombrinae (Nelson, 1976), the anterior kidneys are thick and the common ureter is wide in diameter (Fig. II-155A, E). Extreme anterior kidneys of Auxis sp. are fused completely. In Benthodesmus atlanticus and Trichiurus lepturus (Trichiuridae) the kidneys are long and narrow, the urogenital pore is located anterior to the posterior end of the kidney (Fig. II-155F, G). The ureters of Scomber colias are coiled and wrapped by a thin membrane (Fig. II-155B), which is a specialized condition among fishes. In Scomberomorus sp., the kidney morphology is primitive (type 4C). In Scomberomorus commersonianus the posterior kidney extends to the anal region (type 4C). Auxis sp. and Sarda sarda seem closely related, as indicated by the enlarged common ureter.

Stromateoidei

Anterior kidneys of all stromateoids examined are fused for most part of their length. In Cubiceps sp. and Psenes cyanophrys (Nomeidae; Fig. II-157A, C) there is no separate area in the anterior kidneys. In nomeids (Nomeus gronovii

and Psenes cyanophrys, but not in Cubiceps sp.; Fig. II-157B, C) and stromateids (Pampus argenteus and Peprilus sp.; Fig. II-158A, B), an arm-like out-growth occurs on each side of the extreme anterior kidney embracing the pharyngeal sacs ventrally. These out-growths are fused medially in Nomeus gronovii and Psenes cyanophrys. These structures are synapomorphic, indicating relationship between nomeids and stromateids. Nomeids are characterized by the fusion of these structures. Cubiceps sp. is autapomorphic in having an "isolated" extreme posterior kidney.

Kidneys of Psenopsis anomala (Centrolophidae) and Tetragonurus cuvieri (Tetragonuridae) are similar and primitive (type 4C) in relation to the other two groups of this suborder (Figs. II-156, II-158).

Anabantoides

The kidneys of anabantoids can be sorted into two major types: types 1 and 3. Colisa lalia Trichogaster trichopterus, and Helostoma temminckii (Figs. II-161B, E and II-162) have kidneys of type 1A, although the features of the extreme anterior kidneys are different among them. Other anabantoids have type 3. The transverse distance between the two anterior kidneys varies. In Ctenopoma (C. nanus, C. kingsleyae, and C. nigropannosus), the anterior kidneys are placed closely to the pharyngeal retractor muscles (Fig. II-160B-D) and the distance between them is

short compared with that of Anabas testudineus, Betta splendens, Macropodus opercularis, and M. viridiauratus (Figs. II-160A, II-161A, C, D) in which the anterior kidneys are not close to these muscles, and, as a consequence, the distance is longer. The width of the fused section of the anterior kidneys in Ctenopoma spp. is as wide as that of Colisa lalia and Trichogaster trichopterus, and especially wide in C. nanus. The posterior kidneys of Macropodus opercularis and M. viridiauratus include the base of the first haemal spine, whereas it includes the first three haemal spines in Betta splendens. In Ctenopoma nanus, the posterior kidney extends beyond the first haemal spine, by passing through the haemal canal, and extends to the space between the base of the first and second haemal spines. In this case, the posterior kidney does not include the haemal spine. For other Ctenopoma species, the plate-like base of the first haemal spine stops the posterior development of the posterior kidney. I propose that the character state of Macropodus and Betta is synapomorphic, and that of Ctenopoma nanus is autapomorphic.

The general perciform kidney type (4C) of Luciocephalus pulcher (Luciocephaloidei), which has been considered as close relative of anabantoids, provides information for determining the nature of the character states within anabantoids. Under the assumption that anabantids, belontiids, helostomatids, and osphromenids are monophyletic groups, the following interpretations can be made. That the anter-

ior kidneys are placed away from the pharyngeal retractor muscles is a very unusual character state, shared by anabantids and belontiids. I postulate this an advanced character state at the familial level, one uniting these families as a monophyletic group. Ctenopoma has the autapomorphic character state of the lateral expansion of the kidneys among anabantids. Complete fusion of the kidneys of Colisa and Trichogaster, as a synapomorphic character state, unites these genera as a monophyletic group. Betta and Macropodus form another monophyletic group by sharing the synapomorphic character state of the posterior kidney. Complete fusion of the kidneys is shared also by Helostoma, but its extreme anterior kidney has an anteriorly expanded area different from that of T. trichopterus. However, this expansion implies the possible affinity of this family to Trichogaster and Colisa.

Kidneys of Osphromenus goramy are fused in most parts, except for a small section in the extreme anterior kidneys. The systematic position of O. goramy and Helostoma temmincki remain to be investigated.

Luciocephaloidei

Luciocephalus pulcher has a general perciform type (4C; Fig. II-164). Its relationship to anabantoids is not supported by kidney morphology.

Mastacembeloidei

Complete fusion of the kidneys occurs in Mastacembelus congricus (Fig. II-165A). However, the extreme anterior kidneys remain separate in M. sinensis (Fig. II-165B). Kidneys of these species extend to the anal region.

Pleuronectiformes

Pleuronectiforms exhibit little variation in kidney forms. Pleuronectiform kidneys are consistently found to be fully developed. Amongst those I have studied, the kidneys fall into three main categories: types 3D, 3E, and 1A (Table 1 and figures II-166 to 171). Complete fusion (type 1A) develops independently in bothids, pleuronectids, scophthalmids, cynoglossids, and soleids. Only for soleids is this kidney type characteristic. In these families, there is some variation, which deserves to be mentioned.

The left extreme anterior kidney in Cynoglossus interruptus, Symphurus sp., and Symphurus plagiusa (Cynoglossidae; Fig. II-170A, D, E) is degenerate (or may be lost). In A. interruptus and Symphurus sp. only a small side branch from the right extreme kidney stretches to the left side. In the former, it is placed on the ventral surface of the esophagus, while in the latter it is on the dorsal surface. This side branch of the right extreme anterior kidney is probably synapomorphic.

The left side of the posterior kidney in all soleids examined extends posteriorly to the left secondary body

cavity— a synapomorphic character state in pleuronectiforms.

Interrrelationships of the kidney types generally found in actinopterygians

The distribution of the 24 kidney types generally found in actinopterygians was summarized in Table 4. Due to the small sample size of the examined species in most lower actinopterygians and/or due to the high variation, a dominant type, which does not necessary represent the primitive state of the fish group concerned, cannot be distinguished in some groups. It is found that there seems to be a general tendency for pre-acanthopterygian actinopterygians to have types 1B, 2C, 2D, 4B, and 4F. These types have a long kidney; the posterior kidney extends to the rear end of the peritoneal cavity. For acanthopterygians, especially perciforms, type 3 (mainly 3D, 3E, 3F) is the dominant one in which the posterior kidney is ended anterior to the base of the first haemal spine. As a result, the length of the kidney relative to the total length of the peritoneal cavity is shorter than other actinopterygians. Type 5 is independently developed as the dominant type in callionymoids (type 5C) and in tetraodontiforms (type 5B). They are apparently apomorphic.

In 51 monophyletic groups (Chondrostei, Notopteridae, Mormyridae, Clupeidae, Umbridae, Percopsidae, Gobiesocidae, Exocoetidae, Cyprinodontidae, Atherinidae, Melanotaenidae,

Holocentridae, Syngnathidae, Scorpaenidae, Triglidae, Branchiostegidae, Carangidae, Ambloplites, Enneacanthus, Lepomis, Centropomidae, Cepolidae, Chaetodontidae, Eche-
nidae, Gerridae, Scorpiis, Girella, Leiognathidae, Nandidae, Nemipteridae, Pomacanthus, Pomacanthidae, Pomacentridae, Pomadasyidae, Priacanthidae, Sciaenidae, Mugilidae, Spariso-
ma, Notothenidae, Blennidae, Clinidae, Pholididae, Stichae-
idae, Microdesmidae, Kurtidae, Acanthuridae, Trichiuridae, Mastacembelidae, Bothidae, Pleuronectidae, Scorpthalmidae, and Tetraodontiformes), 51 out of the 300 possible ways of association between two kidney types of the 24 were found and their frequencies of occurrence are listed as follows:

1A-1B, 1; 1A-3D, 5; 1A-3F, 1; 1A-3G, 1; 1A-4B, 1; 1A-4C, 3;
1A-4F, 1; 1B-3E, 2; 1B-4F, 1; 2A-2E, 1; 2B-4A, 1; 2B-2E, 1;
2B-3D, 1; 2B-3E, 1; 2B-3F, 2; 2C-3F, 1; 2C-4C, 1; 2E-4A, 1;
3A-3F, 1; 3A-4D, 1; 3A-4E, 1; 3A-5A, 1; 3A-5B, 2; 3C-3D, 1;
3C-3E, 1; 3C-4D, 1; 3D-3E, 6; 3D-3F, 4; 3D-4D, 1; 3E-3F, 8;
3E-3G, 1; 3E-4A, 1; 3E-4B, 1; 3E-4C, 2; 3E-4D, 1; 3E-4F, 2;
3E-5D, 1; 3F-3G, 1; 3F-4A, 1; 3F-4E, 1; 3G-4A, 1; 4A-4D, 1;
4A-4E, 1; 4A-5D, 1; 4B-4C, 2; 4B-4E, 1; 4C-4E, 1; 4C-4F, 4;
4C-5C, 1; 4E-5D, 1; 4B-5D, 1.

Because all the possible ways of association not dis-
tribute evenly in this sample, one may consider that (1)
the present small sample is subject to significant sampl-
ing error; (2) the unevenness is caused by the factor that
some kidney types are rare in actinopterygians; (3) the
unevenness reflects the existence of some factors which de-

termine the occurrence of kidney types. The high frequency of association among types 1A-3D-3F-3G suggests their affinity (Fig. II-178). These types share a common character in that the posterior kidney ends anterior to the base of the first haemal spine. They seem to represent a kidney configurational group, in which the primitive state resembles type 3D. Because of the association of type 3 with many other forms, it seems to give rise to several forms as shown in figure II-178. Types 1B and 2B are related to type 3 as shown by their associations. The association of types 2A, 2E, and 4A is interesting since the latter two types have isolated extreme posterior kidney. Their relationships to the other forms are obscure.

Types 4B, 4C, 4E, and 4F are related. They are not only closely associated with each other but are found to be related to 1A, 3E, and 3F. Since 1A is also associated with 4C, type 4B, 4C, 4E, and 4F are considered as one form relating to type 3.

It is likely that type 3A is more closely related to types 5B and 5A than it is to either type 3F or type 4E because of the higher frequency of association between types 3A and 5B and of the common character of types 3A, 5A, and 5B. Type 3C is derived from type 3; type 4D seems to be related to type 3.

On the basis of this set of data, the interrelationships of types 2C, 2D, 5A, 5B, 5C, 5B-3A, 2A-2E-4A with the other types are not clear.

Comparing figure II-178, which summarizes the postulated interrelationships of most of the kidney types, with Table 4, in which the distribution of the kidney types in actinopterygians are listed, it seems that types 1B and 4B-4C-4E-4F may be the primitive forms for actinopterygians. For acanthopterygians, type 3 is the primitive form. The remaining types are considered as apomorphic states at various levels.

Posterior cardinal system

The posterior cardinal system of primitive gnathostomes consists of (1) the paired renal portal veins represent the hind part of the protoposterior cardinal veins which present in the embryonic stage of chondrichthyans and also in the adult stage of the cyclostomes (see below), (2) the medial unpaired caudal vein joining the renal portal vein at its anterior end, and (3) the paired neoposterior cardinal vein which is the composite of the subcardinal vein and the anterior section of the protoposterior cardinal vein.

In elasmobranchs such as Squalus a connection between the anterior section of the protoposterior cardinal and the subcardinal on each side is formed early in ontogeny (Walker, 1956). The left and right subcardinal veins, with no connections to the posterior sections of the protoposterior cardinal veins, communicate medially by some short cross anastomoses at their posterior sections. These anastomoses may be absent in the adult, e.g., Squalus acanthias, S. sucklii (O'Donoghue et al., 1928) and Scyllium canicula (O'Donoghue, 1914). A medial interrenal vein is present posteriorly in these species. This vein may be composed of the fused posterior (or the subcardinal) sections of the neoposterior cardinals or of only one of these veins when the other has lost its posterior section. About the interrenal vein O'Donoghue and Abbott (1928:873) wrote, "We have no evidence to show whether this single inter-renal portion of the posterior cardinal in Squalus is formed by the

fusion of the two limbs of the loop (loop of Jacobson), or whether only one of them persists, as for example in Mustelus antarcticus and Heptanchus maculatus."

Besides this posterior fusion of the neoposterior cardinal veins, a spacious medial sinus formed by the fused area of the anterior parts of the neoposterior cardinals occurs frequently in adult chondrichthyans such as Squalus acanthias, S. sucklii, Scyllium canicula (O'Donoghue, 1914; O'Donoghue et al., 1928), Raja nasuta (Parker, 1881), and Chimaera colliei (Stahl, 1967). This anterior sinus is insignificant in Mustelus antarcticus (Parker, 1886:pl.34). The time of its appearance is variable. It develops in late embryonic stages in Scyllium canicula (O'Donoghue et al., 1928), but appears only in the adult form of Squalus (Walker, 1956).

There are some resemblances between the posterior cardinal system of holocephalian fishes— Chimaera colliei, and the elasmobranchs. In the former, there are numerous, sizable communications between the left and right neoposterior cardinals, and posteriorly at the origin of the trunk between the kidneys, there is a single median portion (the interrenal vein; Stahl, 1967). Stahl made no mention of the component of the interrenal vein.

There are some generalized characters of the chondrichthyan posterior cardinal system: (1) the left and right neoposterior cardinals are recognizable and equivalent in length; (2) the posterior parts of these veins are connected

by anastomoses; (3) a median anterior sinus is present; (4) the extreme anterior sections of these veins (or the neoposterior cardinal sinuses) tend to increase in diameter. The primitive nature of the first character is due to the fact that neoposterior cardinals of equal length occur in the embryonic and adult stages of some elasmobranchs (e.g., Walker, 1956). Reduction in length of either one of these veins or longitudinal fusion of their posterior sections have been developed in chondrichthyans. The left neoposterior cardinal is shortened in Mustelus antarcticus; the short left neoposterior cardinal has short transverse anastomoses joining the long right one which is also larger in diameter (Parker, 1886). Burne (1923:246) observed reduction in length of the neoposterior cardinal in Lamanda cornubica and wrote, "It is clear that the posterior cardinal system has to all intents and purposes been eliminated, so far as the trunk circulation is concerned and its place taken by the sub-renal rete and lower lateral cutaneous vein."

In order to decide the nature (advancement or primitiveness) of the interrenal vein of the chondrichthyans, more studies have to be made. It might be apomorphic for chondrichthyans since it is absent not only from the embryonic stage (e.g., Squalus; Walker, 1956), but also from the adult stage (e.g., Raja nasuta; Parker, 1881) of some elasmobranchs. However, because of its presence in holocephalians, outgroup comparison provides a conflicting view

to the above suggestion. Therefore, the nature of the interrenal is obscure. During the process of the development of the postcava, which exists in all living tetrapods (except mammals), dipnoans, polypteriforms, and coelacanth (also see below), the subcardinal portions of the neoposterior cardinals tend to fuse medially giving rise to the interrenal vein (Smith, 1960). In most tetrapods, the interrenal vein extends anteriorly and joins the right hepatic vein forming the postcava. Except for modern urodeles, the anterior sections of the neoposterior cardinals are separate from the postcava. In modern urodeles, these sections of the neoposterior cardinals retain their connections with the postcava. Unlike chondrichthyans, this anterior fused area of the neoposterior cardinals does not enlarge to form a sinus. The presence of an anterior median sinus may be apomorphic for vertebrates, supporting the monophyly of chondrichthyans. There is no fusion of the subcardinal portions of the neoposterior cardinals in dipnoans, polypteriforms, and coelacanth. It seems that this character has developed twice in vertebrates (chondrichthyans and tetrapods). There is not enough information at the present time to judge whether it represents a plesiomorphic character of gnathostomes.

In dipnoans, e.g., Protopterus annectens, the large postcava, or protopostcava, which is a composite of the right hepatic vein and the subcardinal portion of the right neoposterior cardinal vein, is connected to the left neo-

posterior cardinal vein by several transverse anastomoses (Fig. II-6; Parker, 1892). Both veins of this species are equally long. A vein homologous to the dipnoan postcava has been reported in Latimeria chalumnae (Robineau and Anthony, 1971). This species is slightly different from Protopterus annectens in that the left neoposterior cardinal vein drains directly into the posterior section of the postcava, without anastomoses (Robineau and Anthony, 1971), whereas the left neoposterior cardinal vein and the postcava of Protopterus annectens are connected by several cross anastomoses along their length.

The neoposterior cardinal veins of Polypterus spp. and Calemoichthys calabaricus are asymmetrical in diameter and length. The left vein was not observed in P. ornatipinnis and C. calabaricus. In the former species, the right neoposterior cardinal vein branches into two at the mid-section of the right kidney; the left branch crosses to the left kidney and runs to the posterior end of the peritoneal cavity, where it connects to the distal end of the hepatic vein. In P. palmas and C. calabaricus, the right neoposterior cardinal vein crosses to the left kidney at the mid-section of the right kidney. In the latter species, the distal end of the neoposterior cardinal vein on the left kidney sometimes branches into two; the right one is large, crosses to the right kidney, and later connects to the hepatic vein. The left neoposterior cardinal vein does appear in P. palmas. Kerr (1910) seems to be the only worker who reported the

same observation. He (1910:104) stated, "The hepatic vein is of great size and the main trunk of it traverses the liver right to its posterior end, and then runs free for a considerable distance through the splanchnocoele along the right side of the right lung till it joins the interrenal vein which I have described as a true primitive posterior vena cava of the same type as that in lungfishes and peculiar only in the fact that its communication with the interrenal (posterior cardinal) vein is further back than usual." The connection between the posterior ends of the right neoposterior cardinal vein and the hepatic vein at the posterior end of the peritoneal cavity; and the degeneration of the left neoposterior cardinal vein distinguish polypterids from coelacanth and dipnoans. The connection between the hepatic and neoposterior cardinal veins is an advanced character relative to that of the actinopterygians and the chondrichthyans in which these veins remain separate. Two opposite views regarding the nature of the character of polypterids are proposed: it is either the plesiomorphic state of sarcopterygians assuming that the characters of polypterids and other sarcopterygians are homologous; or an autapomorphic character of vertebrates. Under the former hypothesis, coelacanth are more closely related to dipnoans and tetrapods than are polypterids; and these four taxa form a monophyletic group. The latter hypothesis is uninformative concerning the phylogenetic position of the polypterids, but indicates the monophyly of coelacanth, dipnoans, and tetra-

pods. If information about the posterior cardinal systems of juvenile coelacanth, dipnoans, and polypterids were available, one would be able to decide between these two hypotheses. The second hypothesis seems more likely because the adult condition of dipnoans and coelacanth, in which the hepatic vein connects to the anterior end of the posterior part of the right neoposterior cardinal vein, can hardly be derived from the condition of the polypterids, in which the posterior ends of these veins join.

In the vast majority of teleostean kidneys, the right neoposterior cardinal vein is the major vein. The left one is much smaller, both in diameter and in length, and in some cases is absent (pers. obs.; Ogawa, 1961). In most teleosts, no anastomosis was found between these veins, although in some cases, e.g., Anguilla rostrata, some small branches from the right neoposterior cardinal vein run transversely to the left kidney, but do not connect to the short left neoposterior cardinal vein. Jollie (1962), however, showed that in salmon two transverse anastomoses connect the large right and short left neoposterior cardinal veins.

The two neoposterior cardinals in chondrosteans and ginglymoids do not differ significantly in length. In Acipenser stellatus and Polyodon spathula, the left one is longer, whereas it is only slightly longer in Lepisosteus oculatus and L. platyrhincus (Figs. II-8A, B and 9A, B). Anastomoses are absent from these groups.

Interestingly, Amia calva does not resemble the other

lower forms mentioned. It achieves a character state similar to higher neopterygians in that the right neoposterior cardinal is much longer than the left, of which only a short section drains the left extreme anterior kidney.

In most osteoglossomorphs, the left neoposterior cardinal vein is much longer than the right (Fig. II-11). In Gymnarchus niloticus the character state is different in that a branch from the anterior section of the long right neoposterior cardinal vein runs transversely to the left kidney and continues to its posterior section (Fig. II-11F). Although the condition of most osteoglossomorphs is somewhat similar to that of chondrosteans, it is more likely that it is developed independently in these groups; and that it is an advanced actinopterygian character state. The side branch of G. niloticus is autapomorphic. However, its long right neoposterior cardinal reflects its similarity to other teleostean patterns.

Cyclostomes lack subcardinal veins (Smith, 1960). The hagfishes, such as Myxine glutinosa and Bdellostoma dombeyi, resemble each other in their posterior cardinal system in that (1) the left protoposterior cardinal vein is considerably larger than the right; (2) they are joined by a large number of short transverse commissural vessels locating along their length; (3) the common protoposterior cardinal vein (the anterior section of the left protoposterior cardinal vein) passes forward to the left side and empties into the posterior end of the sinus venosus; (4) the anterior section of the

right protoposterior cardinal vein is much reduced in size or may even be absent as in B. dombeyi; (5) a connection between the caudal vein and the protoposterior cardinal veins is present (equivalent to the connection of the caudal vein and the renal portal veins of gnathostomes; Jackson, 1901; Johansen, 1963). Lampreys are different in some aspects from the hagfishes: (1) the right protoposterior cardinal is larger than the left; (2) the left protoposterior cardinal joins the right just posterior to the level of the heart and both cardinals drain into the sinus venosus through the right duct of Cuvier (Jollie, 1962). Cyclostomes in general are characterized by (1) the absence of subcardinals, (2) the presence of anastomoses, and (3) asymmetrical development of the two protoposterior cardinals and the extreme anterior end of these veins.

Smith (1960) suggested that the absence of subcardinals in cyclostomes is secondary. In the lack of ontogenetic evidence, it would seem reasonable to say that the nature of this character (absence of these veins) is obscure.

In summary, several propositions can be made:

- (1) the presence of postcava in tetrapods, dipnoans, and coelacanth is synapomorphic, favoring the monophyly of these groups. The difference in the manner of connection between the hepatic and neoposterior cardinal veins of polypteriforms and aforementioned groups raises questions concerning the homology of these two "characters". Data about the development of the

posterior cardinal system and the hepatic vein of polypterids are necessary.

- (2) Neoposterior cardinal veins being equally long is plesiomorphic for actinopterygians. Halecostomes (including halecomorphs and teleosts) seem to be a monophyletic group, because they share the apomorphic character state that the left neoposterior cardinal vein is much longer. A similar state in some elasmobranchs seems due to chance only.
- (3) The right neoposterior cardinal being larger than the left is apomorphic within halecostomes suggesting the monophyly of osteoglossomorphs (including hiodontids).
- (4) The transverse connection between the neoposterior cardinals by anastomoses is plesiomorphic for vertebrates. The loss of this connection in most actinopterygians would seem to be apomorphic at certain level within this group.

Section III. Gas secreting complex

In those perciform fishes which have a single, thin-layered gas-gland, the gland is either V-shaped, inverted V-shaped, X-shaped, H-shaped, ring-shaped or oval-shaped. Among perciforms, the inverted V- and oval-shaped types are very common. In the former, the degree of separation of the two lobes of the gland varies from group to group (Table 5). A well-developed ring-shaped gas-gland appears in Nandus nebulosus (but not in Monocirrhus polyacanthus and Pristolepis fasciata). The central area of the ring-shaped gas-gland is occupied by a single large rete mirabile. The V-shaped gas-gland has been observed in apogonids (Apogon cooki and Sphaeramia nematoptera), scombrids (Scomber colias and S. japonicus). It had been found also commonly in tetraodontiform fishes such as triacanthodids (Hollardia, Parahollardia, Johnsonina and Atrophacanthus; Mok, 1975).

There are fewer perciforms in which the gas secreting complex includes more than one gland than those having one. For those with two glands, two types have been observed: in one, the glands are lateral to each other, whereas in the other type, they are placed antero-posteriorly. The former is much more common than the latter, I have seen the former type in Vomer declivifrons (Carangidae), chaetodontids (Table 5), Hyperoglyphe perciformis (Centrolophidae), Haplochromis eucinostomus (Cichlidae), Enoplosus sp. (Enoplosidae), Drepane sp. (Ephippidae), Centropyge bicolor

(Pomacanthidae), Eupomacentrus variabilis (Pomacentridae), Pomatomus saltatrix (Pomatomidae), Pseudopriacanthus altus (Priacanthidae), Stellifer rastrifer (Sciaenidae), Mugil cephalus, Liza macrolepis (Mugilidae), Sphyraena borealis (Sphyraenidae). The second type has been found in Gazza minuta, Leiognathus rivulatus (Leiognathidae), Nemipterus sp. (Nemipteridae), and Perca flavescens (Percidae).

In species with more than two gas-glands (usually 3-5), the glands are either laid closely together or arranged in a circle. These character states have been found in Lepomis gulosus (Centrarchidae), Clethrchromis bowleyi (Cichlidae), Cymatogaster aggregata (Embiotocidae), Gadopsis marmoratus (Gadopsidae), Grammistes sexlineatus (Grammistidae), Acerina schraetser (Percidae; Table 5). When there are numerous gas-glands in the complex, e.g., in some apogonids (Fraser, 1972), they are usually arranged in groups in various patterns (see below). Multiplicity of gas-glands has not been found developed in all members of any supraspecific taxon (e.g., genus or family). Detailed studies of this complex may provide new information about interrelationships.

Marshall (1960) noticed that the actinopterygian retia mirabilia are formed by an artery and vein that enter the swimbladder either at the anterior or posterior end. The latter characterizes some "salmoniforms" (e.g., the stomiatoids), cetomimiforms (e.g., the mirapinnids), beryciforms (e.g., the stephanoberycoids). For the other acanthopterygians he studied (amongst them, Chiasmodon niger is the only

perciform species), the retial artery and vein (or the retial complex) enter the anterior part of the swimbladder. My study reveals no example of perciform which contradicts the generalization that the retial complex does not enter the posterior part of the swimbladder.

Like those of a vast majority of acanthopterygians, the perciform retia mirabilia are unipolar (pers. obs.; Marshall, 1960); after entering the swimbladder the retial complex approaches the gas-gland; a rete mirabile, formed at its anterior end, drains the gas-gland. When there are several glands, the retial complex branches anteriorly and, at the ends of the branches, retia mirabilia are formed. In an unusual type (the bipolar rete mirabile), which has only been reported in some stomiatoids such as Astronesthidae, Gonostomatidae, Sternoptychidae, the retial capillaries (the retia mirabilia) recombine to form an artery (or arteries) and a vein(s) which supply the gland(s). In this type there is only one rete mirabile no matter how many glands there are in the complex. Not all stomiatoid retia mirabilia are dipolar. Stomias affinis and S. colubrinus (Stomiatidae) possess a unipolar type (Marshall, 1960).

In some perciforms, e.g., Caranx crysos (Carangidae), Cepola rubescens, Acanthocephala krusensternii (Cepolidae), Merolepis sp. (Emmelichthyidae), Gazza minuta, Leiognathus rivulatus (Leiognathidae) and Peprilus sp. (Stromateidae), the gas-glands are thick. The arrangements of the retial complex become difficult to observe.

In perciforms, juveniles do not differ from adults in the shape and number of gas-glands. As such, it seems to be difficult, if not impossible, to obtain evidence from ontogeny to test the hypothesis that the separate gas-glands are phylogenetically derived, from the type with fewer numbers of glands, through the process of segregation. However, this hypothesis is favorable because a large percentage of perciforms possess a single gas-gland.

Variations of gas-gland morphology in several perciform families may be pointed out. Character states of other perciform families are summarized in Table 5, in which all taxa are listed in alphabetical order.

Apogonidae

Fraser (1972) has revealed a tremendous amount of information about the gross morphology of the gas secreting complex of apogonids. This was not applied to his interpretation of the generic interrelationships. In his paper no names were given for all of the types of gas-glands he depicted. It becomes impossible to take full advantage of his work in order to interpret the interrelationships of apogonids. My present study offers some additional data for this complex in apogonids. Apogonid gas-glands can be sorted into 5 types.

Type 1: (1) Gas-gland is small, V-shaped, oval or round, (2) few retia mirabilia (1-3), (3) the retia mirabilia may be completely or partly included in the area of the gas-gland. This type can be subdivided into 4

groups (Fig. III-1A-D).

Examples: 1A - Fraser, 1972 (Fig. III-1A).

1B - Apogon cookii, Archamia lineolata,
Sphaeramia nematoptera (Fig. II-1B).

1C - Fraser, 1972 (Fig. III-1C).

1D - Apogon savagensis, A. taeniophosus,
A. cyanosoma, Astrapogon stellatus
(Fig. III-1D).

Type 2: (1) Gas-gland large and long, (2) retial complex radiates to branches distributing to (3) two long retia mirabilia on both sides of the gas-gland (Fig. II-1E; Fraser, 1972).

Type 3: (1) Gas-gland large, (2) the retial complex may approach the gland anteriorly or laterally, (3) numerous retia mirabilia arranged closely beside one another, (4) retia mirabilia may be completely or partly included in the area of the gland, (5) the retia mirabilia may or may not be symmetrically placed. This type can be subdivided into 4 groups.

Examples: 3A - Fraser, 1972 (Fig. III-1F).

3B - Chilodipterus isostigma, C. quinque-
lineatus, Glossamia aprion (Fig. III-
1G).

3C - Fraser, 1972 (Fig. III-1H).

3D - Cheilodipterus macrodon (Fig. III-
1I).

Type 4: (1) Gas-gland large and long, (2) retial complex

branches beneath the mid-area of the gland, (3) retia mirabilia are widely separate. Two subgroups are included.

Examples: 4A - Fraser, 1972 (Fig. III-1J).

4B - Fraser, 1972 (Fig. III-1K).

Type 5: (1) Gas secreting complex uniquely composed of group (s) of small gas-glands, (2) the retial complex runs along the floor of the swimbladder and gives rise to branches, (3) the forward ends of these branches, a group of retia mirabilia and gas-glands are attached to. There may be only one group of these structures. It is further divided into 2 groups.

Examples: 5A - Fraser, 1972 (Fig. III-1L).

5B - Fraser, 1972 (Fig. III-1M).

Carangidae

Most carangids have single, large, thin-layered gas-glands; they are either long, oval-shaped (e.g., Caranx marginatus, Decapterus muroadsi, Selar sp., Trachurus japonicus), inverted V-shaped (e.g., Alectis ciliaris). Vomer declivifrons is the only species examined with 2 separate gas-glands. Caranx crysos has a long and thick gland.

Cepolidae

The gas-glands of cepolids are special among the perciforms I have studied. They are large and thick glands. The gas-gland of Acanthocepola krusensternii is a folded and complex structure. It is an inverted V-shaped gland in which the right lobe is larger than the left; the left lobe is folded.

The retial complex approaches the gland anteriorly at the branching point of the two branches, where the inverted V-shaped rete mirabile appears. In Cepola rubescens the retial complex runs antero-posteriorly toward the oval-shaped gland. The elongate rete mirabile originates anterior to the front edge of the gland; it attaches to the mid-portion of the gland.

Owstoniids have been suggested as a group possibly related to cepolids. Owstonia tosaensis has a thick, square-shaped gas-gland. The retial complex runs antero-posteriorly to the posterior edge of the gland; the large and long rete mirabile runs postero-anteriorly instead toward the gas-gland and attaches to its mid-area. The condition of this retial complex is unique among perciforms. The well developed gas-gland and rete mirabile of these families are not unique to them. Their monophyletic status is not supported by the present data.

Cichlidae

The shape of the cichlid gas-gland varies. For most Cichlasoma species, e.g., C. heterospilum, C. hyorhynchum, C. motaguense, the gland is inverted V-shaped. The gland of other Cichlasoma spp. such as C. champotonis, C. intermedium and C. salvini, is X- or H-shaped. Haplochromis eucinostomus has two glands, whereas Cleithrochromis bowleyi has six. Except for the inverted V-shaped form, the other types in the family may be postulated as advanced character states within the family.

Emmelichthyidae

I have looked at the gas-glands only of Merolepis sp. and Dipterygonotus gruveli. The gland of the latter species is inverted V-shaped, whereas the gland gland of Merolepis sp. is special. It is basically an inverted V-shaped gland, but its anterior portion is enlarged. Because of the unique morphology of this species, the gas-glands of other members of this family might be fruitfully studied.

Leiognathidae

Gazza minuta and Leiognathus rivulatus have two antero-posteriorly placed glands. The anterior one is smaller, thicker, and is covered by silvery membrane; the posterior one is larger and not covered by silvery membrane. This is a unique character in perciforms. These glands are different from that of Parequula bicornis, a leiognathid and Eucinostomus pseudogula, a gerrid. P. bicornis has a ring-like gland; E. pseudogula has a round gas-gland. Gas-gland morphology indicates the close relationship of G. minuta and L. rivulatus.

Nandidae

The gas-gland of Pristolepis fasciata is well developed. It is not a compact gland but shows a net-like structure.

Nandus nebulosus has a ring-like structure. The central area is occupied by a huge bundle of retial capillaries. Monocirrhus polyacanthus has an inverted V-shaped gas-gland with numerous retia mirabilia. Specimens of

Badis badis were unavailable for this study.

There is no common unique characteristic of the gas secreting complex limited to these families, and their relationships are unable to be resolved on the basis of these data.

Pomatomidae

Pomatomus saltatrix has two large and widely separate glands at the anterior tip of the swimbladder. The gland of Cookeolus boops is large and inverted V-shaped.

Labridae

Labrids have a specialized gas secreting complex not shared by other perciforms. The large oval-shaped gas-gland is enclosed in a thin-membraned sac. This structural unit is attached to the floor of the anterior or middle part of the swimbladder. The gas-gland is a thin layered tissue; in some cases, the large gland curves to both sides of the sac. In Clepticus parrai, Tautoga onitis, and Tautogolabrus adspersus, no gas-gland was found within the sac.

Microdesmidae

A transverse septum occurs at the mid-portion of the swimbladder of Pholidichthys leucotaenia. It separates the gas-glands. There are two in the anterior chamber and one in the posterior chamber. These glands are closely attached to the septum and the floor of the swimbladder. This is unique character among perciforms.

Scombridae

From Auxis sp., Scomberomorus commersonianus, and

Scomberomorus sp. gas-glands are absent. Scomber colias and Scomber japonicus, on the contrary, have a V-shaped gas-gland. This type might be treated as an advanced character state because it seldom occurs in perciforms.

Sphyraenidae

The gas-gland of Sphyraena barracula is H-shaped. The anterior part of the swimbladder is forked. Interestingly, a longitudinal internal septum is present at the anterior end of the bladder (it does not extend to the mid-part of the bladder). The two gas-glands are attached to both sides of this septum.

Section IV. Liver morphology

Liver shape of some representative perciforms is depicted in Table 5 and for other non-perciform gnathostomes, the liver shape is shown in the figures of this section.

The liver of most perciform fishes is composed of two lobes located on both sides of the anterior part of the gastrointestinal tract where they fuse beneath the esophagus. To my knowledge, there are only a few exceptions that deviate from this general structure. For instance, in Gramma loreta (Pseudochromidae) and Pempheris sp. (Pempheridae), the lobes are fused on top of the esophagus. Another example is found in non-perciform gnathostomes: no direct fusion between the left and right lobes in Gobiesox stumosus (Gobiesocidae); they are connected by the hepatic duct placed underneath the esophagus (Table 5). The liver of Salarias sp. (Blenniidae) is another exception in that the liver tissue occupies the space between the intestine and the esophagus. Similarly, lobes of some non-perciform fishes such as cyprinoids, are not well defined, with an irregular form that fills the space around the digestive tract. This character state occurs in some cyprinids, e.g., Cyprinus carpio, Carassius auratus (Fig. IV-11L); some catostomids, e.g., Erismyzon oblongus, Hypentelium nigricans (but not in Catostomus latipinus); homalopterids, e.g., Hemimyzon zebroidus; psilorhynchids, e.g., Psilorhynchus balitora

(cobitids, gymnotoids, characoids, and siluriforms, like perciforms have a liver-form characterized by definable liver-lobes; the shape of gyrinochelid liver is not known). Not all perciform livers are bi-lobed. Sarda spp. (Scombridae), for instance, has three lobes (pers. obs. and Collette et al., 1975). A similar character state has been observed also in some non-perciform teleosts: most characoids (Rowntree, 1903; Gregory et al., 1938), some cyprinids (e.g., Hemiculter kneri and Notropis hudsonius; pers, obs.). Relative size of the lobes varies among species. Interestingly, Rowntree (1903:55) argued that, with respect to the significance of this character, "these conditions of the relative size of the lobes though apparently specifically fairly constant, I regard as being merely adaptive to the exigencies of space and pressure in the abdominal cavity and therefore of but slight significance."

Relative size of the lobes is an interesting character in actinopterygians. In order to interpret the character states within the group, some baseline knowledge with respect to the character in pre-actinopterygian gnathostomes and cyclostomes seems to be necessary.

The liver of cyclostomes, e.g., Ichthyomyzon castaneus and Lampetra lamottei, is one-lobed, and lies ventral to the proximal end of the gastrointestinal tract (Fig. IV-1). In elasmobranchiomorphs, the two lobes of Squalus acanthias are approximately the same in size and length (Fig. IV-2A). In Taeniura meyeni and Urogymnus africanus the left lobe is

slightly larger than the right (Fig. IV-2B, C). Urmanov (1975) also reported similar conditions that (1) the lengths and weights of the right and left lobes in most sharks are about equal or they differ by only a little, (2) in the skates Mobula diabolus, Dasyatis kuhli, and Muliobatis australis, the right, smaller lobe is narrow, whereas the left, by contrast, is widened, especially in its caudal parts. Chimaera phantasma (also in Hydrolagus sp., Callorhynchus milii; Urmanov, 1975), on the other hand, has a larger and longer right lobe (Fig. IV-2D).

Like the liver of cyclostomes, liver-lobes of polypterids are hardly distinguishable. The right side of the liver extends posteriorly into a narrow rod of tissue (Fig. IV-3), a condition slightly resembling that of a dipnoan (Lepidosiren paradoxa), in which the lobes are placed ventral to the esophagus and are not clearly distinguishable (Fig. IV-4).

Equality of lobe size seems to be of general occurrence in lower actinopterygians, for instance, in Polyodon spathula, Acipenser stellatus, and Scaphirhynchus platyrhynchus (Fig. IV-5) (Lepisosteus spp., however, have one lobe, placed ventral to the esophagus as shown in figure IV-6). Scattered examples were found in teleosts: Elops saurus (Fig. IV-9A); some characoids (e.g., Micralestes sp.; Fig. IV-11); some cyprinoids (e.g., Catostomus latipinnis; Fig. IV-11E); some siluriforms (e.g., Ictalurus melas; Fig. IV-11J), some polymixioids (e.g., Polymixia sp.; Fig. IV-18A), some scorpaenoids (e.g., Peristedion miniatum; Fig. IV-22), and some

perciform (Table 5). For most of the other non-perciform teleosts examined, the left lobe is much larger than the right (Figs. IV-9 to 16, 18 to 22; Table 5), with a few species showing the reverse condition (see below).

The former character state in actinopterygians first appears in Amia calva; two lobes are clearly distinguishable, and the left lobe is much larger than the right (Fig. IV-7). It reappears in elopoccephalans.

The character state of having a larger right lobe is unusual among actinopterygians. This state occurs in osteoglossomorphs (except Gymnarchus niloticus; Fig. IV-8), some atherinoids (Fig. IV-17), most species of gasterosteiforms, and a few acanthopterygians (Table 5). Interestingly, in the former two groups, this character state of the liver-lobes is correlated with the left-ward displacement of the anterior section of the intestine in relation to the esophagus. At first glance, it seems likely that either one of these structures affects the outcome of the other. However, this proposition may not necessary be true in all cases, because the same liver morphology occurs also in Strogylura marina, Apeltes quadracus, and Odax pullus, which have a simple intestinal pattern different from that of osteoglossomorphs and atherinoids.

Phylogenetic implications of liver morphology

Osteoglossomorpha

The shape of the right liver-lobe shows a great varia-

tion within this group. The lobe in Notopterus sp. and Osteoglossum bicirrhosum is similar: the right liver-lobe is L-shaped (Fig. IV-8D, E). In Xenomystus nigri, the inverted U-shaped right-lobe may be a derivative of that of Osteoglossum bicirrhosum. If the L-shaped feature of this lobe is a special condition within osteoglossomorphs, it would indicate that notopterids and osteoglossoids are sister-groups. The character states of the livers of Hiodon alosoides (Notopteroidei), Mormyrops deliciosus (Mormyridae), and Pantodon buchholzi (Osteoglossoidae) seem autapomorphic (Fig. IV-8B, C, F).

Perciformes (also see Table 5)

As a broad generalization, the left lobe of perciforms is long, reaching the mid-part (or further backward) of the peritoneal cavity. The left lobe shows much higher variability in shape than the right. There are several general features of the left lobe: (1) an isosceles lobe with its short-side placed anterior to the other sides, (2) an obtuse triangular lobe, with the long-side placed ventral to the other sides, (3) a rectangular lobe, (4) an oval lobe, (5) a bi-lobed structure in which the upper and lower portions are longer than the mid-portion; the relative size of these three portions varies in different species and also show some developmental variations as observed in the 36 specimens of Lepomis gibbosus, (6) a tri-lobed structure in which the posterior edge of the lobe upper-, mid-, and lower

lobes; their relative size varies.

Bathyclupeidae

The left lobe of Bathyclupea sp. has a special feature- it is a inverted U-shaped structure. There is only one genus with four species in this family. Comparisons of the shape of this lobe in other bathyclupeid species might provide evidence for their interrelationships.

Centropomidae

The left lobe of centropomids varies. The left and right lobes of Lates calcarifer are long (the right being shorter), whilst in Centropomus nigrescens and Chanda gymnocephalus, the lobes are much shorter. Chanda gymnocephalus has even lost the right lobe. The relatively long right lobe of L. calcarifer is special condition in perciforms.

Echeneidae and Rachycentridae

These families have been considered to be closely related. The liver of Rachycentron canadum differs remarkably in the relative development and shape of the two lobes. The left lobe of R. canadum is longer than the right. However, this character state does not occur in echeneids. Within the family Echeneidae, the lobes of Echeneis naucrates are short but equal in size and length. The left-lobe of Remora brachyptera, R. remora, and Rhombochirus osteochir is smaller and shorter than the right.

Embiotocidae

Relative size and shape of the lobes in three examined species of embiotocids vary remarkably, such that no char-

acter state is found in common among them. The right lobe of Cymatogaster aggregata, unlike that of the Brachyistius frenatus and Ditrema temmincki, is much larger than the left, which is an elongate band of tissue—an unusual perciform liver-shape. Morphology of other embiotocids deserves further attention.

Gerridae

Shape and size of lobes of Diapterus, Eucinostomus and Gerres are different. The left-lobe of D. olisthostomus and Eucinostomus spp. is long, whilst in G. cinereus the lobe is short. Among the species of Eucinostomus examined, E. gula and E. pseudogula have lobes of equal size and length. Elongate lobes of equal lengths, as in the latter two species, are unusual, but have been observed only in Aplodinotus grunniens, Cynoscion regalis, Equetus acuminatus (Sciaenidae), Siniperca chuatsi (Serranidae), Lethrinus ornatus (Lethrinidae), and pomadasyids. The right lobe of D. olisthostomus is much smaller than the left.

Lutjanidae

The left lobe of Lutjanus griseus and Ocyurus chrysurus shows distinctive upper and lower portions, being narrow in the middle. L. gibbus seems to be a variant of this type. The upper portions of the liver of these species are high, reaching the dorsal edges of the esophagus. On the other hand, the lobes of Symphysanodon typus reach only the lower edge of the esophagus—an unusual condition in perciforms.

Leiognathidae

Interestingly, the right lobe of Gazza minuta and Leiognathus rivulatus is absent. This lobe is present in Parequula melbournensis and also in gerrids. The character states of Gazza minuta and Leiognathus rivulatus are treated as synapomorphic, implying that these two species are more closely related than to Parequula melbournensis.

Pomadasyidae

Species of this family I have examined share the same liver structure. The lobes are long and equal in length. This is the only family, to my knowledge, in which this type consistently occurs.

Pseudochromidae

The upper margin of the lobes of Gramma melacara. Pseudogramma polyacantha reaches only the lower edge of the esophagus, a special character state. Dampiera cyclophthalma has a general perciform liver type, in that the upper margin reaches the upper edge of the esophagus. More observations on this structure in other pseudochromids are suggested.

Sciaenidae

Aplodinotus grunniens, Cynoscion regalis, Equetus acuminatus, Plagioscion squamosissima have long lobes of equal length. Bairdiella chrysura, Macrodon ancylodon, Menticirrhus americanus, Nebris microps, Odontoscion dentex have a long left lobe. Stellifer rastrifer is the only sciaenid examined with a longer right lobe. This species and Macro-

don ancylodon have much shorter total liver length than any other sciaenids studied.

Serranidae

Size and shape of liver-lobes vary significantly in serranids. A small liver characterizes Anthias squamipinnis, Bostockia porosa, Centropristes striata, Roccus americanus. In Acanthistius serratum, Morone americana, Liopropoma mowbrayi, the liver is of the general perciform type. Siniperca chauatsi, on the other hand, has long and equal lobes.

Odacidae

Haletta semifasciata has two equal-sized lobes. Odax pullus has a much longer right lobe.

Scaridae

Sparisoma viride is specialized not only in its intestinal pattern, but also in its liver morphology. The left lobe includes upper and lower narrow branches; the upper branch bends forward at the rear part of the peritoneal cavity. This feature of the left lobe has never been observed in any other fishes.

Gobioididae

Gobioides sp. and Sericagobioides lighti differ in their liver morphology. The latter species has only left lobe, which is long. There is no left lobe in Gobioides sp.; the anterior portion of the long right lobe is well developed, such that it folds dorsally over the esophagus on the left side.

Section V. Generic interrelationships of chaetodontid
fishes

Ahl (1923) listed eleven genera (Coradion, Chaetodon, Chelmo, Chelmonops, Forcipiger, Hemitaenichthys, Heniochus, Microcanthus, Parachaetodon, Prognathodes, and Vinculum) in the family Chaetodontidae. Within the family, the genus Chaetodon has remained the major genus, including almost 90 % of the species. New genera have been created, based upon modifications of the snout, length of the dorsal spines, and development of the lateral line and teeth (e.g., Ahl, 1923 and Weber et al., 1936). The opinion has been repeatedly expressed by various authors, such as Hubbs and Rehnitz (1958); that the resemblance of the long snout in Chelmo, Chelmonops, Forcipiger, and Prognathodes might not reflect common ancestry. A possible result of creating genera in this manner is that the genus Chaetodon becomes a paraphyletic group.

Given this situation, studies of generic interrelationships, if they treat all nominal genera as monophyletic groups, risk masking the true interrelationships of the species. I therefore approach this problem by (1) assuming the genera (except Chaetodon) to be monophyletic groups, and (2) considering that Chaetodon might be a paraphyletic group, which might be divisible into a number of groups that can be sister-groups of other genera. The results of this study are likely to be different from those proposed by previous authors, who treated Chaetodon as a natural group and

reached their conclusions by studying morphometric, meristic and osteological characters (e.g., Fraser-Brunner, 1945; Hubbs and Rehnitz, 1958; Hubbs, 1963; Randall, 1961; Nalbant, 1965, 1971, 1974, to name a few). The disparities among the conclusions of these authors have arisen mainly from the diversities in their speculations about the beak-like modifications of the snout. Further complicating the issue is the fact that overall similarity, used as a criterion of relationship by these authors, suffers from subjective bias.

Coelomic organs of these fishes have been left "untouched" by the above authors, as is generally true for other perciform groups. The complex intestinal patterns of acanthurids and zancids, which bear evidence of their relationships (Mok, 1977), and the highly diverse kidney morphology of the centrarchids, as potential indices of phylogenetic relationships, led me to a thorough study of these organs in chaetodontids. The long intestine of most chaetodontids, with the small volume of their small body cavity, generally results in complex intestinal patterns. With regard to the reconstruction of phylogenetic relationships, these complex patterns are more informative than a simple one. Encouragingly, chaetodontid kidneys also show various structural forms. I believe that they offer some promise for progress in the systematics of this group.

Gross kidney morphology

The posterior kidneys of all chaetodontids examined fuse anterior to the base of the first haemal spine. A transformation series of this part of the kidney may be recognized for the family. The posterior kidneys of Microcanthus and Vinculum end right in front of the base of the first haemal spine. Their long ureters run posteriorly along the sides of the first haemal spine and the basal anal pterygiophore, and converge into the urinary bladder (Fig. V-1A, B).

The rear portion of the posterior kidneys of Hemitaurichthys, Heniochus, and Forcipiger, in contrast, extend bilaterally to a certain degree beyond the base of the first haemal spine (Fig. V-1C-G). The extensions of the posterior kidneys do not fuse at the base of the basal anal pterygiophore.

In Chelmo rostratus, Chelmonops truncatus, Coradion chrysozonus, Parachaetodon ocellatus, Prognathodes aculeatus, and the "Chaetodon species" examined, the extensions of the posterior kidney fuse at the base of the basal anal pterygiophore, giving rise to the extreme posterior kidney (Fig. V-1H-P). The ureters beyond the extreme posterior kidney are much shorter than those of the two aforementioned groups.

The character state of the posterior kidneys of Microcanthus strigatus and Vinculum sexfasciatus evidently is primitive in this transformation series. It is broadly dis-

tributed in many perciform fishes, such as Centropyge bicolor, Holacanthus tricolor, Pomacanthus sp., Scorpiis georgianus, Kyphosus vaigiensis, and Micropterus salmonoides.

With regard to the kidney morphology, no synapomorphic character or character state has been found to support the monophyletic status of Microcanthus, Vinculum, and all other chaetodontid genera.

The character state of the kidneys of Forcipiger, Hemitaurichthys, and Heniochus is the intermediate form in the transformation series, between that of Microcanthus and Vinculum, and all other chaetodontid genera. It becomes an advanced character state with reference to that of Microcanthus and Vinculum. Accordingly, Forcipiger, Hemitaurichthys, Heniochus, Chelmo, Chelmonops, "Chaetodon", Coradion, Parachaetodon, and Prognathodes form a monophyletic group. The last six genera may form another monophyletic group, because the character state of the posterior kidney they share is at the advanced pole of this series.

Intestinal pattern

The intestinal pattern of an 87-mm individual of Microcanthus strigatus has a dextral winding loop a (Fig. V-2A). This is a generalized winding tendency of this loop in perciform fishes. However, in a larger individual of 122 mm, loop a exhibits a spiral pathway (Shen, pers. comm.) - an unusual character state in perciforms. This pattern is not common among other species in the families that may have a

close affinity to chaetodontids, e.g., pomacanthids.

In Forcipiger flavissimus, the intestine winds sharply downward at the rear part of the peritoneal cavity (Fig. V-2B, C; long arrow shows this turning direction). Loop a (stippled area in Fig. V-2B, C) occupies the posterior part of the cavity.

Individuals of Hemitaurichthys polylepis have their intestinal patterns in various forms. In most specimens dissected, the anterior section of the intestine bends downward distinctively (short arrow in Fig. V-2D, E, G indicates this bending); another downward bending at the rear part of the peritoneal cavity occurs in two specimens (long arrow in Fig. V-2F, G). From the 132-mm SL specimen, the anterior bending is absent (Fig. V-2F); its pattern looks very much the same as that of Forcipiger flavissimus. In spite of these variations, the species pattern of Hemitaurichthys polylepis can be diagnosed by the sharp bendings of the intestine at the anterior and/or posterior parts of the peritoneal cavity. Because these bendings of the intestine are also shared by Forcipiger, among the chaetodontid genera, I postulate that this is a synapomorphic character state uniting them as sister-taxa.

The developmental changes of the intestinal pattern of Heniochus permutatus and H. acuminatus were studied (Figs. V-3 and V-4). A small loop (loop s) occurs consistently in the specimens of H. permutatus (41-42 mm; Fig. V-3A, B; heavy line represents the section of loop s). It can not be

recognized in the larger specimens (46-47 mm) in which a leftward folding takes place in the corresponding section of loop s in the intestine (Fig. V-3C, D; heavy line and arrow represents and indicates this section and its folding direction, respectively.) Loop a is recognizable in these specimens (Fig. V-3; stippled areas).

In Heniochus acuminatus, a loop homologous to loop s of H. permutatus is hypothesized (heavy-line sections in Fig. V-4). This loop in the two small specimens of H. acuminatus (45-51 mm) looks exactly the same (Fig. V-4A, B). The loop seems to be formed by a counter-clockwise coiling process (arrow in Fig. V-4A, B shows this coiling pathway). It varies rather unexpectedly in larger specimens (e.g., the specimens of 51 and 78 mm; Fig. V-4C and D) and follows a clockwise coiling pathway in the 51 mm specimen (Fig. V-4C; arrow points to the coiling pathway). The appearance of this loop in the 78-mm specimen (Fig. V-4D) does not resemble that of the other conspecific individuals but shows some resemblance to the 46-mm specimen of H. permutatus (Fig. V-3C). The homologous loop of loop s can also be logically postulated in the patterns of H. monoceros, H. singularis, and H. varius (Fig. V-2H, I, J; heavy-line sections). Except the 51- and 78-mm specimens of H. acuminatus, loop a is recognizable in Heniochus species (Figs. V-2H-J; V-3, and V-4; stippled areas). We may define the unique character state of the pattern of Heniochus by the extra-coiling (loop s), which varies rather considerably, but consistently

appears at the anterior section of the intestine in the Heniochus species.

At least four types of intestinal pattern exist in the species traditionally classified in the genus Chaetodon; in one, the dextral loop a folds downward to various degrees (Fig. V-5; short arrows indicate this folding direction). In Prognathodes aya (= Chaetodon aya), this section of loop a is only slightly folded (Fig. V-5A); whereas those of C. argentatus and C. triangulum are deeply folded and also tilted in their folding directions (Fig. V-5B, C). Interestingly, this shallow downward folding occurs also in Para-chaetodon ocellatus and Prognathodes aculeatus (Fig. V-5D, F). The pattern of the latter species looks very much the same as that of P. aya, because their intestine is shorter than that of other chaetodontids. In the second pattern, loop a not only folds downward (short arrows in Fig. V-6), but its tip also turns to the right. The latter condition of loop a may be the result of the left-ward folding that occurs at the anterior section of the intestine (long arrows in Fig. V-6). As a consequence, the rear end of loop a occurs in a S-shaped configuration (Fig. V-6A-E; stippled areas). C. aureus, C. auriga, C. capistratus, C. lunula, and C. vagabundus have this pattern (Fig. V-6A-E). In the third type, as in Microcanthus, loop a coils in a spiral pathway; the down- or right-ward folding does not appear. This pattern was observed in Chaetodon modestus (Shih, pers. comm.). The fourth pattern, in C. unimaculatus, was not

observed in any other chaetodontids examined (an autapomorphic character state). A special loop (loop m) is located before the tip of the spirally coiled loop a (fine stippling in figure V-6F). The section of the intestine posterior to loop m extends beyond the boundary (to the right) of the previous section of the intestine (dotted lines in Fig. V-6F). This pattern is considered a variation of the third pattern.

Chelmo rostratus and Chelmonops truncatus share a similar pattern in which only the left-ward folding of the second pattern of "Chaetodon species" can be found (Fig. V-7; long arrows point to this folding); loop a follows a dextral winding pathway (Fig. V-7; double-line arrows).

Coradion chrysozonus has a rather long intestine. Its pattern occurs in various forms in individuals of different body lengths (Fig. V-8A-C). I am unable to notice any consistent pattern of this species.

The intestine of Vinculum sexfasciatus is short; there is no left-ward folding near the middle part of loop a. A right-ward folding, however, is present (Fig. V-9; arrow points to this folding). This pattern might be a variation of the first pattern of "Chaetodon".

Ontogenetic data from some Atlantic "Chaetodon species" examined allow me to draw the following conclusions. The left-ward folding makes its first appearance in individuals of about 20 mm in body length (at least longer than 19 mm in Chaetodon capistratus; 21 mm in C. ocellatus; 20 mm in

C. striatus: Fig. V-10A-H). Smaller individuals of these species exhibit either the downward folding (e.g., C. capistratus and C. ocellatus) or show the spiral pathway first and the downward folding later (e.g., C. striatus). We may consider the biogenetic law (Balinsky, 1970), to the effect that features of ancient origin (primitive or plesiomorphic characters or character states) develop early in ontogeny, and feature of recent origin (advanced or apomorphic characters or character states) develop late. Under these assumptions, I am in a position to propose the following hypotheses. (1) With regard to the folding at the tip of loop a, the down- or right-ward folding is an apomorphic character state relative to the strictly spiral pathway of loop a. (2) As for the folding at the middle section of loop a, namely, the left-ward folding, the presence of this folding is the advanced state with respect to its absence.

If the left-ward foldings of Chelmo, Chelmonops, and some "Chaetodon species" are homologous structures, two hypotheses concerning the generic interrelationships of chaetodontids (Fig. V-11A, B) can be made, based on the distributions of the left-ward and down- or right-ward foldings. In the first hypothesis (Fig. V-11A), the left-ward folding develops early in the evolution of chaetodontids, and is an advanced character state (character state 5 in this figure) at branch point A. This folding is later lost (the loss considered as advanced character state 11), development of the downward or right-ward folding occurs after

the appearance of the left-ward folding (at branch point B in Fig. V-11A). In the alternative hypothesis (Fig. V-11B), the left-ward folding develops later in the evolution (at branch point D)— after the appearance of the down ard or right-ward folding (branch point C). The downward or right-ward folding, however, is lost during further evolution of this group (character state 6).

If we reject the assumption that the leftward foldings of Chelmo -Chelmonops and "Chaetodon species" are homologous, a third hypothesis can be proposed (Fig. V-11C).

In summary, the present data indicate with confidence only that Prognathodes, Parachaetodon, Vinculum, Chelmo, Chelmonops, and a vast majority of the species classified in the genus Chaetodon, probably form a monophyletic group. Three hypotheses with regard to their interrelationships are made. A detailed study of the developmental changes of the intestinal pattern and also evidence from other systems may test these hypotheses.

The logical reasoning behind the decision on the nature of the character states (primitive versus advanced) within the Chaetodontidae was grounded on the working hypotheses that Microcanthus is a chaetodontid, a proposition held by Ahl (1923), Weber and de Beaufort (1936), Nelson (1976); and that pomacanthids and chaetodontids are sister groups. The monophyly of these groups has been generally agreed upon (e.g., Ahl, 1923; Chen, 1969; Weber et al., 1936; Fraser-Brunner, 1945, and Norman, 1957). It was assumed also that

the genus Chaetodon may not be a monophyletic group.

The systematic position of Microcanthus is problematical. It has been included in the Chaetodontidae from the time it was first described by Cuvier and Valenciennes. This systematic status was questioned by Fraser-Brunner. He suggested that Microcanthus is not a chaetodontid for the reason that "In this fish (Microcanthus strigatus), the gill membranes are united and free from the isthmus, whereas in all the chaetodontids and their immediate relatives, the gill-membranes are joined to the isthmus at least narrowly." "The so-called 'scaly sheath' of the spinous dorsal in the Chaetodontidae is not a true sheath.... In Microcanthus, however, a true scaly sheath is present...." "Microcanthus has a bi-lobed caudal fin, unlike that possessed by any of the true Chaetodontidae wherein emargination of this fin is acquired by growth of some of the rays." "The subfamily Chaetodontinae.... has the distal portion of the ribs much expanded antero-posteriorly, so that their edges are almost in contact, forming a rigid cuirass protecting the abdominal organs....Microcanthus shows its ribs to be quite normally formed." (Fraser-Brunner, 1945:466). He then proposed that the real affinities of Microcanthus lie with the Scorpididae and that its nearest relatives are Atypichthys and Neatypus. It is because "....the only character of significance by which Microcanthus can be differentiated from Atypichthys is the absence of vomerine teeth.... In other respects, all three (Microcanthus, Atypichthys, and Nea-

types) are closely similar...." (Fraser-Brunner, 1945:466). However, the characters shared by these three genera were not specified in his paper.

Microcanthus strigatus has a generalized kidney-type compared with possibly related families, such as Ehippidae, Pomacanthidae, Scatophagidae, as suggested by some authors, for instance, Fraser-Brunner (1945) and Nalbant (1973). The plesiomorphic character state of this organ is no evidence for its close relationship either to chaetodontids or scorpidids. But the synapomorphy of the intestinal pattern of Microcanthus and other chaetodontids indicates their affinity. More over, the intestinal pattern of scorpidids (e.g., Scorpiis aequipinnis, S. georgianus) and girellidids (e.g., Girella punctata, G. melanichthys) are similar and deviated from a basic type in which loop a displays a Z-shaped winding pathway (type Z). Kyphosids have a longer intestine and, as a consequence, they have a more complex pattern. Because this Z-shaped winding tendency of loop a is consistent within scorpidids, Atypichthys and Neatypus, of which specimens were unavailable to me, likely have this basic pattern. If this supposition is correct, Microcanthus differs from these two scorpidid genera in the intestinal pattern. In short, available evidence suggests that Microcanthus is a chaetodontid.

Nalbant repeatedly pointed out a few species character states of the lateral line termination, subopercular suture, and distribution of scales on the dorsal fin as evidence to

proposed that "Within the family Chaetodontidae there are six main phyletic series belonging to ten genera (Microcanthus is not included) :1. The series of Forcipiger.... 2. The series of Heniochus and Hemitaurichthys....3. The series of Chelmo and Chelmonops....4. The series of Coradion and Parachaetodon....5. The series of Chaetodon nigrrostris....6. The series of Prognathodes and Chaetodon." (Nalbant, 1973:313). Except for the character, common to Coradion and Parachaetodon, that scales cover the six to eight spines, other character states that Nalbant held as evidence are not limited only to the 'closely-related groups' concerned but in most cases, appear in other chaetodontid genera as well. I can, therefore, only treat these species character states as plesiomorphic at the relevant levels in the phylogeny. Sympleisomorphic character states do not indicate monophyly: a core axiom of phylogenetic systematics. As for the similarity between Coradion and Parachaetodon, I have noticed also that they have low number of dorsal spines (5-6 in Coradion and 6 in Parachaetodon; Weber et al., 1936, and pers. obs.), whereas other chaetodontids have about 10-13 dorsal spines (pomacanthids have even more dorsal spines). Another observation with respect to Parachaetodon is that its swimbladder is separated into a small anterior chamber and a large posterior chamber by a bottle-neck region. A similar character state has been found only in Chaetodon triangulum (Shen, pers. comm.). Interestingly, both of these species possess only the right-ward folding,

while the left-ward folding is absent. Their possible affinity deserves further attention. With regard to the relationship of Coradion, I can suggest only that it is a member of the group including Chaetodon, Chelmo, Chelmonops, Parachaetodon, and Prognathodes, as supported by evidence of the kidney morphology (Fig. V-11). I am unable to deal with this problem further because I could not recognize a stereotypic intestinal pattern of this species. The possible relationships of Parachaetodon-Chaetodon triangulum and Parachaetodon-Coradion remain to be investigated.

The long-snout chaetodontids, Chelmo, Chelmonops, Forcipiger, and Prognathodes, pose a controversial systematic problem. It is generally agreed that these genera are not derived from a common ancestor (Hubbs et al., 1956; Randall, 1961; Hubbs, 1963; Nalbant, 1971, 1974). Randall (1961) held the idea that Chelmo, Chelmonops, and Forcipiger are a monophyletic group (Prognathodes was not included). Interestingly, the intestinal pattern of these genera varies enormously: Forcipiger resembles Hemitaurichthys in a special character; Prognathodes resembles Chaetodon (= Prognathodon) aya in an advanced character; Chelmon and Chelmonops have the same pattern. It seems clear to me that their resemblance in snout morphology is only a matter of accident.

Hubbs and Rechnitzer (1958), Randall (1961), and Nalbant (1965, 1971) came to the conclusion that P. anuleatus is more closely related to Chaetodon (or Prognathodes) aya

and its related species (e.g., C. falcifer and C. marcellae) than to other genera. Nalbant (1965) erected a new genus Bauchotia for C. aya, C. guyanensis, C. falcifer, and C. marcellae. In his 1974 paper, he treated this group as a subgenus of Prognathodes. With regard to the species interrelationships within this genus, he stated "Analysis of the skeleton of the dorsal fin in the species belonging to Prognathodes disclosed two evolutionary lines. The first would consist of the species marcellae and falcifer in which the free pterygiophores are wide-set and remote from the lamina of pterygiophores 3 and 4; a second line would be represented by species of aculeatus and aya in which the first pterygiophores are almost fused, located next to the lamina 3 and 4." (Nalbant, 1974:306). The character state of P. aculeatus and P. aya seems to me to be advanced. This leads me to the hypothesis that these species are closely related. If so, the subgenus (or genus) Bauchotia is a paraphyletic group.

The monophyly of Chelmo and Chelmonops is agreed upon by Randall (1961) and Nalbant (1971; 1974). Randall suggested also that these genera are related to Forcipiger. The kidney morphology and intestinal pattern do not conflict with the monophyly of Chelmo and Chelmonops.

The genus Vinculum was created by Ahl (1923), but was not accepted by Randall, Hubbs, Rechnitzer, and Nalbant, who have worked on this family. Its intestinal pattern and kidney morphology conflict. Chaetodon is a large genus, in-

cluding about 90 species (Nalbant, 1974), and the secondary loss of the extensions of the posterior kidney might be expected in some species. If so, the posterior kidney seems primitive but really is advanced, paralleling the advanced character state of the intestinal pattern, shared also by some "Chaetodon species." I think that Vinculum is a member of the group including some "Chaetodon species," Chelmo , Chelmonops, Parachaetodon, and Prognathodes, in which loop a is not strictly spiral.

DISCUSSION

Morphological variation of coelomic organs has been considered the passive result of the development of other structures, or the result of ecological and structural, rather than phylogenetic factors (e.g., Rowntree, 1903). The phylogenetic significance of coelomic organs became de-emphasized because of these opinions. On the basis of the present data, I reexamined these opinions and will discuss here the phylogenetic significance of coelomic organs.

Ecological factors seem to play little role in affecting the gross morphology of coelomic organs. Morphological variation of the kidney, in groups of which the members live in diverse habitats (e.g., centropomids, trachinoids, and scorpaeniforms), is usually no more significant than the variations in groups of which members live only in one type of habitat. In-group and out-group variation of kidney morphology are equally prominent in these groups. There are

also no clear correlations between (1) degree of development of the kidney or (2) kidney configuration, and the habitats. Although Ogawa (1961) pointed out that two kidney types (in one, the kidneys are completely separate, and in the other, only a small area at the caudal end of the posterior kidneys is fused) occur only in marine fishes, I found examples in freshwater species such as Kurtus gulliveri (with completely separate kidneys) and Gadopsis marmoratus (in which fusion of the kidneys appears only at the caudal end of the kidneys). It is likely that histological variation of the kidney is more prominent as an ecological adaptation. The gas secreting complex, on the other hand, may be more correlated with ecological factors, such as depth.

Ecological factors such as feeding habits do not directly and significantly determine the intestinal pattern. The pattern is determined by (1) intestinal length, (2) volume of peritoneal cavity, (3) shape of peritoneal cavity, (4) developmental mechanism. To some extent, feeding habits may correlate with the first determining factor of intestinal pattern. Fishes with a similar food habit may be different in their intestinal length, but unique characteristic(s) of their patterns may still be retained. For instance, Zebrosoma flavescens and Z. veliferum are filamentous-algae feeders (Jones, 1968). They differ in intestinal length and complexity of pattern, but the unique acanthurid pattern still appears. In some cases, related species with different feeding habits were also found to share a unique intestinal pat-

tern. For example, plankton feeders such as Paracanthurus hepatus, Naso hexacanthus, Acanthurus hexacanthurus, and A. thompsoni (Acanthuridae; Jones, 1968; Randall, pers. comm.) and algae feeders such as Naso annulatus (pers. obs) and Acanthurus nigrofuscus (Jones, 1968) have the unique acanthurid pattern.

Although the short intestine of carnivores and piscivores generally contains less information, it does not necessarily reduce to zero the phylogenetic significance of the intestinal pattern. The unique pattern of the piscivorous Hexagrammos and Agrammus (Hexagrammidae) is an adequate example.

Structural factors (e.g., volume, shape of peritoneal cavity, occurrence of secondary body cavity, occurrence of pharyngeal retractor muscles, positions of the first haemal spine and the basal anal pterygiophore, size and shape of other organs) are more significant in determining the morphology of coelomic organs. The correlation of swimbladder and kidney morphology in teraponids and cyprinids exemplifies this relation. It is, however, likely that structural characters tend to be more similar in closely related groups than in remotely related groups.

Differences in character state may sometimes be found in two groups with similar structure (e.g., sinistral and dextral coiling loop a within the right secondary body cavity). This difference is no doubt caused by variation in developmental mechanism, which may be also genetically determined.

The developmental process, which brings about the unique pattern of all acanthurids, rather than several different patterns, even though the general form of the peritoneal cavity is similar in acanthurines, but different in zancelines. This is an example supporting the idea that genetic factors are at work.

In summary, morphological diversity in coelomic organs is not random. Nevertheless, my impression is that the phylogenetic significance of the coelomic organs is less than that of osteological structures, because the development of coelomic organs is more prominently interferred with other structures. This drawback, notwithstanding, detailed comparison of coelomic organs does sometimes reveal similarity that reflects the interrelationships of the groups concerned.

SUMMARY

A survey of the intestinal pattern, kidney morphology, posterior cardinal system, gas secreting complex, and liver morphology of actinopterygians (special attentions were given to perciforms) was conducted to understand the extent of individual, developmental, and taxonomic variations of these structures and to apply any of these variations to elucidate interrelationships of these fishes. The methods of phylogenetic analysis were used to interpret the data.

General part

(A) Intestinal patterns.

- (1) eleven basic types were recognized in actinopterygians (p. 10).
- (2) occurrence of these types is not random; taxonomic variation indicates that some types usually occur together within a monophyletic group (p. 85).
- (3) type LA dominates the patterns of lower actinopterygians; type B in turn dominates some acanthopterygian groups including channiforms, scorpaeniforms, perciforms, and pleuronectiforms; the remaining types are apomorphic at various levels of the phylogeny (p. 118).
- (4) individual variation is insignificant in the species examined (p. 17); species are different in the rates of reaching the adult pattern. However, this pattern seems to be developed in small adults (p. 17-18).
- (5) developmental evidence indicates that types HZ and

S can develop to type Z (p. 38).

(B) Kidney morphology.

- (1) based on the relative development of the various parts of the kidney, 24 types of actinopterygian kidneys were defined (p. 88).
- (2) individual and developmental variations are insignificant (p. 91-92).
- (3) kidney types are not randomly distributed (p. 152).
- (4) it seems that types 1B and 4B-4C-4E-4F may be the primitive forms for actinopterygians; for acanthopterygians, type 3 is the primitive one; the remaining types are considered apomorphic (p. 151).
- (5) complete separation of the two kidneys has been developed several times in actinopterygians (p. 101).
- (6) kidney and swimbladder shapes are related in some cases as exemplified by the similarity between ostariophysans and teraponids (pp. 109, 137).
- (7) neoposterior cardinal veins being equally long is considered plesiomorphic for actinopterygians (p. 161).

(C) Gas secreting complex.

- (1) in those perciforms with one gland, this gland is either V-, inverted V-, X-, H-, ring-, or oval-shaped; the inverted V-shaped and oval-shaped types are most common in perciforms (p. 165).
- (2) in those perciforms with two gas-glands, they are either lateral to each other or placed antero-

posteriorly (p. 165).

(3) in those perciforms with several gas-glands, they are either laid closely together or arranged in a circle (p. 166).

(4) perciform retia mirabilia are unipolar (p. 167).

(D) Liver morphology

(1) the plesiomorphic character state of the connection of the liver lobes of actinopterygians is that the left and right lobes are connected underneath the esophagus (p. 175).

(2) equality of liver-lobe sizes seems to be of general occurrence in lower actinopterygians (p. 177).

(3) the character state of having a larger right liver lobe is unusual among actinopterygians (p.178).

Taxonomic part

Elasmobranchiomorphi: the presence of an median sinus in the anterior parts of the neoposterior cardinals of most adult chondrichthyans may be apomorphic for vertebrates, suggesting the monophyly of chondrichthyans (p. 156, 158).

Actinistia: evidence of kidney morphology (fusion of the two kidneys) suggests that Latimera chaulumnae is the plesiomorphic sister-group of Dipnoi-Brachiopterygii-Tetrapoda (p. 106); postcava is present in L. chaulumnae and is similar to the state of dipnoans (p. 159); the nature of this similarity with regard to the phylogenetic positions of Latimera, Dipnoi, and Brachiopterygii is unsettled (p. 160).

Brachiopterygii: complete separation of the two kidneys indicates the monophyly of polypterids, dipnoans, and tetrapods (p. 104); hepatic vein and neoposterior cardinal are connected at the rear of the peritoneal cavity - a state different from that of Latimera and dipnoans (p. 160).

Paleopterygii: extreme anterior kidneys of Polyodon spathula (polyodontidae) extend anteriorly to the anterior part of the parasphenoid (p. 106).

Halecomorpha: halecostomes seem to form a monophyletic group in sharing the synapomorphic character state that the left neoposterior cardinal is much longer than the right (p. 161-162).

Osteoglossomorpha: the reverses of relative sizes of neoposterior cardinals (except for Gymnarchus niloticus), and liver lobes as compared with other actinopterygians, characterize most osteoglossomorphs (pp. 162, 178); Hiodon is, therefore, an osteoglossomorph ; G. niloticus has an autapomorphic state of its neoposterior cardinal system (p. 162); Osteoglossum bicirrhosum and Pantodon are closely related in sharing a synapomorphic kidney character state (p. 107).

Elopomorpha: muraenids may be a monophyletic group as supported by the character that numerous ureters from the extreme posterior kidney drain into the elongate urinary bladder (p. 108).

Ostariophysi: stomach morphology suggests that gymnotoids

and cyprinoids may be monophyletic (p. 67); stomach and intestinal patterns suggest the monophyly of catostomids-cyprinids-psilorhynchids (p. 68); intestinal patterns suggest the monophyly of gyrinocheilids-homalopterids (p. 69); the phylogenetic position of cobitids within the Cyprinoidei is unsettled (p. 70); herbivorous characoids share a specialized intestinal pattern (p.71).

Salmoniformes:

Salmonidae: left and right kidneys of salmonids are completely fused (a synapomorphic state; p. 113).

Argentinidae: anterior kidneys of Argentina sp. are widely separated (p. 113).

Umbridae: in umbrids, extreme anterior kidneys are well developed; anterior and posterior kidneys are degenerate; posterior kidney is extremely well developed (p. 113).

Myctophidae: extreme anterior kidneys of Myctophum sp. extend medially underneath the pharyngeal retractor muscles (p. 113).

Paracanthopterygii: complete separation of the kidneys is the advanced character state in this group suggests the monophyly of Percopsiformes and Lophiiformes (p. 115).

Atherinomorpha: anterior section of the intestines of most atherinoids examined displaces to the left of the esophagus; at what level that this state becomes a synapomorphic state is unclear at this point (p. 11); extreme anterior kidneys of Cyprinodon variegatus are fused and vertically placed (p. 116).

Beryciiformes:

Polymixiidae: kidneys of Polymixia sp. are unusually wide (p. 117).

Holocentridae: posterior kidneys of Myripristis jacobus and Plectrypops retrospinis develop laterally to an extraordinarily size (a synapomorphic state; p. 117).

Channiformes: sharing the specialized state that the ureters pass to the right side of the first haemal spine on their way to the urogenital pore, Ophicephalus argus, O. micropeltes, and O. obscurus may be closely related (p. 120).

Scorpaeniformes: intestinal pattern suggests that Hexagrammos and Agrammus are sister-groups (p. 76); this conclusion agrees with current taxonomic of Hexagrammidae.

Perciformes:

Apogonidae: the digestive tracts of Apogon, Archamia, and Sphaeramia are coated with a dark-brown layer of pigment (a synapomorphic state; pp. 19-20); gas-glands of apogonids are very diversified (p. 169).

Centrarchidae: the monophyly of the group including Lepomis, Enneacanthus, Ambloplites, Acantharchus, Archoplites, Centrarchus, and Pomoxis is supported by the possession of extreme posterior kidney; Centrarchus and Pomoxis form a monophyletic group by sharing two synapomorphic character states: the fused extreme anterior kidneys and the fusion of the posterior kidneys behind

the base of the first haemal spine; the monophyly of Lepomis is indicated by the thick tissue layer over the extreme posterior kidney; Pomoxis is a monophyletic group as shown by the V-shaped extreme posterior kidney (pp. 122-125); conflicts among some kidney characters found in this study indicate possible convergences or parallelisms (p. 123).

Cepolidae: cepolids and owstoniids are sister-groups in sharing the specialized coiling pattern of loop a (type D2) (p. 56); their gas-glands are also well developed (p. 171).

Chaetodontidae: Microcanthus strigatus belongs to the Chaetodontidae (p. 187); kidney morphology suggests the monophyly of Forcipiger, Hemitaurichthys, Heniochus, Coradion, Parachaetodon, Prognathodes, Chelmo, Chelmonops, and "Chaetodon", and the group formed by the last six genera (p. 187); intestinal patterns suggest the monophyly of (1) Forcipiger and Hemitaurichthys (p. 118), (2) Heniochus spp. (pp. 189-190), (3) some "Chaetodon species", Parachaetodon, Prognathodes, and Vinculum (pp. 190-191); (3) Chelmo and Chelmonops (p. 193).

Cheilodactylidae: kidney of aplodactylids, cheilodactylids, chironemids, and cirrhitids are well developed compared to those of gadopsids (pp. 131-132).

Cichlidae: cichlids have an enlarged pyloric diverticulum in their stomach, a structure uncommon in perciforms (p. 24), intestinal patterns belong to type Z (p. 24);

the posterior kidneys of Cichlasoma intermedium and C. motaguwnse extend continuously to the anal region (p.132).

Kyphosidae: kyphosines, girellines, and scorpines have similar intestinal pattern (type Z; p. 29).

Leiognathidae: Gazza minuta and Leiognathus rivulatus are closely related: their anterior gas-gland is smaller, thicker than the posterior one and is covered by silvery membrane (p. 172).

Lethrinidae: Gnathodentex aurolineatus and Monotaxis grandocalis may be closely related due to the similarity in the special condition of their intestinal pattern (p. 30).

Percidae: type LA dominates Etheostomatini (p. 34).

Pomacanthidae: Centropyge and Holacanthus have complex and specialized intestinal patterns; the former has a pattern derived from type Z, but with its own detailed unique characteristics; the pattern of the latter is characterized by a group of loops at the anterior part of the body cavity (p. 35); unlike chaetodontids, most parts of the pomacanthid kidneys are fused (p. 135).

Pomacentridae: a transformation series of pomacentrid patterns can be arranged, namely, types B-S-Z; two hypotheses concerning their interrelationships were proposed (pp. 38-39); a piece of kidney tissue develops between the proximal ends of the ureters next to the posterior kidneys of Dascyllus trimaculatus, Eupomacentrus spp. and Microspathodon chrysurus (p. 136).

Priacanthidae: Cookeolus boops has a unique intestinal pattern in that its loop a winds sinistrally (p. 40).

Serranidae: the posterior kidneys of Liopropoma mowbrayi and Siniperca chuatsi are slightly enlarged laterally; to them a huge uninary bladder is attached (p. 137).

Mugilidae: Mugil and Liza may form a monophyletic group in sharing the advanced state of an extraordinarily long intestine (p. 45); M. curema and M. trichodon may be more closely related to each other than to L. macrolepis in sharing the synapomorphic character of possessing loop c (p. 45).

Labridae: gas-glands of most labrids are enclosed in a thin-membraned sac (p. 173); Bodianus rufus—Clepticus parrai, Cirrhilabrus solorensis, and Tautoga onitis—Tautogolabrus adspersus possess specialized kidney characters of their own (pp. 137-138).

Scaridae: Sparisoma viride has unique characters of its intestinal pattern, kidney feature and liver morphology (pp. 48, 138, 183, respectively).

Blennioidei: the intestinal patterns of blennioids can be classified into three groups: in one group, the pattern is percoid-like and it includes only the stichaeids; in the second group, including zaprorids, ophioblenniines, and salariinae, the pattern is extremely complex but rather similar; in the third group, the intestine is short and the pattern is simple, it includes the rest of the blennioids (pp. 50-53); kidneys of Pholis

- gunnellus are overlain by a thick muscle layer (p. 140).
- Icosteoides: the intestinal pattern of Icosteus aenigmaticus is unique (pp. 85-86).
- Callionymoides: complete separation of the kidneys occurs in all callionymids examined (p. 141).
- Gobioidei: parts of the kidneys of Awaous sp. and Eleotris fusca are degenerated (p. 142); a transverse septum in the swimbladder of Pholidichthys leucotaenia separates the two gas-glands in the anterior chamber from the one in the posterior chamber (p. 173).
- Kurtoidei: kidneys of kurtids, acanthurids, and tetraodontiforms are degenerate posteriorly; complete separation of the kidneys occurs also in some members of these groups (pp. 142-146).
- Acanthuroidei: a synapomorphic character is shared by acanthurines and zancloids: possession of loop b (p. 58); degeneration of the posterior kidneys and the intestinal patterns of these two groups are not shared by siganids (pp. 59, 60, 144, 145); Lo vulpinus, however, has a specialized kidney (pp. 144-145).
- Scombroidei: the common ureters of Auxis sp. and Sarda sarda are enlarged (p. 146).
- Stromateoides: the intestinal patterns of Nomeus gronovii and Pampus argenteus are specialized conditions within Nomeidae and Stromateidae, respectively (pp. 61, 62); the monophyly of nomeids and stromateids is supported by kidney evidence (pp. 146-147); Cubiceps sp. has an aut-

apomorphic kidney feature (p. 147).

Anabantoidei: intestines of most anabantoids coil in a spiral manner (type SP; pp. 64-65); left and right kidneys of Colisa, Trichogaster, and Helostoma are completely fused (p. 149); Macropodus and Betta are closely related as indicated by the condition of the fusion of the posterior kidneys (p. 148); Ctenopoma nanus has an autapomorphic state of this character (p. 148).

Pleuronectiformes:

Psettodidae: Psettodes has a generalized intestinal pattern (p. 77).

Bothidae: Rhombosolea tapirina, Synacium papillosum, and Tephrineches sinensis are closely related in sharing a synapomorphic intestinal pattern (pp. 77-78).

Pleuronectidae: Platyichthys stellatus and Pleuronichthys cornutus are related as suggested by the specialized intestinal pattern (p. 78).

Scophthalmidae: scophthalmids share a synapomorphic character state of the positions of the uro-genital pore and the anus (p.83).

Soleidae: soleids are monophyletic since loop a occupies the secondary body cavity (a synapomorphic character) (p. 79); Archirus lineatus and Trinectes maculatus may be related: they lack melanophores from both inner sides of the body cavity (p. 79); Synaptura marginata and Zebrias zebra share a synapomorphic intestinal pattern (p. 79).

Cynoglossidae: Cynoglossus monopus and Paraplagusia bilineata share a specialized intestinal pattern (p.80).

Species Examined	Catalogue Number of Specimen Examined	Standard Length in Millimeters	Figure Number of Intestinal Pattern	Type of Intestinal Pattern	Figure Number of Kidney Configuration	Type of Kidney Configuration

Cyclostomata

<u>Lampetra lamottei</u> (LeSueur)	AMNH 36713	178	-	-	-	***

Elasmobranchimorphi

<u>Chimaera phantasma</u> Jordan and Snyder	AMNH uncat.	150	-	-	II-2	4F
<u>Scoliodon terraenovae</u> (Richardson)	AMNH 16635	290	-	-	II-3A	4E
<u>Squalus acanthias</u> Linnaeus	AMNH 1023	160	-	-	II-3B	4E
<u>Taeniura meyeni</u> Müller and Henle	AMNH uncat.	450	-	-	II-4A	5D
<u>Urogymnus africanus</u> (Bloch and Schneider)	AMNH uncat.	226	-	-	II-4B	4E

Actinistia

<u>Latimeria chalumnae</u> Smith	AMNH 36941	1300	-	-	II-5	***

Dipnoi

<u>Lepidosiren paradoxa</u> Natterer	GD 7.068.1	540	-	-	-	-

<u>Protopterus annectens</u> (Owen)	1)	-	-	-	II-6	5D
Branchiopterygii						
<u>Calamoichthys calabaricus</u> Smith	AMNH uncat.	190, 240	-	-	II-7B	5D
<u>Polypterus ornatipinnis</u> Boulenger	AMNH 6349	108	-	-	II-7A	5D
<u>Polypterus palmus</u> Ayres	AMNH 6300	110, 114	-	-	-	5D
Actinopterygii						
Chondrostei						
<u>Acipenser stellatus</u> Pallas	AMNH 20694	157	I-63A	B	II-8A	4C
<u>Scaphirhynchus platyrhynchus</u> (Rafinesque)	AMNH 4485	122, 123	-	LA	-	-
<u>Polyodon spathula</u> (Walbaum)	AMNH uncat.	288	I-63B	LA	II-8B	2D
Ginglymodi						
<u>Lepisosteus oculatus</u> (Winchell)	AMNH 37370	148	I-64	***	II-9A	4F
<u>Lepisosteus platyrhincus</u> DeKay	AMNH 27734	237	-	-	II-9B	4E
Halecomorphi						
<u>Amia calva</u> Linnaeus	AMNH uncat.	107	I-65	B	II-10	4F
Teleostei						
Osteoglossomorpha						
Osteoglossidae						
<u>Osteoglossum bicirrhosum</u> Agassiz	AMNH uncat.	75, 80	-	-	II-11A	3F
Pantodontidae						
<u>Pantodon buchholzi</u> Peters	AMNH uncat.	75	-	-	II-11B	3B
Hiodontidae						
<u>Hiodon alosoides</u> Rafinesque	AMNH 23754	60, 67	-	-	II-11C	3D

Notopteridae							
<u>Notopterus</u> sp.	AMNH uncat.	150, 160	-	-	II-11D	3E	
<u>Xenostystus nigri</u> (Günther)	AMNH uncat.	150, 160	-	-	II-11E	1B	
Gymnarchidae							
<u>Gymnarchus niloticus</u> Cuvier	PM uncat.	312	-	B	II-11F	4F	
Mormyridae							
<u>Gnathonemus</u> sp.	AMNH 19671	110	-	-	II-11G	1B	
<u>Mormyrope deliciosus</u> (Leach)	AMNH 6892	142	-	-	II-11H	4F	
<u>Petrocephalus</u> sp.	AMNH 6885	84	-	-	II-11I	3E	
Elopomorpha							
Elopidae							
<u>Elops saurus</u> Linnaeus	AMNH uncat.	252	I-66	LA	II-12	***	
Megalopidae							
<u>Megalops cyprinoides</u> (Broussonet)	AMNH uncat.	124	I-67	LA	II-13	4C	
Albulidae							
<u>Albula vulpes</u> (Linnaeus)	AMNH uncat.	130	I-68	LA	II-14	4E	
Anguillidae							
<u>Anguilla rostrata</u> (LeSueur)	AMNH 36091	283	I-69A	LF	II-15A	4E	
Muraenidae							
<u>Gymnothorax moringa</u> (Cuvier)	AMNH 33224	161	I-69B	B	II-15B	4E	
Clupeomorpha							
Clupeidae							
<u>Coilia</u> sp.	AMNH 10321	140	I-70A	LA	II-16A	***	

<u>Clupea</u> sp.	AMNH 3072	110	I-70B	B	II-16B	1A
<u>Dorosoma</u> sp.	AMNH 25673	86	I-70C	***	II-16C	1A
<u>Pomolobus pseudoharengus</u> (Wilson)	AMNH 33224	161	I-70D	LA	II-16D	1B
<u>Sardinops</u> sp.	AMNH 7100	58	-	-	II-16E	1B
Engraulidae						
<u>Anchoa mitchilli</u> (Cuvier and Valenciennes)	AMNH 36593	75, 80	I-71	LA	II-17	1A
Chirocentridae						
<u>Chirocentrus dorab</u> (Forskål)	AMNH uncat.	170	-	-	II-18	3E
Euteleostei						
Ostariophysi						
Characidae						
<u>Astyanax</u> sp.	AMNH uncat.	59	I-72A	B	II-19A	3E
<u>Citharinus citharus</u> Geoffrey	AMNH 9562	105	I-72D	***	-	-
<u>Distichodus maculatus</u> Boulenger	AMNH 5822	82	I-72E	***	-	-
<u>Ephippicharax</u> sp.	AMNH uncat.	45	I-72B	B	II-19B	2C
<u>Micralestes</u> sp.	AMNH 6290	64	I-72C	B	II-19C	2C
Electrophoridae						
<u>Electrophorus electricus</u> (Linnaeus)	DG uncat.	738	I-73A	***	II-20A	4C
Gymnotidae						
<u>Eigenmannia virescens</u> (Valenciennes)	AMNH 30442	182	I-73B	B	II-20C,	3D
		178			II-20D	3A
<u>Gymnotus</u> sp.	AMNH 32913	140	I-73C,	***	II-20B	4C
			I-73D			

Cyprinidae

<u>Cyprinus carpio</u> Linnaeus	AMNH 21026	45	I-75A	***	II-21A	***
	AMNH 36086	56	I-75B	***		
<u>Carassius auratus</u> (Linnaeus)	AMNH 20961	44	I-75C	***	II-21B	***
			I-75D			
<u>Hemiculter kneri</u> WarPachowski	AMNH 35832	88	I-75E	***	II-21C	2C
<u>Notropis cornutus</u> (Mitchill)	AMNH 36008	110	I-75F	***	-	-
<u>Notropis hudsonius</u> (Clinton)	AMNH 73722	93	I-75G	***	-	-
<u>Notropis rubellus</u> (Agassiz)	AMNH 32973	182	I-75H	***	-	-

Catostomidae

<u>Catostomus latipinnis</u> Baird and Girard	AMNH 27269	62	I-75I	***	II-22A	***
<u>Erimyzon oblongatus</u> (Mitchill)	AMNH 23716	72	I-75J	***	-	-
<u>Hypentelium nigricans</u> (LeSueur)	AMNH 27248	45, 52	I-75K,	***	II-22B	3D
		63	I-75L			

Psilorhynchidae

<u>Psilorhynchus balitora</u> (Buchanan)	AMNH 13811	20	I-75M	***	-	-

Gyrinochelidae

<u>Gyrinocheilus aymonieri</u> (Tirant)	AMNH uncat.	49	I-76A	***	-	-

Homalopteridae

<u>Gastromyzon punctulatus</u> Inger and Chin	AMNH 68938	42	I-76B	***	II-23A	3E
<u>Hemimyzon zebroidus</u> Nichols	AMNH 11054	71	I-76C	***	II-23B	3E

Cobitidae

<u>Barbatula posteroventralis</u> Nichols	AMNH 10328	65	I-77A	***	-	-
<u>Botia citraurata</u> Nichols	AMNH uncat.	78	-	-	II-24A	2B

<u>Leptobotia elongata</u> (Bleeker)	AMNH 10419	67	-	-	II-24B	3D
<u>Leptobotia fasciata</u> Dabry de Thiersant	AMNH 10298	62	I-77B	LA	-	-
<u>Nemachilus</u> sp.	AMNH 10355	15	I-77C	B	-	-
<u>Misgurnus anguillicaudatus</u> (Cantor)	AMNH 10288	94	-	-	-	-
Ariidae						
<u>Arius felis</u> (Linnaeus)	AMNH uncat.	54, 60	-	-	II-25	2A
Bagridae						
<u>Bagrus</u> sp.	AMNH 6623	110	I-78	B	II-26A	2A
<u>Leiocassis</u> sp.	AMNH 10369	51	-	-	II-26B	2A
Callichthyidae						
<u>Callichthys</u> sp.	AMNH uncat.	60, 70	I-79	LA	II-27	***
Clariidae						
<u>Clarias fuscus</u> (Lacépède)	AMNH 10371	100	I-80	B	II-28	1A
Ictaluridae						
<u>Ictalurus melas</u> (Rafinesque)	AMNH uncat.	66	I-81	B	II-29	2A
Loricariidae						
<u>Hypostomus</u> sp.	AMNH 26374	20	I-82A	SP	-	-
<u>Loricaria cataphracta</u> Linnaeus	AMNH uncat.	80	I-82B	SP	II-30	1A
Pimelodidae						
<u>Rhamdia</u> sp.	AMNH 32064	76	-	-	II-31	***
Plotosidae						
<u>Plotosus lineatus</u> Cuvier and Valenciennes	AMNH 35805	172	I-83	B	II-32	***
Gonorynchidae						
<u>Gonorynchus greyi</u> (Richardson)	AMNH 32973	180	-	LA	-	-

Protacanthopterygii

Salmonidae

Salmo gairdneri Richardson AMNH 36277 98 I-84 *** II-33 1B

Salvelinus fontinalis (Mitchill) AMNH 23777 101 - LA - -

Osmeridae

Mallotus villosus (Müller) AMNH 26286 157 - LA II-34A 1B

Osmerus sp. AMNH 27683 115 - LA II-34B 1B

Argentinidae

Argentina sp. AMNH 29840 185 - - II-35 ***

Galaxiidae

Galaxias sp. AMNH 31474 70 - - II-36 4F

Esocidae

Esox americanus Gmelin AMNH uncat. 67 I-85 *** II-37 2D

Umbridae

Dallia pectoralis Bean AMNH 1526 110 - - II-38A 4B

Umbra pygmaea (DeKay) AMNH 33406 51 - LA II-38B 4E

Umbra limi (Kirtland) AMNH 26657 55 - LA II-38C 4E

Aplepocephalidae

Talismania sp. AMNH 35398 102 I-86 *** II-39 2D

Myctophidae

Myctophum sp. AMNH 24160 90 I-87 LA II-40 3E

Synodontidae

Synodus synodus (Linnaeus) AMNH 29882 42 - B II-41 4C

Paracanthopterygii

Amblyopsidae

Amblyopsis spelaea De Kay AMNH 12112 76 I-88 *** II-42A 5A

Percopsidae

Percopsis omiscomaycus (Walbaum) AMNH 28627 75 - LA II-42B 5D

Percopsis transmontana (Eigenmann and Eigenmann) AMNH 36308 45 - LA II-42C 5B

Batrachoididae

Opsanus tau (Linnaeus) AMNH 36043 43 - - II-43 3D

Gobiesocidae

Gobiesox strumosus Cope AMNH 16453 65 - ST II-44A 3E

Tomicodon sp. AMNH 22828 40 - ST II-44B 3F

Antennariidae

Histrio histrio (Linnaeus) AMNH 16626 61 - B II-45 5A

Chaunacidae

Chaunax sp. AMNH 13578 75 I-89 *** II-46A 5A

Ogcocephalidae

Ogcocephalus nasutus (Cuvier and Valenciennes) AMNH 16458 60 I-90 *** II-46B 5A

Gadidae

Microgadus tomcod (Walbaum) AMNH 32659 105 - B II-47 4B

Ophidiidae

Lepophidium sp. AMNH uncat. 210 I-91 B II-48 4C

Zoarcidae

Zoarcis viviparus (Linnaeus) AMNH 2860 272 I-92 B II-49 4C

Atherinomorpha

Belonidae

<u>Strongylura marina</u> (Walbaum)	AMNH 28561	213	-	ST	-	-

Exocoetidae

<u>Arrhamphus sclerolepis</u> Günther	AMNH 40003	65	-	ST	-	-
<u>Chriodorus atherinoides</u> Goodes and Bean	AMNH 27708	128	-	ST	-	-
<u>Halocypselus evolans</u> (Linnaeus)	AMNH 13507	56	-	ST	II-50A	4C
<u>Hemiramphus brasiliensis</u> (Linnaeus)	AMNH 25837	96	-	ST	II-50B	4B
<u>Hyporhamphus unifasciatus</u> (Ranzani)	AMNH 3848	90	-	ST	-	-

Anablepidae

<u>Anableps dowii</u> Gill	AMNH 24433	53	I-94	LF	II-51	4F

Cyprinodontidae

<u>Cyprinodon variegatus</u> Lacepede	AMNH 4323	43	I-95A	B	II-52A	3A
<u>Fundulus heteroclitus</u> (Linnaeus)	AMNH 36101	67	-	LA	II-52B	4E
<u>Fundulus majalis</u> (Walbaum)	AMNH 36495	55	-	LA	-	-
<u>Profundulus punctatus</u> (Günther)	AMNH 24432	50	I-95B	LA	-	3F

Goodeiidae

<u>Goodea</u> sp.	AMNH 18504	107, 140	-	SP	II-53A	***

Oryziatidae

<u>Oryzias latipes</u> (Temminck and Schlegel)	AMNH 13134	33	I-96	***	II-53B	5B

Poeciliidae

<u>Belonesox belizanus</u> Kner	AMNH 24536	85	I-97	T	II-54A	***
<u>Gambusia</u> sp.	AMNH 35061	30	-	-	II-54B	5C
<u>Poecilia vivipara</u> Bloch and Schneider	AMNH 20708	47	I-98	***	-	-

Atherinidae						
<u>Allanetta harringtonensis</u> (Goode)	AMNH 27782	62	I-3A	***	-	-
<u>Atherinops affinis</u> (Ayres)	AMNH 2690	80	I-3B	***	II-55A	1B
<u>Membras vagrans</u> (Goode and Bean)	AMNH 28659	95	I-3C	***	II-55D	3D
<u>Menidia menidia</u> (Linnaeus)	AMNH uncat.	77	I-3D	***	-	-
Melanotaeniidae						
<u>Chilatherina</u> sp.	AMNH 15028	78	I-3E	***	II-55B	4B
<u>Melanotaenia nigrans</u> (Richardson)	AMNH 18541	87	I-3F	***	II-55C	1B
Acanthopterygii						
Beryciformes						
Polymixiidae						
<u>Polymixia</u> sp.	AMNH 28144	87	I-99	***	II-56	***
Holocentridae						
<u>Adioryx vexillarius</u> (Poey)	AMNH 24949	50, 56	-	-	II-57A	3B
<u>Holocentrus rufus</u> (Walbaum)	AMNH 29109	72	I-100	***	II-57B	3C
<u>Myripristis jacobus</u> Cuvier	AMNH 23380	66	-	B	II-57C	***
<u>Plectrypops retrospinis</u> (Guichenot)	AMNH 33268	65	-	B	II-57D	***
Zeiformes						
Grammicolepididae						
<u>Xenolepidichthys dalgleishi</u> Gilchrist	AMNH 29455	68	I-101	LA	II-58	3D
Macrurocyttidae						
<u>Zenion hololepis</u> (Goode and Bean)	AMNH 29463	57	I-102	***	II-59	5A
Zeidae						
<u>Zeus japonicus</u> Cuvier and Valenciennes	AMNH 26767	100	-	B	II-60	3E

Lampridiformes

Veliferidae

Velifer hypselopterus Bleeker

AMNH uncat. 115 I-103 *** II-61 2B

Gasterosteiformes

Gasterosteidae

Apeltes quadracus (Mitchill)

AMNH 36048 32 I-104 LF II-62 3E

Aulostomidae

Aulostomus maculatus Valenciennes

AMNH 34665 254 - ST II-63 2C

Macrorhamphosidae

Macrorhamphosus scolopax (Linnaeus)

AMNH 13576 103 I-105 LF II-64 3F

Syngnathidae

Corythoichthys sp.

AMNH 35771 98 - ST II-65A 4B

Hippocampus hudsonius DeKay

AMNH 9025 180 I-106 LF II-65B 3E

Syngnathus fuscus Storer

AMNH 28567 172 - ST II-65C 4B

Channiformes

Channidae

Channa asiatica (Linnaeus)

AMNH 12140 78 - - - -

Ophicephalus argus Cantor

AMNH 11063 91 - B II-66 4C

Ophicephalus gachua Hamilton-Buchanan

AMNH 10640 61 - - - -

Ophicephalus micropeltes (Cuvier and
Valenciennes)

AMNH uncat. 82 - - - -

Ophicephalus obscurus Günther

AMNH 60419 61 - - - -

Synbranchiformes

Synbranchidae							
<u>Synbranchus marmoratus</u> Bloch	AMNH 8817	254	-	ST	II-67	***	
Scorpaeniformes							
Scorpaenidae							
<u>Scorpaena</u> sp.	AMNH 4326	37	-	-	II-68A	3A	
<u>Scorpaenodes caribbaeus</u> Meek and Hildebrand	AMNH uncat.	63	-	LA	II-68B	3A	
Triglidae							
<u>Lepidotrigla stonuchii</u> Steindachner	AMNH 26792	100	-	B	II-69A	4C	
<u>Peristedion miniatum</u> Goode	AMNH 13577	72	-	B	II-69B	5C	
<u>Pterygotrigla hemisticta</u> Temminck and Schlegel	AMNH uncat.	132	I-107A	***	II-69C	4C	
Hexagrammidae							
<u>Hexagrammos decagrammus</u> (Pallas)	AMNH 17210	128	I-107B	***	-	-	
<u>Hexagrammos lagocephalus</u> (Pallas)	AMNH 11810	108	-	***	-	-	
<u>Hexagrammos stelleri</u> Tilesius	AMNH 2761	83, 218	-	***	-	-	
<u>Ophiodon elongatus</u> Girard	AMNH 2719	83	I-107D	***	-	-	
<u>Pleuragrammus antarcticum</u> Boulenger	AMNH 12987	180	I-107C	***	-	-	
Cottidae							
<u>Cottus cognatus</u> Richardson	AMNH 32615	36, 40	-	B	II-70	4C	
<u>Myoxocephalus quadricornis</u> (Linnaeus)	AMNH 37369	77	-	D1	-	-	
Perciformes							
Percoidae							
Aplodactylidae							

<u>Crinodus lophodon</u> (Günther)	WAM I18064-	115	I-7A	***	II-71	3D
	007					
Apogonidae						
<u>Apogon affinis</u> Poey	AMNH 23514	48	I-8A	B	-	-
<u>Apogon bandanensis</u> Bleeker	AMNH 31481	67	-	-	-	-
<u>Apogon binotatus</u> (Poey)	AMNH 30771	52	I-8B	B	-	-
<u>Apogon cyanosoma</u> Bleeker	AMNH 33943	56	-	-	-	-
<u>Apogon endekataenia</u> Bleeker	AMNH 33766	48	-	-	-	-
<u>Apogon taeniophosus</u> (Bleeker)	AMNH 33927	42, 58	-	-	-	-
<u>Archamia lineolata</u> (Ehrenberg)	AMNH 33805	60	I-8C	B	II-72A	3E
<u>Astrapogon stellatus</u> (Cope)	AMNH 23833	44	I-8D	***	-	-
<u>Cheilodipterus isostigma</u> (Jordan and Seale)	AMNH 33696	54	-	-	-	-
<u>Cheilodipterus macrodon</u> (Lacépède)	AMNH 33719	85	I-8E	B	II-72B	3E
<u>Cheilodipterus octovittatus</u> Cuvier and Valenciennes	AMNH 9411	142	-	-	-	-
<u>Cheilodipterus quinquelineatus</u> (Cuvier)	AMNH 33718	58	-	-	-	-
<u>Glossamia aprion</u> (Richardson)	AMNH 31496	75	I-8F	B	II-72C	3E
<u>Sphaeramia nematoptera</u> (Bleeker)	USNM 130785	61	I-8G	B	-	-
Arripidae						
<u>Arripis trutta esper</u> Whitley	AMNH 31384	162	-	B	-	-
Bathyclupeidae						
<u>Bathyclupea</u> sp.	USNM 197351	136	-	B	II-73	3E
Branchiostegidae						

<u>Branchiostegus japonicus</u> (Houttuyn)	AMNH 12993	225	I-9A	B	II-74A	4E
<u>Caulolatilus princeps</u> (Jenyns)	AMNH 7486	195	I-9B	***	II-74B	4C
<u>Malacanthus plumieri</u> (Bloch)	AMNH 21465	167	I-9C	B	II-74C	4E
Banjosidae						
<u>Banjos typus</u> Bleeker	AMNH 35845	55	-	B	II-75	3F
Carangidae						
<u>Alectis ciliaris</u> (Bloch)	AMNH 899	113	I-10A	LA	II-76A	3D
<u>Caranx crysos</u> (Mitchill)	AMNH 7901	140	I-10B	B	II-76B	2B
<u>Decapterus muroadsi</u> (Temminck and Schlegel)	AMNH 26822	163	I-10C	B	II-76C	2B
<u>Decapterus russelli</u> (Ruppell)	AMNH 15935	140	-	-	II-76D	3F
<u>Megalaspis cordyla</u> (Linnaeus)	AMNH 32576	82	I-10D	B	II-76E	2B
<u>Oligoplites saurus</u> (Bloch and Schneider)	AMNH 16124	115	I-11B	B	-	-
<u>Scomberoides tolooo</u> Bleeker	AMNH 8089	150	I-11A	D1	II-76F	3F
<u>Selar</u> sp.	AMNH 2340	143	I-10E	B	II-76G	2B
<u>Selene vomer</u> (Linnaeus)	AMNH 1618	82	I-10G	D1	II-76H	3D
<u>Seriola falcata</u> Cuvier and Valenciennes	AMNH 18373	50	I-12B	LA	II-76I	3D
<u>Seriola zonata</u> (Mitchill)	AMNH 30147	160	I-12A	B	II-76J	3E
<u>Trachinotus</u> sp.	AMNH 27819	43	-	-	II-76K	3E
<u>Trachurus japonicus</u> (Temminck and Schlegel)	AMNH 13231	135	I-10F	B	II-76L	3E
<u>Vomer declivifrons</u> Meek and Hildebrand	AMNH 13583	94	I-10H	D1	II-76M	3E
Centrarchidae						
<u>Acantharchus pomotis</u> (Baird)	AMNH 5376	74	-	B	II-77A	4C
<u>Ambloplites cavifrons</u> Cope	AMNH 30262	87	-	-	II-77B	4D
<u>Ambloplites rupestris</u> (Rafinesque)	AMNH 20982	87	-	B	II-77C	4A
<u>Archoplites interruptus</u> (Girard)	CAS 39682	72, 82, 85	-	-	II-77D	2B

<u>Centrarchus macropterus</u> (Lacépède)	AMNH 3220	85	-	B	II-77E	2E
<u>Elassoma zonatum</u> Jordan	CU uncat.	22, 22	-	LA	II-77F	3F
<u>Enneacanthus chaetodon</u> (Baird)	AMNH 33543	38, 45	-	B	II-77G	4E
<u>Enneacanthus gloriosus</u> (Holbrook)	AMNH 26270	45	-	-	II-77H	4A
<u>Enneacanthus obesus</u> (Baird)	AMNH 23742	60	-	-	II-77I	5D
<u>Lepomis cyanellus</u> Rafinesque	AMNH uncat.	65, 80	-	-	II-77J	2E
<u>Lepomis gibbosus</u> (Linnaeus)	AMNH uncat.	43, 43, 45	-	-	II-77K	2E
		45, 49, 50				
		50				
	AMNH 36095	49				
	AMNH 30279	24-70 ²⁾				
<u>Lepomis gulosus</u> (Cuvier and Valenciennes)	AMNH uncat.	88	-	-	II-77L	2E
<u>Lepomis humilis</u> (Girard)	AMNH uncat.	48, 60	-	-	II-77M	2A
<u>Lepomis macrochirus</u> Rafinesque	AMNH uncat.	96	-	-	II-77N	2E
<u>Lepomis marginatus</u> (Holbrook)	CU 15261	78	-	-	II-77O	4A
<u>Lepomis megalotis</u> (Rafinesque)	AMNH uncat.	72, 95	-	B	II-77P	2E
<u>Lepomis microlophus</u> (Günther)	AMNH uncat.	80, 97, 97	-	-	II-77Q	2E
<u>Lepomis punctatus</u> (Valenciennes)	CU 26230	72	-	-	II-77R	4A
<u>Lepomis symmetricus</u> Forbes	CU 21286	32	-	-	II-77S	2E
<u>Micropterus coosae</u> Hubbs and Bailey	AMNH uncat.	110	-	-	II-77T	3F
<u>Micropterus salmoides</u> (Lacépède)	AMNH 30003	104	-	B	II-77U	3F
<u>Pomoxis annularis</u> Rafinesque	AMNH 23979	93, 102	-	B	II-77V	2E
<u>Pomoxis nigromaculatus</u> (Lesueur)	AMNH 30128	150, 170	I-13A-C	-	II-77W	2E
Centropomidae						

<u>Centropomus undelcimalis</u> (Bloch)	AMNH 2017	85	-	B	II-78A	3F
<u>Centropomus nigrescens</u> Günther	AMNH 16752	94	-	B	-	-
<u>Chanda gymnocephalus</u> (Lacépède)	AMNH 32521	42	-	B	II-78B	3E
<u>Lates calcarifer</u> (Bloch)	AMNH 17721	118	-	B	II-78C	3D
	ANSP 86363	115				
Cepolidae						
<u>Acanthocephala krusensternii</u> (Temminck and Schlegel)	AMNH 13003	125	I-14A	***	II-79A	3E
<u>Cepola rubescens</u> Linnaeus	AMNH 2932	192	I-14B	***	II-79B	3F
Chaetodontidae						
<u>Chaetodon argentatus</u> Smith and Radcliffe	ZMNTU uncat.	53, 64, 73	V-5B	***	V-1M	4D
<u>Chaetodon aureus</u> Temminck and Schlegel	ZMNTU uncat.	98, 134	V-6A	***	-	-
<u>Chaetodon auriga</u> Forskål	AMNH 33605	145	V-6B	***	V-1N	4D
	ZMNTU uncat.	58				
<u>Chaetodon aya</u> Jordan	AMNH 13740	87	V-5A	***	-	-
<u>Chaetodon capistratus</u> (Linnaeus)	AMNH 21279	19	V-6C	***	-	-
	AMNH 26299	31	V-10A, B	***	-	-
	AMNH 37144	74				
<u>Chaetodon lunula</u> (Lacepede)	ZMNTU uncat.	103	V-6D	***	-	-
<u>Chaetodon ocellatus</u> Bloch	AMNH 28537	21, 37	V-10C- E	***	-	-
	AMNH 17054	110				
<u>Chaetodon sexdentarius</u> Poey	AMNH 19032	77, 80				
	AMNH 29115	27				
<u>Chaetodon striatus</u> Linnaeus	AMNH 21220	20	V-10F- H	***	-	-

	AMNH 36698	55				
	AMNH 997	80				
<u>Chaetodon triangulum</u> Cuvier and Valenciennes	ZMNTU uncat.	40	V-5C	***	-	-
<u>Chaetodon unimaculatus</u> Bloch	ZMNTU uncat.	60, 97, 107	V-6F	***	V-10	4D
<u>Chaetodon vagabundus</u> Linnaeus	AMNH 14790	58	V-6E	***	V-1P	4D
<u>Chelmc rostratus</u> (Linnaeus)	AMNH 16665	90	V-7A	***	V-1H	4D
	CAS 37641					
<u>Chelmonops truncatus</u> (Kner)	WAM P13745	131	V-7B	***	V-1I	4D
<u>Coradion chrysozonus</u> (Cuvier and Valenciennes)	ZMNTU uncat.	110, 142	V-8	***	V-1J	4D
	AMNH 18390	85				
<u>Forcipiger flavissimus</u> Jordan and Mc Gregor	ZMNTU uncat.	94, 130	V-2B, C	***	V-1G	3C
<u>Hemitaurichthys polylepis</u> (Bleeker)	ZMNTU uncat.	76, 122 134	V-2D, G	***	V-1C	3C
	AMNH uncat.	91, 132				
<u>Heniochus acuminatus</u> (Linnaeus)	ZMNTU uncat.	45, 51 52, 78	V-4	***	V-1D	3C
<u>Heniochus monoceros</u> (Cuvier and Valenciennes)	ZMNTU uncat.	75, 101	V-2H	***	-	-
<u>Heniochus permutatus</u> Cuvier and Valenciennes	ZMNTU uncat.	41, 42 46, 46	V-3	***	V-1E	3C
<u>Heniochus singularis</u> Cuvier and Valenciennes	ZMNTU uncat.	42, 61	V-2I	***	-	-

<u>Heniochus varius</u> (Cuvier)	ZMNTU uncat.	50, 52, 77	V-2J	***	V-1F	3C
<u>Microcanthus strigatus</u> (Cuvier and Valenciennes)	AMNH 33608	87	V-2A	D	V-1A	3D
<u>Parachaetodon ocellatus</u> (Cuvier)	WAM P25095-091	83	V-5D	***	V-1K	4D
<u>Prognathodes aculeatus</u> (Gray)	AMNH 34556	60	V-5E	***	V-1L	4D
<u>Vinculum sexfasciatus</u> (Richardson)	SAM F1291	177	V-9	***	V-1B	3D
Cheilodactylidae						
<u>Goniistius zonatus</u> (Cuvier and Valenciennes)	ZMNTU uncat.	90	-	B	II-80A	3D
<u>Nemadactylus macropterus</u> (Bloch and Schneider)	AMS I-10015	130	-	B	II-80B	3D
Chironemidae						
<u>Chironemus marmoratus</u> Günther	AMS I-17343-009	115, 138	I-7B	D2	II-81	3D
Cichlidae						
<u>Cichlasoma champotonis</u> Hubbs	AMNH 24547	72	I-15A	B	II-82A	3C
<u>Cichlasoma heterospilum</u> Hubbs	AMNH 25102	69	I-15B	Z	II-82B	3C
<u>Cichlasoma hyorhynchum</u> Hubbs	AMNH 25104	70	I-15C	B	II-82C	3C
<u>Cichlasoma intermedium</u> (Günther)	AMNH 32142	71	I-15D	D***	II-82D	4C
<u>Cichlasoma motaguense</u> Günther	AMNH 35178	75	-	-	II-82E	4C
<u>Cichlasoma salvini</u> Günther	AMNH 35008	72	I-15E	B	II-82F	3C
<u>Cichlasoma spilurum</u> (Günther)	AMNH 32183	45	I-15F	Z	-	-

<u>Haplochromis eucinostomus</u> Regan	AMNH 31855	78	I-15G	Z	II-82G	3C
<u>Melanochromis johanni</u> (Eccles)	MO uncat.	65	I-15H	Z	-	-
Cirrhitidae						
<u>Amblycirrhitus pinos</u> (Mowbray)	AMNH 25796	54	-	B	II-83A	3D
<u>Cirrhitichthys falco</u> Randall	AMNH 28672	58	I-7E	D1	II-83B	3D
<u>Paracirrhites bimacula</u> (Jenkins)	AMNH 30912	45	I-7D	S	II-83C	3D
<u>Paracirrhites</u> sp.	USNM uncat.	100	I-7C	B	II-83D	3D
Coryphaenidae						
<u>Coryphaena hippurus</u> Linnaeus	AMNH uncat.	123	-	B	II-84	3E
Echeneidae						
<u>Echeneis naucrates</u> Linnaeus	AMNH 2607	174	I-16A	B	II-85A	-
<u>Remora brachyptera</u> Bleeker	AMNH 16149	128	I-16B	ST	II-85B	3E
<u>Remora remora</u> Bleeker	AMNH 15791	85	I-16C	B	II-85C	4C
<u>Rhombochirus osteochir</u> (Cuvier)	AMNH 15359	120	I-16D	***	II-85D	4F
Embiotocidae						
<u>Brachyistius frenatus</u> Gill	AMNH 5409	80	I-17A	T	II-86A	4A
<u>Cymatogaster aggregata</u> Gibbons	AMNH 2739	90	I-17B	LA	II-86B	4A
<u>Ditrema temmincki</u> Bleeker	AMNH 3720	148	I-17C	B	II-86C	4A
Emmelichthyidae						
<u>Dipterygonotus gruveli</u> Chabanaud	ANSP 107348	76	-	B	II-87	3D
	MZUM 100242	75				
<u>Emmelichthys nitidus</u> Richardson	WAM IB.518-9	220	-	B	-	-
<u>Merolepis</u> sp.	ANSP 12413-418	120	-	B	-	-
Enoplosidae						

<u>Enoplosus armatus</u> (White)	AMS I17178- 007	95	-	B	II-88	4A
Ephippidae						
<u>Chaetodipterus faber</u> (Broussonett)	USNM 188288	80	I-18A	***	II-89	4A
<u>Drepane punctata</u> (Linnaeus)	ANSP 62704-34	36, 43	I-18B	***	-	-
<u>Platax</u> sp.	AMNH uncat.	84	I-18C	***	-	-
Gadopsidae						
<u>Gadopsis marmoratus</u> Richardson	AMS I19061- 001	130	-	LA	II-90	4E
Gerridae						
<u>Diapterus olisthostomus</u> (Goode and Bean)	AMNH uncat.	105	I-19A	B	II-91A	3D
<u>Eucinostomus gula</u> (Quoy and Gaimard)	AMNH uncat.	55	-	-	-	-
<u>Eucinostomus pseudogula</u> Poey	AMNH 2424	78	I-19C	B	II-91B	3E
<u>Gerres cinereus</u> (Walbaum)	AMNH 1591	75	I-19D	B	II-91C	3E
<u>Gerres</u> sp.	AMNH 3878	50	-	-	-	-
Grammistidae						
<u>Grammistes sexlineatus</u> (Thunberg)	AMNH 14931	84	-	B	-	-
<u>Rypticus saponaceus</u> Cuvier and Valenciennes	AMNH 24668	68	-	B	II-92	3E
Kuhliidae						
<u>Kuhlia taeniura</u> (Cuvier and Valenciennes)	ANSP 83524	65	I-20A	D1	-	-
<u>Kuhlia malo</u> Cuvier and Valenciennes	AMNH 17090	64	I-20C	D1	II-93A	3E
<u>Kuhlia marginata</u> (Cuvier and Valenciennes)	AMNH 20206	40	I-20B	B	II-93B	3E
<u>Nannatherina balstoni</u> Regan	AMNH 31357	51	I-20D	B	-	-

Kyphosidae

<u>Girella melanichthys</u> (Richardson)	ZMNTU uncat.	46	I-21E	Z	II-94A	3E
<u>Girella mezinga</u> Jordan and Starks	AMNH 26935	108	I-21F	Z	II-94B	3D
<u>Hermosilla azurea</u> Jenkins and Evermann	AMNH 11770	240	I-21A	Z	II-94C	3D
<u>Kyphosus sectatrix</u> (Linnaeus)	AMNH uncat.	230	I-21B	Z	-	-
<u>Kyphosus vaigiensis</u> (Quoy and Gaird)	AMNH 14804	135	I-21C	Z	II-94D	3D
<u>Sectator ocyurus</u> Jordan	AMNH 12659	28	I-21D	Z	II-94E	3D
	SIO 68-268	92, 138				
<u>Scorpius aequipinnis</u> Richardson	AMNH 31314	63	I-21G	Z	II-94F	3C
<u>Scorpius georgianus</u> Cuvier and Valenciennes	AMNH 31315	77	I-21H	Z	II-94G	3D

Labracoglossidae

<u>Labracoglossa argentiventris</u> Peters	AMNH 13100	145	-	B	II-95	3F

Lactariidae

<u>Lactarius lactarius</u> (Bloch and Schneider)	AMNH 32523	60, 96	-	B	II-96	3E

Latrididae

<u>Latridopsis forsteri</u> (Castelnau)	AMS 117576-007	148	-	B	II-97	3D

Leiognathidae

<u>Gazza minuta</u> (Bloch)	AMNH 14903	70, 72	I-19D	B	II-98A	3E
<u>Leiognathus rivulatus</u> (Temminck and Schlegel)	AMNH 26819	90	I-19E	HZ	II-98B	3E
<u>Parequula melbournensis</u> (Castelnau)	AMS 117904-002	110	I-19F	B	II-98C	3D

Lethrinidae

<u>Gnathodentex aurolineatus</u> (Lacépède)	ANSP 108347	186, 188	I-22A	***	-	-
<u>Lethrinus ornatus</u> Cuvier and Valenciennes	AMNH 14916	77	-	-	II-99A	3E
<u>Lethrinus rhodopterus</u> Bleeker	AMNH 14910	85	I-22B	B	II-99B	3E
<u>Monotaxis grandoculis</u> (Forskål)	ZMUM 185926	105	I-22C	***	II-99C	3E
<u>Pentapodus</u> sp.	ANSP 90134	90	I-22D	B	-	-

Lobotidae

<u>Lobotes</u> sp.	AMNH uncat.	56	-	B	II-100	4E

Lutjanidae

<u>Lutjanus gibbus</u> (Forskål)	AMNH 14912	85	-	B	II-101A	3E
<u>Lutjanus griseus</u> (Linnaeus)	AMNH 30366	110	-	B	II-101B	3E
<u>Ocyurus chrysurus</u> (Bloch)	AMNH 2825	75	-	B	II-101C	3E
<u>Symphysanodon typus</u> Bleeker	ZMUM 174017	96	-	B	II-101D	3E

Menidae

<u>Mene annocarolina</u> Lacépède	USNM 102665	95	I-23	***	II-102	4D

Monodactylidae

<u>Monodactylus falciformis</u> Lacépède	ANSP 77588	127	I-24	D***	-	-

Mullidae

<u>Mullus barbatus</u> Linnaeus	AMNH 20467	95	-	B	II-103A	3D
<u>Parupeneus malabaricus</u> (Cuvier and Valenciennes)	AMNH 14919	81	-	-	II-103B	3D
<u>Pseudupeneus maculatus</u> (Bloch)	AMNH 19501	110	-	-	II-103C	3D

Nandidae

<u>Monocirrhus polyacanthus</u> Heckel	GD	68	I-25A	B	II-104A	5D
<u>Nandus nebulosus</u> Bleeker	ZMUM 195508	80	I-25B	***	II-104B	3E

<u>Pristolepis fasciata</u> Bleeker	AMNH uncat.	87	I-25C	***	-	
Nemipteridae						
<u>Nemipterus</u> sp.	AMNH 16676	80	I-26	LA	II-105A	4C
<u>Scolopsis bilineatus</u> (Bloch)	AMNH 14945	72	-	B	II-105B	3E
Oplegnathidae						
<u>Oplegnathus</u> sp.	USNM uncat.	62	I-27	D1	II-106	4D
Owstoniidae						
<u>Owstonia tosaensis</u> Kamohara	AMNH uncat.	162	I-14C	***	II-107	-
Pempheridae						
<u>Parapriacanthus</u> sp.	USNM uncat.	52	-	-	II-108A	3E
<u>Pempheris</u> sp.	USNM uncat.	75	-	B	II-108B	3E
Percidae						
<u>Acerina schraetser</u> (Linnaeus)	AMNH 20690	65	-	B	II-109A	2B
<u>Ammocrypta vivax</u> Hay	AMNH uncat.	43	-	-	II-109B	2B
<u>Aspro streber</u> Siebold	AMNH 20687	110	-	B	II-109C	4F
<u>Etheostoma caeruleum</u> Storer	AMNH 21172	42	-	LA	II-109D	3D
<u>Etheostoma olmstedii</u> Storer	AMNH 32595	63	-	LA	II-109E	3E
<u>Perca flavescens</u> (Mitchill)	AMNH 23761	83	-	B	II-109F	2B
<u>Percina caprodes</u> (Rafinesque)	AMNH uncat.	74	-	LA	II-109G	2B
Plesiopidae						
<u>Plesiops melas</u> Bleeker	AMNH 14926	57	-	B	II-110	-
Pomacanthidae						
<u>Centropyge bicolor</u> (Bloch)	AMNH uncat.	55	I-28A	***	II-111A	1A
<u>Centropyge flavissimus</u> (Cuvier)	AMNH 30907	60	I-28B	***	-	-

<u>Holacanthus tricolor</u> (Bloch)	AMNH 28703	70	I-28C	***	II-111B 1A
<u>Pomacanthus paru</u> (Bloch)	AMNH 30340	62	-	-	II-111C 3D
<u>Pomacanthus</u> sp.	AMNH uncat.	57	I-28D	***	II-111D 3F
Pomacentridae					
<u>Abudefduf saxatilis</u> (Linnaeus)	AMNH 21437	66	I-29A	HZ	II-112A 3F
	AMNH 37150	116	-	HZ	- -
<u>Abudefduf taurus</u> (Müller and Troschel)	AMNH 20851	55	I-29B	HZ	- -
	AMNH uncat.	135	-	Z	- -
<u>Amphiprion ocellaris</u> Cuvier and Valenciennes	AMNH 14869	17	-	S	- -
	AMNH 14607	40	I-29C	Z	II-112B 3E
<u>Chromis cyanea</u> (Poey)	AMNH 34604	80	I-29D	B	II-112C 3G
<u>Chromis multilineatus</u> (Guichenot)	AMNH 3311	74	I-29E	B	II-112D 3G
<u>Dascyllus trimaculatus</u> (Rüppell)	AMNH 14902	70	I-29F	***	II-112E 4A
<u>Microspathodon chrysurus</u> (Cuvier)	AMNH 21353	92	I-29H	***	II-112I 4A
<u>Eupomacentrus</u> sp.	AMNH 23799	72	I-29G	Z	II-112F 4A
<u>Eupomacentrus dorsopunicans</u> (Poey)	AMNH 35265	55, 62	-	Z	II-112G 4A
<u>Eupomacentrus partitus</u> (Poey)	AMNH 31175	55	-	-	II-112H 4A
<u>Eupomacentrus variabilis</u> (Castelnau)	AMNH 34681	58	-	-	- -
<u>Premnas biaculeatus</u> Bleeker	ANSP 90188	75	I-29I	S	- -
Pomadasyidae					
<u>Anisotremus virginicus</u> (Linnaeus)	AMNH 28863	97	-	B	II-113A 3E
<u>Bathystoma</u> sp.	AMNH 29898	80	-	B	II-113B 3E
<u>Haemulon chrysargyreum</u> Günther	AMNH 17039	59	-	B	II-113C 3E

<u>Haemulon melanurum</u> (Linnaeus)	AMNH 34619	95	-	B	II-113D	3F
<u>Haemulon sciurus</u> (Shaw)	AMNH 26039	65	-	B	II-113E	3E
<u>Pomadasys jubelini</u> (Cuvier and Valenciennes)	AMNH 32773	94	-	B	II-113F	3F
Pomatomidae						
<u>Pomatomus saltatrix</u> (Linnaeus)	AMNH 36010	132	-	B	-	-
<u>Scombrops boops</u> (Houttuyn)	AMNH 26832	143	-	B	II-114	3E
Priacanthidae						
<u>Cookeolus boops</u> (Schneider)	AMNH 26816	125	I-30A	***	II-115A	***
<u>Priacanthus cruentatus</u> (Lacépède)	AMNH 21464	115	I-30B	B	II-115B	3F
<u>Pseudopriacanthus altus</u> (Gill)	AMNH 20320	65	I-30C	D***	II-115C	2C
Pseudochromidae						
<u>Dampiera cyclophthalma</u> (Müller et Troschel)	AMNH 15781	68	-	D1	-	-
<u>Gramma loreto</u> Poey	AMNH 35305	55	-	B	II-116	3F
<u>Gramma melacara</u> Böhlke and Randall	AMNH 33271	40	-	B	-	-
<u>Pseudogramma polyacantha</u> (Bleeker)	AMNH 30902	45	-	D1	-	-
Rachycentridae						
<u>Rachycentron canadum</u> (Linnaeus)	AMNH 3291	130	-	B	II-117	3E
Rhinoprenidae						
<u>Rhinoprenes pentanemus</u> Munro	ANSP 134860	*	I-31	HZ		
Scatophagidae						
<u>Scatophagus argus</u> (Linnaeus)	AMNH 15878	63	-	SP	II-118	3E
	ZMNTU uncat.	60				

Sciaenidae

<u>Aplodinotus grunniens</u> Rafinesque	AMNH uncat.	145	-	B	II-119A	3C
<u>Bairdiella chrysura</u> (Lacépède)	AMNH 16909	105	-	B	II-119B	3E
<u>Cynoscion regalis</u> (Bloch and Schneider)	AMNH 28511	88	-	LA	II-119C	3E
<u>Equetus acuminatus</u> (Bloch and Schneider)	AMNH 34616	74	-	B	II-119D	3E
<u>Larimus fasciatus</u> Holbrook	AMNH 16295	140	-	B	II-119E	3E
<u>Macrodon ancylodon</u> Bloch and Schneider	AMNH 20767	140	-	B	II-119F	3E
<u>Menticirrhus americanus</u> (Linnaeus)	AMNH 2561	102	-	B	II-119G	3E
<u>Nebris microps</u> Cuvier and Valenciennes	AMNH 9320	113	-	LA	II-119H	3E
<u>Odontoscion dentex</u> (Cuvier)	AMNH 17394	80	-	B	II-119I	3E
<u>Paralonchurus</u> sp.	AMNH 20736	115	-	B	II-119J	3E
<u>Plagioscion squamosissima</u> (Heckel)	AMNH 3755	103	-	B	II-119K	3E
<u>Stellifer rastrifer</u> (Jordan)	AMNH 20741	102	-	D1	II-119L	3E

Serranidae

<u>Acanthistius serratum</u> (Cuvier and Valenciennes)	AMNH 31308	127	-	B	-	-
<u>Anthias anthias</u> Linnaeus	ANSP 13319-42	92	-	B	-	-
<u>Anthias squamipinnis</u> (Peters)	ANSP 106199	57	-	B	-	-
<u>Bostockia porosa</u> Castelnau	AMNH 31443	80	I-32A	***	-	-
<u>Centropristis striata</u> (Linnaeus)	AMNH 4324	58	-	B	-	-
<u>Dicentrarchus labrax</u> (Walbaum)	AMNH 32845	130	-	B	-	-
<u>Liopropoma mowbrayi</u> Woods and Kanazawa	AMNH 31255	53	-	B	II-120A	3G
<u>Morone americana</u> Gill	AMNH 35394	65, 69	-	B	II-120B	3F

<u>Petrometopon cruentatum</u> (Lacépède)	AMNH 33274	96	I-32B	***	II-120C	4A
<u>Percilia gillissii</u> Girard	ANSP 75668	40	-	B	-	-
<u>Siniperca chuatsi</u> Gill	AMNH 10509	88	-	B	II-120D	3F
Sillaginidae						
<u>Sillago bassensis</u> Cuvier and Valenciennes	AMNH 31333	105	-	B	II-121	4B
<u>Sillago maculatus</u> Quoy and Gaimard	AMNH 31397	75	-	B	-	-
Sparidae						
<u>Archosargus probatocephalus</u> (Walbaum)	AMNH 20729	70	I-33A	***	II-122	3E
<u>Calamus pennatula</u> Guichenot	AMNH 4903	132	-	B	-	-
<u>Dentex dentex</u> (Linnaeus)	ANSP 12610-12	95	-	B	-	-
<u>Dentex</u> sp.	ANSP 98928	97	-	D2	-	-
<u>Lagodon rhomboides</u> (Linnaeus)	AMNH 16935	85	I-33B	***	-	-
<u>Stenotomus chrysops</u> (Linnaeus)	AMNH 28533	72	-	B	-	-
Teraponidae						
<u>Amniataba percoides</u> Günther	AMNH 35615	64, 72	-	D1	II-123A	3D
<u>Leiopotherapon unicolor</u> Günther	AMNH 35554	63, 70	-	B	II-123B	3D
<u>Pelates quadrilineatus</u> (Bloch)	AMNH 31415	63	-	B	II-123C	3D
<u>Terapon theraps</u> Cuvier and Valenciennes	AMNH 14616	75	-	B	II-123D	3D
Toxotidae						
<u>Toxotes chatereus</u> (Hamilton and Buchanan)	AMNH 33635	73	I-34	B	II-124	3G
Mugiloidei						
Mugilidae						
<u>Agonostomus monticola</u> Bancroft	AMNH 31550	92	I-35A	***	II-125A	3F
<u>Aldrichetta forsteri</u> (Cuvier and Valenciennes)	AMNH 31401	65	I-35B	B	II-125B	3E

<u>Liza macrolepis</u> (Andrew and Smith)	AMNH 32553	88	I-35C	***	II-125C	3F
<u>Mugil cephalus</u> Linnaeus	AMNH 5358	98	-	-	-	-
<u>Mugil curema</u> Valenciennes	AMNH 36044	102	I-35D	***	II-125D	3E
<u>Mugil trichodon</u> Poey	AMNH 21408	65	I-35E	***	-	-
Sphyraenoidei						
Sphyraenidae						
<u>Sphyraena barracuda</u> (Walbaum)	AMNH 21438	114	I-36A	LA	II-126	2B
<u>Sphyraena borealis</u> DeKay	AMNH 4339	90	I-36B	B	-	-
Polynemoidei						
Polynemidae						
<u>Polydactylus</u> sp.	AMNH 16020	45	I-37	B	-	-
Labroidei						
Labridae						
<u>Bodianus rufus</u> (Linnaeus)	AMNH 34004	90	-	-	II-127A	3C
<u>Cirrhilabrus solorensis</u> Bleeker	AMNH 18342	70	I-38A	B	II-127B	4A
<u>Clepticus parrai</u> (Bloch and Schneider)	AMNH 30728	98	I-38B	***	II-127C	3C
<u>Doratonotus megalepis</u> Günther	AMNH 26117	38	I-38C	B	II-127D	1B
<u>Halichoeres bivittatus</u> (Bloch)	AMNH 31161	57	-	B	II-127E	4C
<u>Halichoeres nebulosus</u> (Cuvier and Valenciennes)	AMNH 14997	68	-	B	-	-
<u>Hemipteronotus splendens</u> (Castelnau)	AMNH 27153	55	-	B	II-127F	3D
<u>Iniistius</u> sp.	ANSP 105326	115	-	ST	-	-
<u>Lachnolaemus</u> sp.	ANSP 87103	52	-	B	-	-

<u>Macropharyngodon meleagris</u> (Cuvier and Valenciennes)	AMNH 15006	55	-	B	II-127G	1A
<u>Pseudojulis notospilus</u> Günther	AMNH 23803	73	-	B	II-127H	1A
<u>Stethojulis phikadopleura</u> (Bleeker)	AMNH 14983	80	-	B	II-127I	3D
<u>Thalassoma bifasciatum</u> (Bloch)	AMNH 22803	58	I-38D	LA	II-127J	3E
<u>Tautoga onitis</u> (Linnaeus)	AMNH 36030	67	I-38E	LA	II-127K	3D
<u>Tautogolabrus adspersus</u> (Walbaum)	AMNH 36079	85	-	LA	II-127L	3D
Odacidae						
<u>Odax pullus</u> (Schneider)	ANSP 113340	63	I-39	LA	II-128	2C
<u>Haletta semifasciata</u> (Cuvier and Valenciennes)	AMS I6609-10	230, 235	-	ST	-	-
Scaridae						
<u>Scaridea</u> sp.	ANSP 91751	180	I-40A	LF	-	-
<u>Scarus croicensis</u> Bloch	AMNH 19580	112	I-40B	LF	II-129A	3D
	AMNH 23912	60				
<u>Sparisoma flavesceus</u> (Schneider)	AMNH 18757	90	I-40C	LF	-	-
<u>Sparisoma radians</u> (Valenciennes)	AMNH 29123	65	I-40D	LF	II-129B	3D
<u>Sparisoma viride</u> (Bonnaterre)	AMNH 34130	70	I-40E	***	II-129C	1A
Trachinoidei						
Bathymasteridae						
<u>Bathymaster signatus</u> Cope	AMNH 17209	113	I-41A	S	II-130	3E
Champsodontidae						
<u>Champsodon</u> sp.	USNM 150759	120	I-41B	B	II-131	4B

Cheimarrichthyidae							
<u>Cheimarrichthys forsteri</u> Haast	AMS 118587-001	120	-	-	II-132	2D	
Creediidae							
<u>Creedia haswelli</u> (Ramsay)	AMS 19002	62	I-41C	B	II-133	4C	
Dactyloscopidae							
<u>Dactyloscopus</u> sp.	USNM 210630	40	I-41D	LA	II-134	3E	
Limnichthyidae							
<u>Limnichthys fasciatus</u> Waite	AMNH 31323	46	I-41E	B	II-135	4B	
Mugiloididae							
<u>Parapercis ommatura</u> Jordan and Snyder	AMNH 26921	80	I-41F	B	II-136A	3F	
<u>Parapercis sexfasciatus</u> Bleeker	AMNH 26859	114	-	-	II-136B	3F	
Opisthognathidae							
<u>Opisthognathus</u> sp.	ANSP 75168	110	I-41G	***	-	-	
<u>Opisthognathus whitehursti</u> (Longley)	ZMMU 199012	41	I-41H	B	II-137	3E	
Trachinidae							
<u>Trachinus vipera</u> Cuvier and Valenciennes	AMNH 4531	58	I-41I	B	II-138	3E	
Trichonotidae							
<u>Trichodon trichodon</u> (Pallas)	USNM 76400	83	I-41J	DI	II-139	3F	
Uranoscopidae							
<u>Astroscopus y-graecum</u> (Cuvier)	AMNH 8761	112	-	-	-	-	
<u>Uranoscopus oligolepis</u> Bleeker	AMNH 26861	70	I-41K	B	II-140	3F	
Notothenioidae							

Bovichthyidae									
<u>Bovichthys</u> sp.	USNM 214717	47	-	B	II-141	3E			
Notothenidae									
<u>Harpagifer bispinis</u> (Schneider)	AMNH 5011	56	-	B	II-142A	3E			
<u>Notothenia</u> sp.	USNM 77338	59	-	B	II-142B	2B			
<u>Trematomus</u> sp.	AMNH 20554	178	I-42	B	II-142C	3F			
Blennioidei									
Blenniidae									
<u>Blennius cristatus</u> Linnaeus	AMNH 28982	52	I-43A	***	II-143-1	3D			
<u>Blennius tentacularis</u> Brünnich	AMNH 20535	62	I-43B	B	II-143-2	3D			
<u>Homesthes caulopus</u> Gilbert	AMNH 20513	67	I-43C	B	II-143-3	3D			
<u>Hypleurochilus geminatus</u> (Wood)	AMNH 33488	52	I-43D	B	II-143-4	3D			
<u>Petroscirtes mitratus</u> Rüppell	AMNH 31460	42	I-43E	B	II-143-5	3E			
<u>Ophioblennius atlanticus</u> (Valenciennes)	AMNH 34719	53	I-43F	***	II-143-6	3D			
<u>Ophioblennius steindachneri</u> Springer	AMNH 23805	64	I-43G	***	II-143-7	3D			
<u>Alticus marmoratus</u> (Bennett)	AMNH 9361	59	I-43H	***	II-143-8	3E			
<u>Entomacrodus nigricans</u> Gill	AMNH 23606	50	I-43I	***	II-143-9	3E			
<u>Salarias enosimae</u> (Jordan and Snyder)	ZMNTY uncat.	88	I-43J	***	II-143-10	4D			
<u>Salarias fasciatus</u> (Bloch)	AMNH 14798	88	-	-	-	-			
<u>Salarias</u> sp.	ZMNTU uncat.	72	I-43K	***	-	-			
Chaenopsidae									
<u>Chaenopsis alepidotus</u> (Gilbert)	AMS SI062-212	92	-	LF	II-143-11	4E			
Clinidae									

<u>Acanthemblemaria maria</u> Böhlke	AMNH 24196	45	I-47A	LA	II-143-12	3E
<u>Cristiceps australis</u> Cuvier and Valenciennes	AMNH 31405	65	I-47B	B	-	-
<u>Emblemaria pandionis</u> Evermann and Marsh	AMNH 28719	41	I-47C	LA	-	-
<u>Labrisomus nuchipinnis</u> (Quoy and Gaimard)	AMNH 34704	85	I-47D	LA	II-143-13	3E
<u>Lepidoblennius marmoratus</u> (Macleay)	AMNH 31326	85	I-47E	LA	II-143-14	3E
<u>Malacoctenus boehlkei</u> Springer	AMNH 34595	109	I-47F	LA	II-143-15	3D
<u>Paraclinus nigripinnis</u> (Steindachner)	AMNH 24188	34	I-47G	LA	II-143-16	3D
<u>Springeratus xanthosoma</u> (Bleeker)	ZMNTU uncat.	63	I-47H,I	LA	II-143-17	3D
<u>Starksia lepicoelia</u> Böhlke and Springer	AMNH 23536	25	I-47J	LA	II-143-18	3D
Pholididae						
<u>Opisthocentrus</u> sp.	ZMUM 55598	71	I-48A	B	II-143-19	4C
<u>Pholis gunnellus</u> (Linnaeus)	AMNH uncat.	111	-	ST	II-143-20	4C
Scytalinidae						
<u>Scytalina cerdale</u> Jordan and Gilbert	ZMUM 63956	88	I-49	***	II-143-21	4E
Stichaeidae						
<u>Anoplarchus purpurescens</u> Gill	AMNH 479	98	I-45A	B	II-143-22	4C
<u>Bryostemma nugator</u> Jordan and Williams	ZMUM 93716	122	I-45B	***	-	-
<u>Cebidichthys violaceus</u> (Girard)	ZMUM 132107	91	I-45C	***	II-143-23	1A
<u>Epigeichthys rupestris</u> (Jordan and Gilbert)	AMNH 2626	138	I-45D	***	II-143-24	4F
<u>Lumpenus lumpretaeformis</u> (Walbaum)	AMNH 20129	208	I-45E	***	II-143-25	4F
<u>Plagiogrammus hopkinsi</u> Bean	ZMUM 142394	97	-	B	-	-

Tripterygiidae							
<u>Tripterygion etheostoma</u>	(Jordan and Snyder) ZMNTU uncat.	46	I-48B	LA	II-143-26	3A	
Zaproridae							
<u>Zaprora silenus</u>	Jordan	BC 61-573	87, 92	I-44	***	II-143-27	1A
Icosteoidei							
Icosteidae							
<u>Icosteus aenigmaticus</u>	Lockington	SU 1171	200	I-50	***	II-144	3D
Ammodytoidei							
Ammodytidae							
<u>Ammodytes americanus</u>	DeKay	AMNH 20792	118, 200 121	I-51A	LA	II-145	4B
<u>Ammodytes hexapterus</u>	Pallus	AMNH 13285	95	I-51B	LA	-	-
Callionymoidei							
Callionymidae							
<u>Callionymus</u>	sp.	USNM uncat.	72	I-52A	***	II-146A	5C
<u>Callionymus japonicus</u>	(Houttuyn)	AMNH 26863	96	I-52B	***	II-146B	5C
<u>Callionymus lunatus</u>	Temminck and Schlegel	AMNH 34781	122	I-52C	***	II-146C	5C
<u>Callionymus richardsoni</u>	Bleeker	AMNH 13028	118	I-52D	***	II-146D	5C
Gobioidei							
Gobiidae							
<u>Acanthogobius flavimanus</u>	(Temminck and Schlegel)	AMNH 34885	70	I-53A	LA	II-147A	4E
<u>Coryphopterus glaucofrenum</u>	Gill	AMNH 30964	47	I-53B	LA	II-147B	1A

	AMNH 31233	42					
<u>Eleotris fusca</u> (Bloch and Schneider)	AMNH 20170	70	I-53C	LA	II-147C	3B	
<u>Gobius hadropterus</u> (Jordan and Snyder)	AMNH 11119	73	I-53D	LA	II-147D	3E	
<u>Gobius fluviatilis</u> Pallus	AMNH 20820	82	I-53E	LA	-	-	
<u>Lophogobius cyprinoides</u> (Pallus)	AMNH 37170	70	-	-	II-147E	4D	
<u>Ophiocara aporos</u> (Bleeker)	AMNH 20197	80	-	-	II-147F	4F	
<u>Awaous</u> sp.	AMNH 35242	90	-	-	II-147G	3B	
<u>Periophthalmus koelreuteri</u> Cuvier and Valenciennes	AMNH 8938	60	I-53F	LA	II-147H	3F	
<u>Plagiogrammus</u> sp.	ZMUM 142394	97	I-53G	B	II-147I	3D	
Gobioididae							
<u>Gobioides</u> sp.	AMNH 10145	164	I-53H	***	II-148	4E	
<u>Sericagobioides lighti</u> Herre	AMNH 15630	138	I-53I	LA	-	-	
Kraemeriidae							
<u>Kraemia samoensis</u> Steindachner	CAS 24929	27	I-53J	ST	II-149	4C	
Microdesmidae							
<u>Gunnellichthys pleurotaenia</u> Bleeker	AMS 115623- 019	102	I-53K	ST	II-150A	4C	
<u>Paragobiodon echinocephalus</u> (Rüppell)	AMNH 27105	17	-	-	II-150B	4C	
<u>Pholidichthys leucotaenia</u> Bleeker	CAS 32048	176	-	-	II-150C	4F	
Trypauchenidae							
<u>Trypauchenichthys</u> sp.	USNM 211295	57	I-53L	LA	II-151	4B	
Kurtoidei							
Kurtidae							

<u>Kurtus gulliveri</u> Castelnau	AMNH uncat.	77	I-54B	LA	II-152A	5A
<u>Kurtus indicus</u> Bloch	USNM uncat.	95	I-54A	B	II-152B	3A
Acanthuroidei						
Acanthuridae						
<u>Acanthurus bahianus</u> Castelnau	AMNH 5284	26	I-55I	***	II-153A	3A
	AMNH 21485	30, 32, 48, 50, 52, 55, 59, 62, 75, 100				
<u>Acanthurus nigrofuscus</u> (Forsk.)	AMNH 1778	40	I-55H	***	-	-
<u>Acanthurus thompsoni</u> (Fowler)	BPBM 9430	96	I-55J	***	-	-
<u>Ctenochaetus striatus</u> (Quoy and Gaimard)	AMNH 30915	132	I-55G	***	II-153B	3A
<u>Naso annulatus</u> (Quoy and Gaimard)	AMNH 18461	55	I-55E	***	II-153C	***
<u>Naso hexacanthus</u> (Bleeker)	BPBM 8519	218	I-55F	***	-	-
<u>Paracanthurus hepatus</u> (Linnaeus)	ANSP 131125	87	I-55L	***	II-153D	3A
<u>Prionurus microlepidotus</u> Lacépède	AMNH 34784	170	I-55K	***	II-153E	5B
<u>Zebrasoma flavescens</u> (Bennett)	AMNH 29301	108	I-55A	***	II-153F	5B
<u>Zebrasoma rostratum</u> (Günther)	BPBM 12847	135	I-55D	***	-	-
<u>Zebrasoma scopas</u> (Cuvier)	BPBM 7652	135	I-55B	***	-	-
<u>Zebrasoma veliferum</u> (Bloch)	BPBM 7824	95	I-55C	***	-	-
Zanclidae						
<u>Zanclus cornutus</u> (Cuvier and Valenciennes)	AMNH 13515	35	I-56	***	II-153G	3D
Siganidae						

<u>Lo vulpinus</u> Schlegel and Müller	AMS I17088-053	140	I-59A	SP	II-154A	***
<u>Siganus rostratus</u> (Cuvier and Valenciennes)	ZMTU uncat.	63	I-59B	SP	-	-
<u>Siganus</u> sp.	AMNH 14918	137	I-59C	SP	II-154B	3D
Scombroidei						
Gempylidae						
<u>Epinnula</u> sp.	ANSP 98601	134	I-60A	LA	-	-
<u>Gempylus serpens</u> Cuvier	AMNH 18130	97	I-60B	LA	-	-
Scombridae						
<u>Auxis</u> sp.	AMNH 17561	103	I-60C	LA	II-155A	1A
<u>Scomber colias</u> (Gmelin)	AMNH 12642	72	I-60D	B	II-155B	3E
<u>Scomber japonicus</u> Houttuyn	AMNH 3066	94	I-60E	B	-	-
<u>Scomberomorus commersonianus</u> (Lacépède)	AMNH 1577	175	I-60F	B	II-155C	4C
<u>Scomberomorus</u> sp.	AMNH 17590	71	I-60G	B	II-155D	4C
<u>Sarda sarda</u> (Bloch)	AMNH 18636	172	I-60H	LA	II-155E	3D
Trichiuridae						
<u>Benthodesmus atlanticus</u> Goode and Bean	AMNH 18801	322	I-60I	LA	II-155F	4B
<u>Trichiurus lepturus</u> Linnaeus	AMNH 37180	47	I-60J	LA	II-155G	4C
Xiphiidae						
<u>Xiphias gladius</u> Linnaeus	ANSP 22559	218	I-60K	LA	-	-
Stromateoidei						
Centrolophidae						
<u>Psenopsis anomala</u> (Temminck and Schlegel)	AMNH 34893	115	I-61A	S	II-156	4C

Nomeidae							
<u>Cubiceps</u> sp.	AMNH uncat.	152	I-61B	Z	II-157A	4A	
<u>Nomeus gronovii</u> (Gmelin)	AMNH uncat.	62	I-61C	***	II-157B	***	
<u>Psenes cyanophrys</u> Cuvier and Valenciennes	AMNH 17254	61	I-61D	Z	II-157C	***	
Stromateidae							
<u>Pampus argenteus</u> (Euphrasen)	AMNH 4025	220	-	-	II-158A	***	
	ANSP 77138	77	I-61E	SP	-	-	
	ANSP 77266	90	I-61F	-	-	-	
<u>Peprilus</u> sp.	AMNH 16307	58, 67, 74	I-61G I-61H	***	II-158B	***	
<u>Stromateus fiatola</u> Linnaeus	ANSP 11355- 358	183	I-61I	***	-	-	
Tetragonuridae							
<u>Tetragonurus cuvieri</u> Risso	USNA 206879	70	I-61J	B	II-159	4C	
Anabantoidei							
Anabantidae							
<u>Anabas testudineus</u> (Bloch)	AMNH 13766	67	I-62A	B	II-160A	3E	
<u>Ctenopoma kingsleyae</u> Günther	AMNH 32761	53	-	-	II-160B	3E	
<u>Ctenopoma nanus</u> (Günther)	AMNH 19695	51	I-62B	B	II-160C	3E	
<u>Ctenopoma nigropannosus</u> Reichener	AMNH 6302	94	-	-	II-160D	3E	
<u>Ctenopoma congicus</u> Boulenger	AMNH 6112	42	I-62C	B	-	-	
Belontiidae							
<u>Belontia</u> sp.	AMNH uncat.	60	I-62D	B	-	-	
<u>Betta splendens</u> Regan	AMNH 18206	36	I-62E	B	II-161A	***	

<u>Macropodus opercularis</u> (Linnaeus)	AMNH 10642	49	I-62F	SP	II-161C	***
<u>Macropodus viridiauratus</u> Lacépède	AMNH 10641	49	-	-	II-161D	***
<u>Colisa lalia</u> Hamilton-Buchanan	AMNH 4995	32	I-62G	SP	II-161B	1A
	AMNH 18207	53				
<u>Trichogaster trichopterus</u> (Pallas)	AMNH uncat.	68	I-62H	SP	II-161E	1A
Helostomatidae						
<u>Helostoma temmincki</u> Cuvier	USNM 87974	52	I-62I	SP	II-162	1A
Osphronemidae						
<u>Osphronemus goramy</u> Lacépède	AMNH 14740	80	I-62J	SP	II-163	3D
Luciocephaloidei						
Luciocephalidae						
<u>Luciocephalus pulcher</u> (Gray)	USNM 197527	81	-	B	II-164	4C
Mastacembeloidei						
Mastacembelidae						
<u>Mastacembelus congicus</u> Boulenger	AMNH 6157	143	-	LA	II-165A	1A
<u>Mastacembelus sinensis</u> (Bleeker)	AMNH 11078	118	-	LA	II-165B	4C
Pleuronectiformes						
Psettodidae						
<u>Psettodes erumeri</u> (Schneider)	ZMUM 142008	134	I-108	B	II-166	3D
Bothidae						
<u>Ancyclopsetta quadrocellata</u> Gill	AMNH 5261	110	-	-	II-167A	3D
<u>Bothus ocellatus</u> (Agassiz)	AMNH 23475	93	I-109A	B	II-167B	1A
<u>Bothus lunatus</u> (Linnaeus)	AMNH 23708	103	I-109B	B	II-167C	1A

<u>Paralichthys albigutta</u> Jordan and Gilbert	AMNH 4381	60	I-109C	B	II-167D	3D
<u>Paralichthys dentatus</u> (Linnaeus)	AMNH 3296	70	I-109D	B	II-167E	1A
<u>Rhombosolea tapirina</u> Günther	USNM uncat.	140	I-109E	***	II-167F	1A
<u>Syacium papillosum</u> (Linnaeus)	USNM uncat.	113	I-109F	***	II-167G	3D
<u>Taeniopsetta radula</u> Gilbert	USNM 51699	110	I-109G	LA	II-167H	3D
<u>Tephrineches sinensis</u> (Lacépède)	AMNH 14385	55, 78	I-109H	***	II-167I	3D
Pleuronectidae						
<u>Ammotretis elongatus</u> McCulloch	AMNH 31408	74	I-110A	B	II-168A	1A
	AMNH 31425	72				
<u>Citharichthys spilopterus</u> Günther	AMNH 37184	95	I-110B	LA	-	-
<u>Eopsetta grigorjewi</u> (Herzenstein)	AMNH uncat.	138	I-110C	***	II-168B	3D
<u>Limanda</u> sp.	AMNH 952	22	I-110E	DI	II-168D	1A
<u>Glyptocephalus zachirus</u> Lockington	AMNH 2728	110	I-110D	LA	II-168C	3D
<u>Liopsetta exilis</u> (Jordan and Gilbert)	AMNH 2265	96	I-110F	B	II-168E	3D
<u>Platyichthys stellatus</u> (Pollas)	AMNH 1826	95	I-110G	***	II-168F	1A
<u>Pleuronichthys cornutus</u> (Temminck and Schlegel)	AMNH 26901	94	I-110H	***	II-168G	3D
<u>Pseudopleuronectes americanus</u> (Walbaum)	AMNH 36069	108	I-110I	***	-	-
Scophthalmidae						
<u>Scophthalmus maculata</u> (Mitchill)	AMNH 5262	102	I-111A	B	II-169A	1A
<u>Scophthalmus aquosus</u> (Mitchill)	AMNH 36475	86	I-111B	B	II-169B	3D
Cynoglossidae						
<u>Cynoglossus interruptus</u> Günther	AMNH 13022	88	I-112A	B	II-170A	***
<u>Cynoglossus monopus</u> (Bleeker)	AMNH 19825	100	I-112B	***	II-170B	1A

<u>Parplagusia bilineata</u> (Bloch)	AMNH 32550	50	I-112C	***	II-170C	1A
<u>Symphurus</u> sp.	USNM 41866	100, 105	I-112D	D	II-170D	***
<u>Symphurus plagiusa</u> (Linnaeus)	AMNH 2578	96	I-112E	D	II-170E	***
<u>Soleidae</u>						
<u>Achirus lineatus</u> (Linnaeus)	AMNH 2416	83	I-113A	D1	II-171A	1A
<u>Heteromycteris japonicus</u> (Temminck and Schlegel)	AMNH 26898	100	I-113B	B	II-171B	1A
<u>Synaptura marginata</u> Boulenger	3)	-	I-113C	***	-	-
<u>Trinectes maculatus</u> (Bloch and Schneider)	AMNH 32693	80, 92	I-113D	B	II-171C	1A
<u>Zebrias zebra</u> (Bloch and Schneider)	AMNH 26897	186	I-113E	***	II-171D	1A
<u>Tetraodontiformes</u>						
<u>Triacanthodidae</u>						
<u>Paratriacanthodes retrospinis</u> Fowler	AMNH uncat.	63	-	-	II-172A	3A
<u>Triacanthidae</u>						
<u>Triacanthus bimaculatus</u> Bloch	AMNH 15883	137	-	-	II-172B	5B
<u>Monacanthidae</u>						
<u>Acanthaluteres</u> sp.	AMNH 31430	80	-	-	II-172C	5B
<u>Monacanthus hispidus</u> (Linnaeus)	AMNH 8755	75	-	-	II-172D	5B
<u>Monacanthus tuckeri</u> Bean	AMNH 24867	50	-	-	II-172E	5B
<u>Balistidae</u>						
<u>Balistes carolinensis</u> Gmelin	AMNH 16348	140	-	-	II-172F	5B
<u>Ostraciontidae</u>						
<u>Acanthostracion quadricornis</u> (Linnaeus)	AMNH 2600	60	-	-	II-172G	5B
<u>Lactoria diaphana</u> (Bloch and Schneider)	AMNH uncat.	68	-	-	II-172H	5B

Canthigasteridae

<u>Canthigaster rostrata</u> (Bloch)	AMNH 17777	82	.	-	-	II-172I 5B

Tetraodontidae

<u>Sphaeroides testudineus</u> (Linnaeus)	AMNH 20740	56		-	-	II-172J 5B

<u>Tetraodon</u> sp.	AMNH 10505	102		-	-	II-172K 5B

Diodontidae

<u>Chilomycterus schoepfi</u> (Walbaum)	AMNH 19456	38		-	-	II-172L 5B

Molidae

<u>Masturus oxyuropterus</u> (Bleeker)	AMNH uncat.	152		-	-	II-172M 5B

TABLE 1

Character state Taxon	A,U	A	U	A	U	A	U	A,U	A,U	A,U
Psettodidae	<u>Psettodes</u> <u>erumeri</u>									
Pleuronectidae		<u>Ammotretis</u> <u>elongatus</u> <u>Glyptocephalus</u> <u>zachirus</u> <u>Limanda</u> sp.				<u>Pseudopleuronectes</u> <u>americanus</u> <u>Liopsetta existis</u> <u>Platyichthys</u> <u>stellatus</u> <u>Pleuronichthys</u> <u>cornutus</u>				
Bothidae		<u>Tephrineches</u> <u>sinensis</u> <u>Cyclopsetta</u> sp.				<u>Paralichthys</u> <u>albigutta</u> <u>Bothus ocellatus</u>		<u>Etropus</u> sp. <u>Synacium</u> <u>papillosum</u> <u>Taeniopsetta</u> <u>radula</u>		
Citharidae									<u>Citharus</u> sp. <u>Brachypleura</u> sp. <u>Citharoides</u> sp. (Hubbs, 1945)	
Scophthalmidae						<u>Lophopsetta</u> <u>maculata</u> <u>Scophthalmus</u> <u>aguosus</u>				

Scleidae	<u>Zebrias</u> <u>zebra</u>		<u>Heteromycteris</u> <u>japonicus</u>	<u>Achirus</u> <u>lineatus</u> <u>Trinectes</u> <u>maculatus</u>		
Cynoglossidae			<u>Cynoglossus</u> <u>gracilis</u>		<u>Symphurus</u> <u>plagiusa</u>	

TABLE 2

Taxon \ Intestinal type	B	D1	SP	S	Z	LA	HZ	T	LF	ST	D2	Others
Chondrostei*	+					+						
Ginglymodi*									+			
Halecomorphi	++											
Osteoglossomorpha	+											++
Elopomorpha	+					++			+			
Clupeomorpha	+					++						+
Ostariophysi	+					+						++
Protacanthopterygii	+					++						
Paracanthopterygii**	+					+				+		
Atherinomorpha**	+		+					+	+	+		+
Acanthopterygii												
Bercyciiformes*	+											+
Zeiformes*	+					+						
Lampridiiformes*									+			
Gasterosteiformes**									+	+		
Channiformes	++											

Taxon \ Intestinal type	B	D1	SP	S	Z	LA	HZ	T	LF	ST	D2	Others
Synbranchiiformes										++		
Scorpaeniformes	++	+				+						
Perciformes	++	+	+	+	+	+	+			+	+	+
Percoidei	++	+	+	+	+	+	+			+	+	
Sphyraenoidei						++						
Polynemoidei*	+											
Labroidei	++					+				+		
Trachinoidei	++	+		+		+						
Notothenoidei	++											
Blennioidei**	+					+			+	+		+
Icosteoidei												++
Ammodytoidei						++						
Callionymoidae												++
Gobioidei	+					++				+		
Kurtoidei**	+					+						
Acanthuroidei			++									+

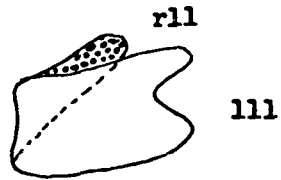
Taxon \ Intestinal type	B	D1	SP	S	Z	LA	HZ	T	LF	ST	D2	Others
Scombroidei	+					++						
Stromateoidei	+		+	+	++							
Anabantoidei**	+		+									
Luciocephaloidei	++											
Mastacembeloidei						++						
Pleuronectiformes	++	+				++						+
Tetraodontiformes**,1)	+					+			+	+		+

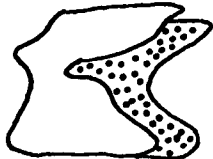
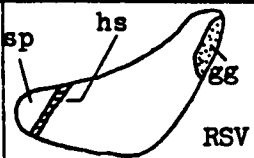
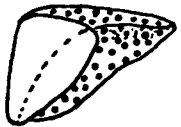
TABLE 3

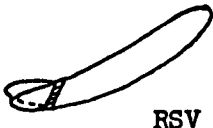
Taxon \ Kidney type	1 1 2 2 2 2 2 3 3 3 3 3 3 3 4 4 4 4 4 4 5 5 5 5 5 Others																									
	A	B	A	B	C	D	E	A	B	C	D	E	F	G	A	B	C	D	E	F	A	B	C	D	E	
Chondrostei*						+											+									
Ginglymodi																				++						
Halecomorphi																				++						
Osteoglossomorpha		+							+		++	++	++							+						
Elopomorpha*																	+		++							+
Clupeomorpha	++	++										+														
Ostariophysi	+		++	++	++			+			+	+					+									+
Protacanthopterygii**	+					+						+					+	+		+	+					
Paracanthopterygii*											+	+	+				+	+			+	+		+		
Atherinomorpha**								+					+				+	+		+	+		+	+		
Acanthopterygii																										
Beryciformes*									+	+																
Zeiformes*								+			+										+					
Lampridiformes*				+																						
Gasterosteiformes					+							++	+				+									
Channiformes*																		+								
Synbranchiformes*																										+
Scorpaeniformes	+													+			+					+				
Perciformes																										
Percoidei	+		+	+	+	+	+				+	++	++	++	+	+	+	+	+					+		

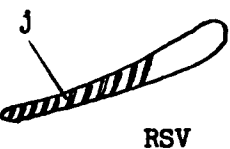
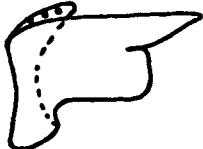
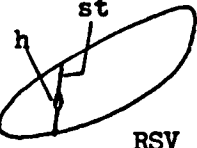
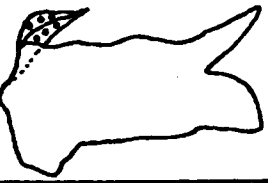
Kidney type Taxon	1 A	1 B	2 A	2 B	2 C	2 D	2 E	3 A	3 B	3 C	3 D	3 E	3 F	3 G	4 A	4 B	4 C	4 D	4 E	4 F	5 A	5 B	5 C	5 D	5 E	Others
Mugiloidei													++	++												
Sphyraenidei*				+																						
Labroidei	+	+			+					+	++	++			+		+									
Trachinoidei											++	++	++			+	+									
Notothenioidei				+									++	++												
Blennioidei	+							+			++	++					+	+	+	+						
Icosteoidi											++															
Ammodytoidei*																	+									
Callionymoidi																							++			
Gobioidei	+							+		+	+	+			+		++	++	++							
Kurtoidei**								+													+					
Acanthuroidei**								+		+												+				+
Scombroidei**	+									+	+						+	+								
Stromateoidi**															+		+									+
Anabantoidei**	+									+	+															+
Luciocephaloidei																	++									
Mastacembeloidei*	+																+									
Pleuronectiformes**	+										+															
Tetraodontiformes								+														++				

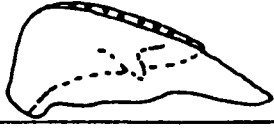
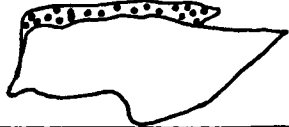
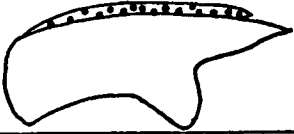
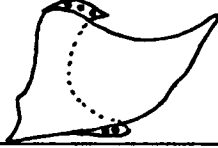
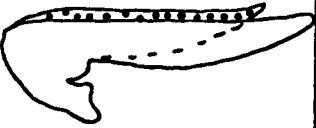
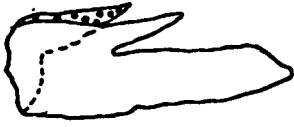
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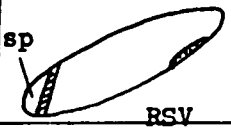
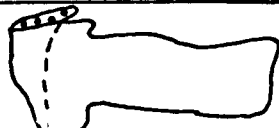
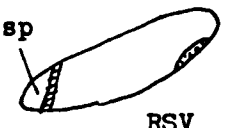
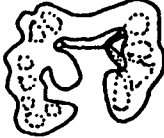
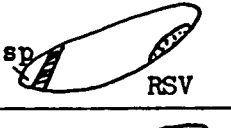
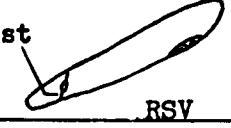
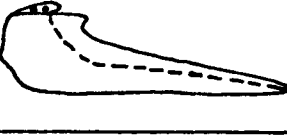
Species	Septum in Swim-bladder	Swimbladder	Gas-gland (dorsal view; anterior above)	Liver Shape (left-side view)
Aplodactylidae <u>Crinodus lophodon</u>	-	-	-	
Apogonidae <u>Apogon affinis</u>	-	+		+
<u>A. bandanensis</u>	-	+		+
<u>A. binotatus</u>	-	+	+	
<u>A. cyanosoma</u>	-	+		+
<u>A. endekataenia</u>	-	+		+
<u>A. taeniophosus</u>	-	+		+
<u>Archamia lineolata</u>	-	+		+
<u>Astrapogon stellatus</u>	-	+		+
<u>Cheilodipterus macrodon</u>	-	+		+
<u>C. octovittatus</u>	-	+		+

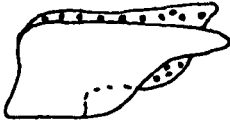
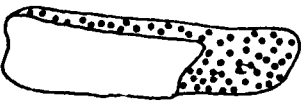
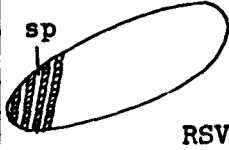
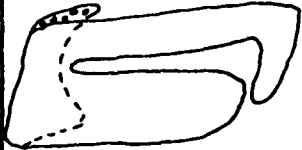
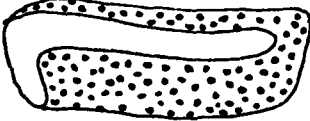
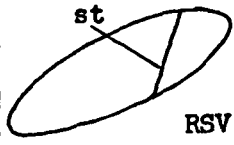
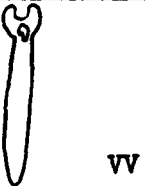
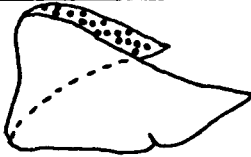
<u>C. quinquelineatus</u>	-	+		+
<u>Glossamia aprion</u>	-	+		+
<u>Sphaeramia nematoptera</u>	-	+		+
Arripidae <u>Arripis geogianus</u>	-	+	?	
Bathyclupeidae <u>Bathyclupea</u> sp.	?	+		
Branchiostegidae <u>Branchiostegus japonicus</u>	?	+	-	+
<u>Caulolatilus princeps</u>	?	+		
<u>Malacanthus plumieri</u>	?	?	?	
Banjsoidae <u>Banjos typus</u>	?	+	?	
Carangidae <u>Alectis ciliaris</u>	-			+
<u>Caranx crysos</u>	-			

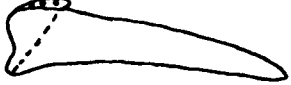
<u>C. marginatus</u>	-			
<u>Decapterus muroadsi</u>	-			
<u>D. russelli</u>	-			
<u>Megalaspis cordyla</u>	-		-	
<u>Oligoplites saurus</u>	-		?	
<u>Scomberoides toloo</u>	-		?	
<u>Selar sp.</u>	-			
<u>Selene vomer</u>	-		-	+
<u>Seriola falcata</u>	?	+	-	
<u>Trachinotus sp.</u>	-		-	
<u>Trachurus japonicus</u>	-			
<u>Vomer declivifrons</u>				

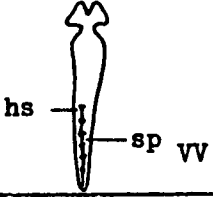
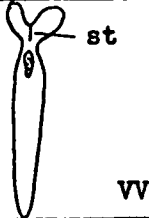
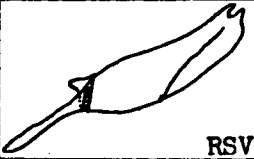
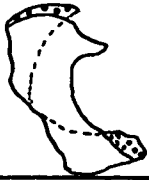
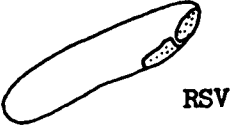
Centrarchidae <u>Archoplites</u> <u>interruptus</u>	-	+		 **
<u>Enneacanthus</u> <u>gloriosus</u>	-	+		+
<u>E. obesus</u>	-	+		+
<u>Lepomis gulosus</u>	-	+		+
Centropomidae <u>Centropomus</u> <u>nigrescens</u>	?	+	-	
<u>Chanda</u> <u>gymnocephalus</u>	-	+		 **
<u>Lates calcarifer</u>	?	+	-	
Cepolidae <u>Cepola rubescens</u>	-	 RSV	 rc rm DV VV	
<u>Acanthocephala</u> <u>krusensternii</u>	-	 j RSV		
Chaetodontidae <u>Chaetodon aya</u>	?	+	?	
<u>Chelmon</u> <u>rostratus</u>	?	+		
<u>Chelmonops</u> <u>truncatus</u>	+	 h st RSV		

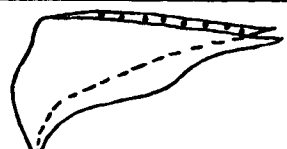
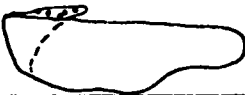
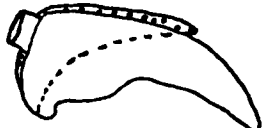
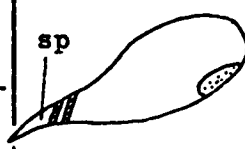
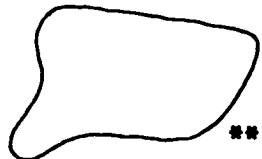
<u>Coradion</u> <u>chrysozonus</u>	+	 RSV		
<u>Forcipiger</u> <u>flavissimus</u>	+	 RSV		
<u>Heniochus</u> <u>acuminatus</u>	+	 RSV		
<u>Hemitaurichthys</u> <u>polylepis</u>	+	 RSV		
<u>Microcanthus</u> <u>strigatus</u>	?	+		
<u>Parachaetodon</u> <u>ocellatus</u>	+	 RSV	-	
<u>Prognathodes</u> <u>aculeatus</u>	-	+	-	
<u>Vinculum</u> <u>sexfasciatus</u>	?	 RSV		
<u>Cheilodactylidae</u> <u>Nemadactylus</u> <u>macropterus</u>	+	 RSV		
<u>Goniistius</u> <u>zonatus</u>	+	+		
<u>Chironemidae</u> <u>Chironemus</u> <u>marmoratus</u>	-	-	-	

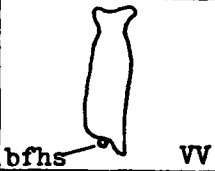
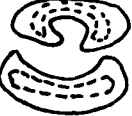
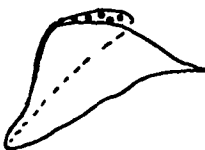
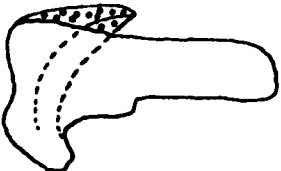
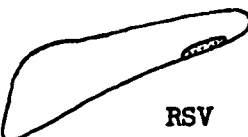
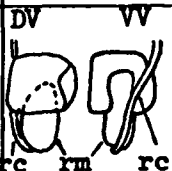
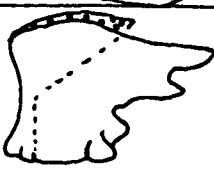
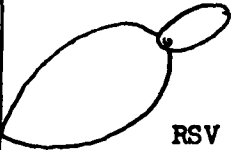
Cichlidae				
<u>Cichlasoma</u>	-			
<u>champtonis</u>				
<u>C. heterospilum</u>	-			
<u>C. hyorhynchum</u>	-			
<u>C. intermedium</u>	+			+
<u>C. motaguense</u>	?	+		
<u>C. salvini</u>	-			+
<u>Haplochromis</u>	+			
<u>eucinostomus</u>				
<u>Cleithrochromis</u>	?	+		+
<u>bowleyi</u>				
Cirrhitidae				
<u>Amblycirrhitus</u>	-	-	-	
<u>pinos</u>				
<u>Cirrhitichthys</u>	-	-	-	
<u>falco</u>				
<u>Paracirrhitus</u>	-	-	-	
<u>bimacula</u>				
<u>Paracirrhitus</u> sp.	-	-	-	

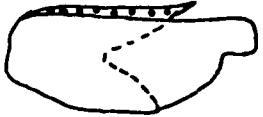
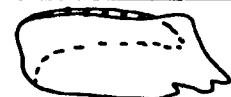
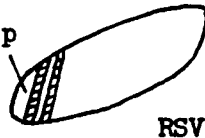
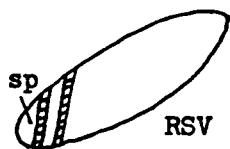
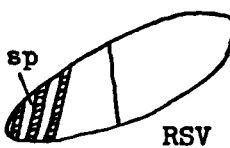
Coryphaenidae				
<u>Coryphaena</u> <u>hippurus</u>	-	-	-	
Echeneidae				
<u>Echeneis naucrates</u>	-	-	-	
<u>Remora</u> <u>brachyptera</u>	-	-	-	
<u>R. remora</u>	-	-	-	
<u>Rhombochirus</u> <u>osteoichir</u>	-	-	-	
Embiotocidae				
<u>Brachyistius</u> <u>frenatus</u>	-		?	
<u>Cymatogaster</u> <u>aggregata</u>	-			
<u>Ditrema temmincki</u>	+		-	
Emmelichthyidae				
<u>Dipterygonotus</u> <u>gruveli</u>	-			
<u>Merolepis</u> sp.	-	+		
Enoplosidae				
<u>Enoplosus armatus</u>	+	+		
Ephippidae				
<u>Chaetodipterus</u> <u>faber</u>	?		?	

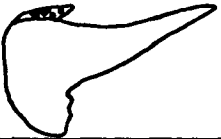
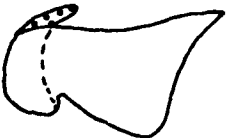
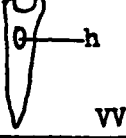
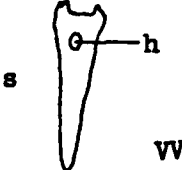
<u>Drepane punctata</u>	?	 VV		
Gadopsidae <u>Gadopsis</u> <u>marmoratus</u>	-	+		
Gerridae <u>Diapterus</u> <u>olisthostomus</u>	-	+	?	
<u>Eucinostomus</u> <u>pseudogula</u>	-	 VV	-	
<u>Eucinostomus</u> <u>gula</u>	-	 VV		
<u>Gerres cinereus</u>	-	 VV	?	
Grammistidae <u>Grammistes</u> <u>sexlineatus</u>	?	+		
<u>Rypticus</u> <u>saponaceus</u>	?	+	-	
Kuhliidae <u>Kuhlia malo</u>	?	+	-	
<u>K. taeniura</u>	?	+	-	
<u>Nannatherina</u> <u>balstoni</u>	?	?	?	
Kyphosidae <u>Girella</u> <u>melanichthys</u>	?	+		

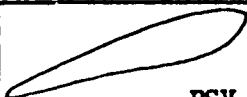
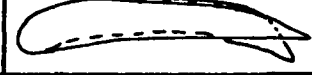
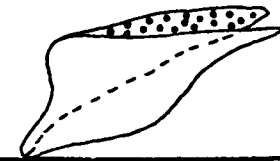
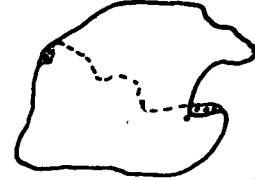
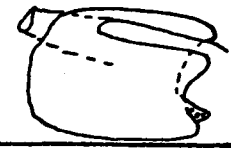
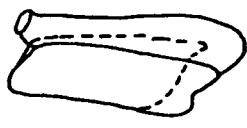
<u>Hermosilla</u> <u>azurea</u>	-	+	-	
<u>Kyphosus</u> <u>sectatrix</u>	-		-	+
<u>K. vaigiensis</u>	-		-	 **
<u>Sectator</u> <u>ocyurus</u>	-			
Labracoglossidae <u>Labracoglossa</u> <u>argentiventris</u>	-	+		
Lactariidae <u>Lactarius</u> <u>lactarius</u>	-		-	
Latrididae <u>Latridopsis</u> <u>forsteri</u>	?	+	-	
Leiognathidae <u>Gazza</u> <u>minuta</u>	-			 **
<u>Leiognathus</u> <u>rivulatus</u>	-	+		 **
<u>Parequula</u> <u>melbournensis</u>	-	+		

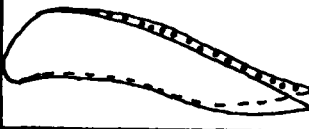
Lethrinidae				
<u>Gnathodentex</u> <u>aurolineatus</u>	-	 RSV	-	
<u>Lethrinus</u> <u>ornatus</u>	-	+	-	
<u>L. rhodopterus</u>	-	+	-	
<u>Monotaxis</u> <u>grandoculis</u>	?	?	?	
<u>Pentapodus</u> sp.	-	+		
Lobotidae				
<u>Lobotes</u> sp.	-	+	-	
Lutjanidae				
<u>Lutjanus gibbus</u>	-	+	-	
<u>L. griseus</u>	-	+	-	
<u>Ocyurus chrysurus</u>	-	+	-	
<u>Symphysanodon</u> <u>typus</u>	-	+	+	
Menidae				
<u>Mene</u> <u>annocarolina</u>	-	 sp RSV		 **

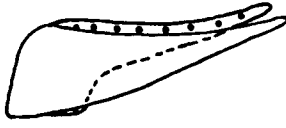
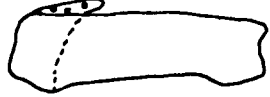
Monodactylidae <u>Monodactylus</u> <u>falciiformis</u>	-	+		
Mullidae <u>Mullus</u> <u>barbatus</u>	?	?	?	
<u>Parupeneus</u> <u>malabaricus</u>	?	+	?	
<u>Pseudupeneus</u> <u>maculatus</u>	?	?	?	
Nandidae <u>Nandus</u> <u>nebulosus</u>	-	+		
<u>Pristolepis</u> <u>fasciata</u>	?	+		
Nemipteridae <u>Nemipterus</u> sp.	-			
<u>Scolopsis</u> <u>bilineatus</u>	?	+	-	
Oplegnathidae <u>Oplegnathus</u> sp.	?	+	-	
Owstoniidae <u>Owstonia</u> <u>tosaensis</u>	-			
Pempheridae <u>Pempheris</u> sp.	+		-	

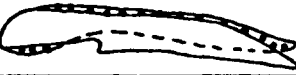
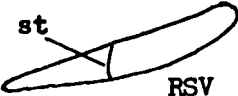
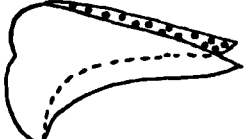
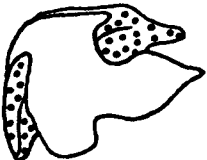
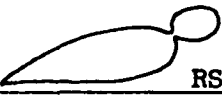
<u>Parapriacanthus</u> sp.	?	+		
Percidae <u>Acerina</u> <u>schræetser</u>	-	+		
<u>Aspro streber</u>	-	-	-	+
<u>Etheostoma</u> <u>caeruleum</u>	-	-	-	
<u>E. olmstedii</u>	-	-	-	
<u>Perca flavescens</u>	-	+		
<u>Percina caprodes</u>	-	+		
Plesiopidae <u>Plesiops melas</u>	-	+		
Pomacanthidae <u>Centropyge bicolor</u>	-	sp  RSV		
<u>C. flavissimus</u>	-	sp  RSV	-	
<u>Holacanthus</u> <u>tricolor</u>	+	sp  RSV	-	
<u>Pomacanthus paru</u>	+	+	-	

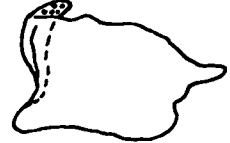
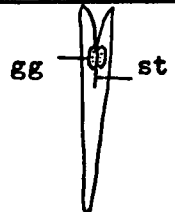
<u>Pomacanthus</u> sp.	+		-	
<u>Pomacentridae</u> <u>Micropathodon</u> <u>chrysurus</u>	-		-	
<u>Premnas</u> <u>biaculeatus</u>	?	+	-	
<u>Chromis</u> <u>multilineatus</u>	-		?	+
<u>Dascyllus</u> <u>trimaculatus</u>	-		?	
<u>Eupomacentrus</u> sp.	?	+	?	
<u>Eupomacentrus</u> <u>variabilis</u>	?	+		+
<u>Amphiprion</u> <u>ocellaris</u>	?	+	?	
<u>Pomadasyidae</u> <u>Anisotremus</u> <u>virginicus</u>	-	+	?	
<u>Bathystoma</u> sp.	-		-	
<u>Haemulon</u> <u>chrysargyreum</u>	-	+	-	
<u>Conodon nobilis</u>	-		-	+

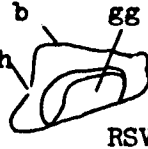
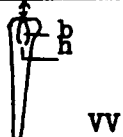
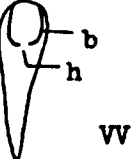
<u>Haemulon</u> <u>melanurum</u>	-	 RSV	-	
<u>H. sciurus</u>	-	 RSV	-	
<u>Pomadasys</u> <u>jubelini</u>	-	+	-	
Pomatomidae <u>Pomatomus</u> <u>saltatrix</u>	?	+	00	
<u>Scombrops boops</u>	-	+		
Priacanthidae <u>Cookeolus boops</u>	?	+		
<u>Priacanthus</u> <u>cruentatus</u>	-	+		
<u>Pseudopriacanthus</u> <u>altus</u>	?	?		
Pseudochromidae <u>Dampiera</u> <u>cyclophthalma</u>	?	+		
<u>Gramma loreta</u>	-	+	-	
<u>G. melacara</u>	?	+	-	
<u>Pseudogramma</u> <u>polyacantha</u>	?	?	?	

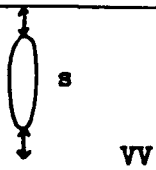
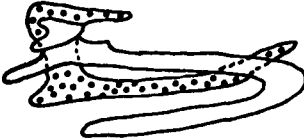
<u>Rachycentridae</u> <u>Rachycentron</u> <u>canadum</u>	?	?	?	
<u>Rhinoprenidae</u> <u>Rhinoprenes</u> <u>pentanemus</u>	?	?	?	
<u>Scatophagidae</u> <u>Scatophagus</u> <u>argus</u>	?	+		
<u>Sciaenidae</u> <u>Aplodinotus</u> <u>grunniens</u>	-	 VV	-	
<u>Bairdiella</u> <u>chrysura</u>	-	 VV	-	
<u>Cynoscion</u> <u>regalis</u>	-	 VV	-	
<u>Equetus</u> <u>acuminatus</u>	-	+	?	
<u>Larimus</u> <u>fasciatus</u>	-	 VV	-	+
<u>Macrodon</u> <u>ancyodon</u>	-	 VV		
<u>Menticirrhus</u> <u>americanus</u>	-	 VV	-	
<u>Nebris</u> <u>microps</u>	-	 VV	-	

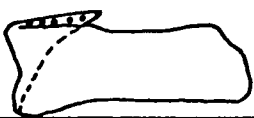
<u>Odontoscion</u> <u>dentex</u>	-	 VV	-	
<u>Paralonchurus</u> sp.	-	 VV	-	+
<u>Plagioscion</u> <u>squamosissima</u>	-	 st VV	-	
<u>Stellifer</u> <u>rastrifer</u>	-	 VV		
Serranidae <u>Acanthistius</u> <u>serratum</u>	?	+	?	
<u>Anthias</u> <u>squamipinnis</u>	-	+	-	
<u>Bostockia</u> <u>porosa</u>	?	+		
<u>Centropristis</u> <u>striata</u>	?	?	?	
<u>Ephinephelus</u> <u>cruentatus</u>	?	 st VV		+
<u>Liopropoma</u> <u>mowbrayi</u>	?	+		
<u>Morone</u> <u>americana</u>	?	?	-	
<u>Percilia</u> <u>gillissii</u>	?	?	?	

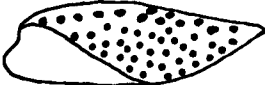
<u>Roccus americanus</u>	?	+	+	
<u>Siniperca chuatsi</u>	+	+	+	
Sillaginidae <u>Sillago bassensis</u>	+	st  RSV	-	
<u>S. maculatus</u>	?	 RSV	8	
Sparidae <u>Archosargus probatocephalus</u>	?	+	-	 **
<u>Calamus pennatula</u>	-	 VV		
<u>Lagodon rhomboides</u>	-	 VV		
<u>Stenotomus chrysops</u>	-	 VV	-	
Teraponidae <u>Amniataba percoides</u>	-	 RSV	-	
<u>Leiopotherapon unicolor</u>	-	 RSV	-	
<u>Pelates quadrilineatus</u>	-	 RSV	-	
<u>Terapon theraps</u>	-	 RSV	-	

<u>Toxotidae</u> <u>Toxotes</u> <u>chatereus</u>	-	+	-	
<u>Mugilidae</u> <u>Agonotomus</u> <u>monticola</u>	?	+	?	
<u>Liza macrolepis</u>	-	+		
<u>Mugil cephalus</u>	-	+		
<u>M. curema</u>	-	+	-	
<u>Sphyraenidae</u> <u>Sphyraena</u> <u>barracula</u>	-	 VV		+
<u>S. borealis</u>	-	 eg st VV		
<u>Labridae</u> <u>Bodianus rufus</u>	-	+	-	
<u>Cirrhilabrus</u> <u>solorensis</u>	-	 VV	-	
<u>Clepticus</u> <u>parrai</u>	-	 b h	b -	

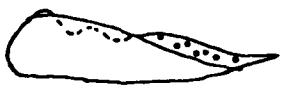
<u>Doratonotus</u> <u>megalepis</u>	-		-	
<u>Halichoeres</u> <u>bivittatus</u>	-	s	b	
<u>H. nebulosus</u>	-	s	-	
<u>Hemipteronotus</u> <u>splendens</u>	-	s	b -	
<u>Iniistius</u> sp.	-	+	+	
<u>Macropharyngodon</u> <u>meleagris</u>	-			
<u>Pseudojulis</u> <u>notospilus</u>	-			
<u>Stethojulis</u> <u>phekadopleura</u>	-	?	?	
<u>Tautoga onitis</u>	-			
<u>Thalassoma</u> <u>bifasciatum</u>	-			
<u>Tautogolabrus</u> <u>adspersus</u>	-			
<u>Odacidae</u> <u>Haletta</u> <u>semifasciata</u>	-		-	

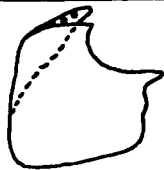
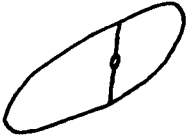
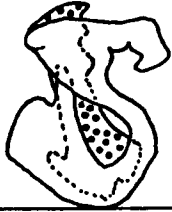
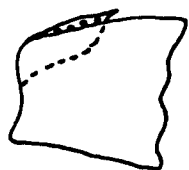
Scaridae				
<u>Scarus croicensis</u>	?	?	?	
<u>Sparisoma flavescens</u>	-	+	?	
<u>S. radians</u>	-	-	-	
<u>S. viride</u>	-		-	
Bathymasteridae				
<u>Bathymaster signatus</u>	?	?	?	
Champsodontidae				
<u>Champsodon sp.</u>	-	+		
Cheimarrichthyidae				
<u>Cheimarrichthys forsteri</u>	?	?	?	 **
Creediidae				
<u>Creedia haswelli</u>	-	-	-	
Dactyloscopidae				
<u>Dactyloscopus sp.</u>	?	?	?	
Limnichthyidae				
<u>Limnichthys fasciatus</u>	-	-	-	

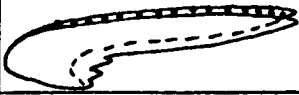
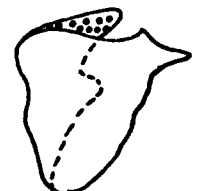
Mugiloididae <u>Parapercis</u> <u>ommatura</u>	-	-	-	
<u>P. sexfasciatus</u>	-	-	-	
Opisthognathidae <u>Opisthognathus</u> sp.	-	-	-	
<u>O. whitehursti</u>	-	-	-	
Trachinidae <u>Trachinus vipera</u>	-	-	-	
Uranoscopidae <u>Uranoscopus</u> <u>oligolepis</u>	-	-	-	
Bovichthyidae <u>Bovichthys</u> sp.	-	-	-	
Nothothenidae <u>Harpagifer</u> <u>bispinis</u>	-	-	-	
<u>Notothenia</u> sp.	-	-	-	
<u>Trematomus</u> sp.	-	-	-	
Blenniidae <u>Alticus</u> <u>marmoratus</u>	-	-	-	

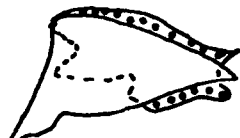
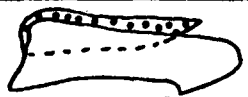
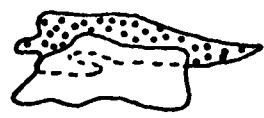
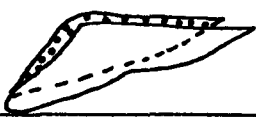
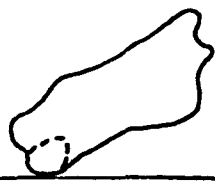
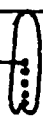
<u>Blennius</u> <u>cristatus</u>	-	-	-	
<u>B. tentacularis</u>	-	-	-	
<u>Hypleurochilus</u> <u>geminatus</u>	-	-	-	
<u>Homesthes</u> <u>caulopus</u>	-	-	-	
<u>Ophioblennius</u> <u>atlanticus</u>	-	-	-	
<u>O. steindachneri</u>	-	-	-	
<u>Petroscirtes</u> <u>mitratus</u>	-	-	-	
<u>Salarias</u> <u>fasciatus</u>	-	-	-	
<u>Chaenopsidae</u> <u>Chaenopsis</u> <u>alepidotus</u>	-	-	-	
<u>Clinidae</u> <u>Acanthemblemaria</u> <u>maria</u>	-	-	-	
<u>Emblemaria</u> <u>pandionis</u>	-	-	-	
<u>Labrisomus</u> <u>nuchipinnis</u>	-	-	-	
<u>Malacoctenus</u> <u>boehlkei</u>	-	-	-	
<u>Paraclinus</u> <u>nigripinnis</u>	-	-	-	

<u>Springeratus</u> <u>xanthosoma</u>	-	-	-	
<u>Starksia</u> <u>lepicoelia</u>	-	-	-	
Pholididae <u>Opisthocentrus</u> sp.	-	-	-	
Stichaeidae <u>Anoplarchus</u> <u>purpurescens</u>	-	-	-	
<u>Cebidichthys</u> <u>violaceus</u>	-	-	-	
<u>Epigeichthys</u> <u>rupestris</u>	-	-	-	
<u>Lumpenus</u> <u>lumpretaeformis</u>	-	-	-	
Tripterygiidae <u>Tripterygion</u> <u>etheostoma</u>	-	-	-	
Zaproridae <u>Zaprora</u> <u>silenus</u>	-	-	-	
Icosteidae <u>Icosteus</u> <u>aenigmaticus</u>	-	-	-	
Ammodytidae <u>Ammodytes</u> <u>americanus</u>	-	-	-	
Callionymidae <u>Callionymus</u> sp.	-	-	-	

<u>C. japonicus</u>	-	-	-	
<u>C. lunatus</u>	-	-	-	
<u>C. richardsoni</u>	-	-	-	
Gobiidae <u>Acanthogobius</u> <u>flavimanus</u>	-	 s VV		
<u>Gobius</u> <u>fluviatilis</u>	?	?	?	
Gobioididae <u>Gobioides</u> sp.	-	 s VV		
<u>Sericagobioides</u> <u>lighti</u>	-	 s VV	-	
Kraemeriidae <u>Kraemeria</u> <u>samoensis</u>	-			
Microdesmiidae <u>Pholidichthys</u> <u>leucotaenia</u>	+	 st gg VV	 st	
Trypauchenidae <u>Trypauchenichthys</u> sp.	-	 s VV	-	
Kurtidae <u>Kurtus gulliveri</u>	-	 RSV		
<u>K. indicus</u>	-	+	 rm	

Acanthuridae <u>Acanthurus</u> <u>coeruleus</u>	+	 RSV		
<u>Acanthurus</u> sp.	+	 RSV	?	+
<u>Ctenochaetus</u> <u>striatus</u>	-	+	-	+
<u>Naso</u> <u>annulatus</u>	-	+	+	
<u>N.</u> <u>hexacanthus</u>	-	+		+
<u>Naso</u> sp.	?	+		+
<u>Prionuris</u> <u>microlepidotus</u>	?	+	?	
<u>Zebrasoma</u> <u>flavescens</u>	-	+	-	
Zanclidae <u>Zanclus</u> <u>cornatus</u>	+	 RSV	-	
Siganidae <u>Lo</u> <u>vulpinus</u>	-	+		

<u>Siganus</u> sp.	-	 VV	-	+
Gempylidae <u>Ephinnula</u> sp.	-	-	-	
<u>Gempylus</u> <u>serpens</u>	-	-	-	
Scombridae <u>Scomber</u> <u>colias</u>	-	+		
<u>Scomber</u> <u>japonicus</u>	-	+		
<u>Scomberomorus</u> <u>commersonianus</u>				
<u>Scomberomorus</u> sp.				
Trichiridae <u>Trichiurus</u> <u>lepturus</u>	-	 VV		
<u>Benthodesmus</u> <u>atlanticus</u>	-	+	?	
Xiphiidae <u>Xiphias</u> <u>gladius</u>	-	-	-	
Nomeidae <u>Cubiceps</u> sp.	?	 hs VV		

<u>Nomeus gronovii</u>	?	 VV	?	
Centrolophidae				
<u>Psenopsis anomala</u>	?	?	?	
Stromateidae				
<u>Pampus argenteus</u>	?	?	?	
<u>Stomateus fiatola</u>	?	?	?	
<u>Peprilus</u> sp.	?	 VV		
Tetragonuridae				
<u>Tetragonurus cuvieri</u>	-	-	-	
Anabantidae				
<u>Anabas testudineus</u>	-	 VV		
<u>Ctenopoma nanus</u>	-	 VV	-	
Belontiidae				
<u>Betta splendens</u>	-	 VV		
<u>Trichogaster trichopterus</u>	-	 bhs VV	-	
<u>Colisa fasciata</u>	-	 bhs VV	-	

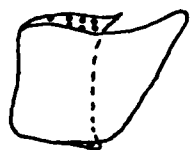
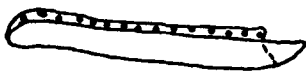
<u>Macropodus</u> <u>opercularis</u>	-			
Halostomatidae <u>Helostoma</u> <u>temmincki</u>	-	+	?	
Osphronemidae <u>Osphronemus</u> <u>goramy</u>	-		?	
Luciocephalidae <u>Luciocephalus</u> <u>pulcher</u>	-		-	
Mastacembelidae <u>Mastacembelus</u> <u>congius</u>	-	+	-	
<u>M. sinensis</u>	-	+	-	

TABLE 5

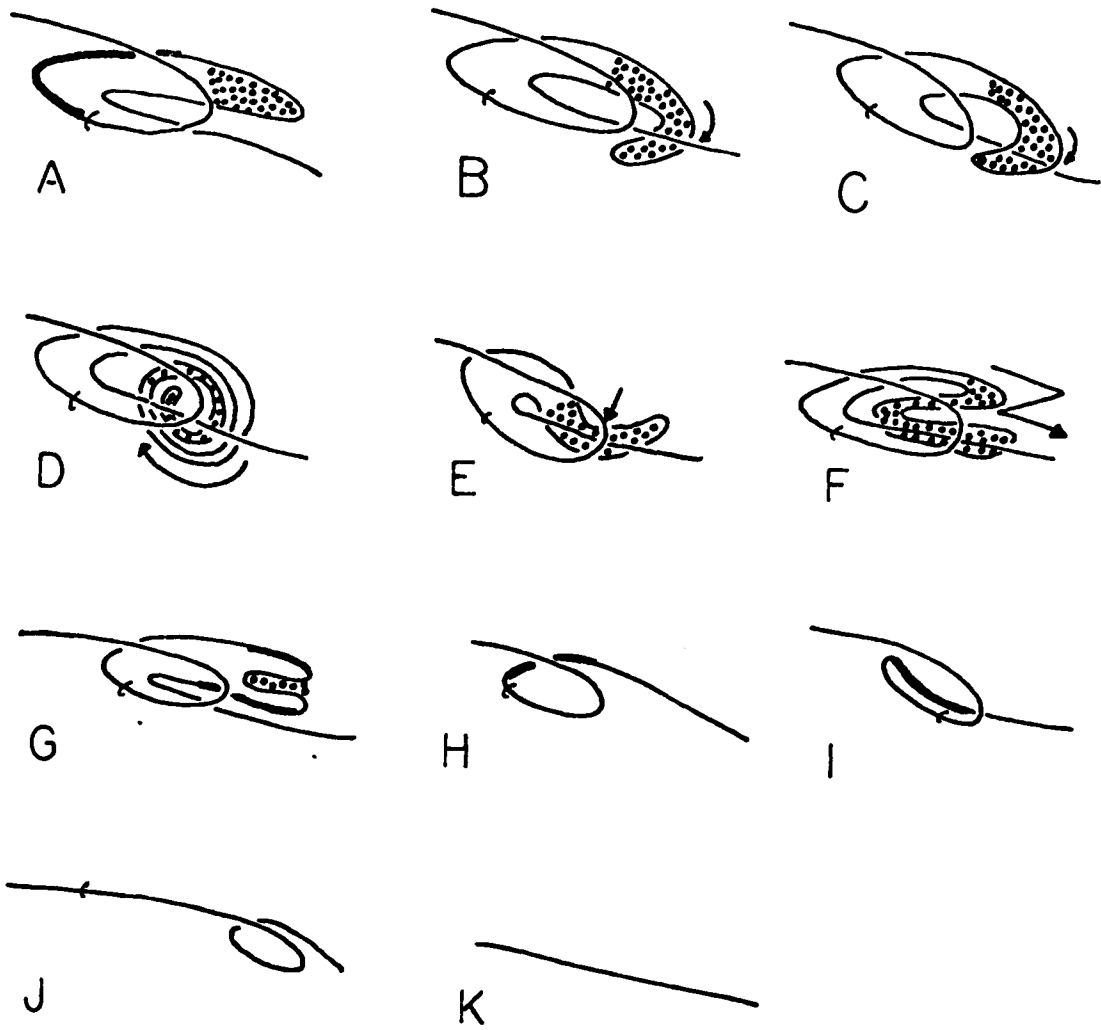


FIG. 1-1

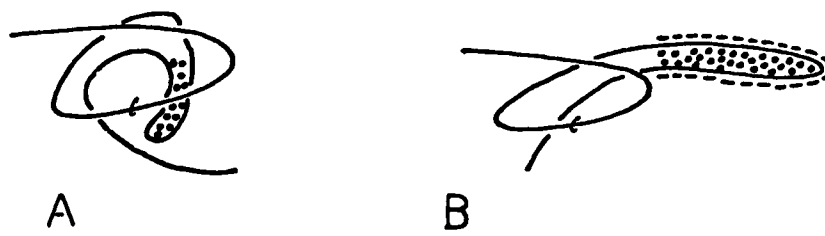


FIG. 1-2

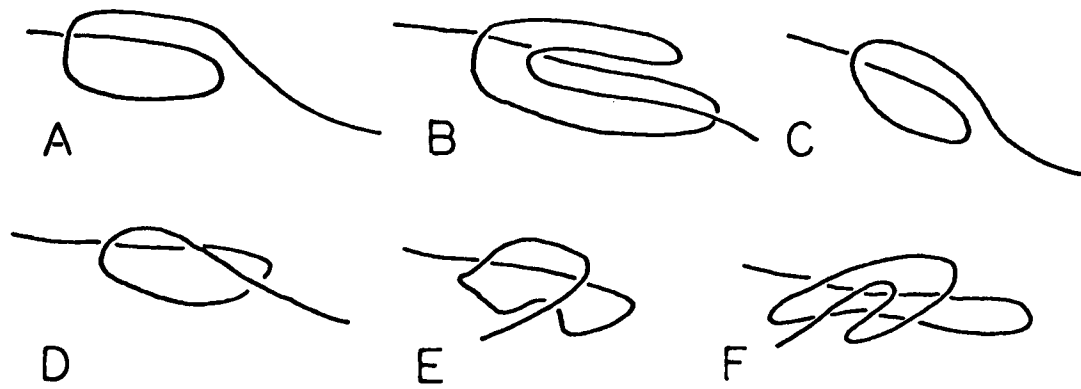


FIG. I-3

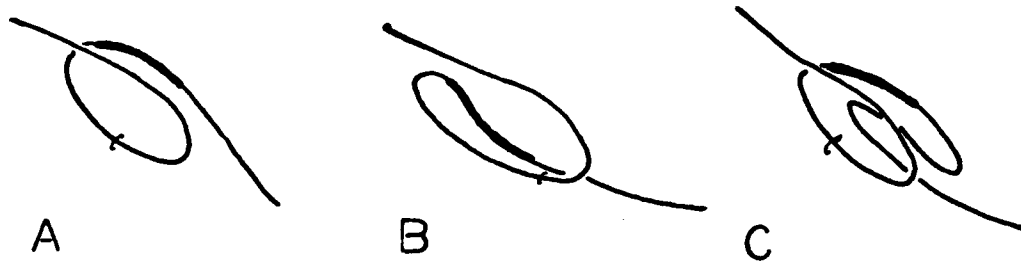
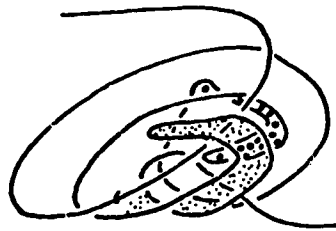
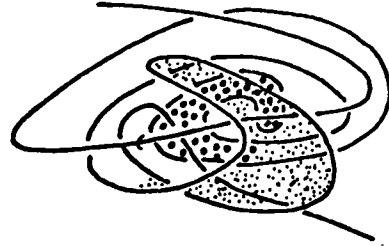


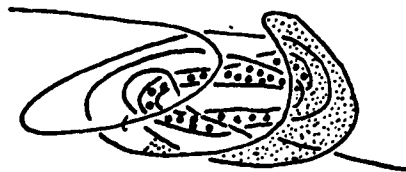
FIG. I-4



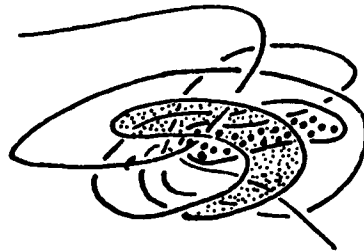
A



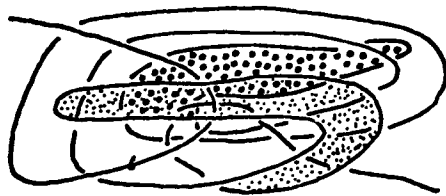
B



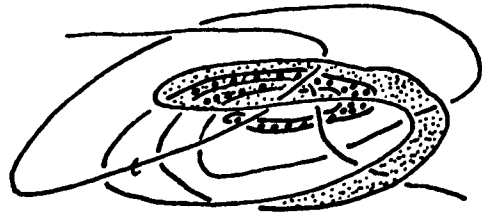
C



D



E



F

FIG. 1-5

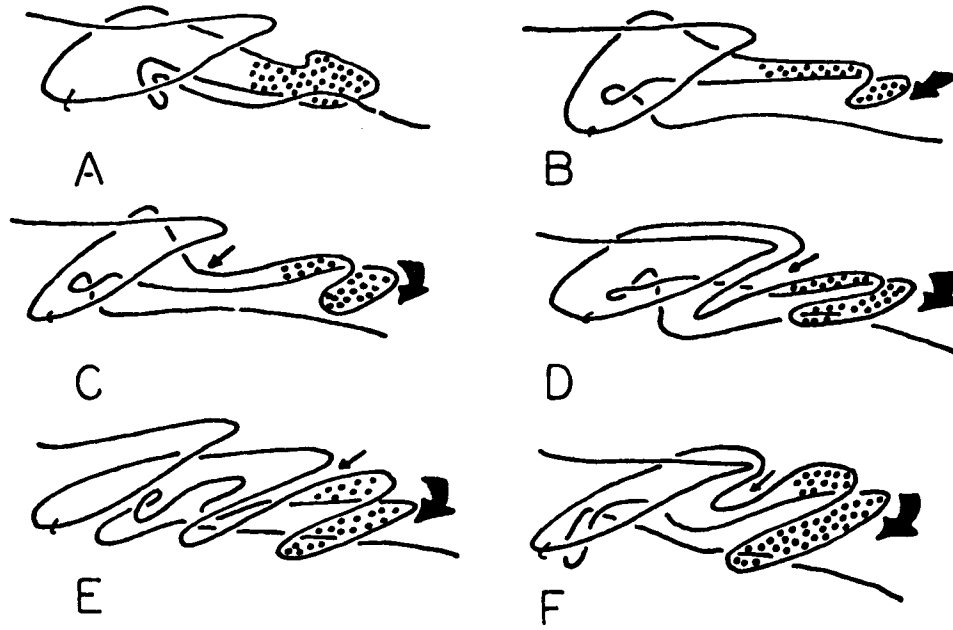


FIG. I-6

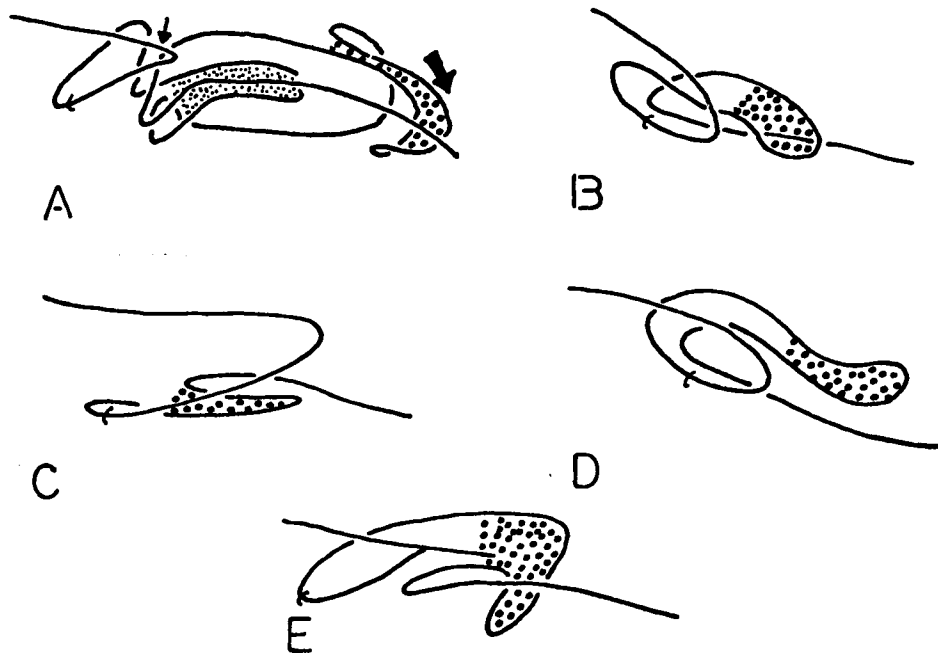


FIG. I-7

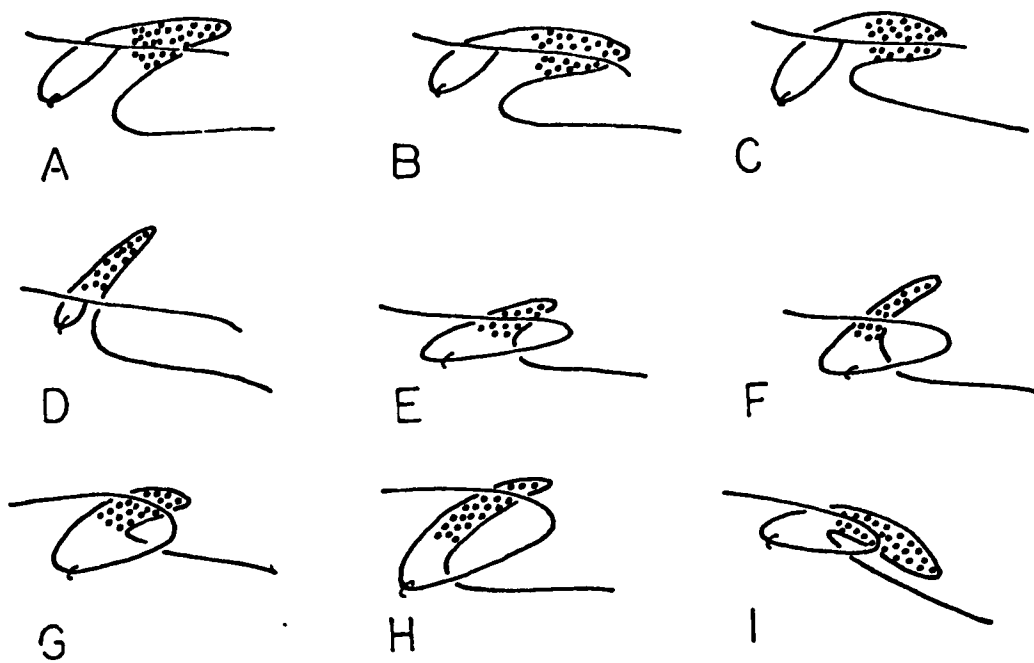


FIG. 1-8

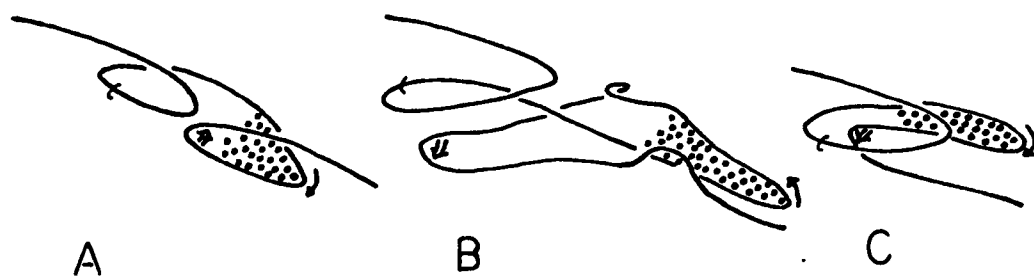


FIG. 1-9

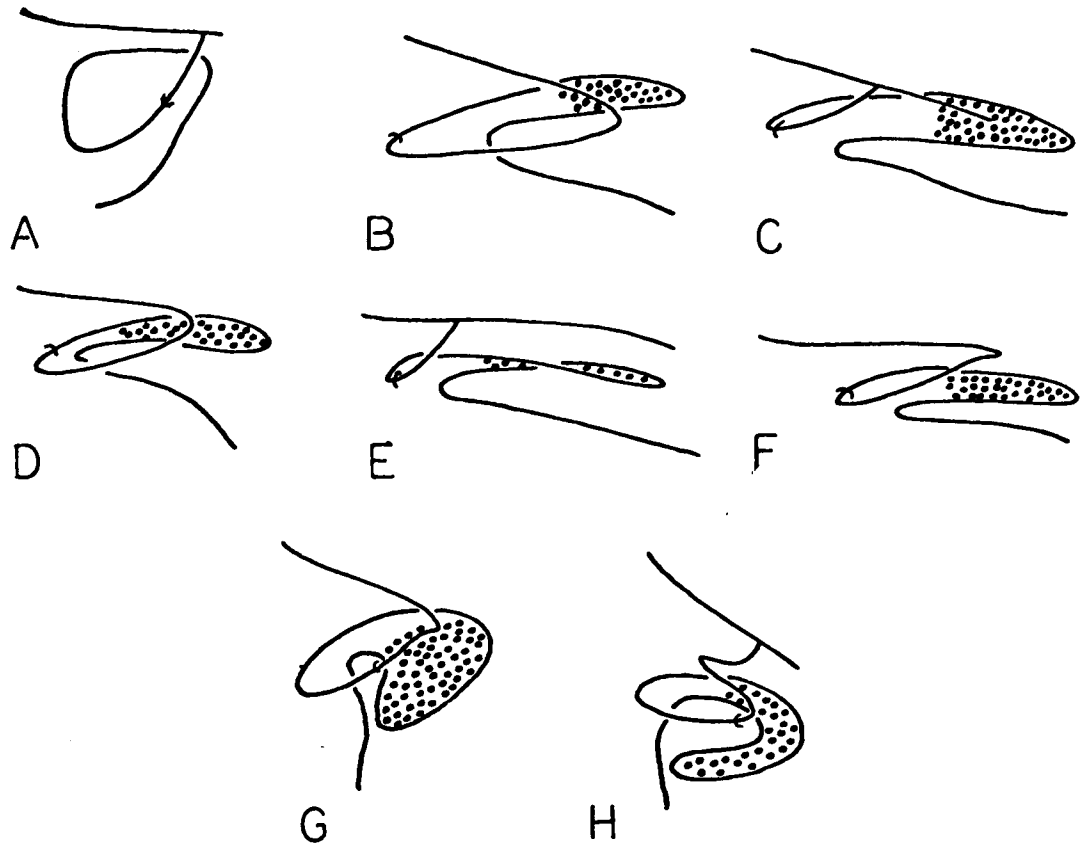


FIG. I-10

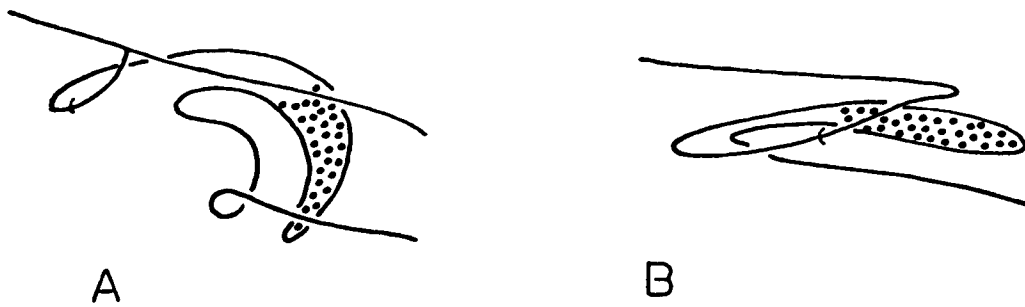


FIG. I-11

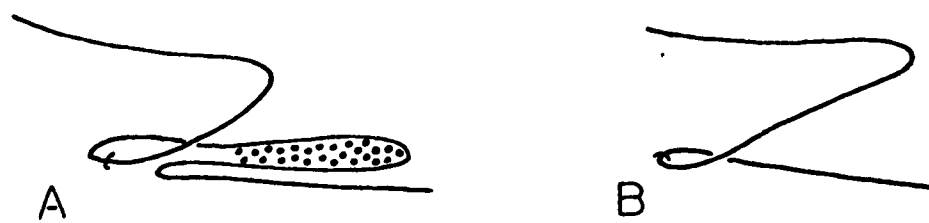


FIG. I-12

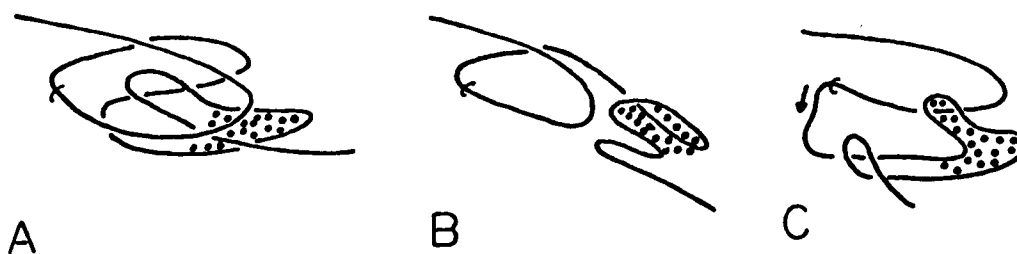


FIG. I-13

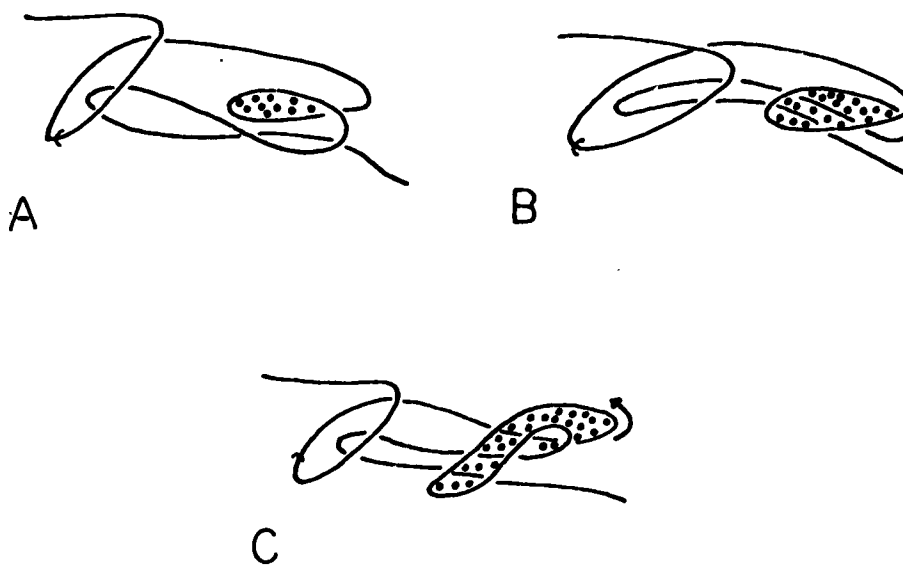


FIG. I-14

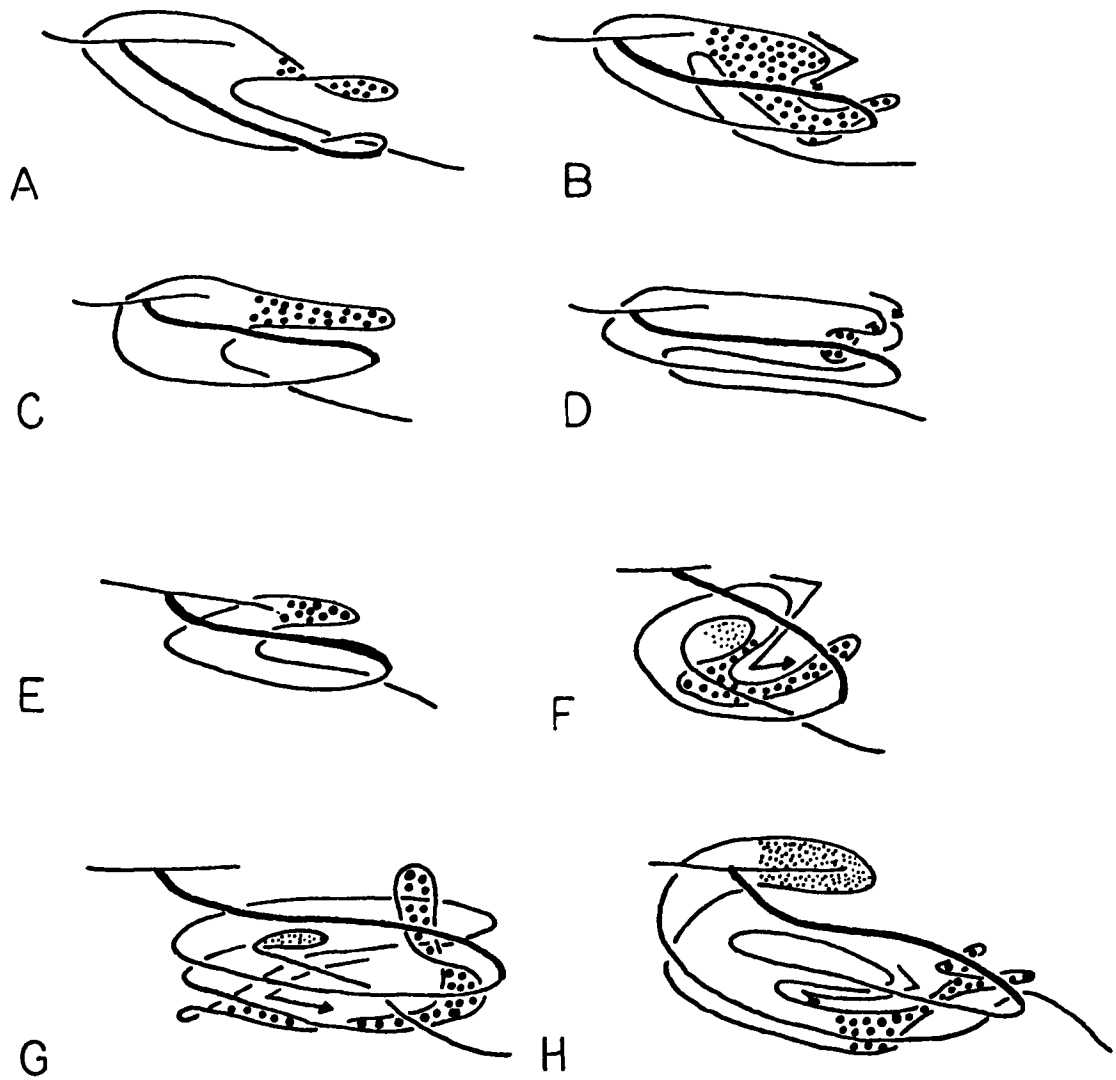


FIG. 1-15

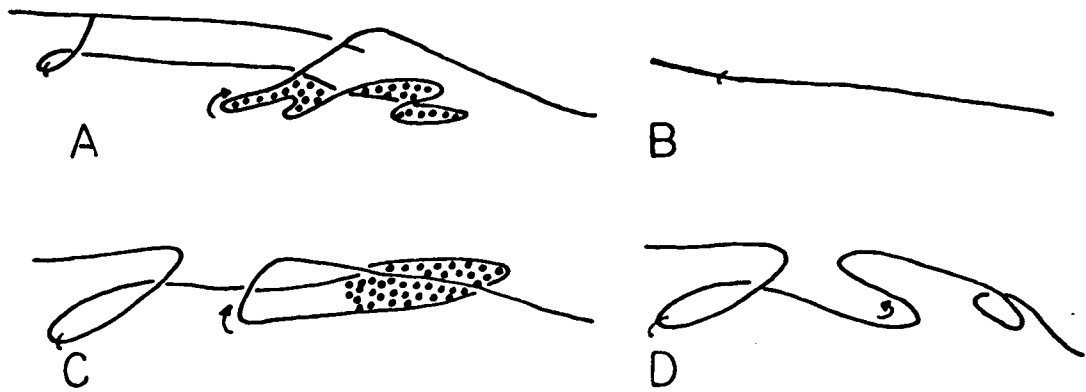


FIG. I-16

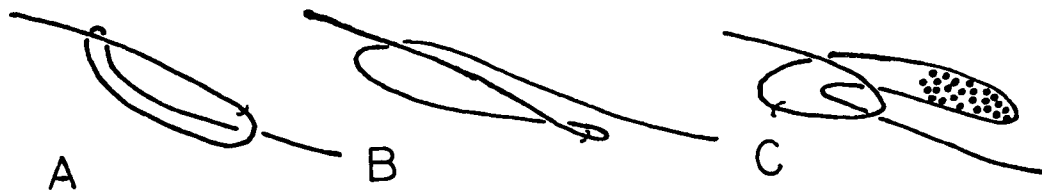


FIG. I-17

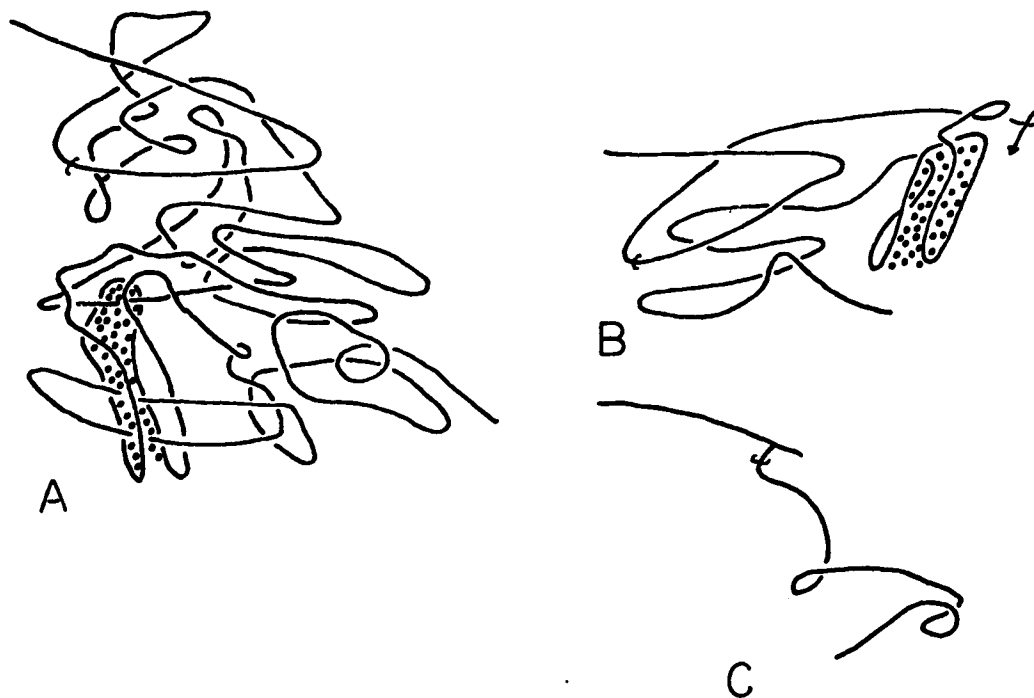


FIG. I-18

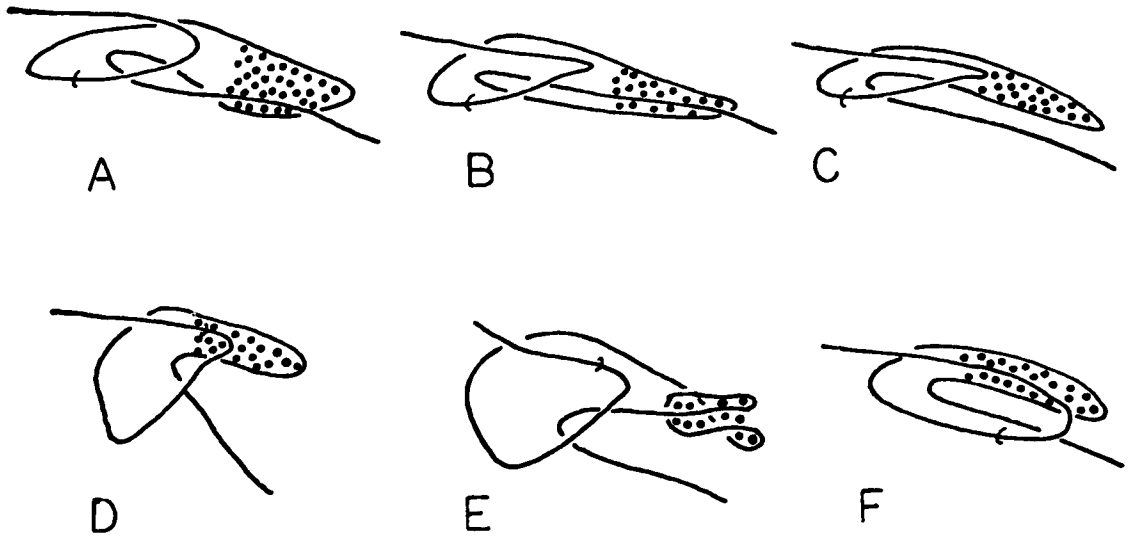


FIG. I-19

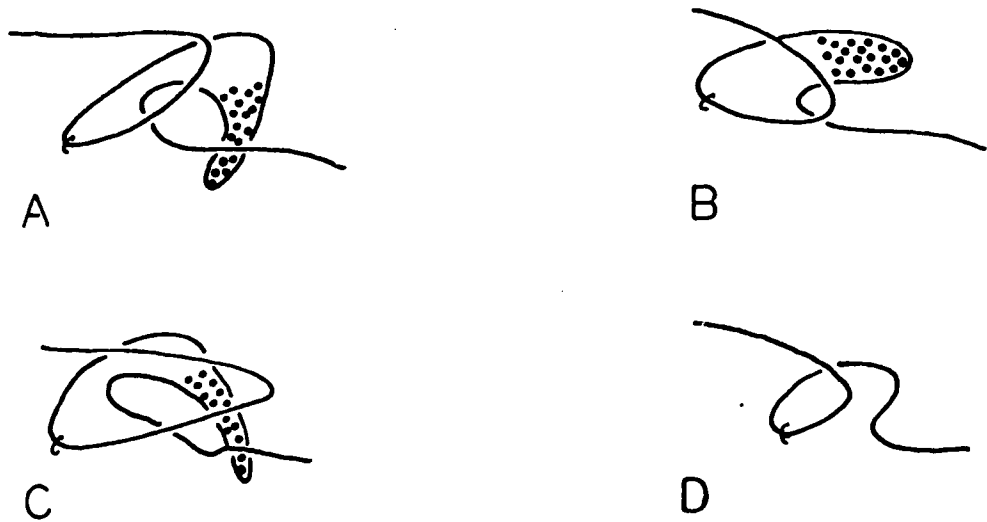


FIG. I-20

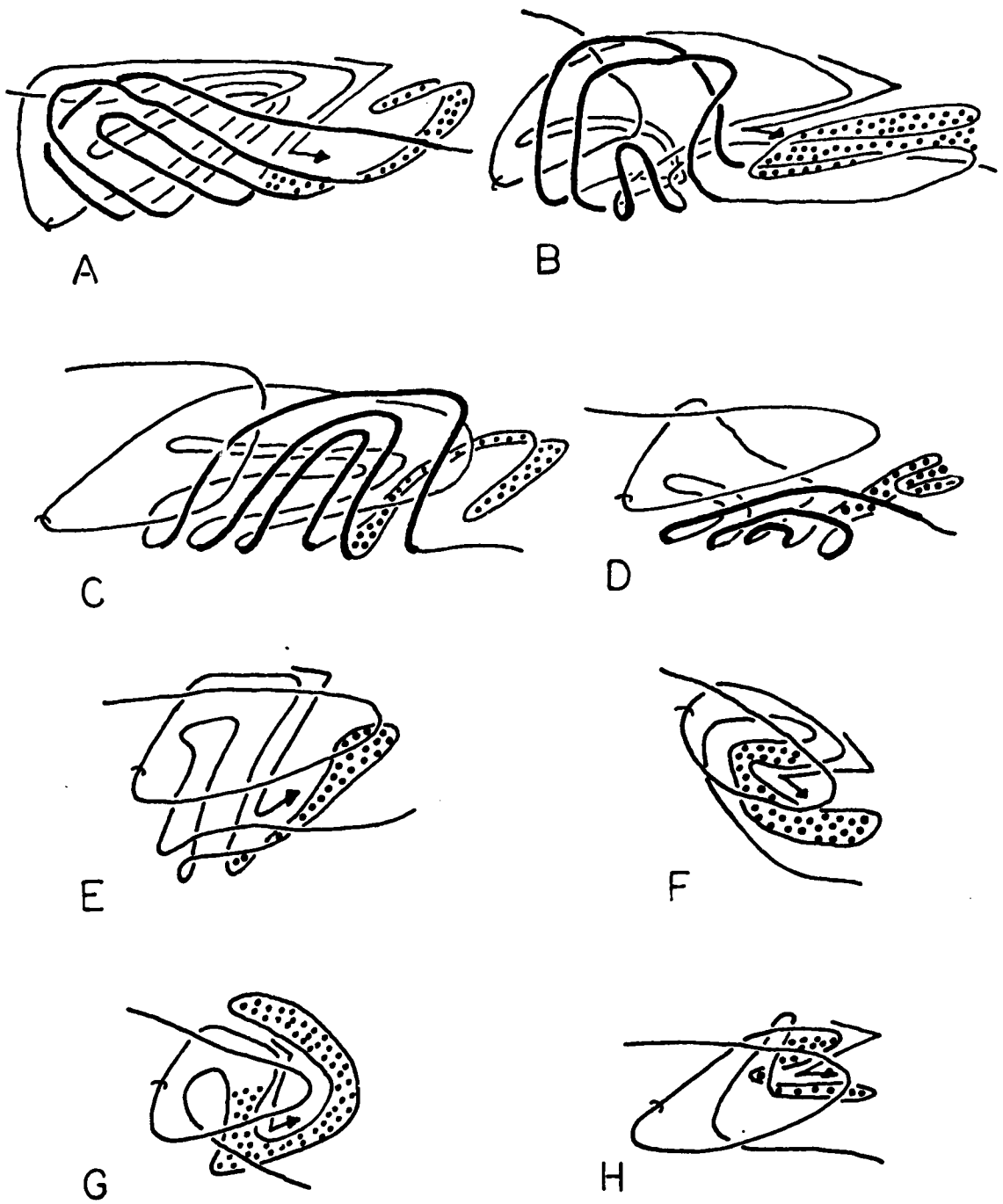


FIG. I-21

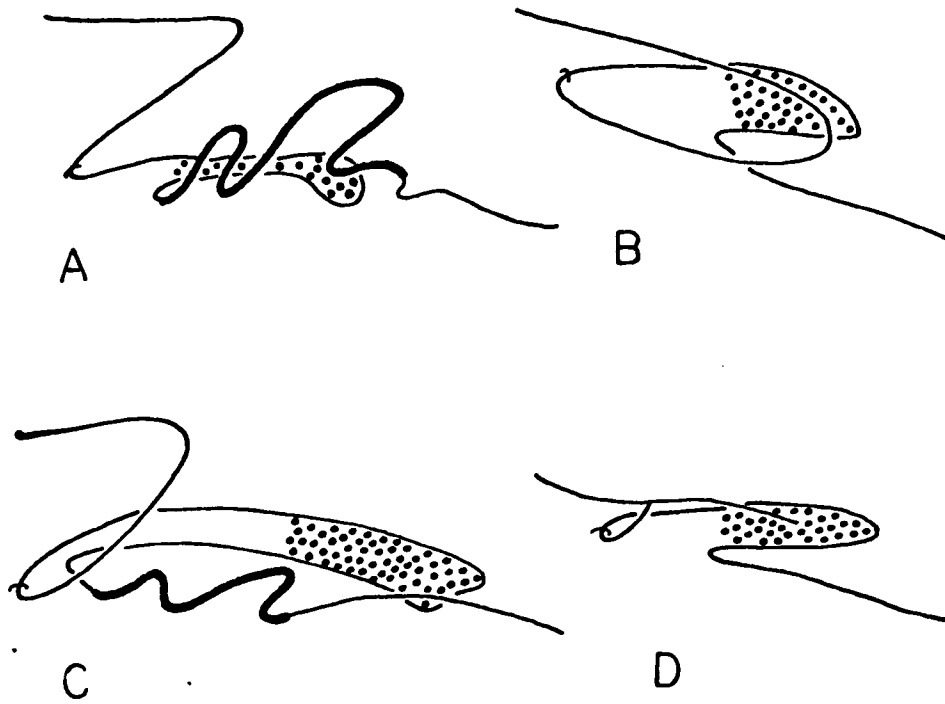


FIG. I-22

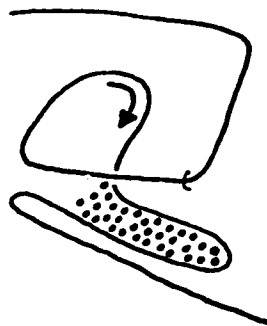


FIG. I-23

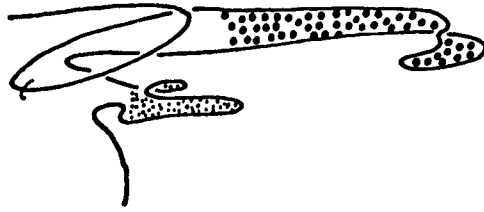


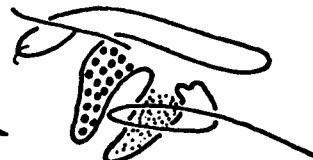
FIG. I-24



A



B



C

FIG. I-25



FIG. I-26

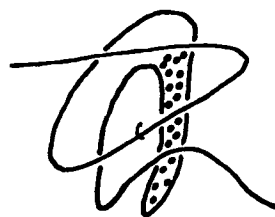


FIG. I-27

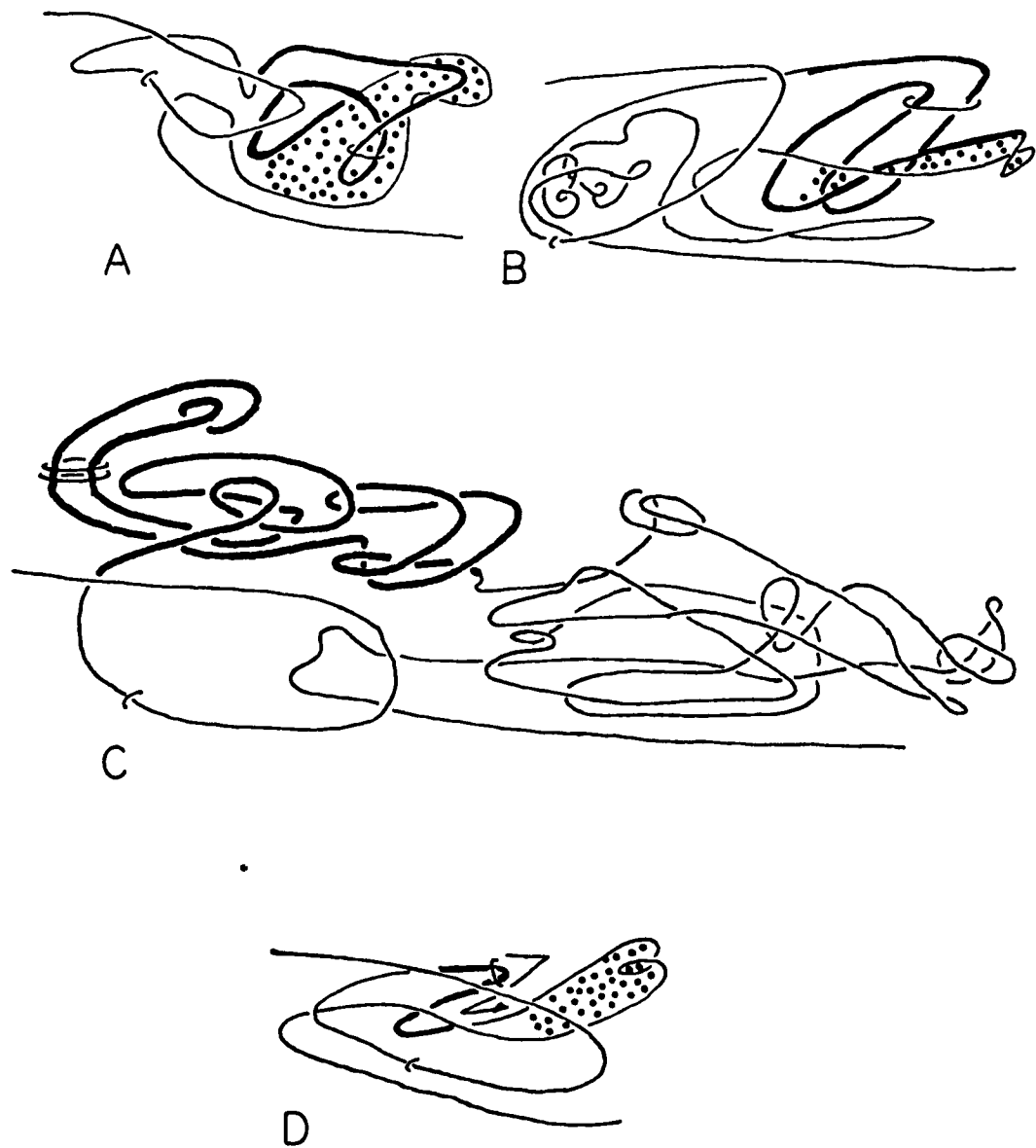


FIG. I-28

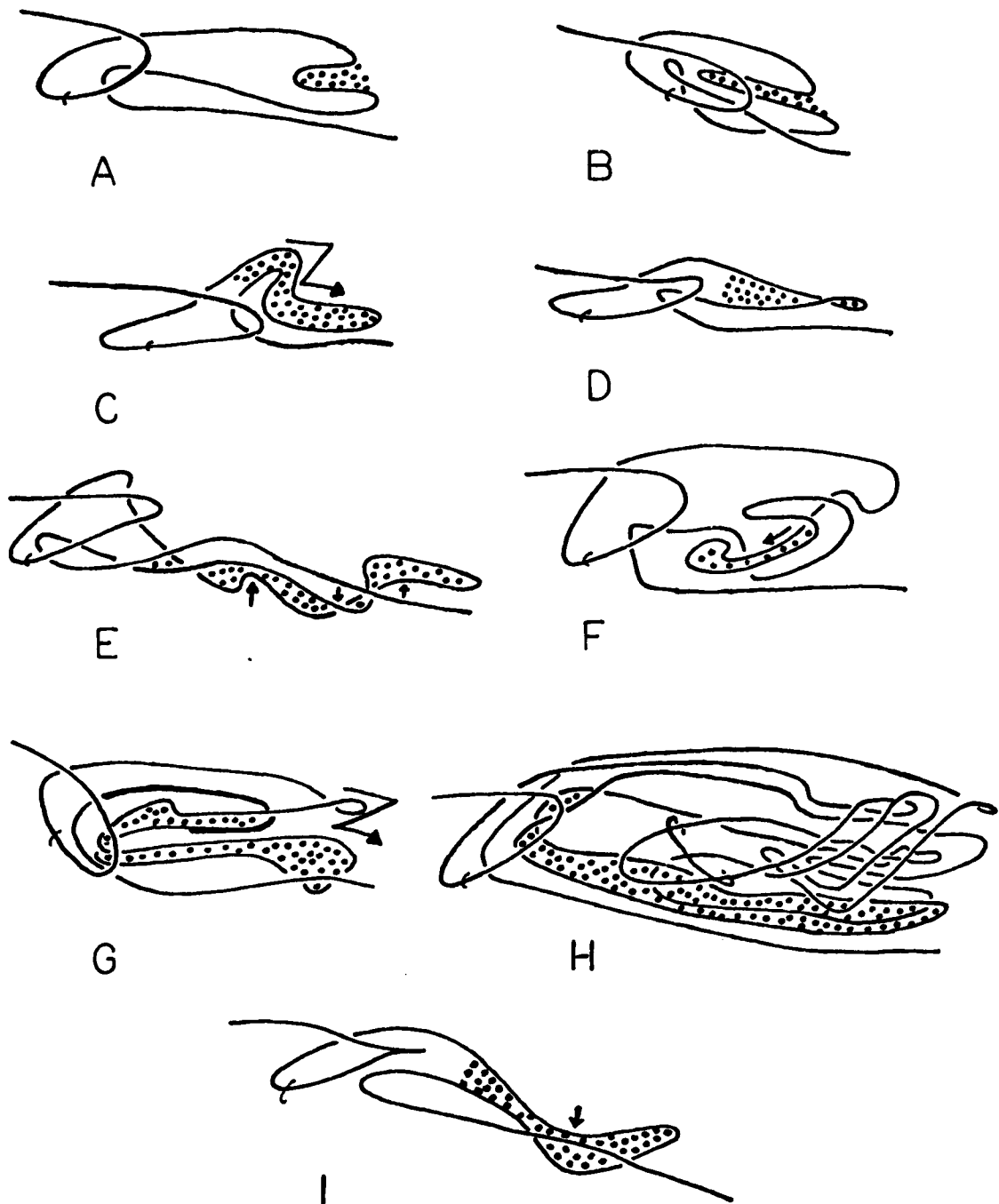


FIG. I-29

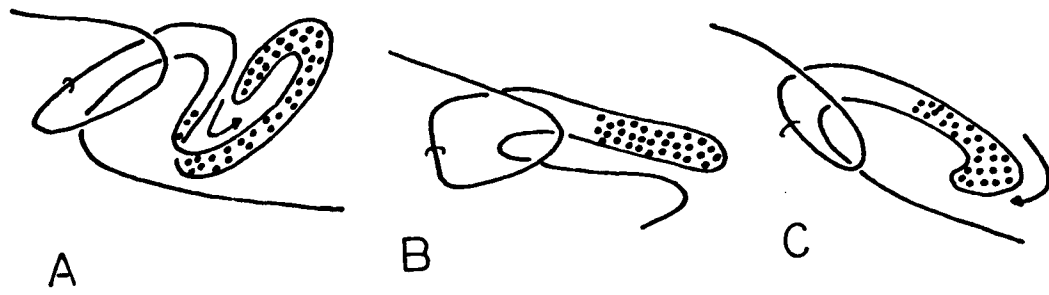


FIG. I-30

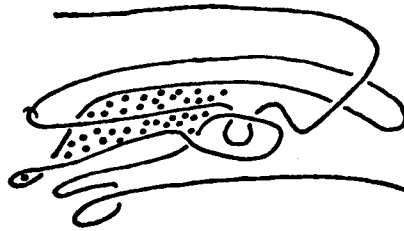


FIG. I-31

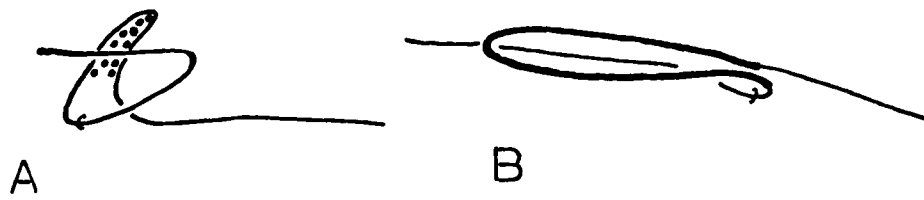


FIG. I-32

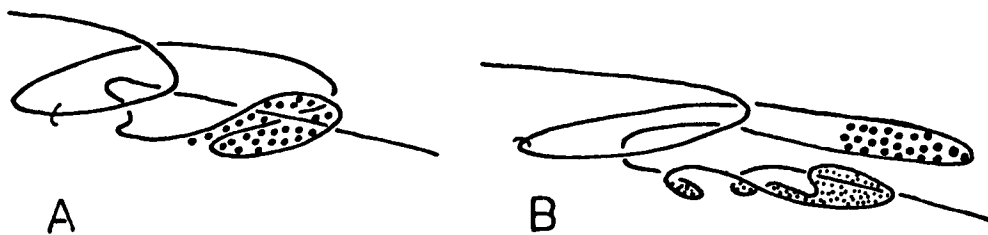


FIG. I-33

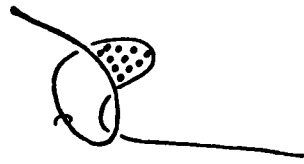
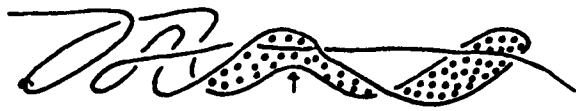
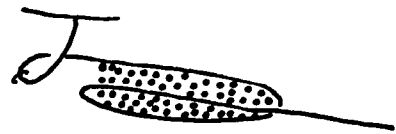


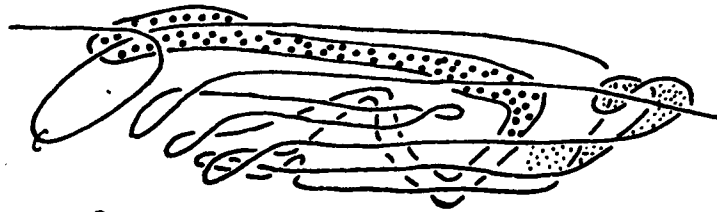
FIG. I-34



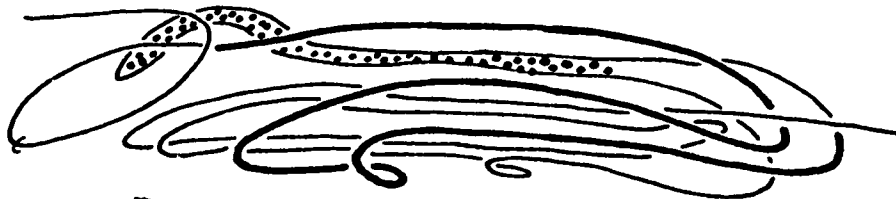
A



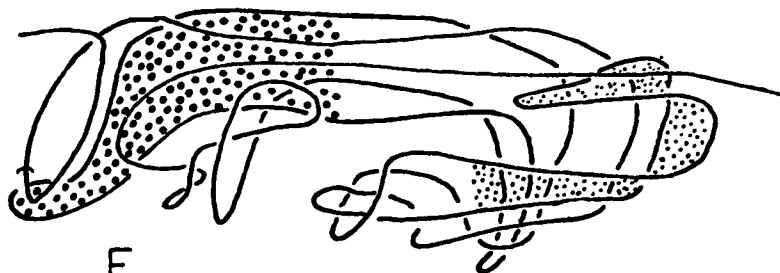
B



C



D



E

FIG. I-35

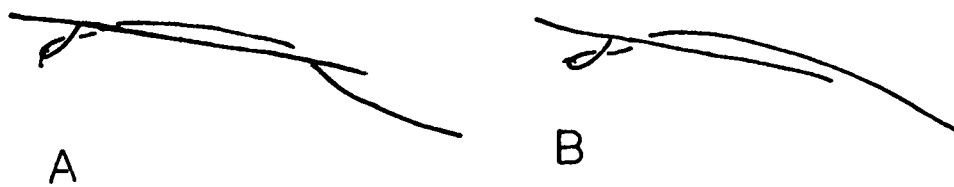


FIG. I-36

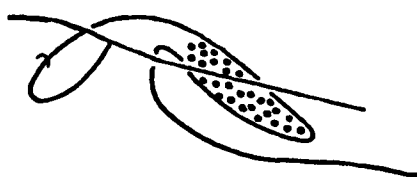


FIG. I-37

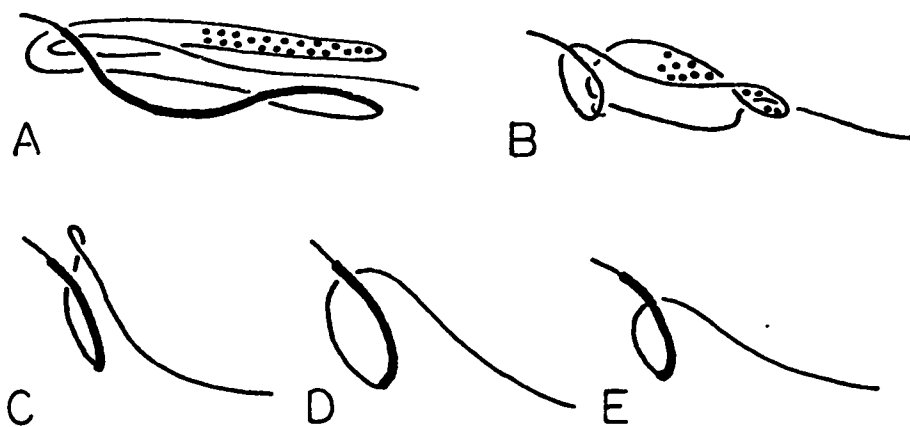


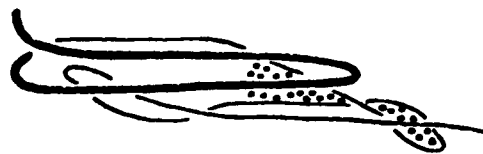
FIG. I-38



FIG. I-39



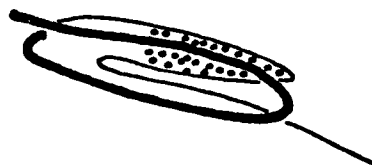
A



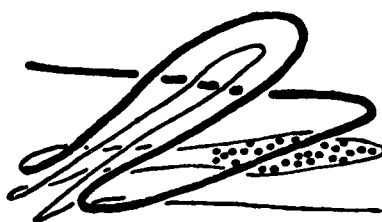
B



C



D



E

FIG. I-40

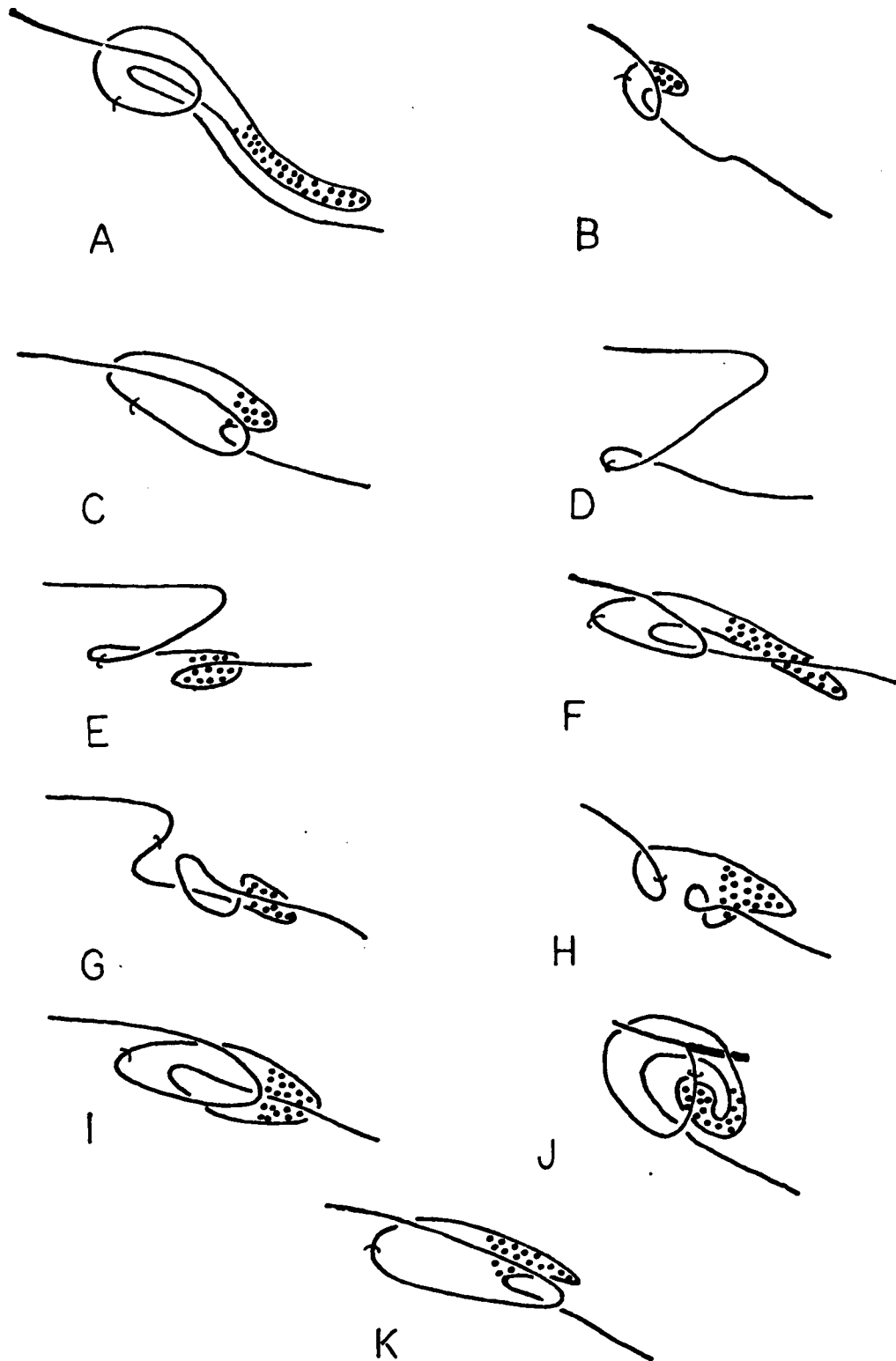


FIG. I-41

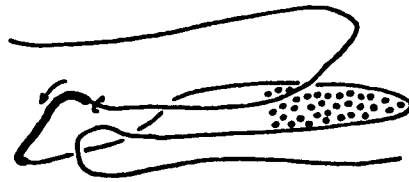
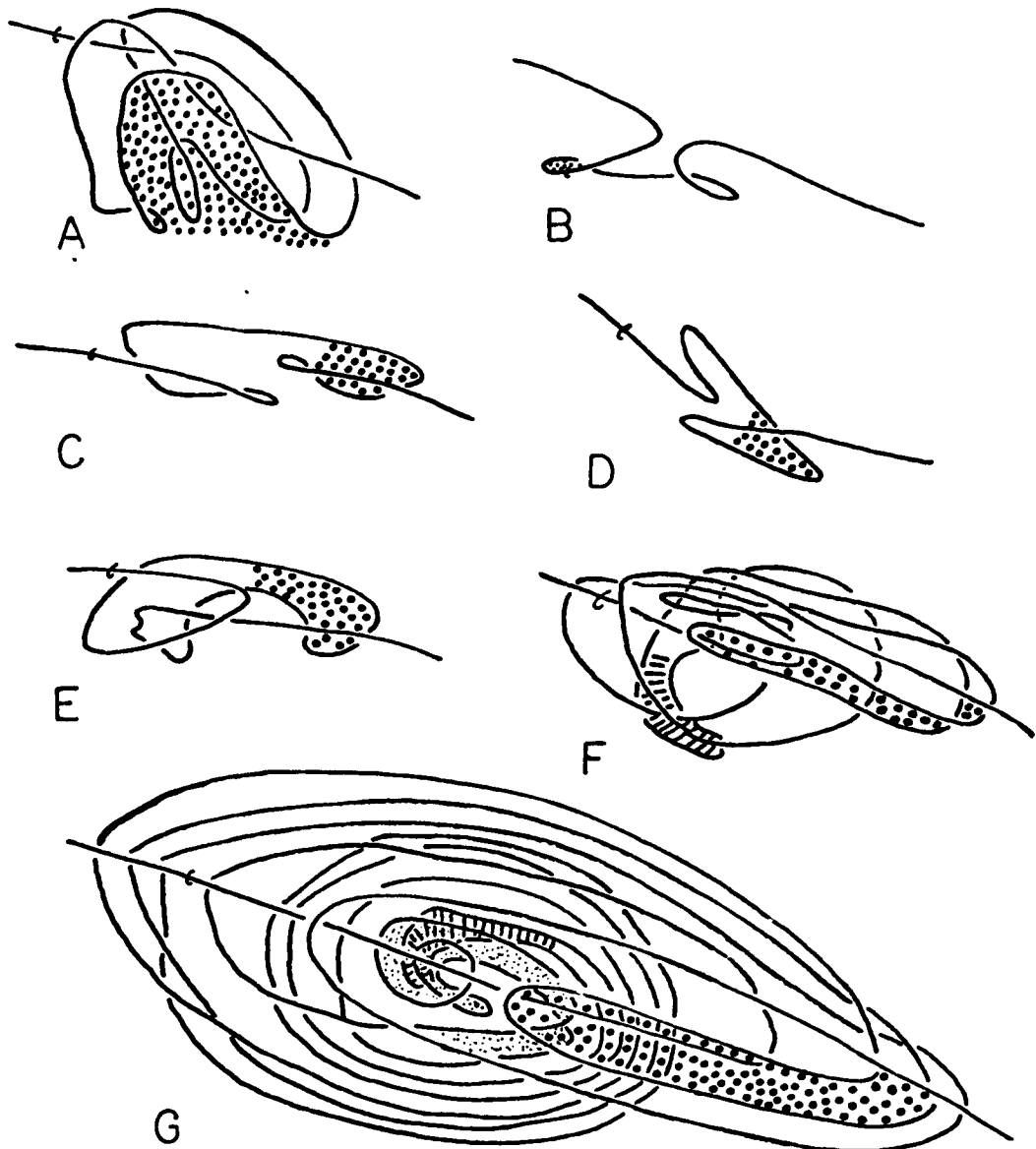


FIG. I-42



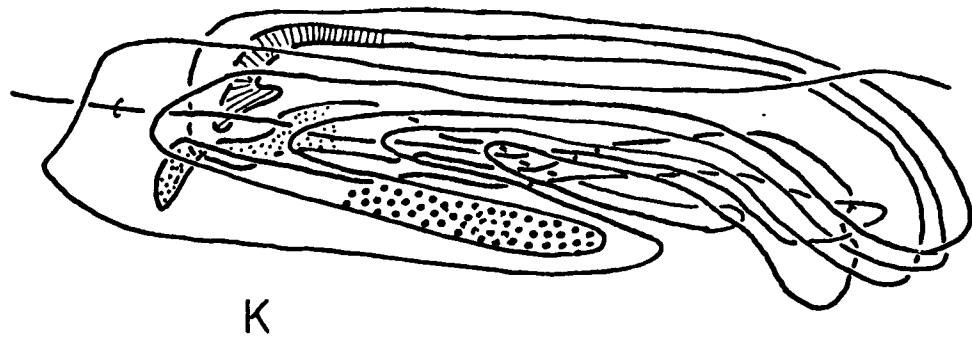
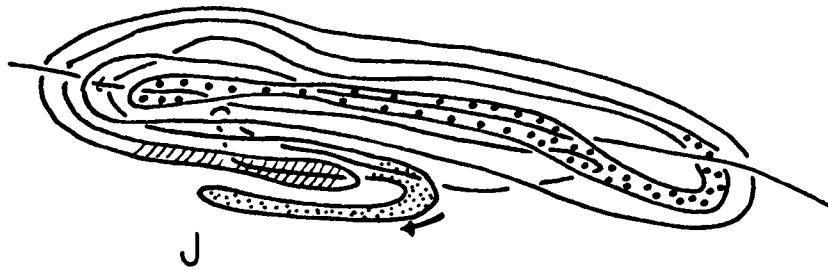
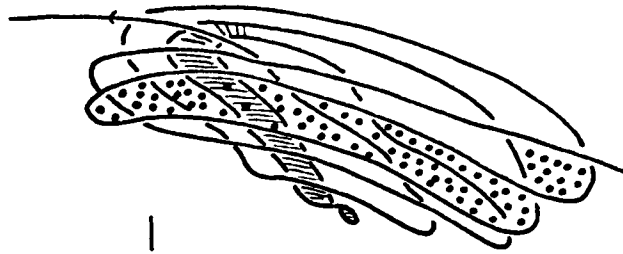
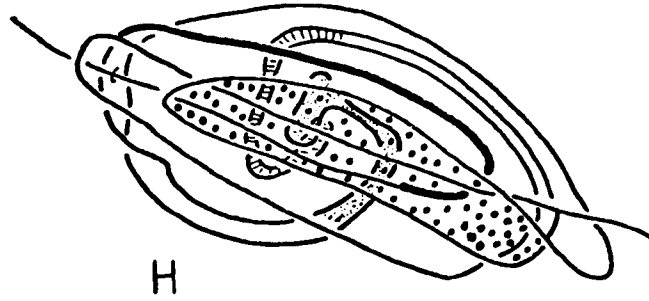


FIG. I-43

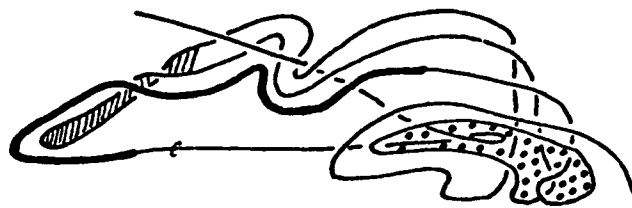


FIG. I-44

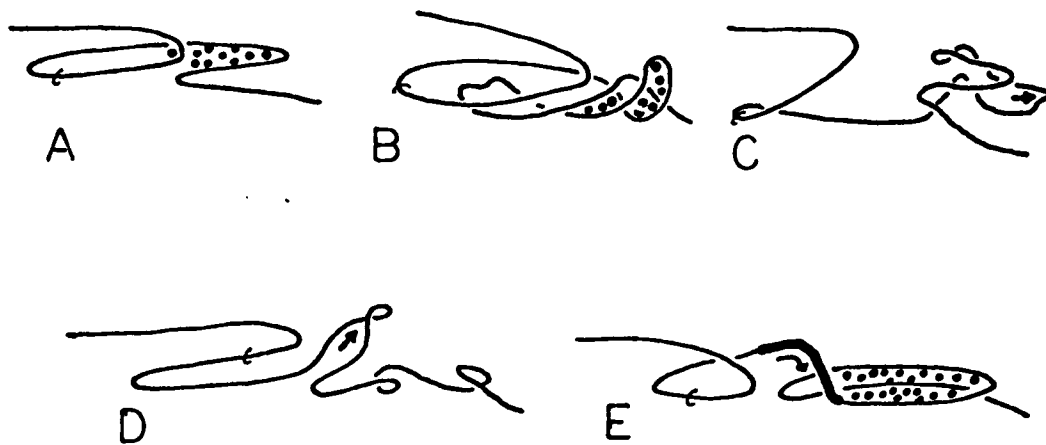


FIG. I-45



FIG. I-46

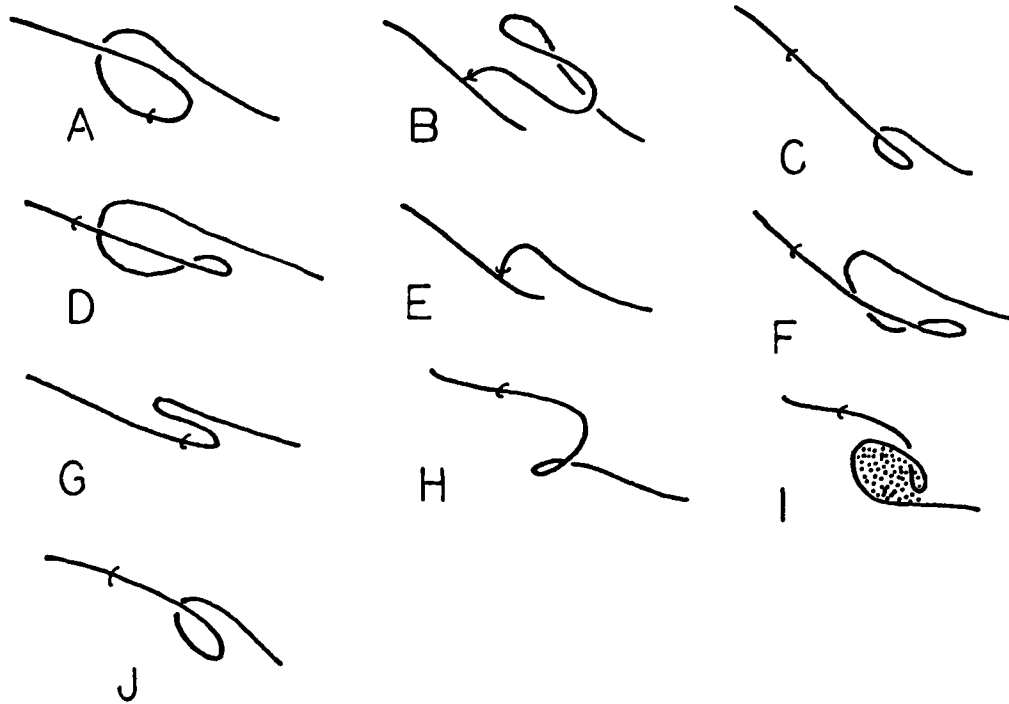


FIG. I-47

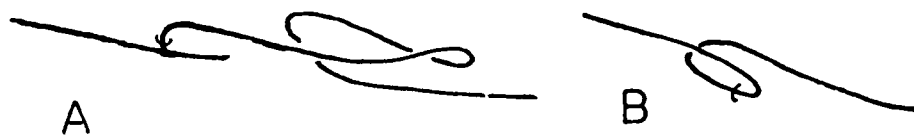


FIG. I-48



FIG. I-49

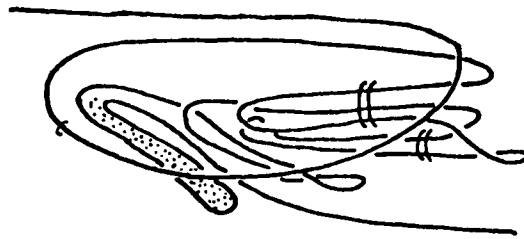
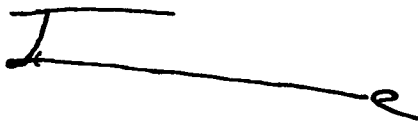


FIG. I-50



A

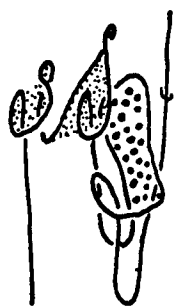


B

FIG. I-51



A



B



C



D

FIG. I-52

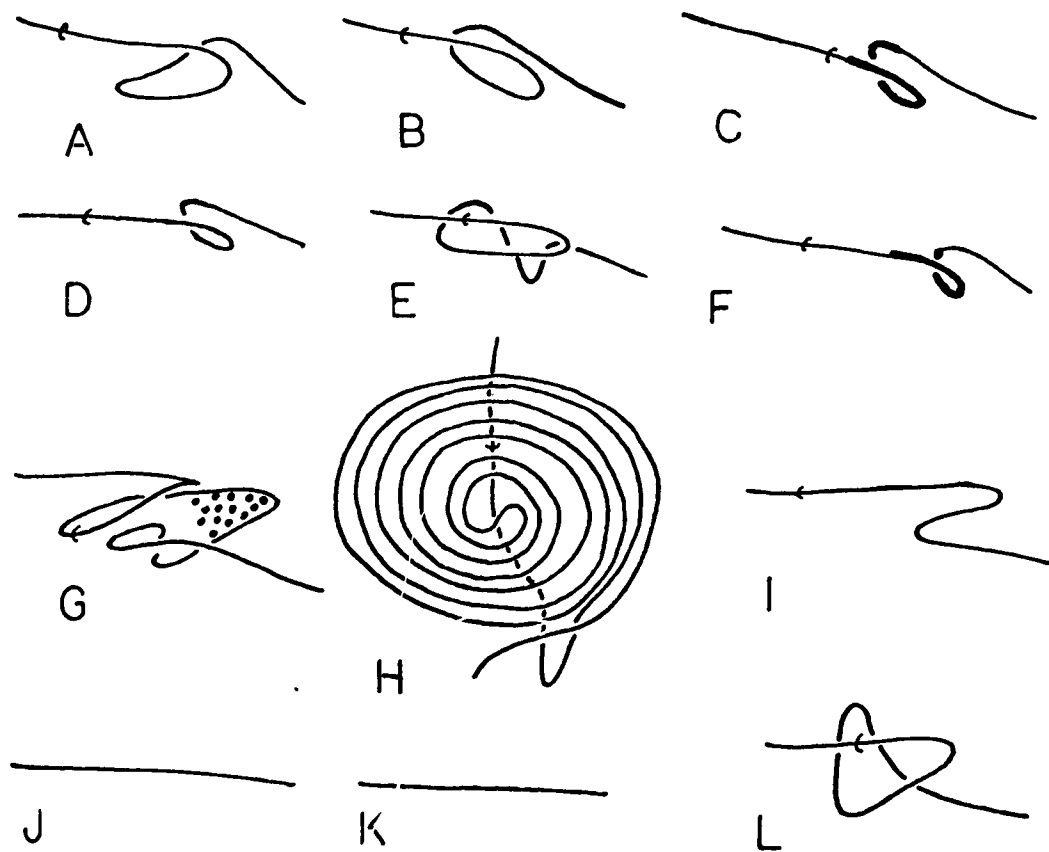


FIG. I-53

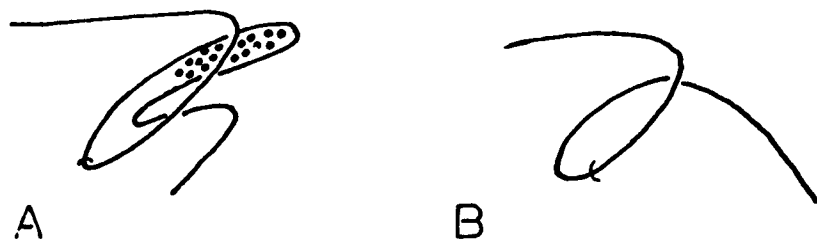
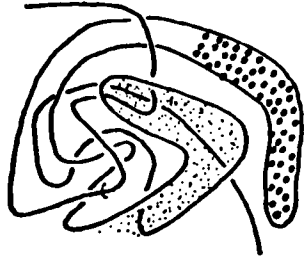
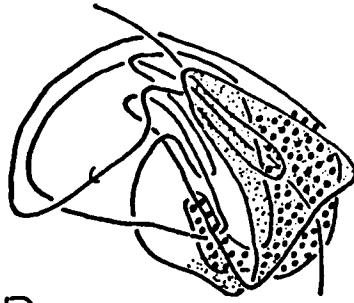


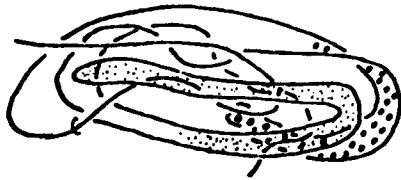
FIG. I-54



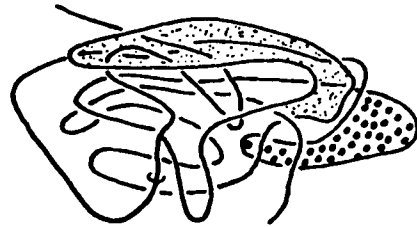
A



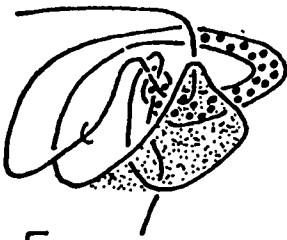
B



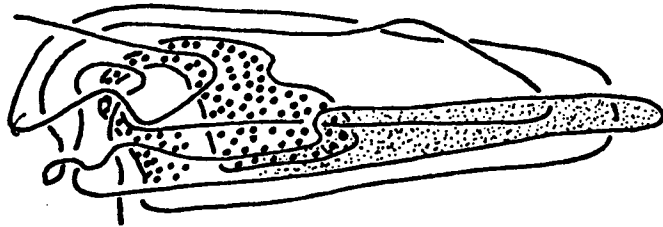
C



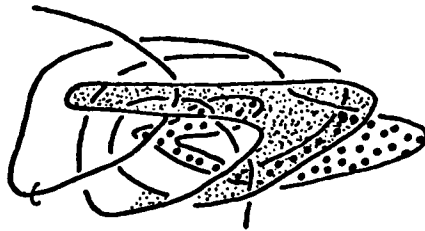
D



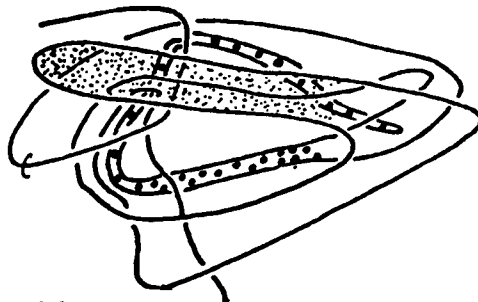
E



F



G



H

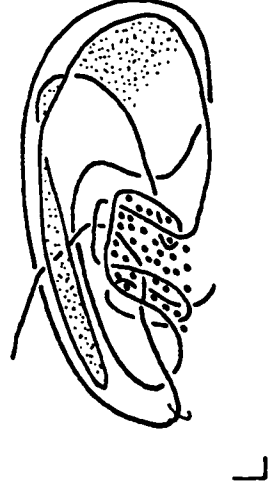
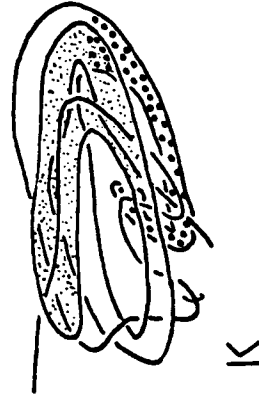
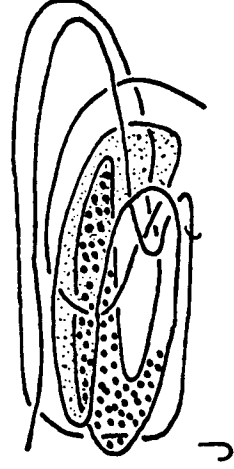
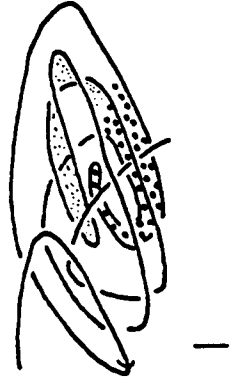


FIG. 1-55



FIG. 1-56

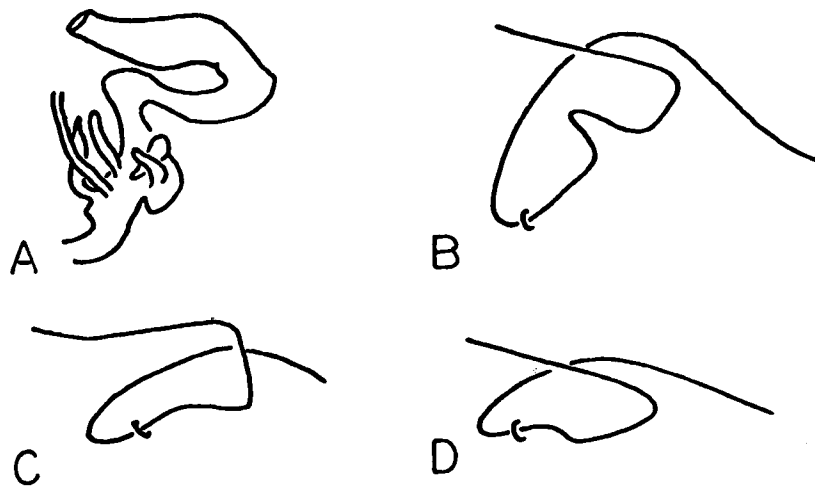
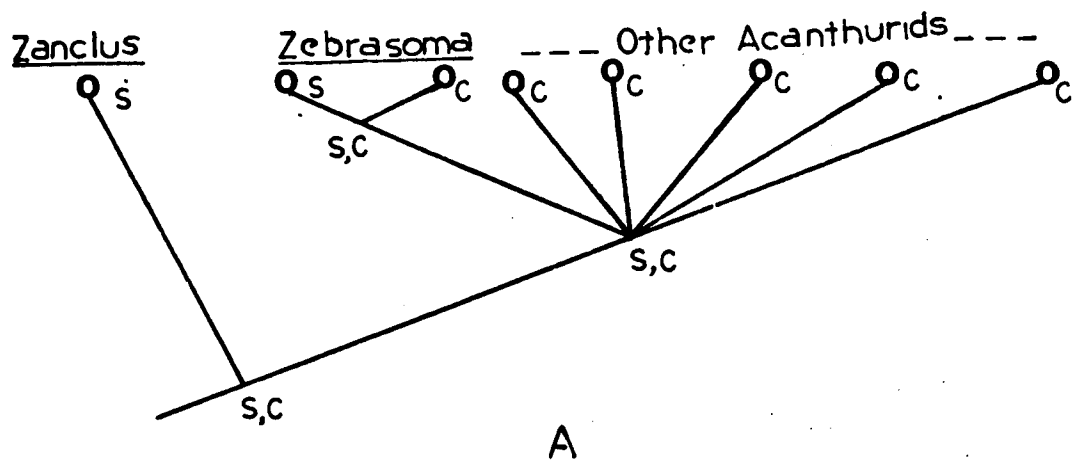
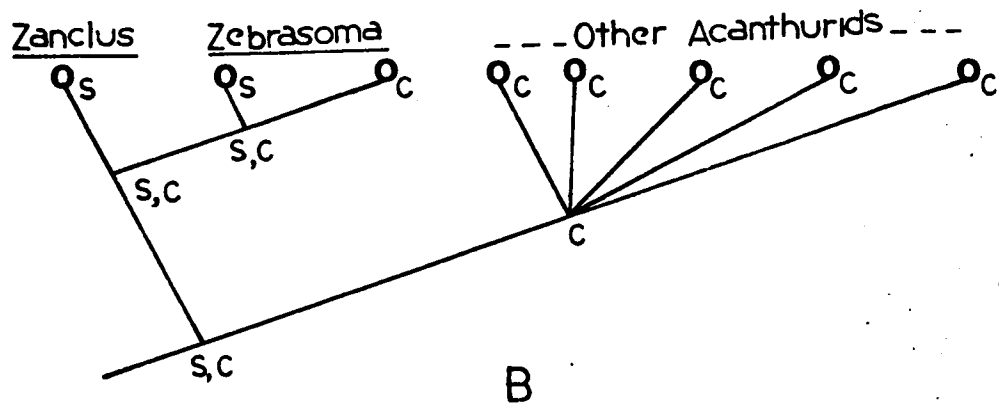


FIG. I-57



A



B

FIG. I-58

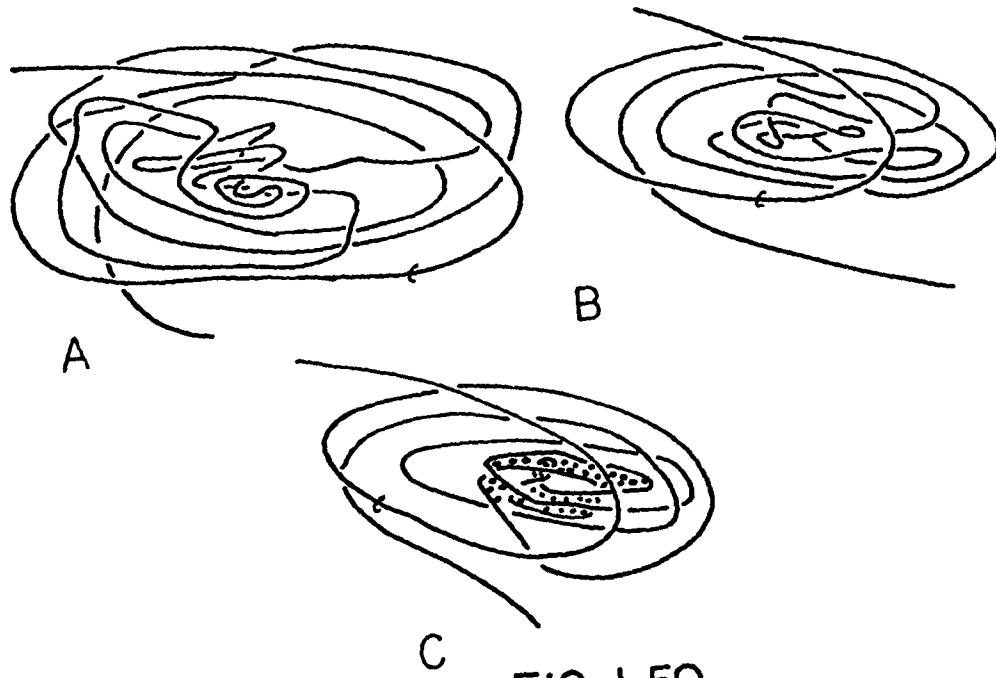


FIG. I-59

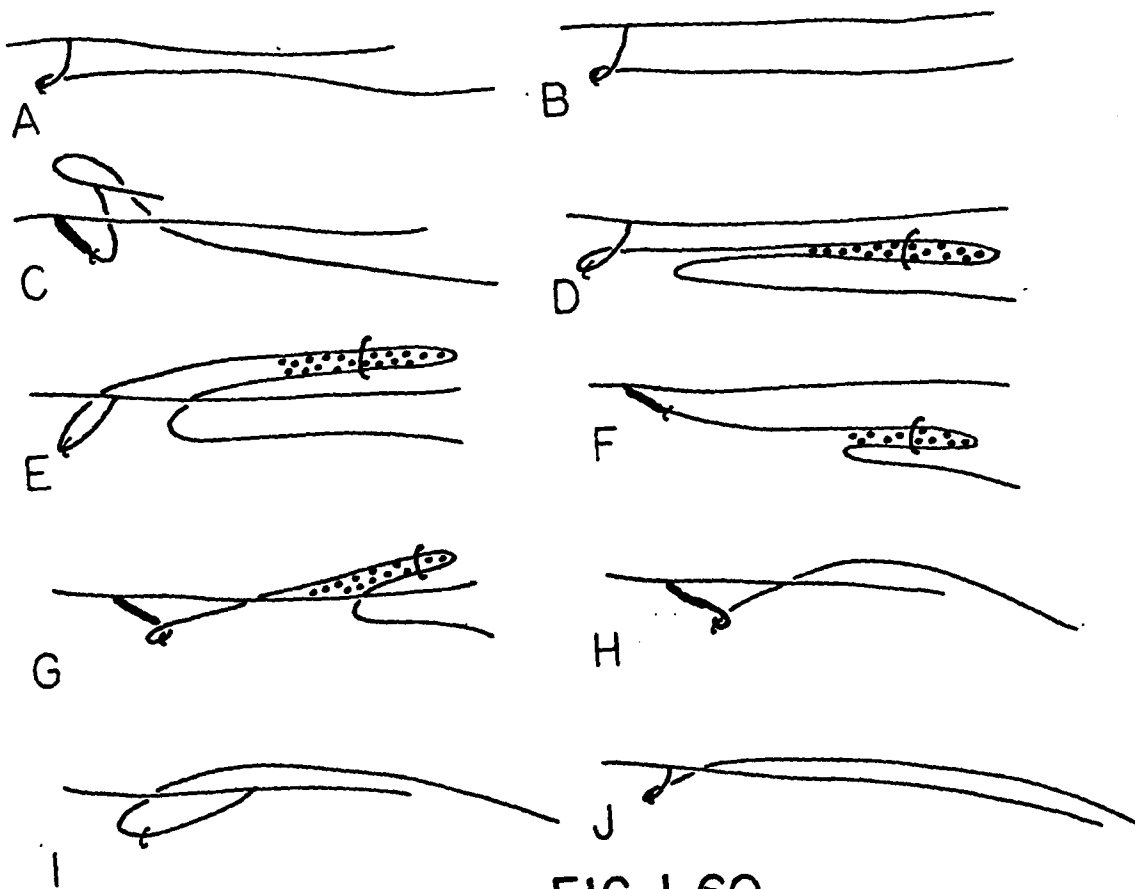


FIG. I-60

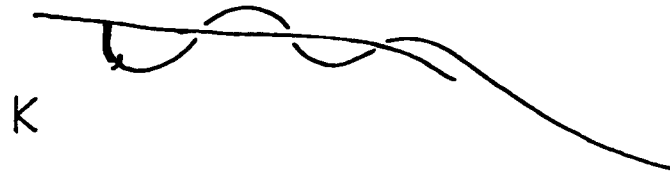


FIG. I-60

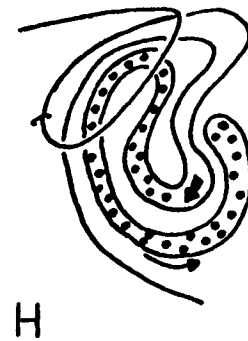
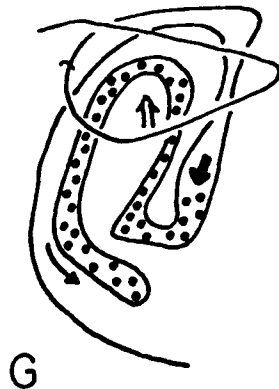
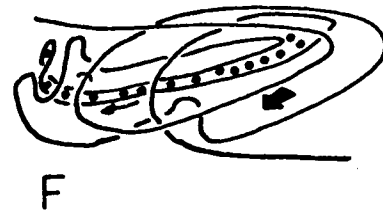
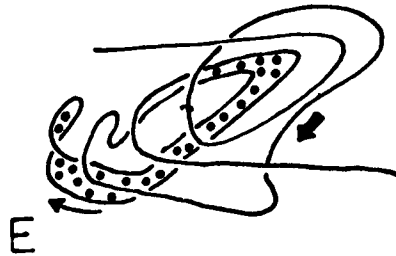
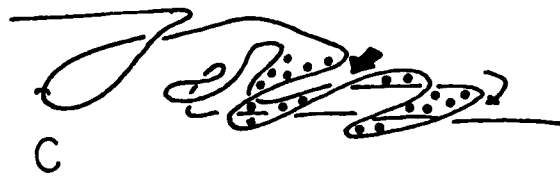
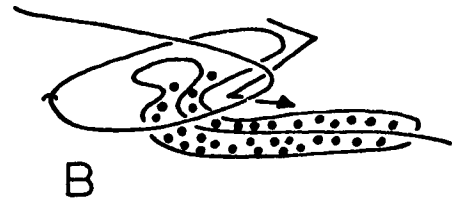
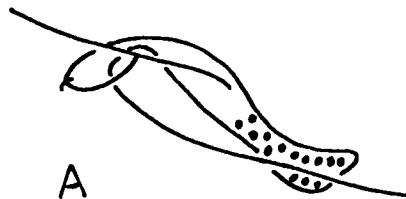


FIG. I-61



FIG. I-G1

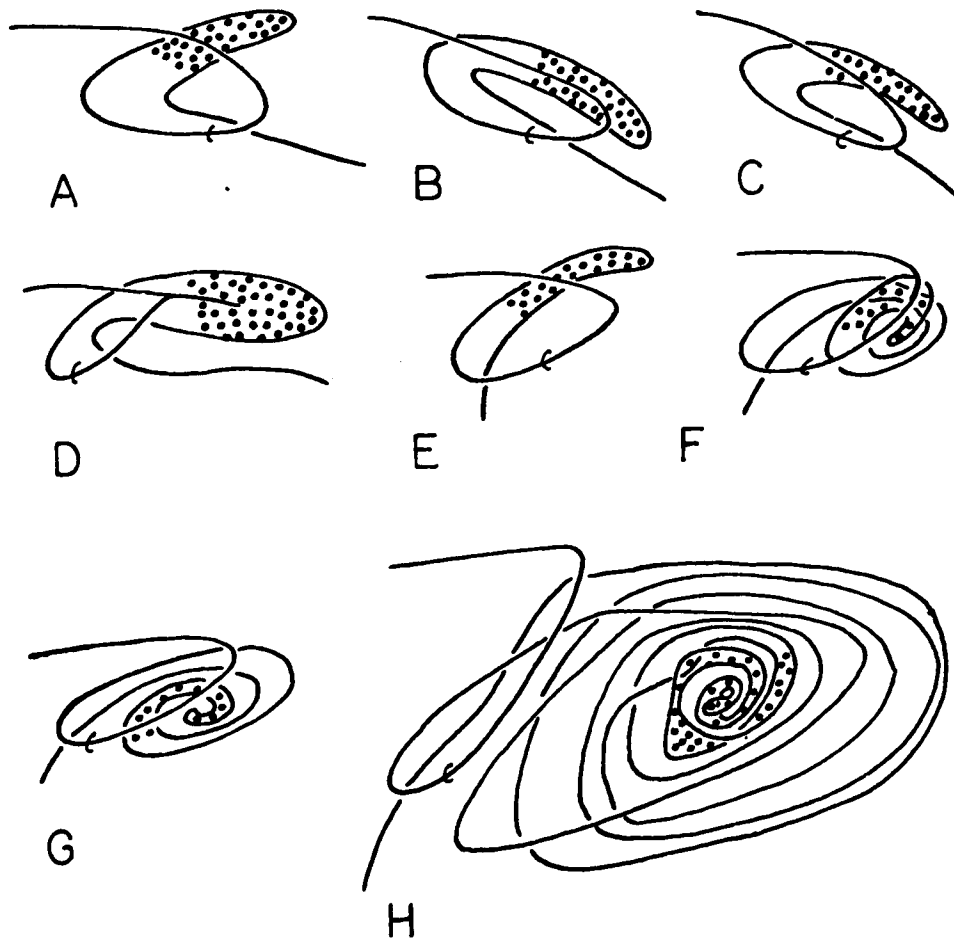


FIG. I-G2

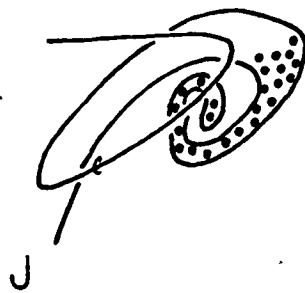
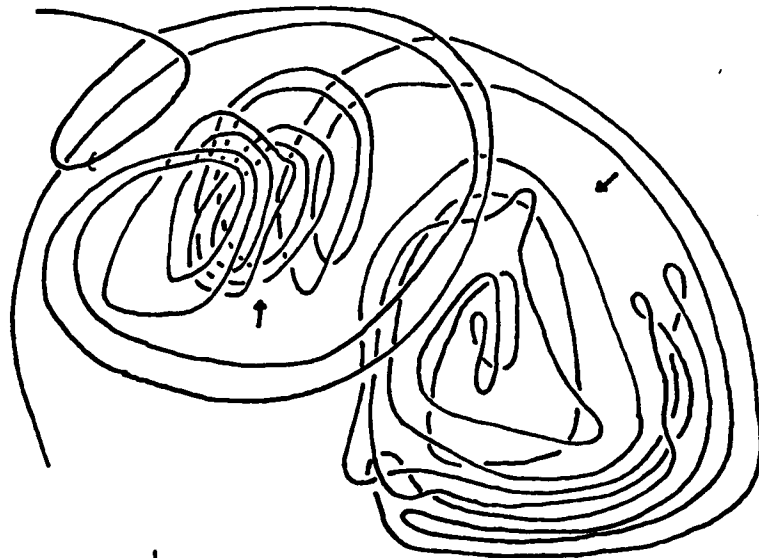


FIG. I-62

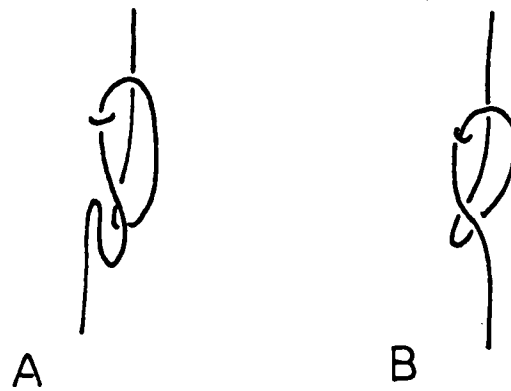


FIG. I-63



FIG. I-64



FIG. I-65

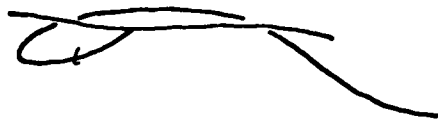


FIG. I-66



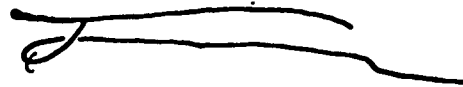
FIG. I-67



FIG. I-68



A



B

FIG. I-69

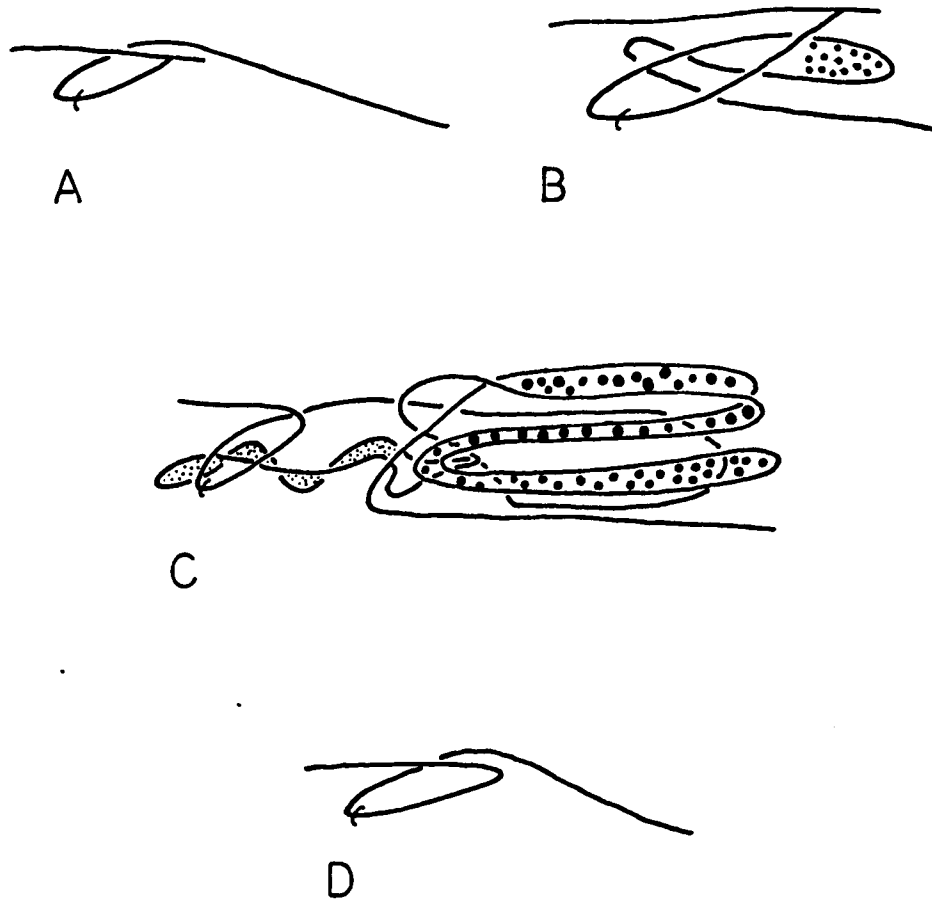


FIG. I-70



FIG. I-71

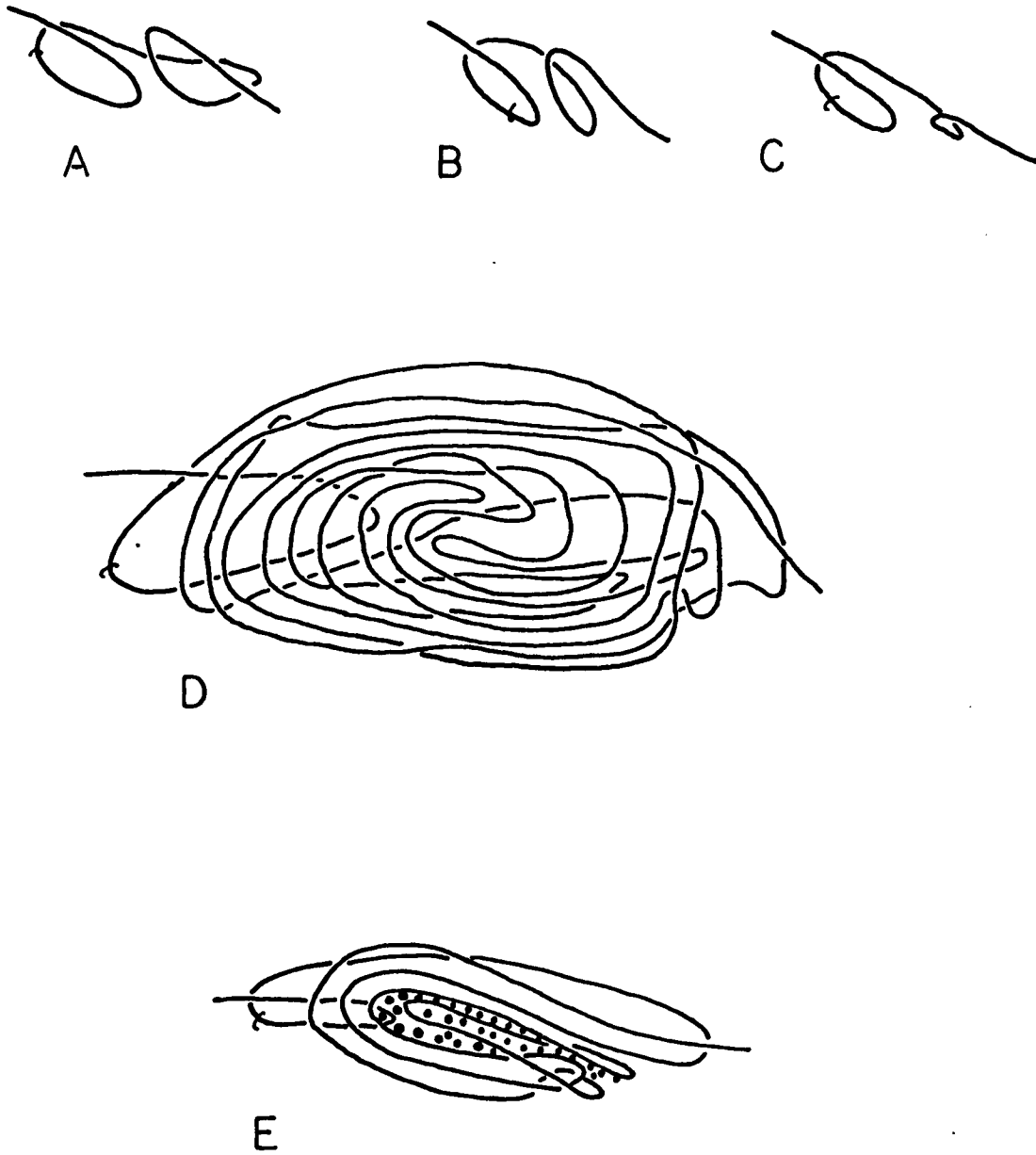


FIG. I-72

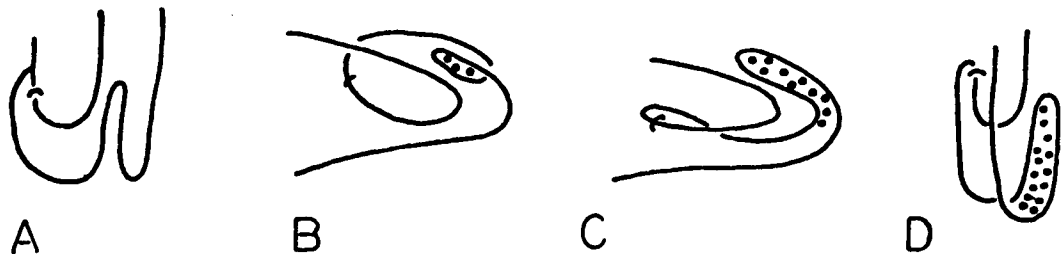


FIG. I-73

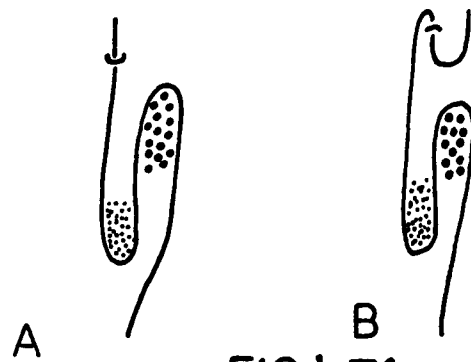


FIG. I-74

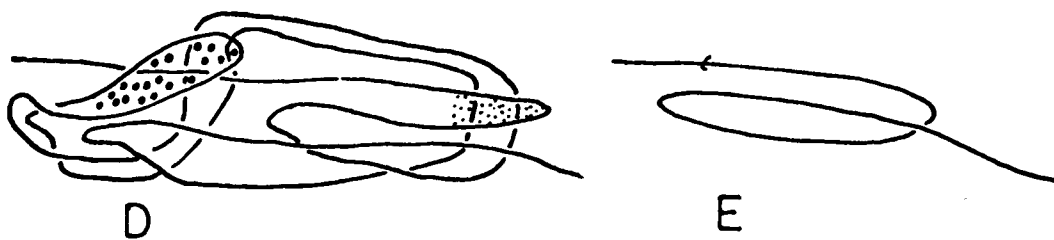
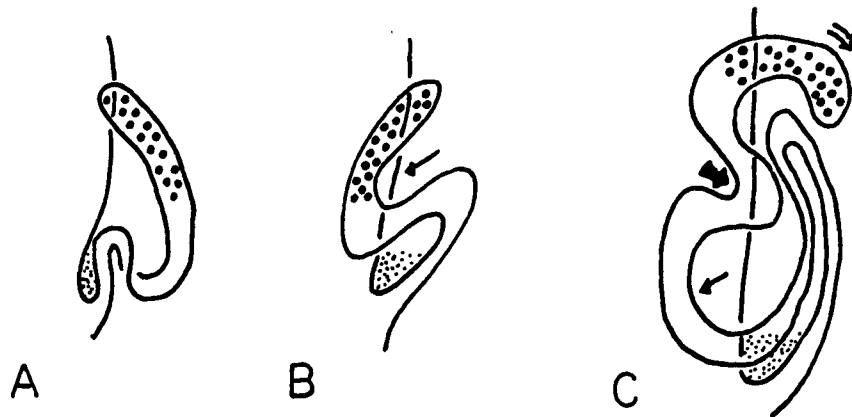


FIG. I-75

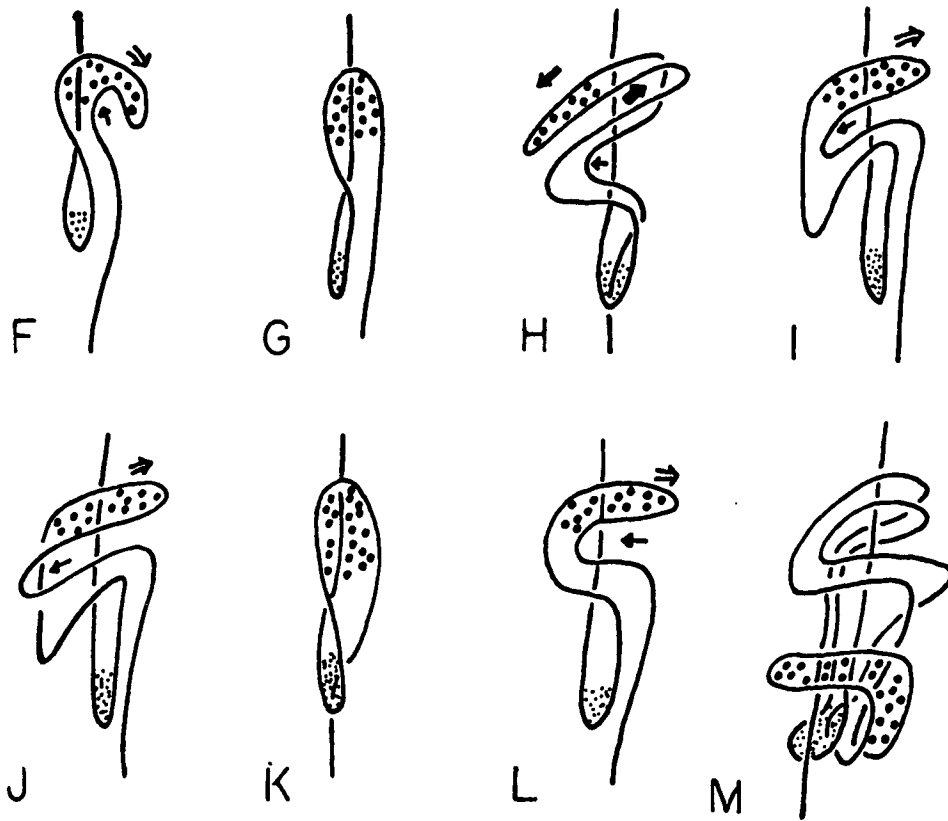


FIG. I-75

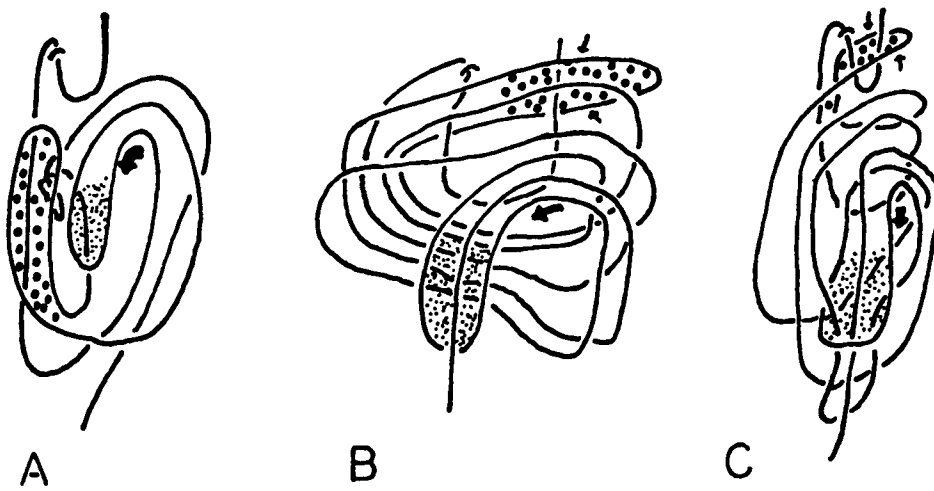


FIG. I-76

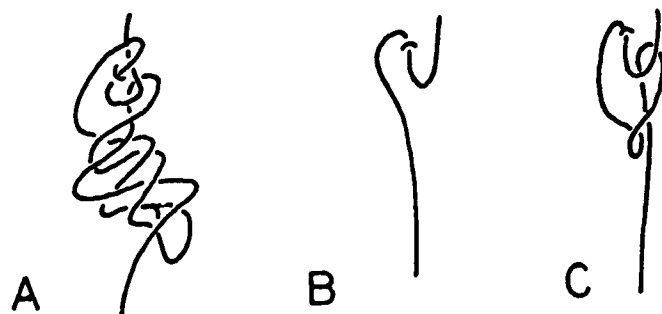


FIG. I-77

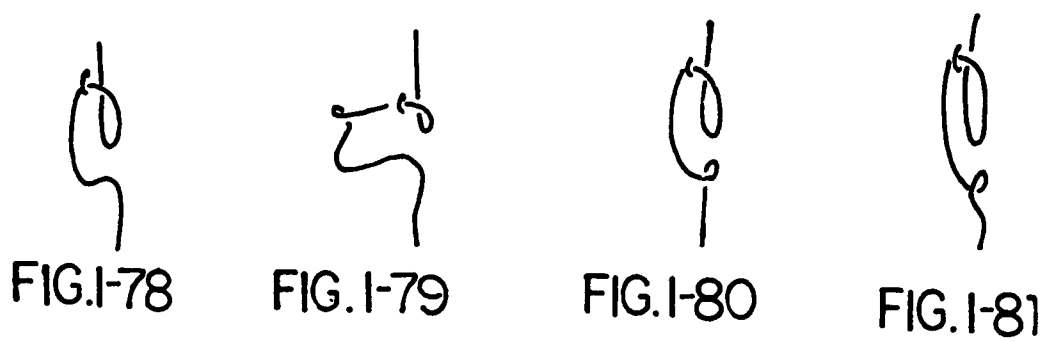


FIG. I-82

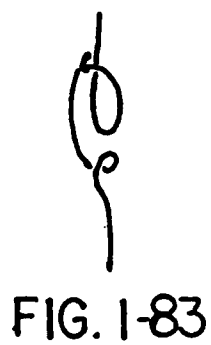




FIG. I-84



FIG. I-85



FIG. I-86



FIG. I-87



FIG. I-88



FIG. I-89



FIG. I-90

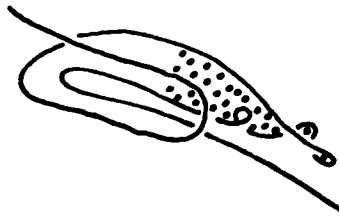


FIG. I-91



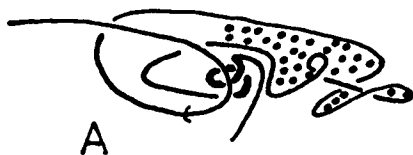
FIG. I-92



FIG. I-93



FIG. I-94



A



B

FIG. I-95



FIG. I-96



FIG. I-97



FIG. I-98

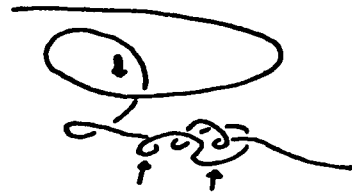


FIG. I-99



FIG. I-100

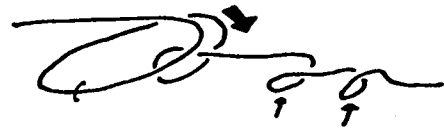


FIG. I-101



FIG. I-102

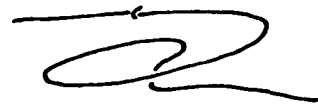


FIG. I-103



FIG. I-104



FIG. I-105

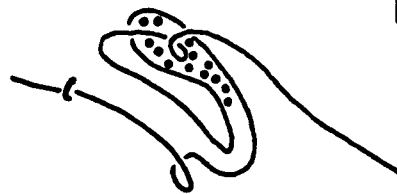
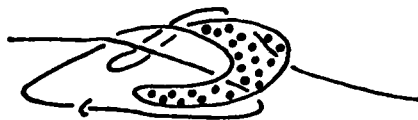


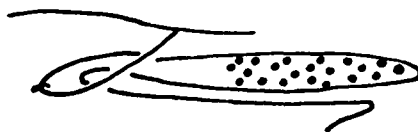
FIG. I-106



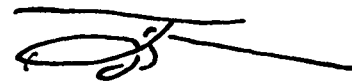
A



B



C



D

FIG. I-107

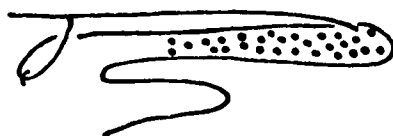


FIG. 1-108

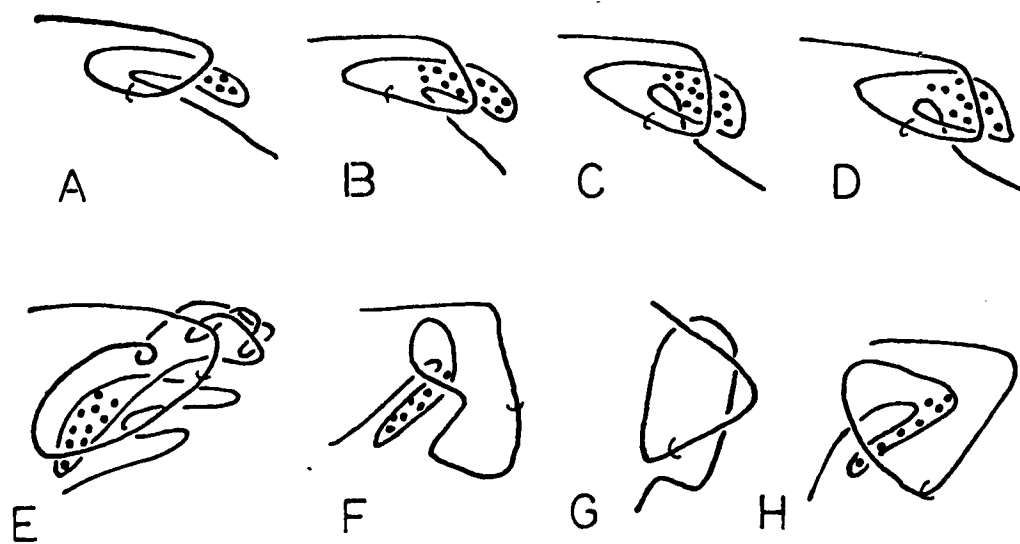


FIG. 1-109

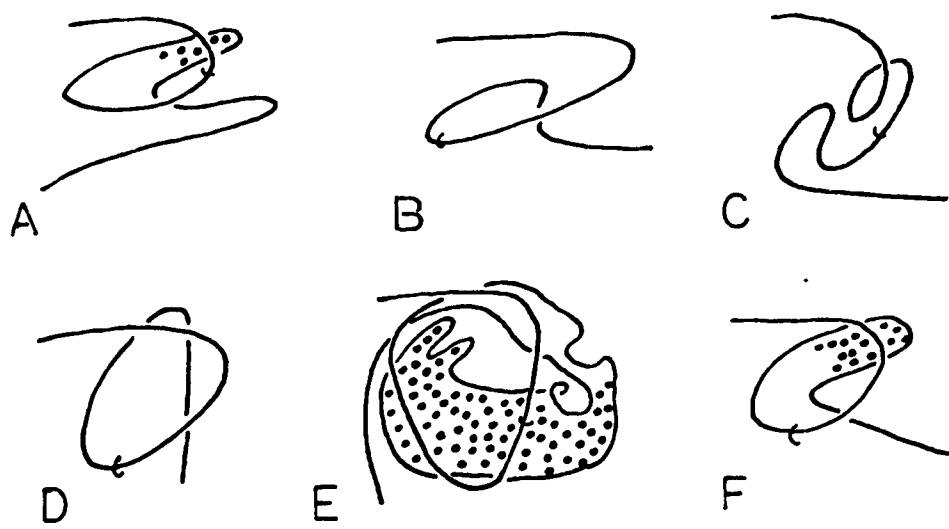


FIG. 1-110

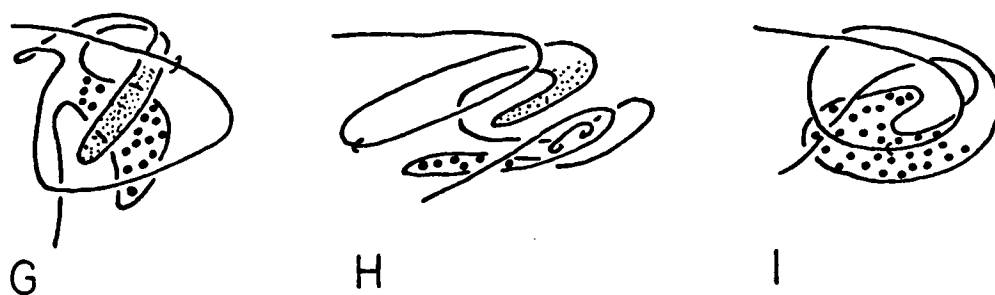


FIG. I-110

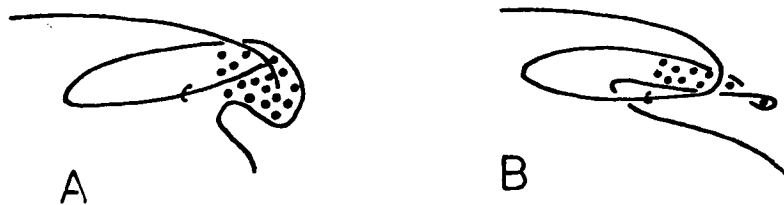


FIG. I-111

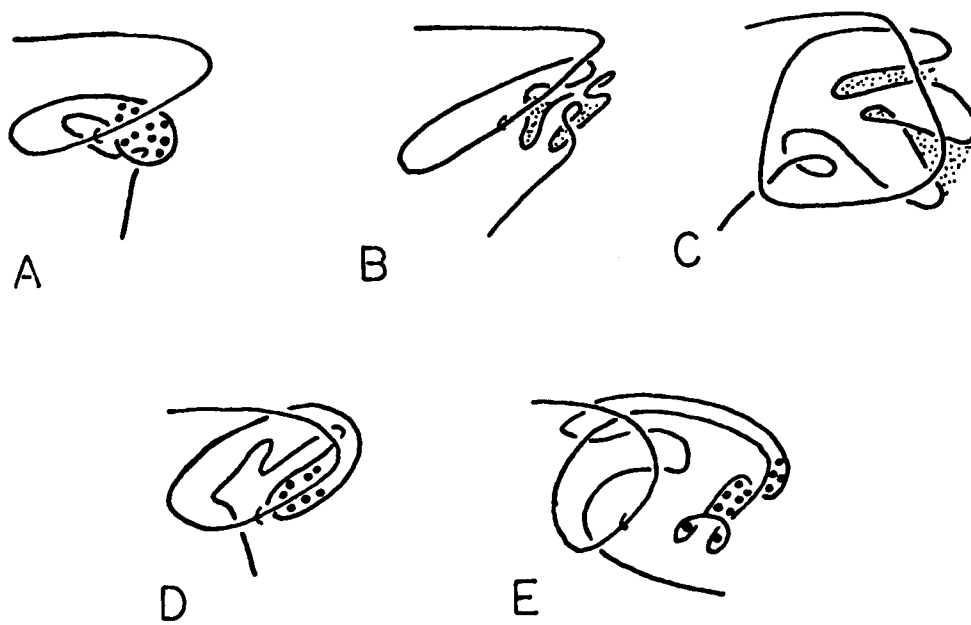


FIG. I-112

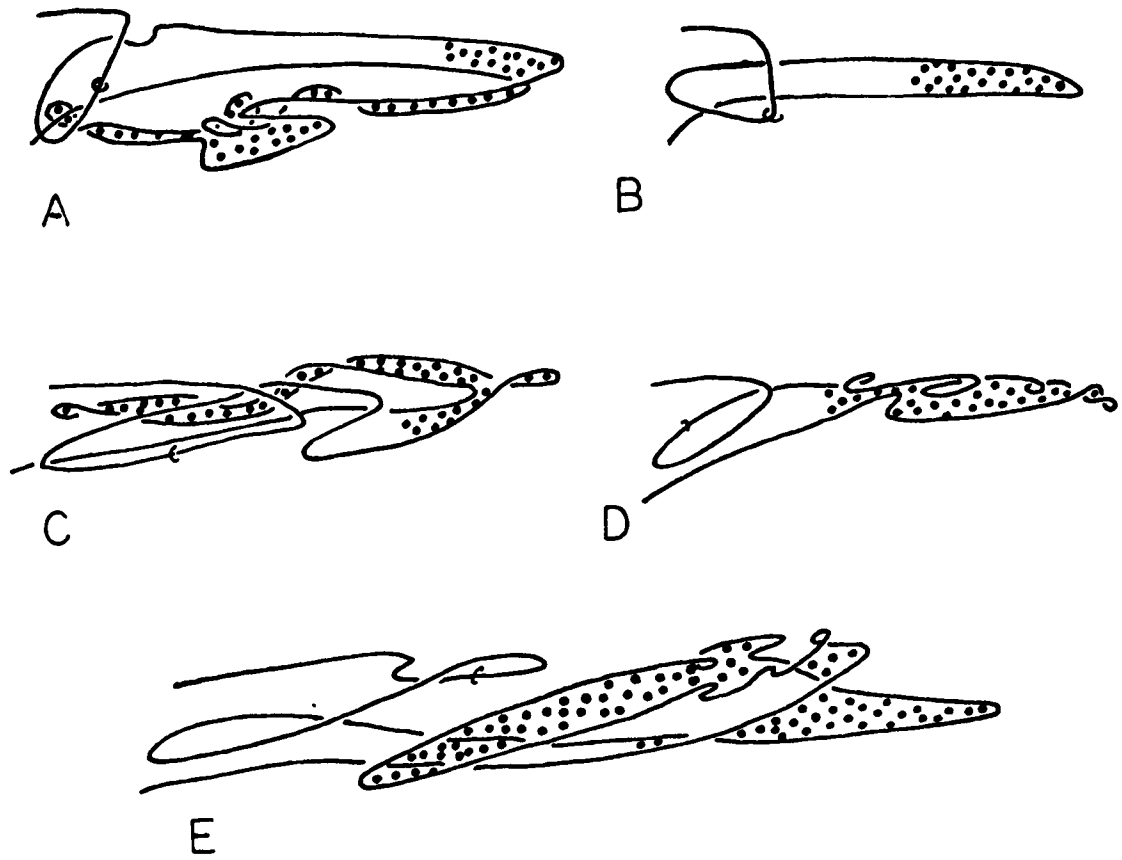


FIG. I-113

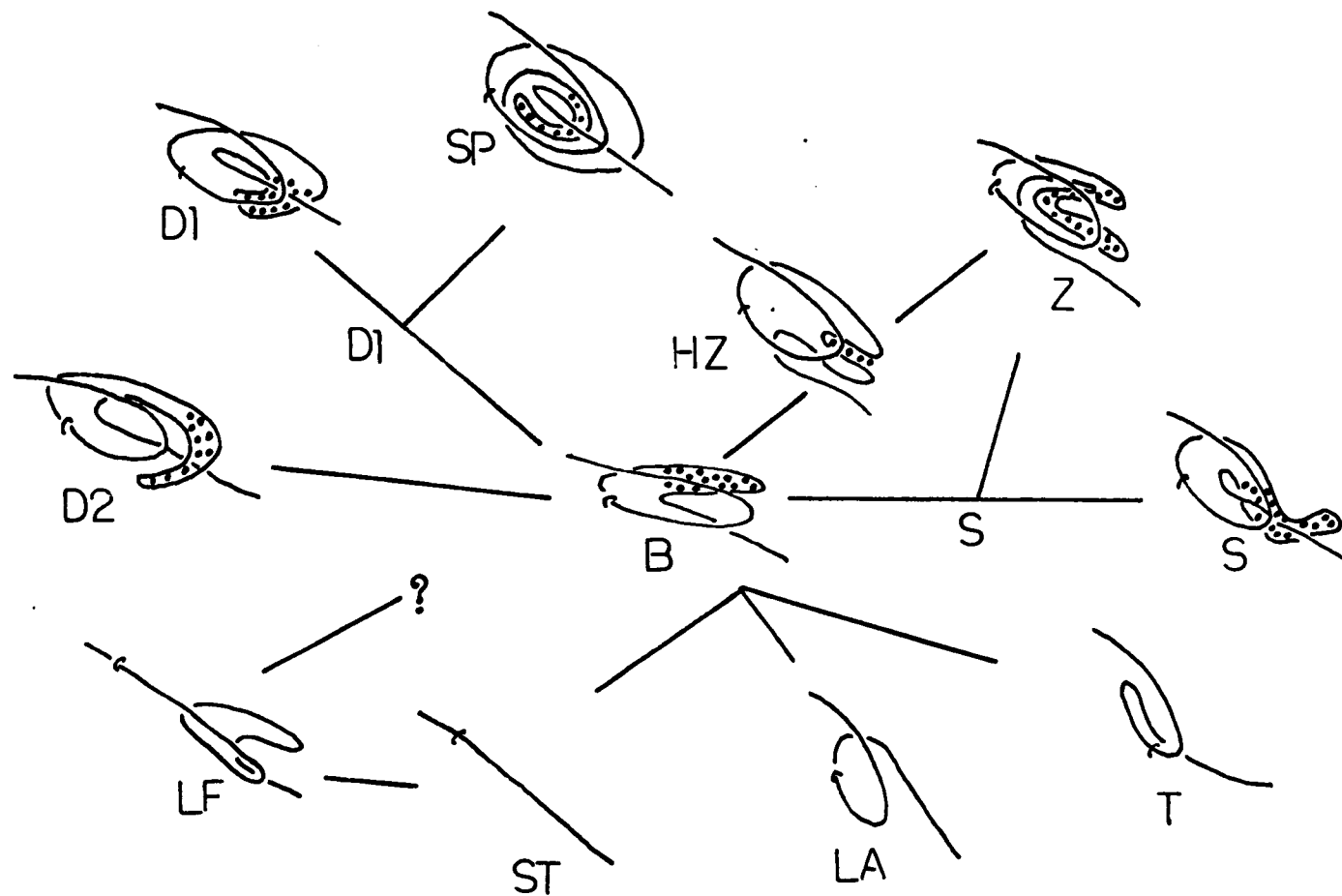


FIG. I-114

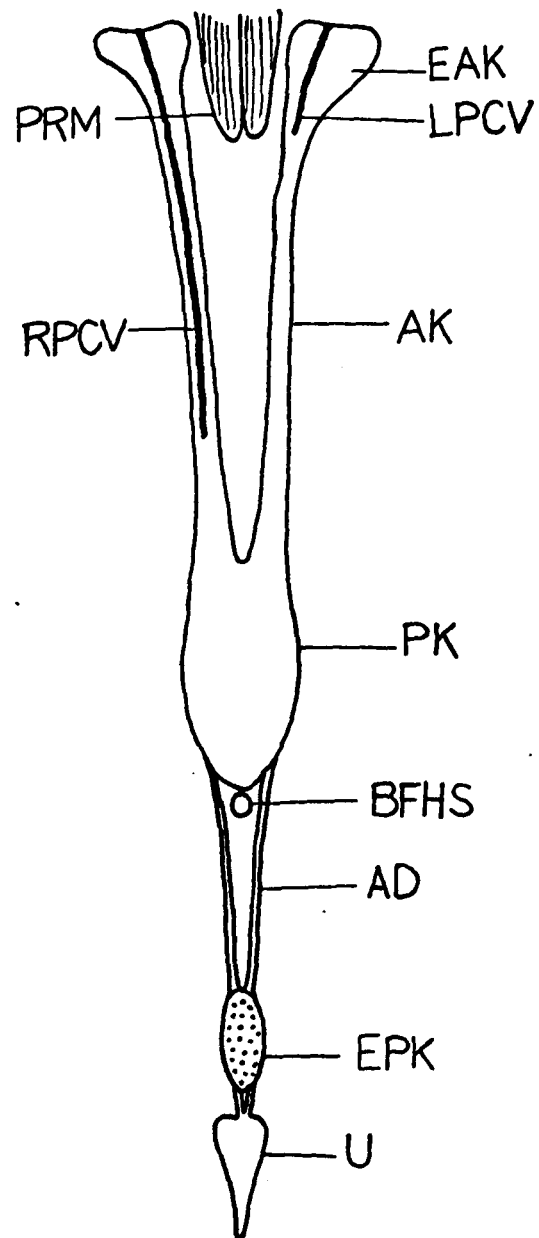
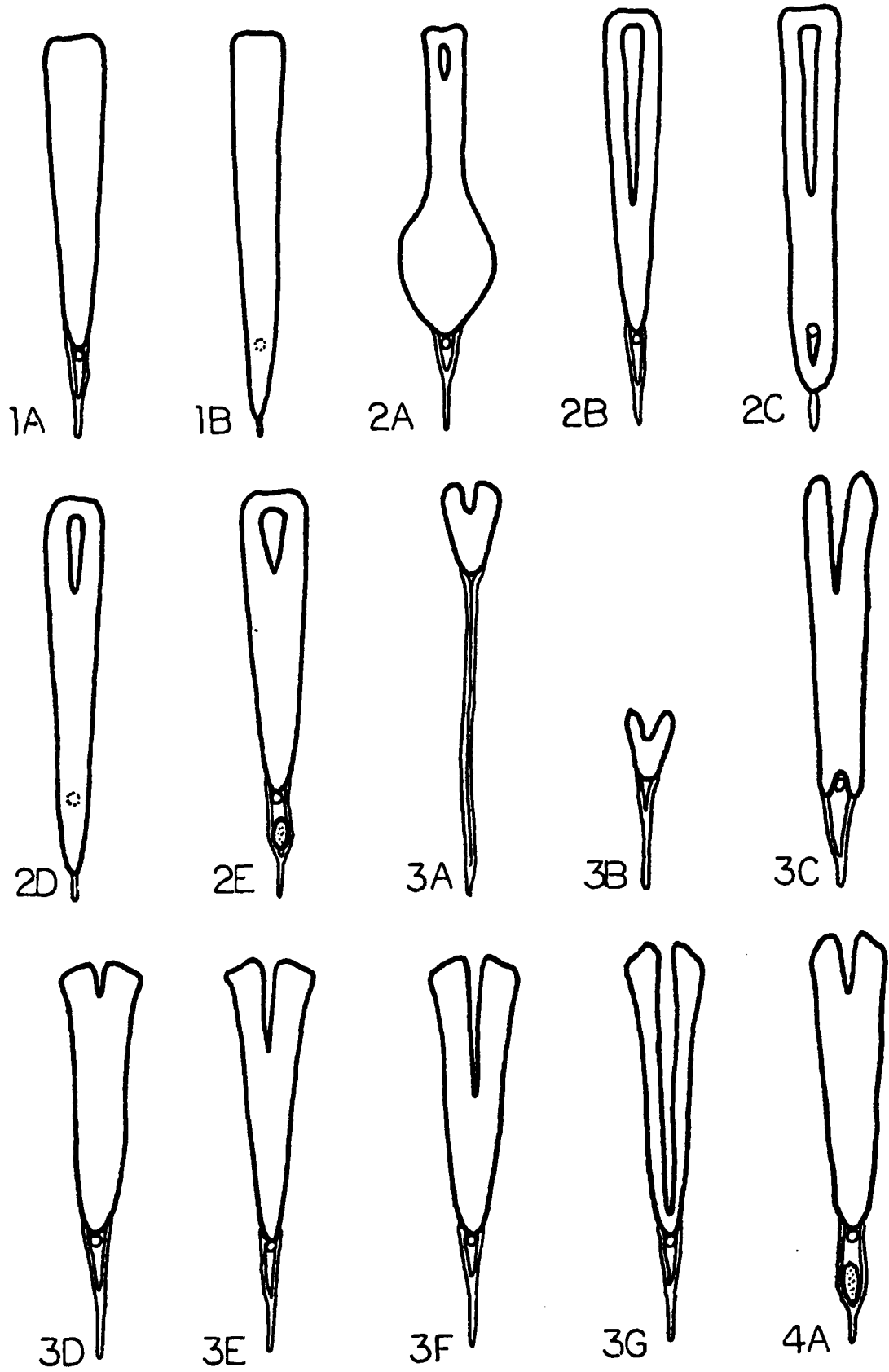


FIG. 11-1A



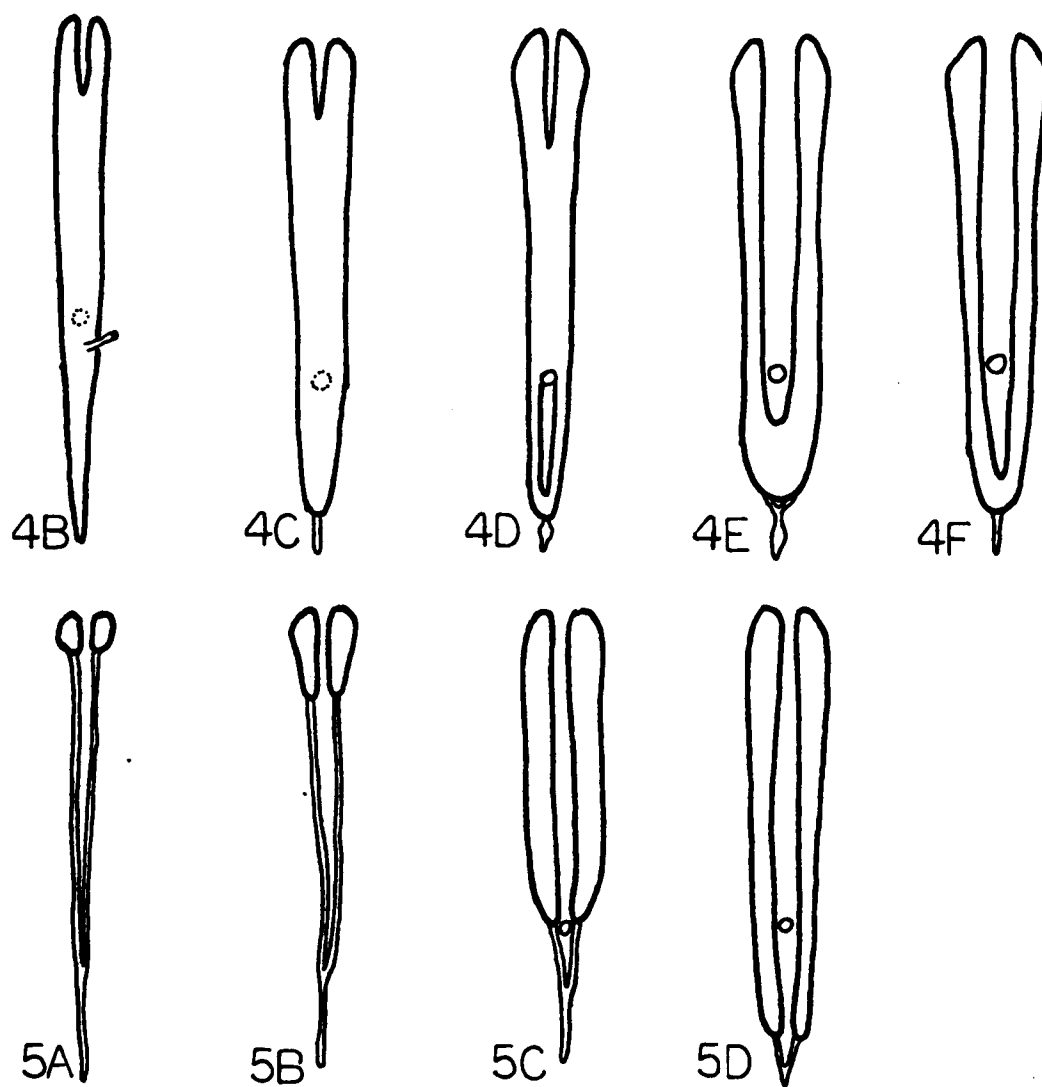
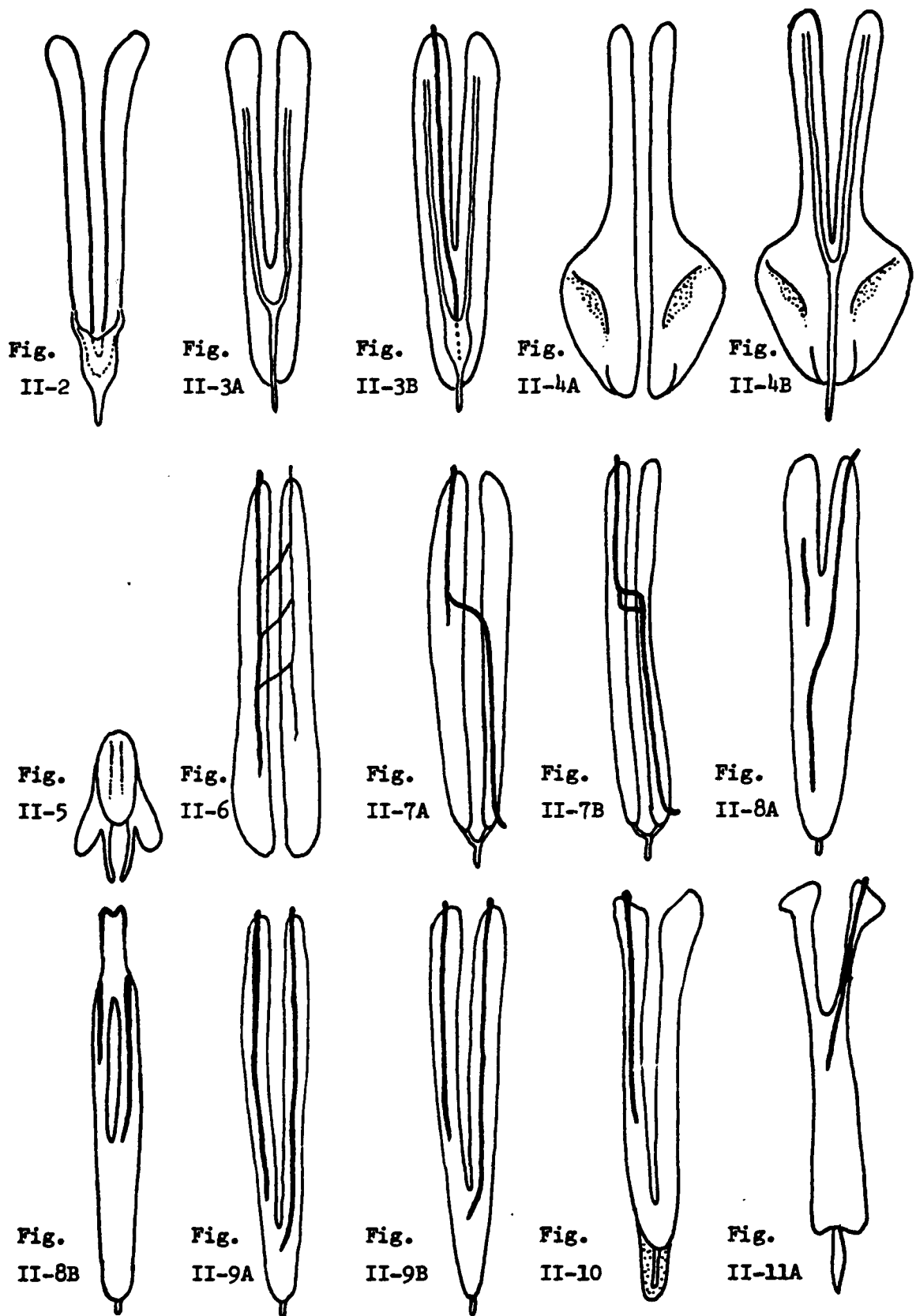
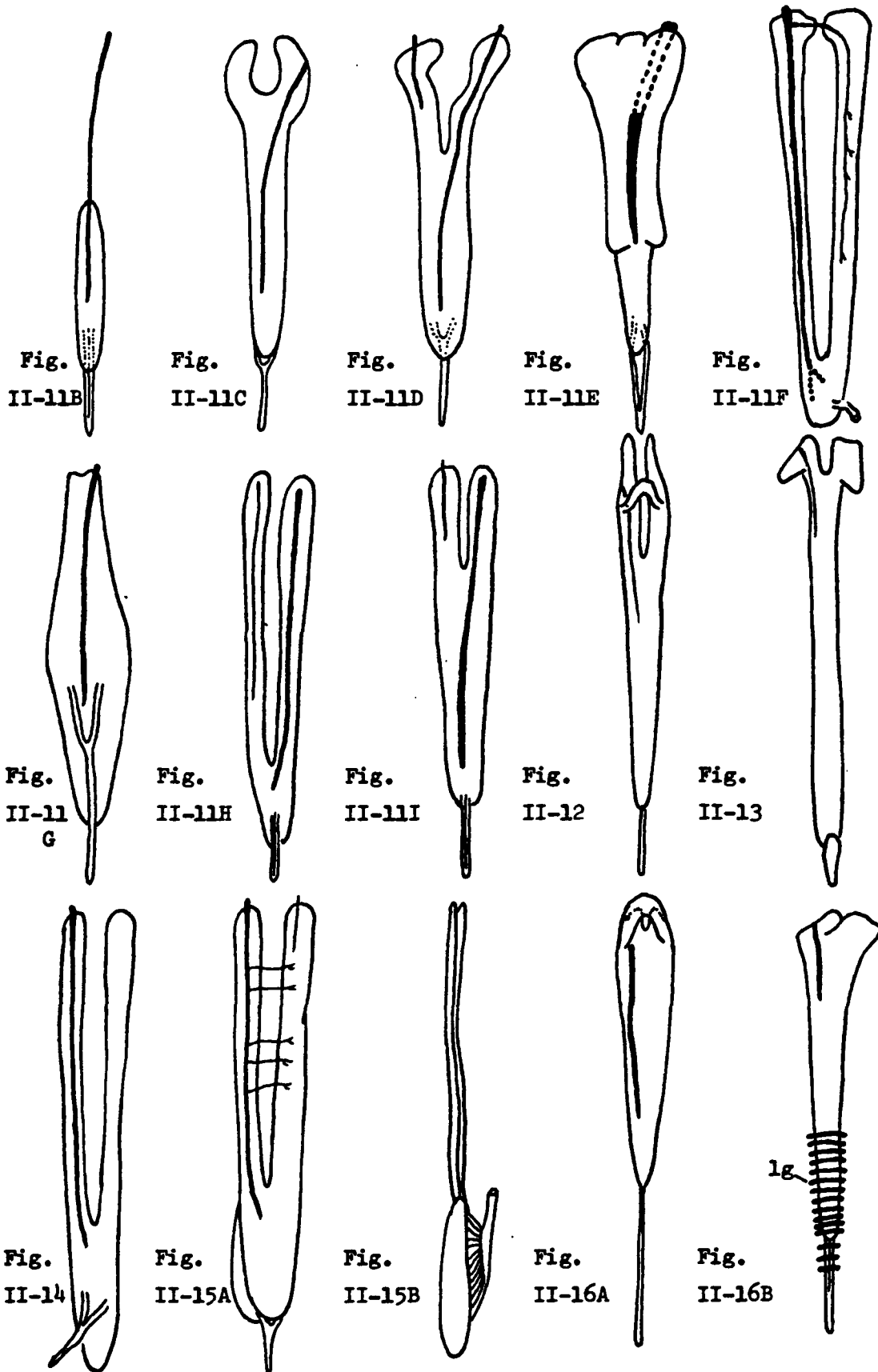
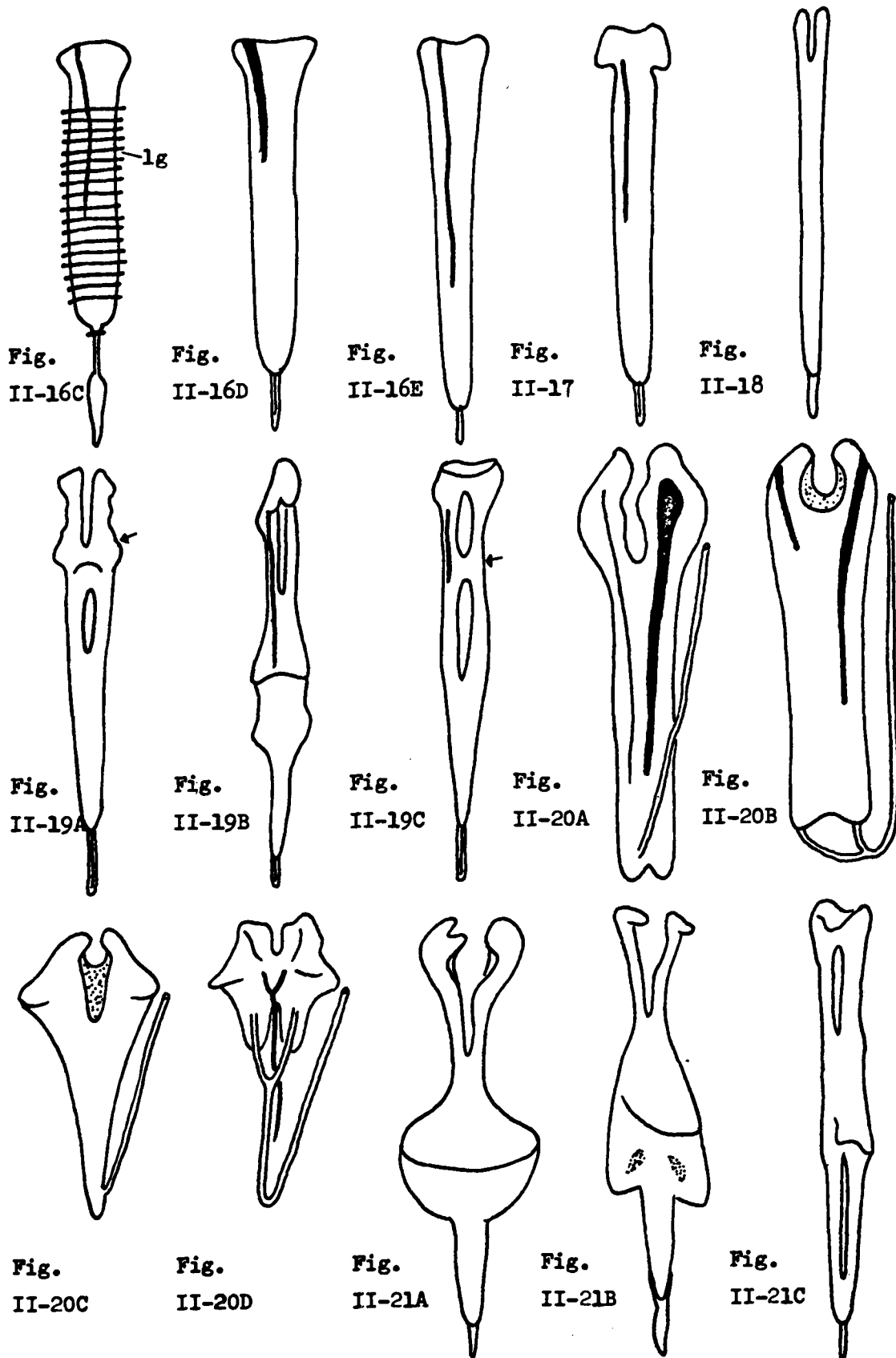


FIG. II-1B







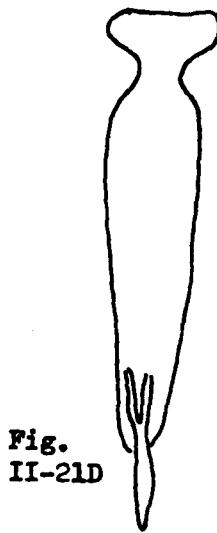


Fig.
II-21D



Fig.
II-22A



Fig.
II-22B



Fig.
II-23A



Fig.
II-23B



Fig.
II-24A



Fig.
II-24B

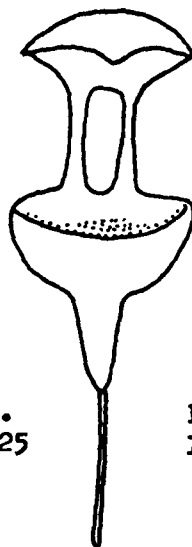


Fig.
II-25

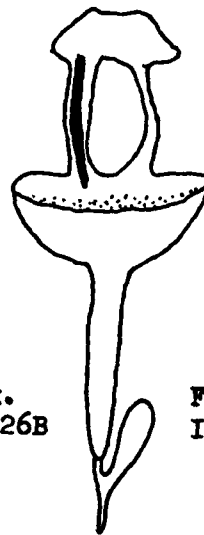


Fig.
II-26B

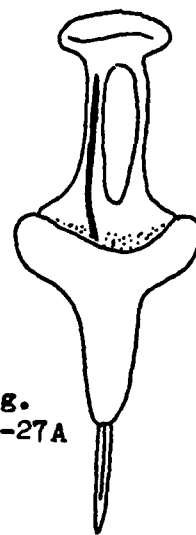


Fig.
II-27A



Fig.
II-27
B

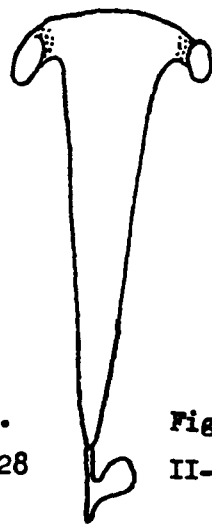


Fig.
II-28



Fig.
II-29



Fig.
II-30

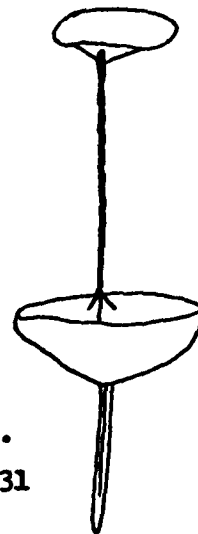


Fig.
II-31

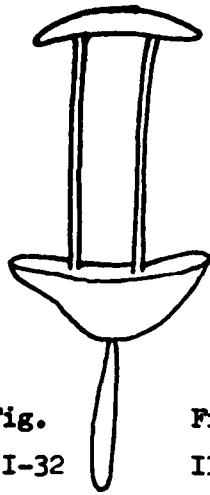


Fig.
II-32



Fig.
II-33



Fig.
II-34A



Fig.
II-34B

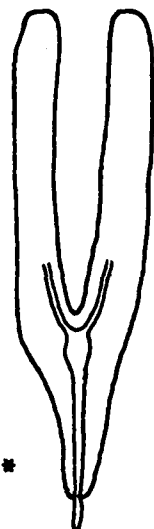


Fig.
II-35 *



Fig.
II-36

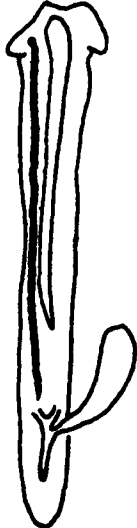


Fig.
II-37



Fig.
II-38A

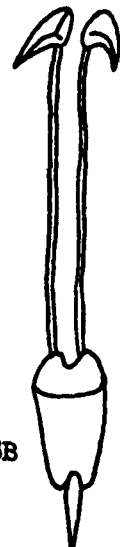


Fig.
II-38B



Fig.
II-38C



Fig.
II-39



Fig.
II-40



Fig.
II-41

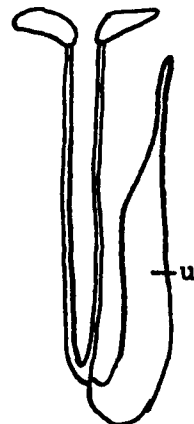


Fig.
II-42A



Fig.
II-42B



Fig.
II-42C

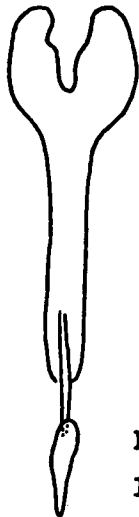


Fig.
II-43



Fig.
II-44A

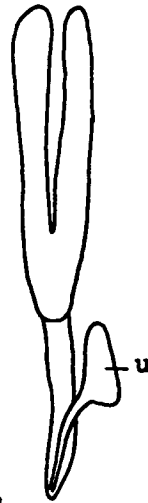


Fig.
II-44B



Fig.
II-45

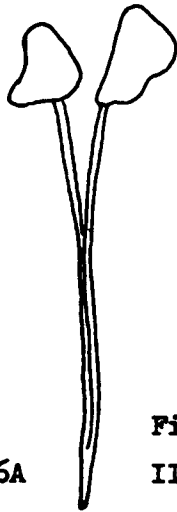


Fig.
II-46A

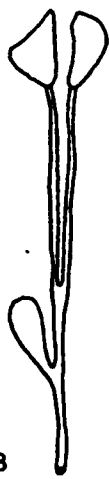


Fig.
II-46B



Fig.
II-47



Fig.
II-48



Fig.
II-49

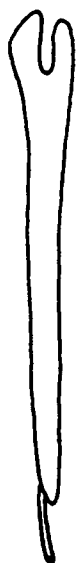


Fig.
II-50A



Fig.
II-50B

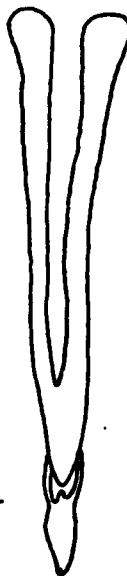


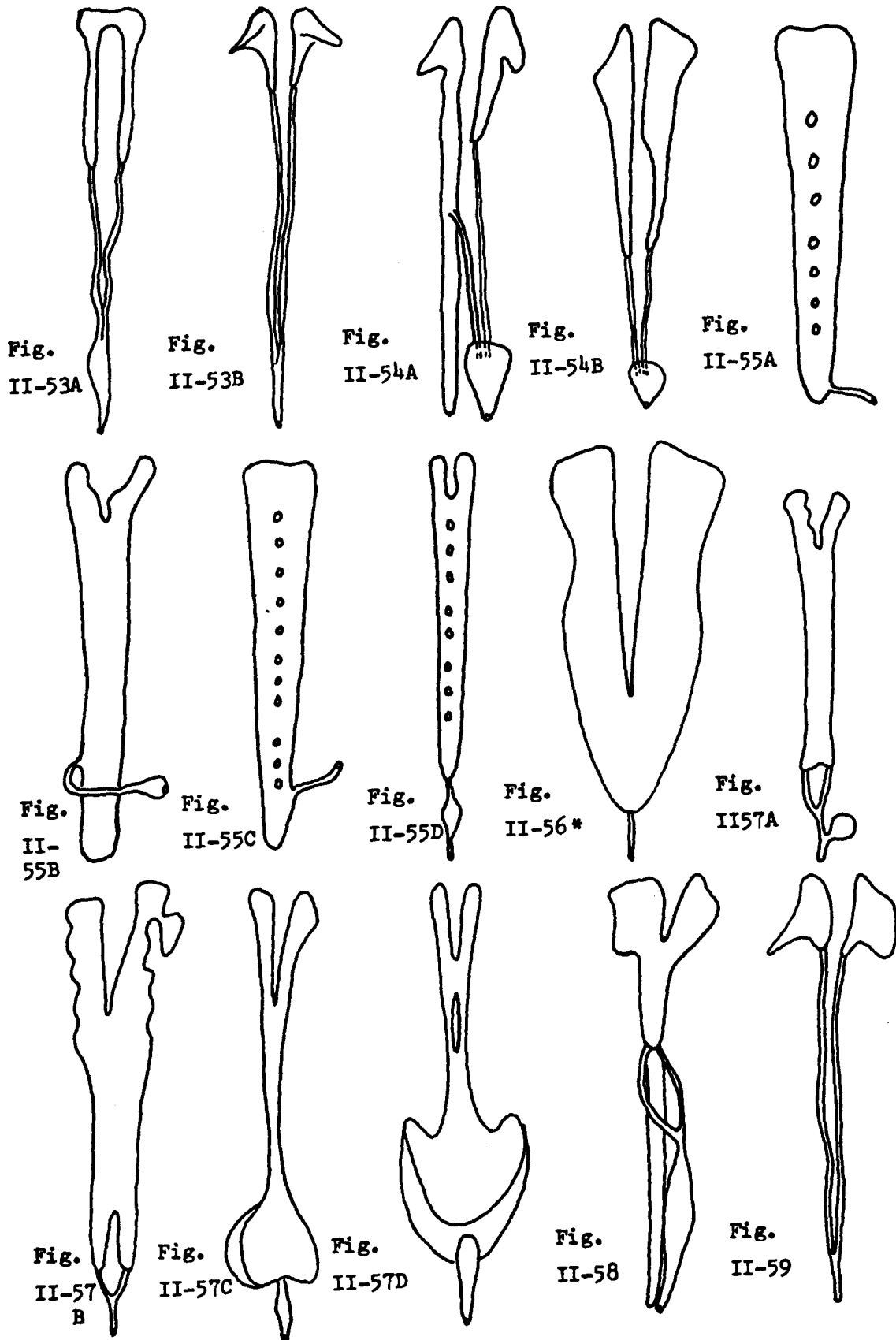
Fig.
II-51



Fig.
II-52A
*



Fig.
II-52B



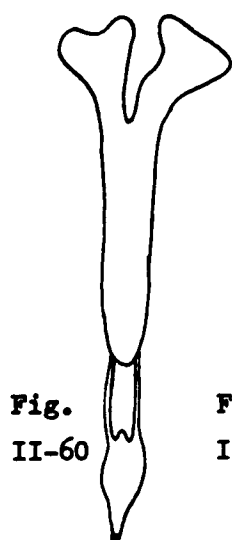


Fig.
II-60



Fig.
II-61



Fig.
II-62



Fig.
II-63



Fig.
II-64



Fig.
II-65A



Fig.
II-65B



Fig.
II-65C



Fig.
II-66



Fig.
II-67



Fig.
II-68A

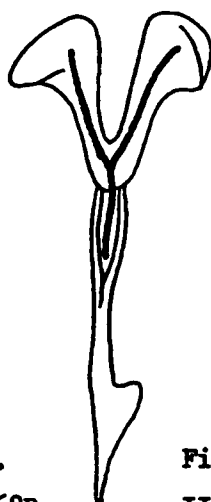


Fig.
II-68B



Fig.
II-69A

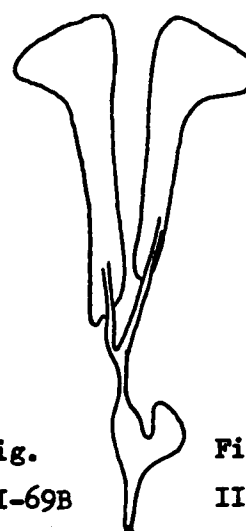


Fig.
II-69B



Fig.
II-69C

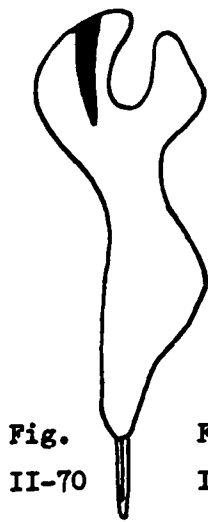


Fig.
II-70



Fig.
II-71



Fig.
II-72A



Fig.
II-72B



Fig.
II-72C



Fig.
II-73

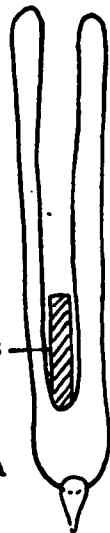


Fig.
II-74A

hs

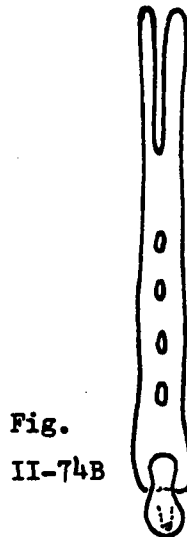


Fig.
II-74B



Fig.
II-74C



Fig.
II-75

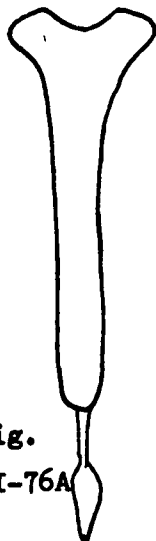


Fig.
II-76A



Fig.
II-76B

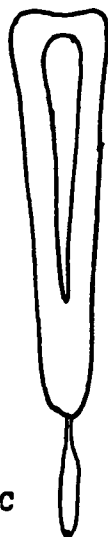


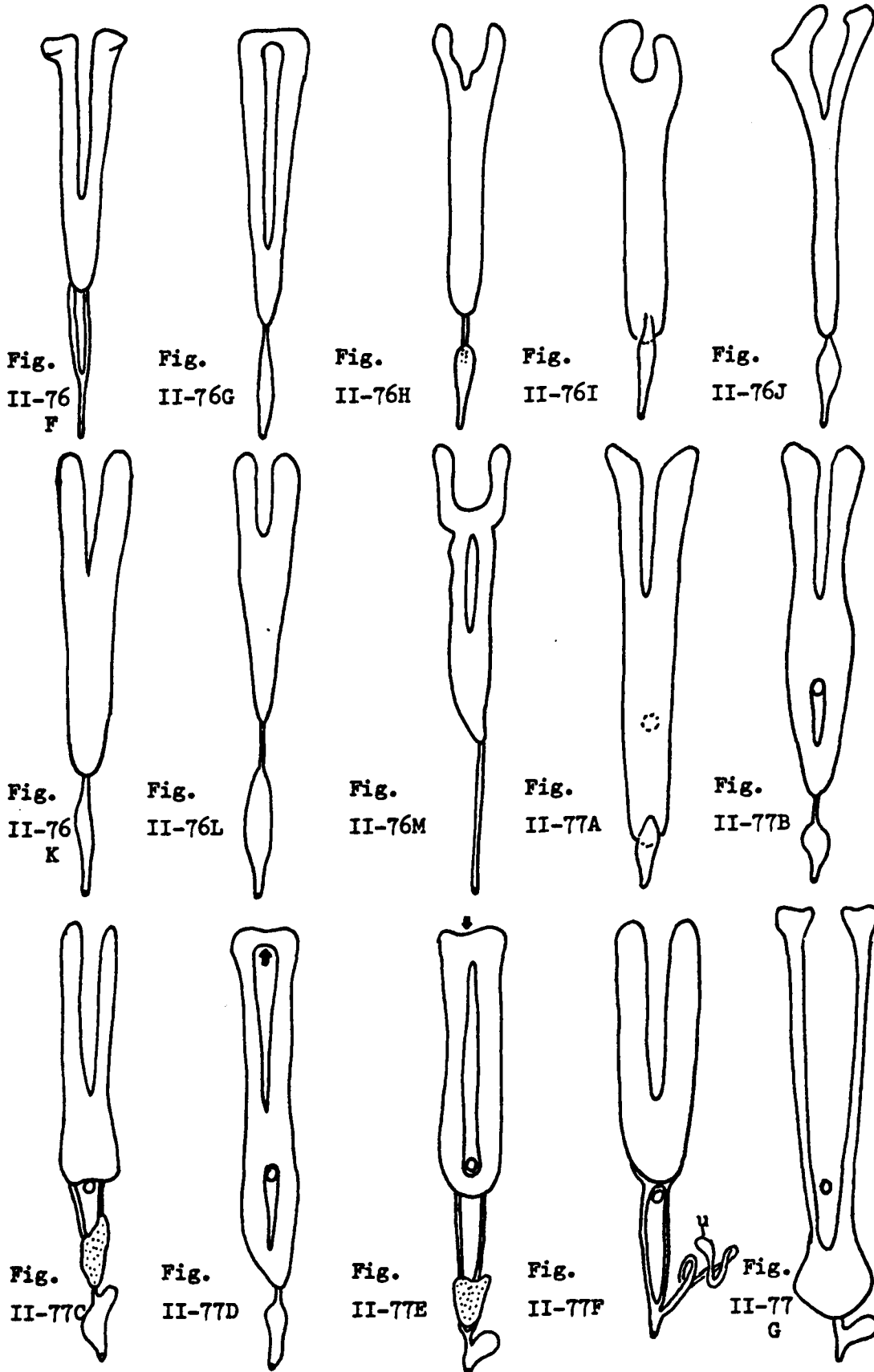
Fig.
II-76C

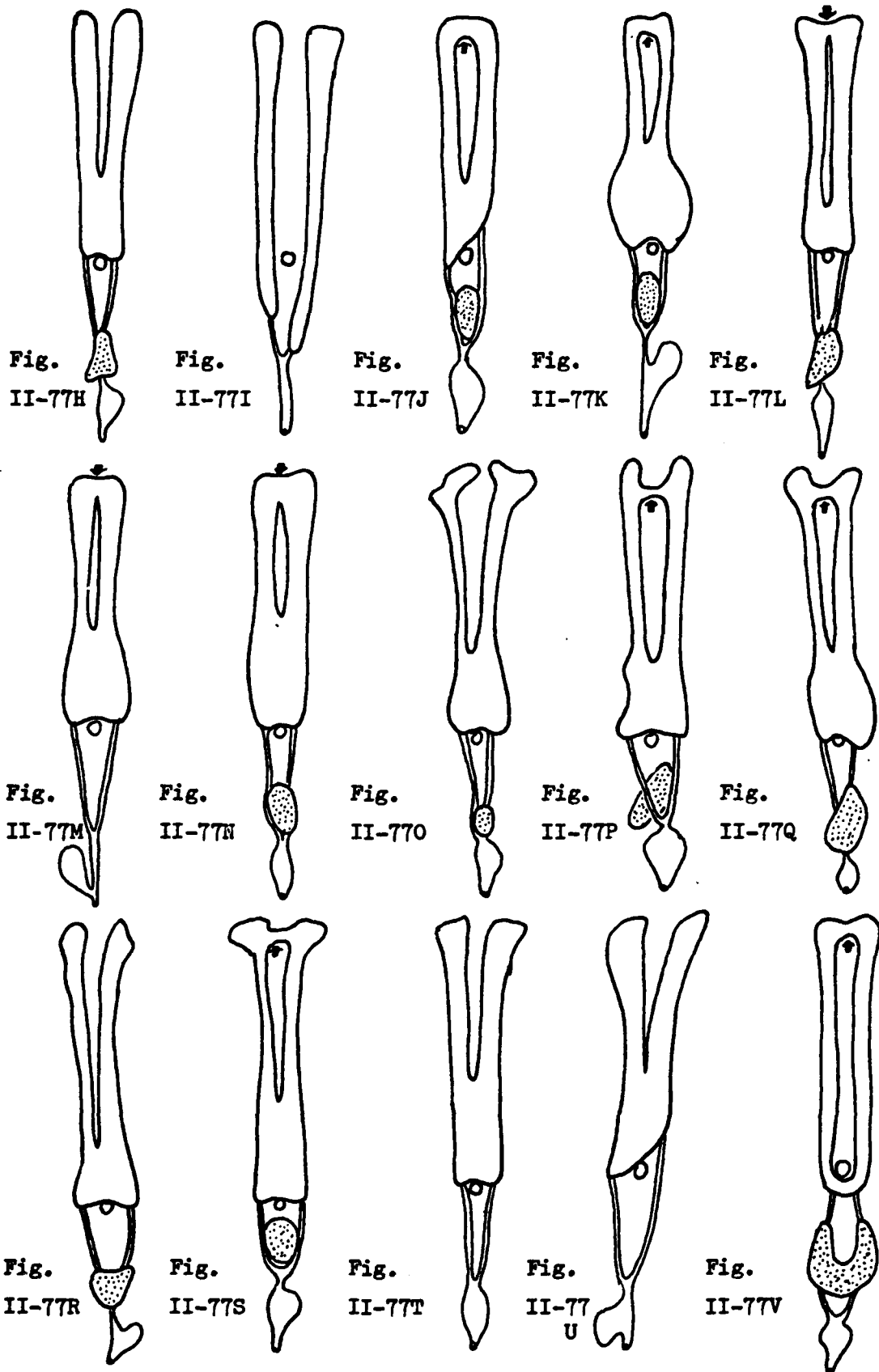


Fig.
II-76D



Fig.
II-76E





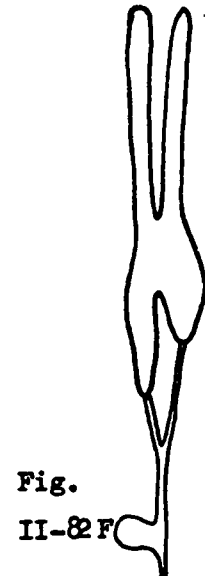
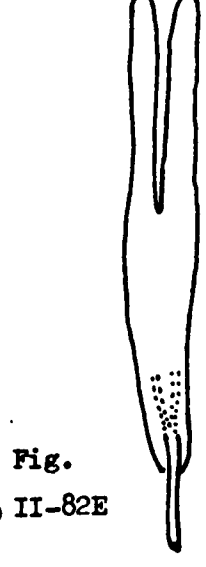
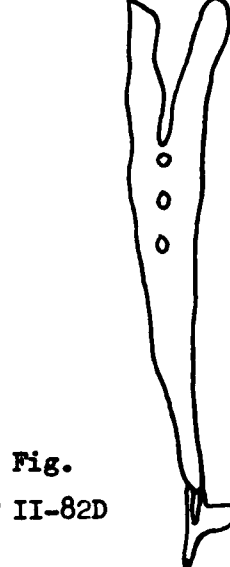
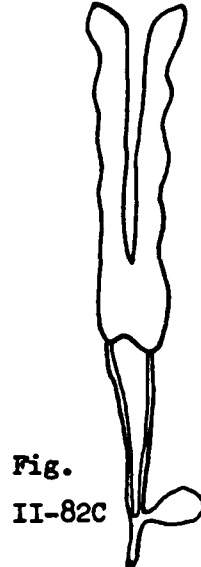
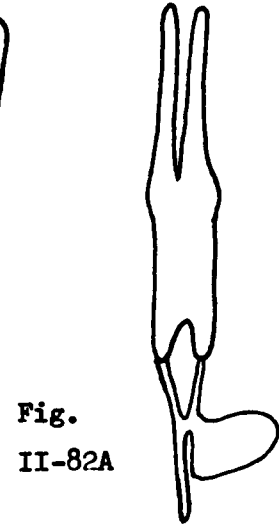
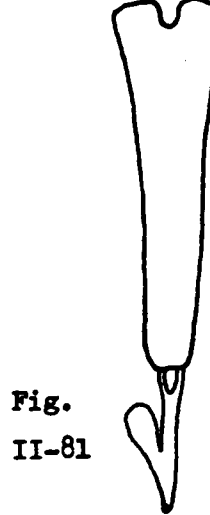
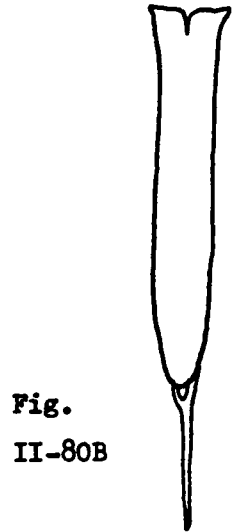
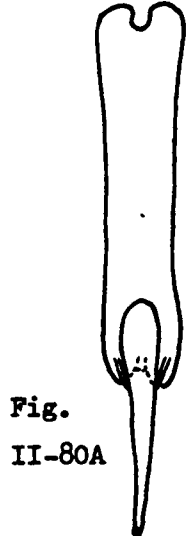
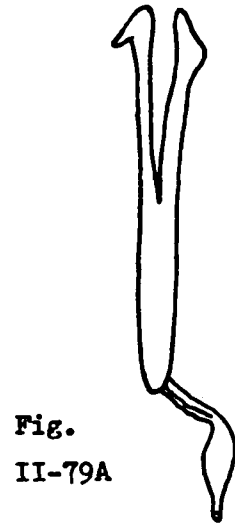
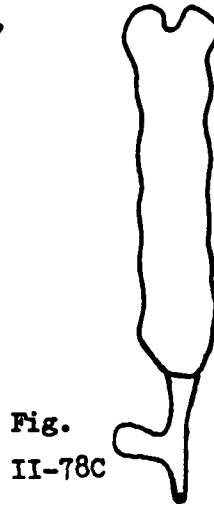
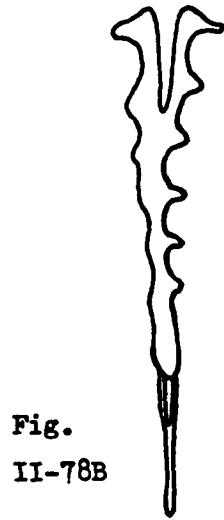
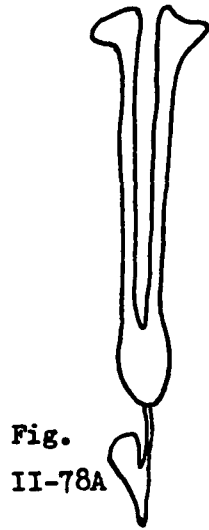
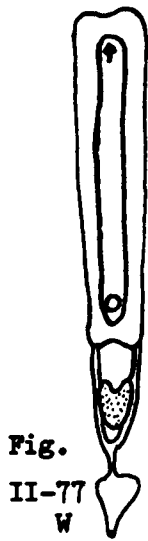




Fig.
II-
82G

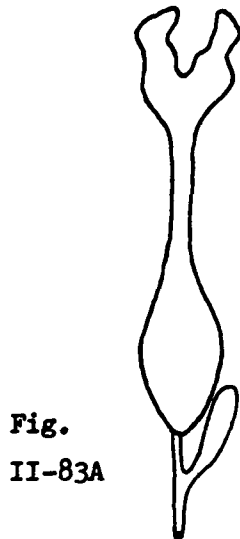


Fig.
II-83A

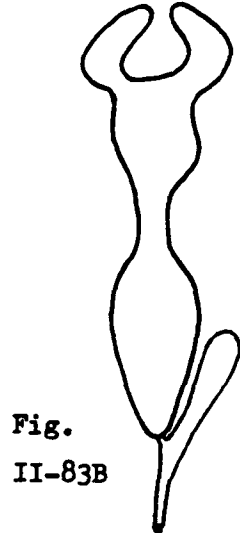


Fig.
II-83B

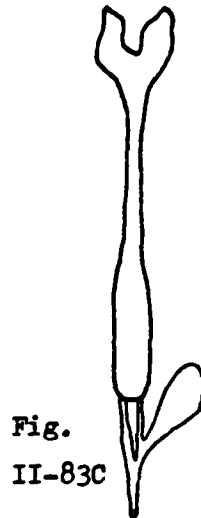


Fig.
II-83C



Fig.
II-83D



Fig.
II-
84

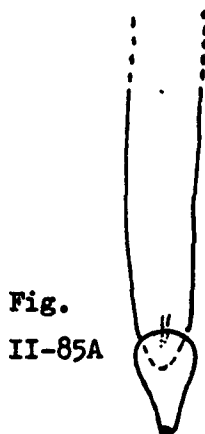


Fig.
II-85A

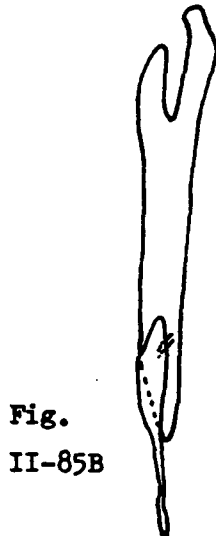


Fig.
II-85B

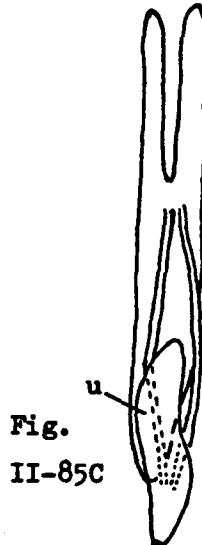


Fig.
II-85C

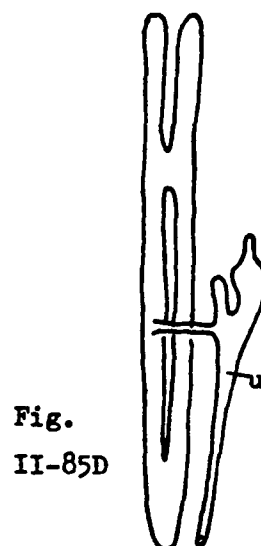


Fig.
II-85D

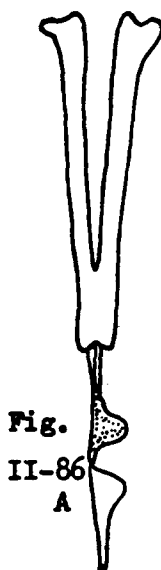


Fig.
II-86
A

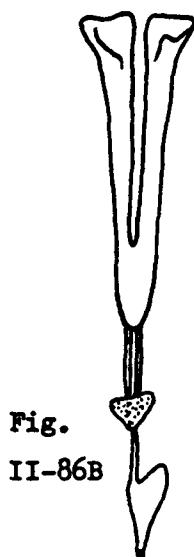


Fig.
II-86B

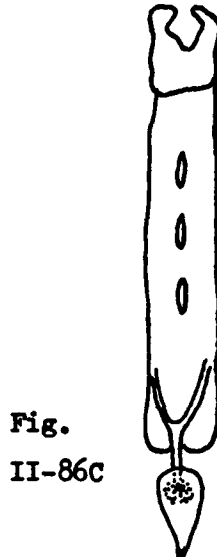


Fig.
II-86C

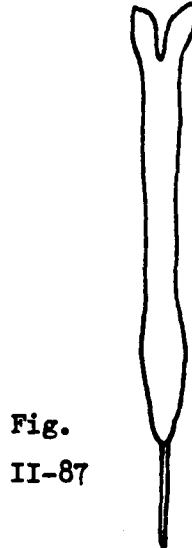


Fig.
II-87

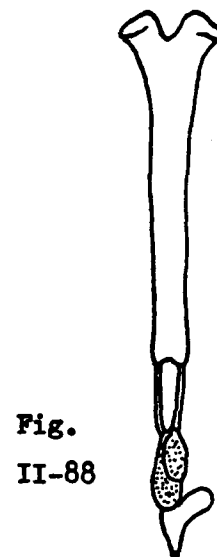
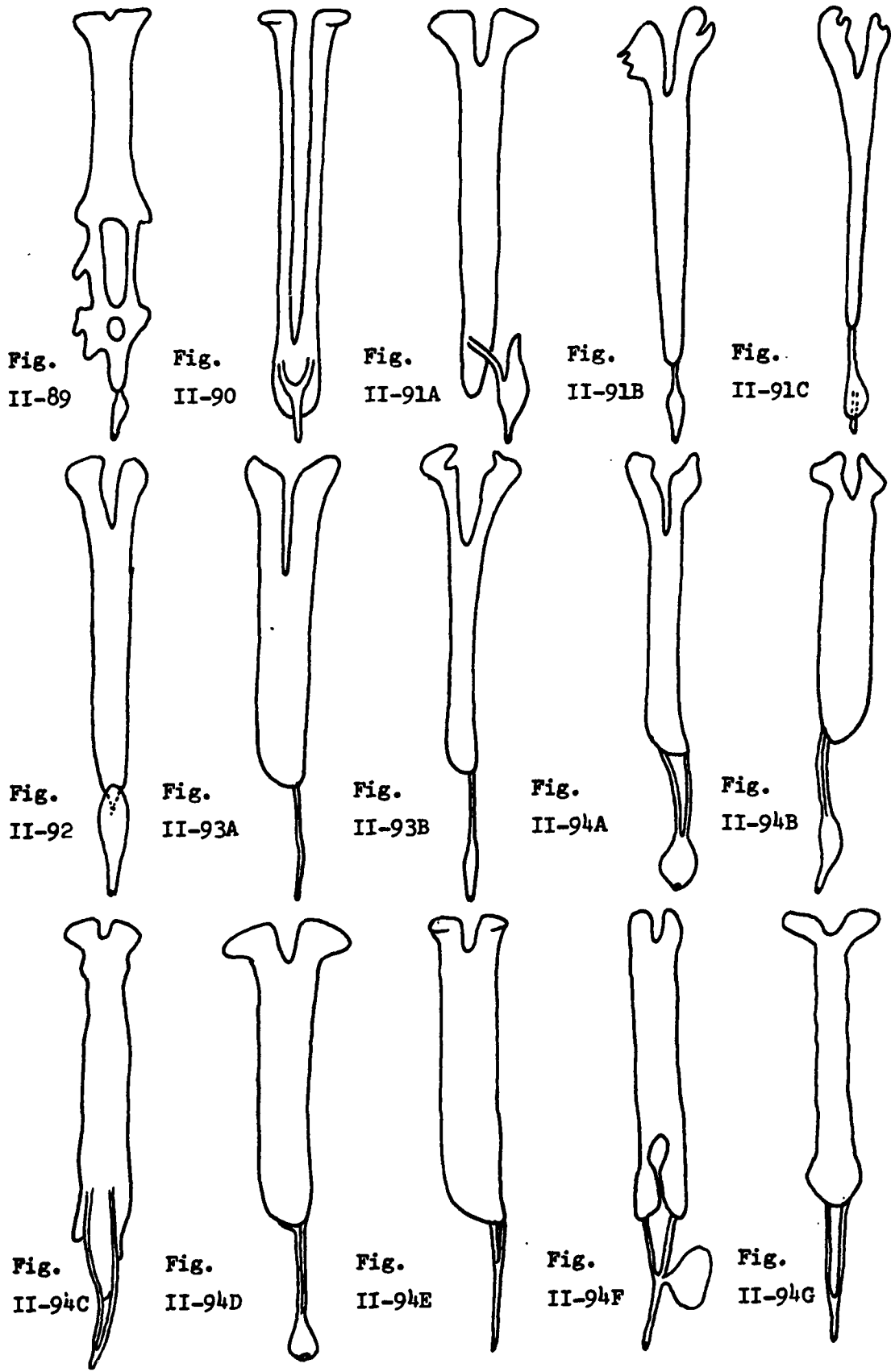
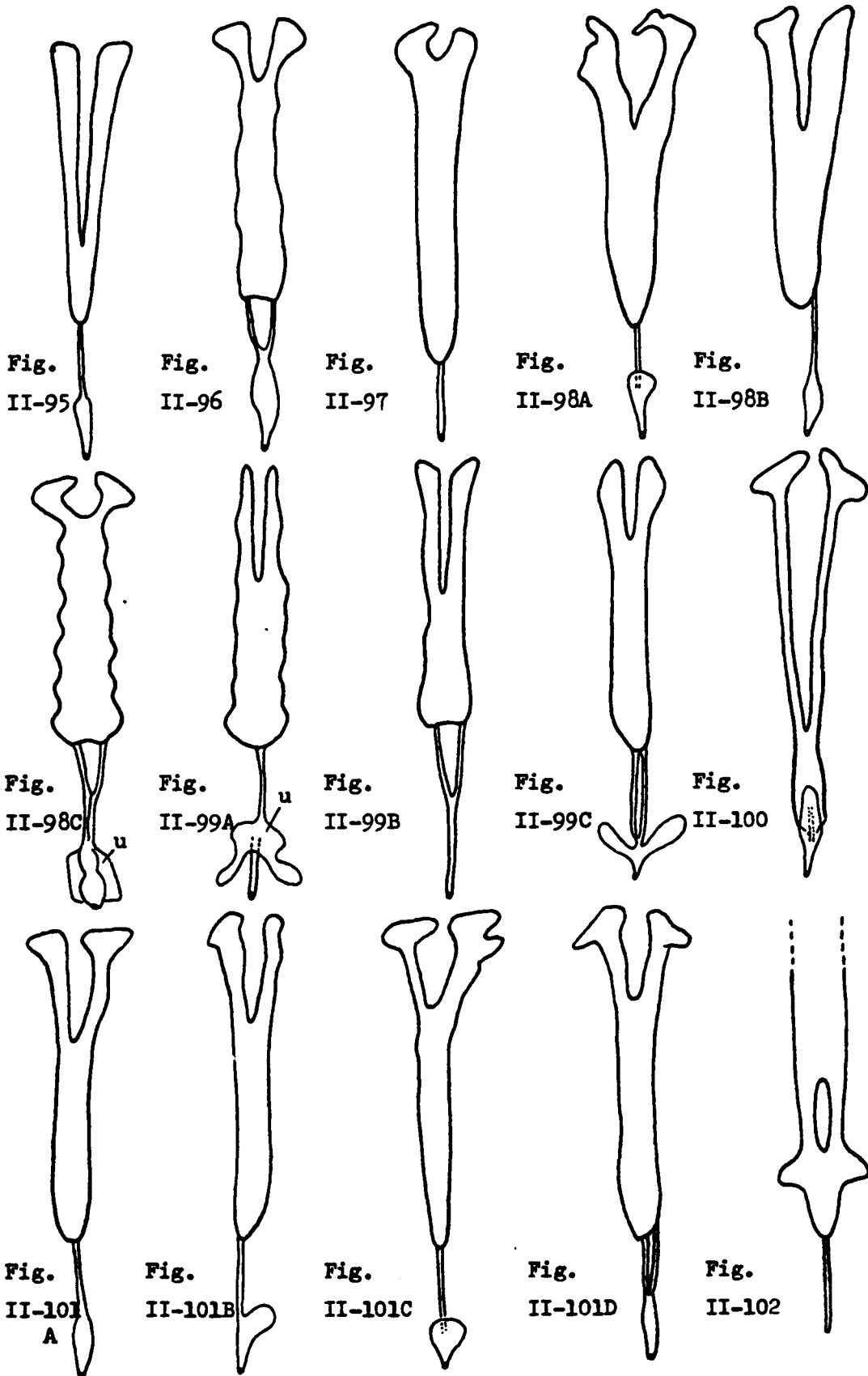
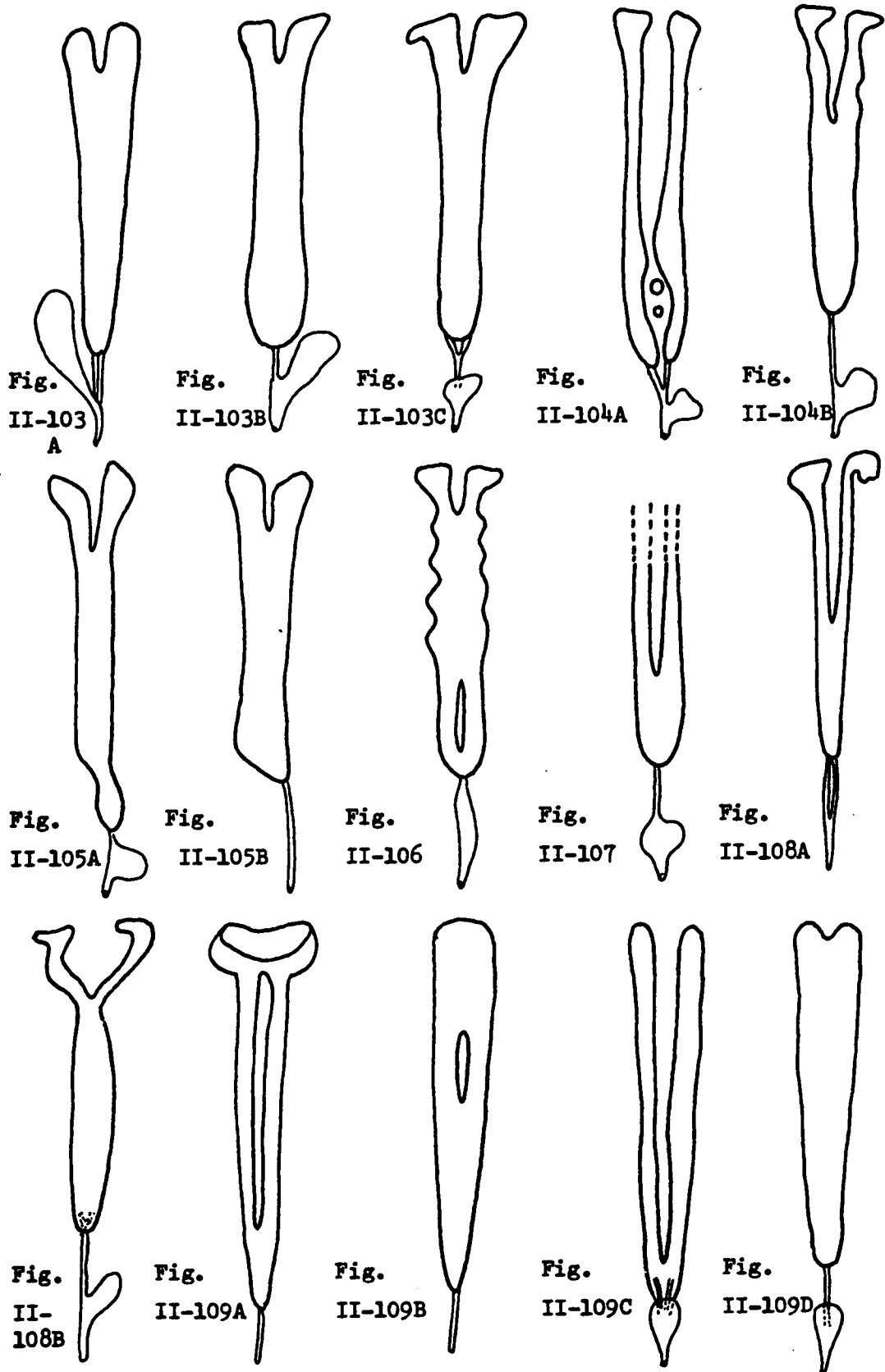
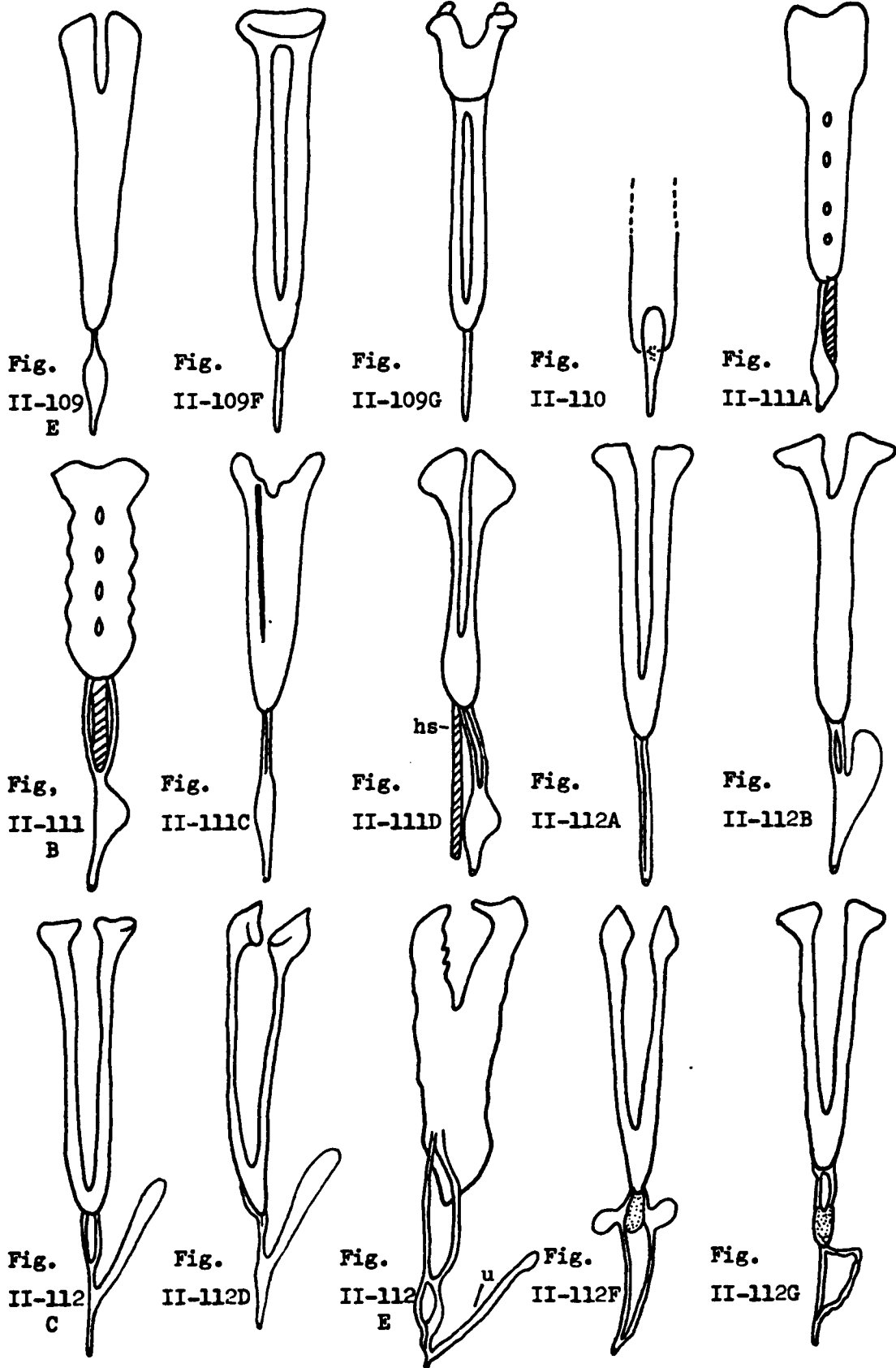


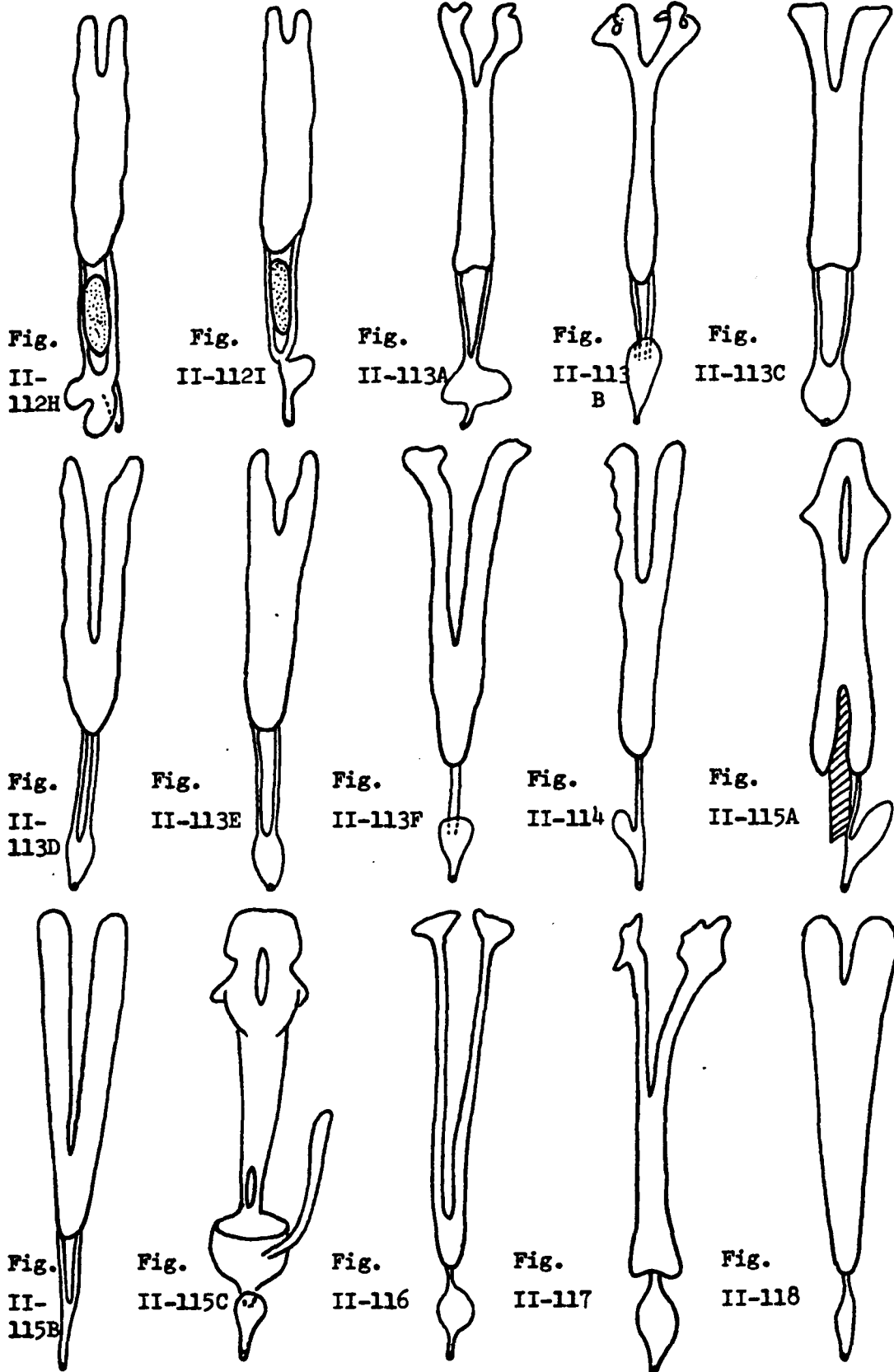
Fig.
II-88

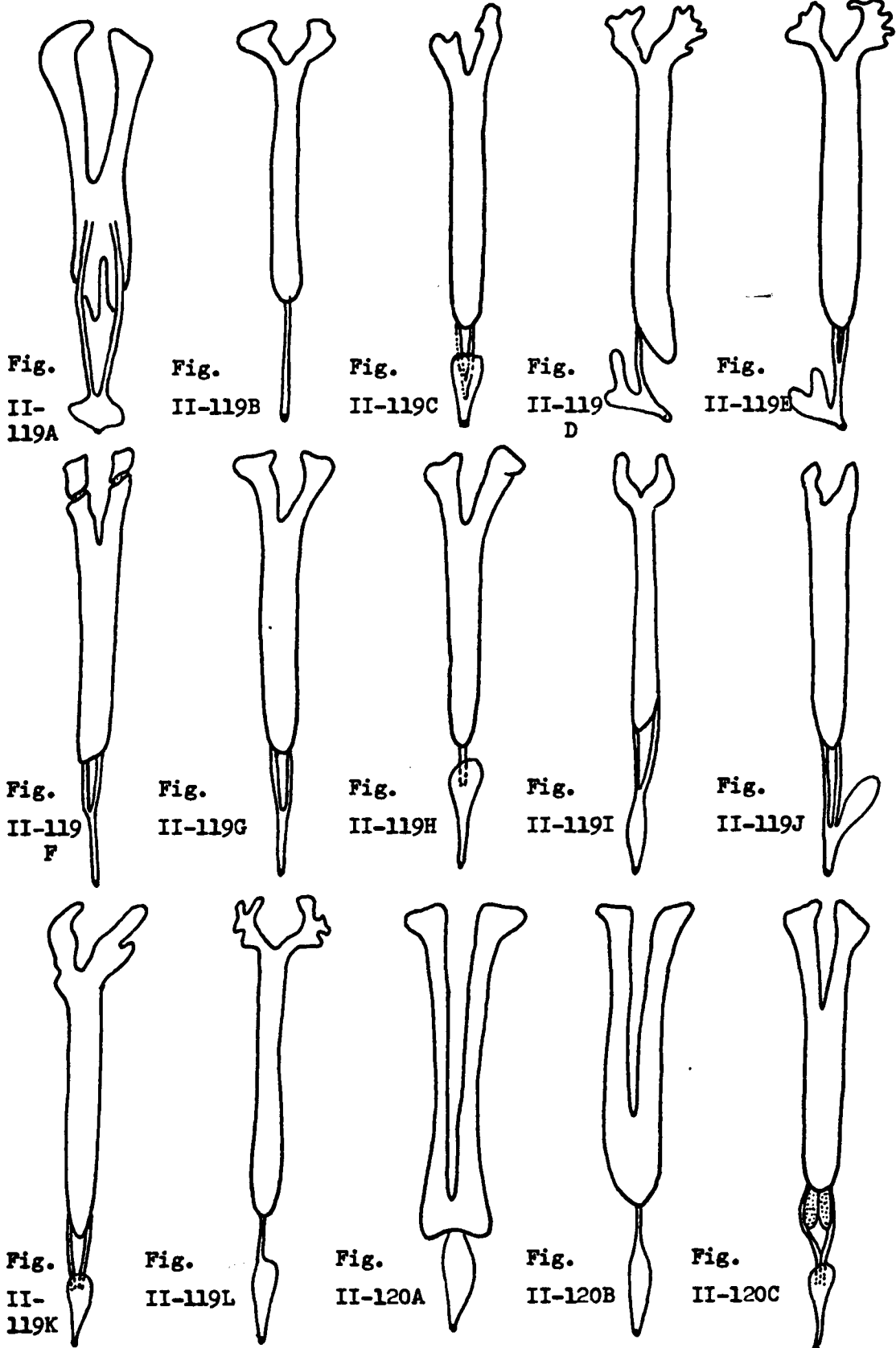


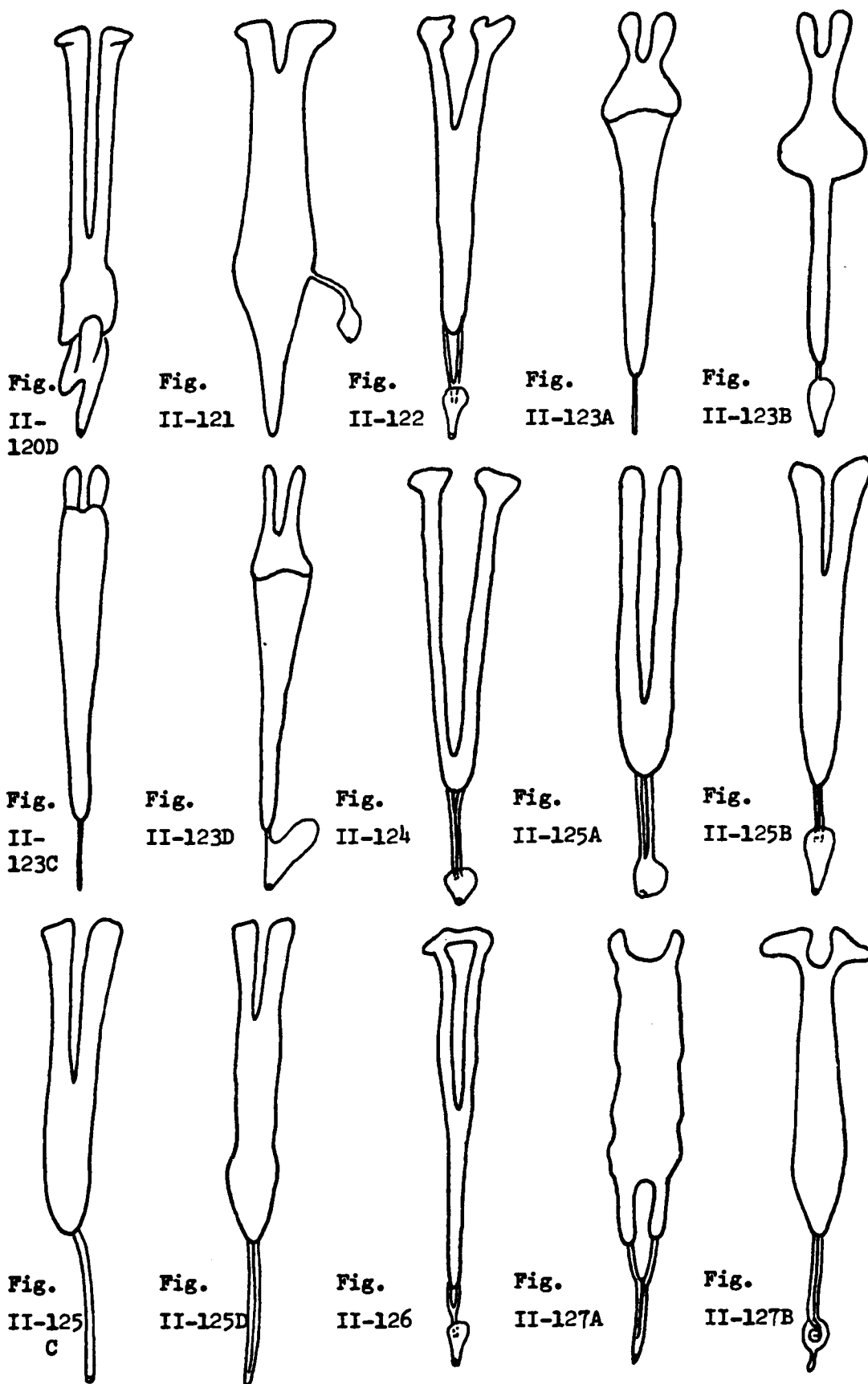


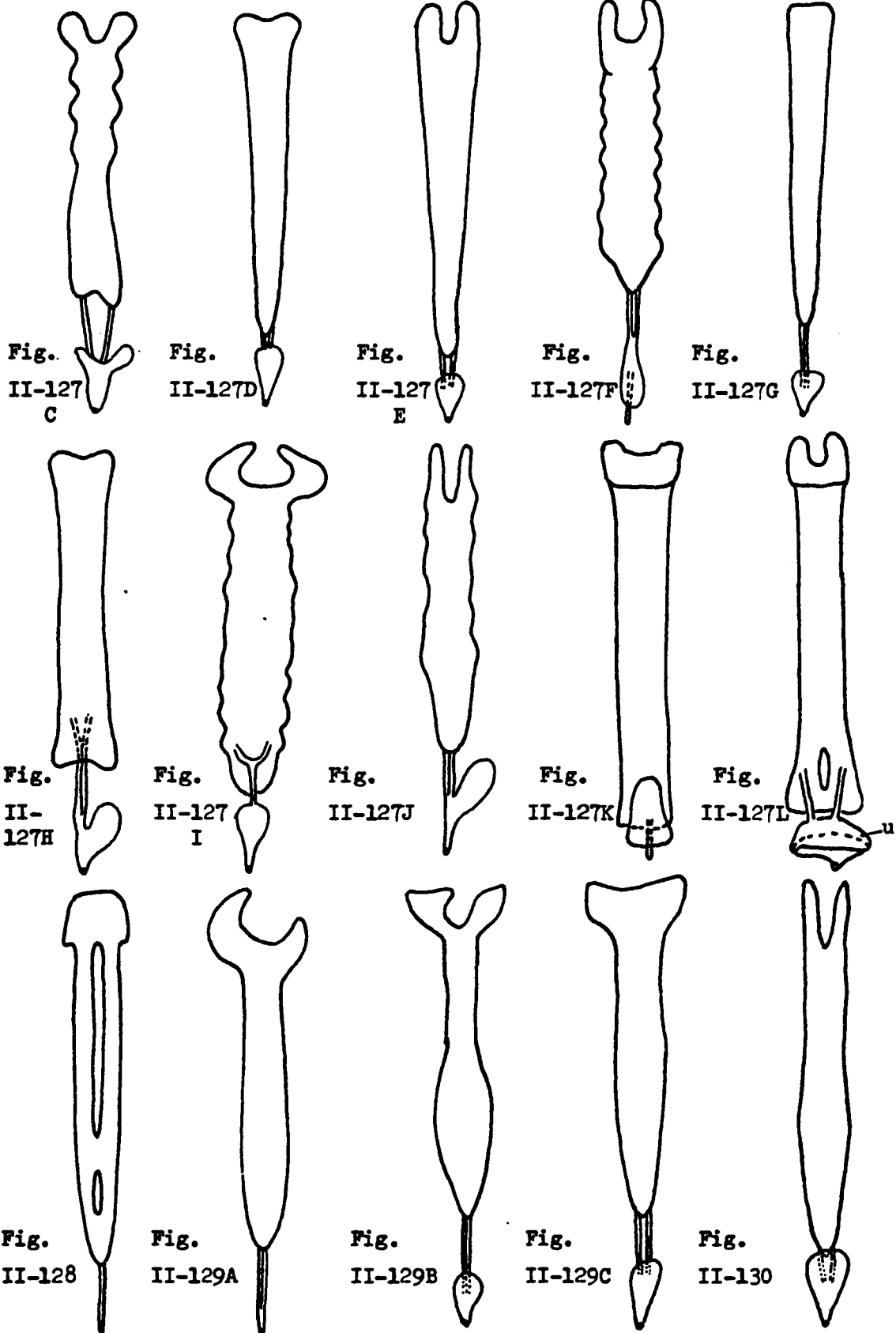


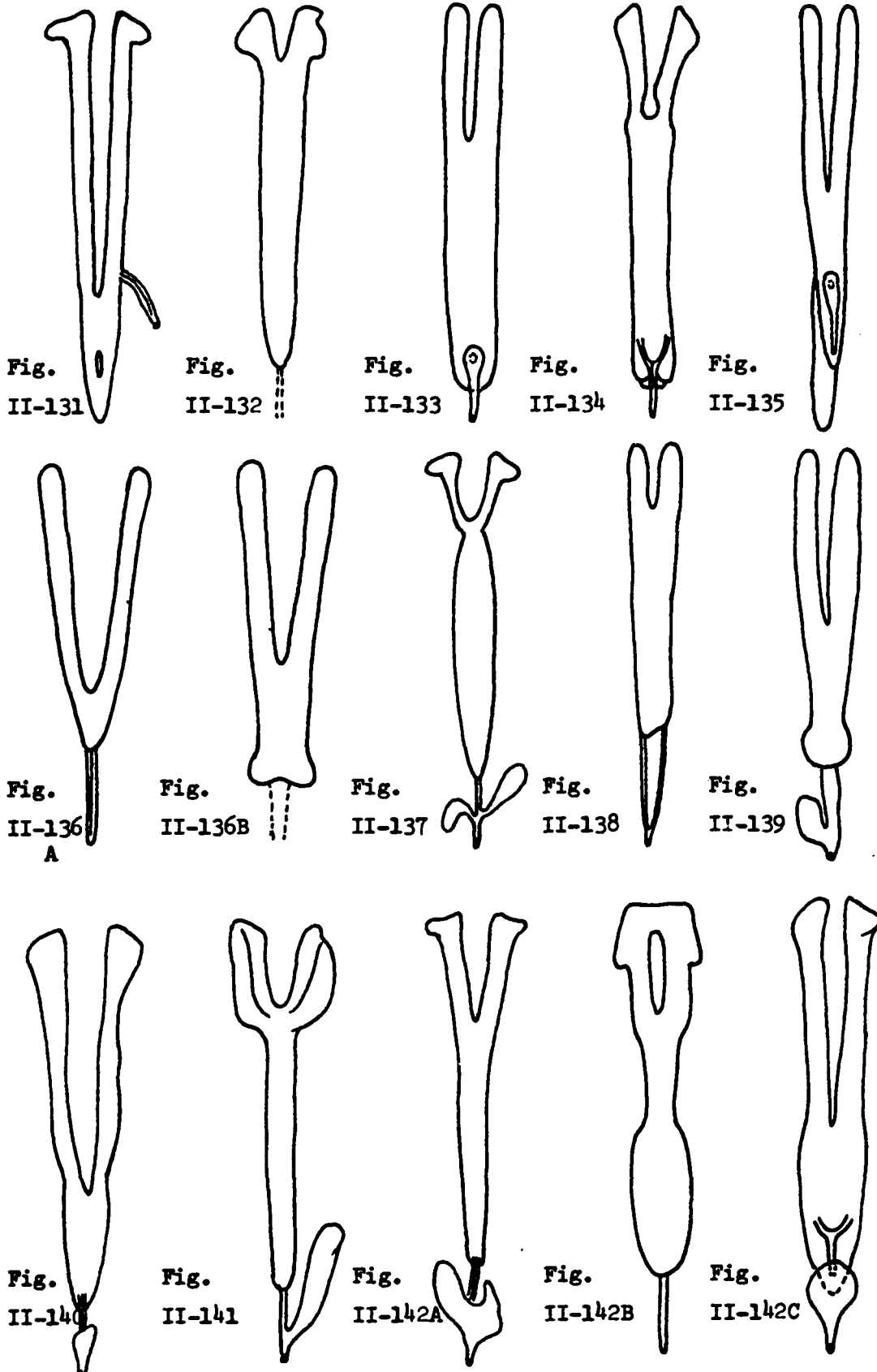


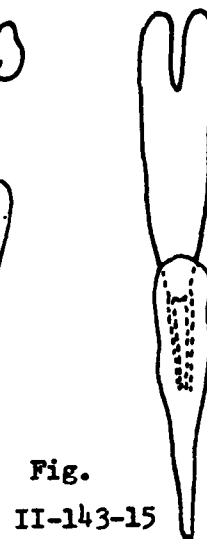
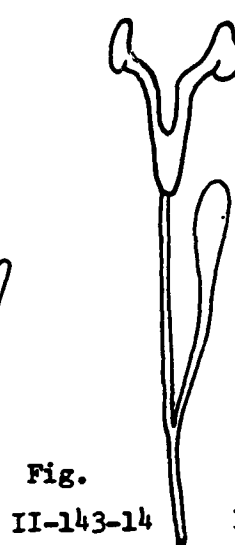
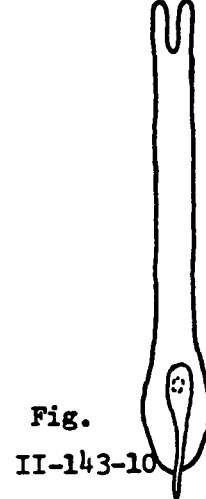
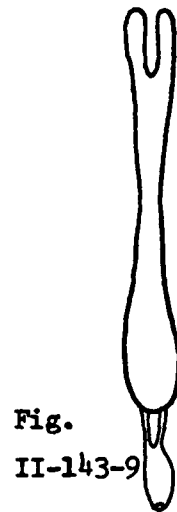
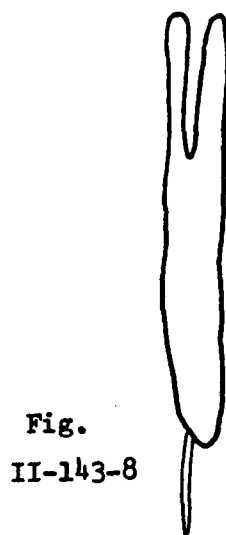
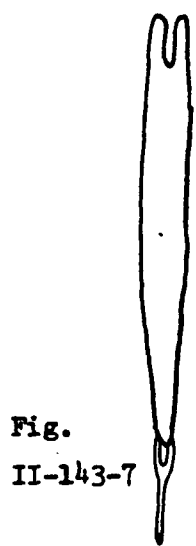
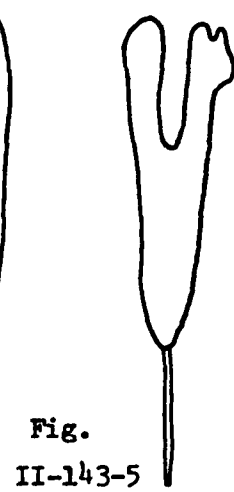
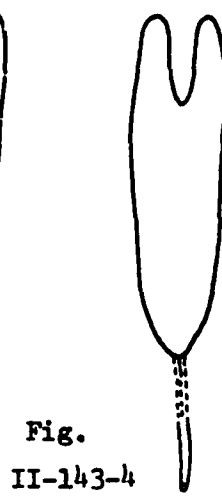
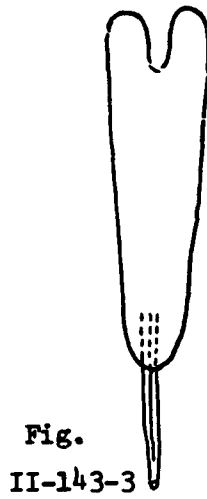
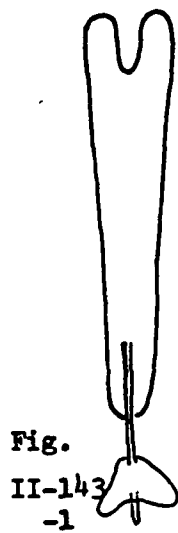


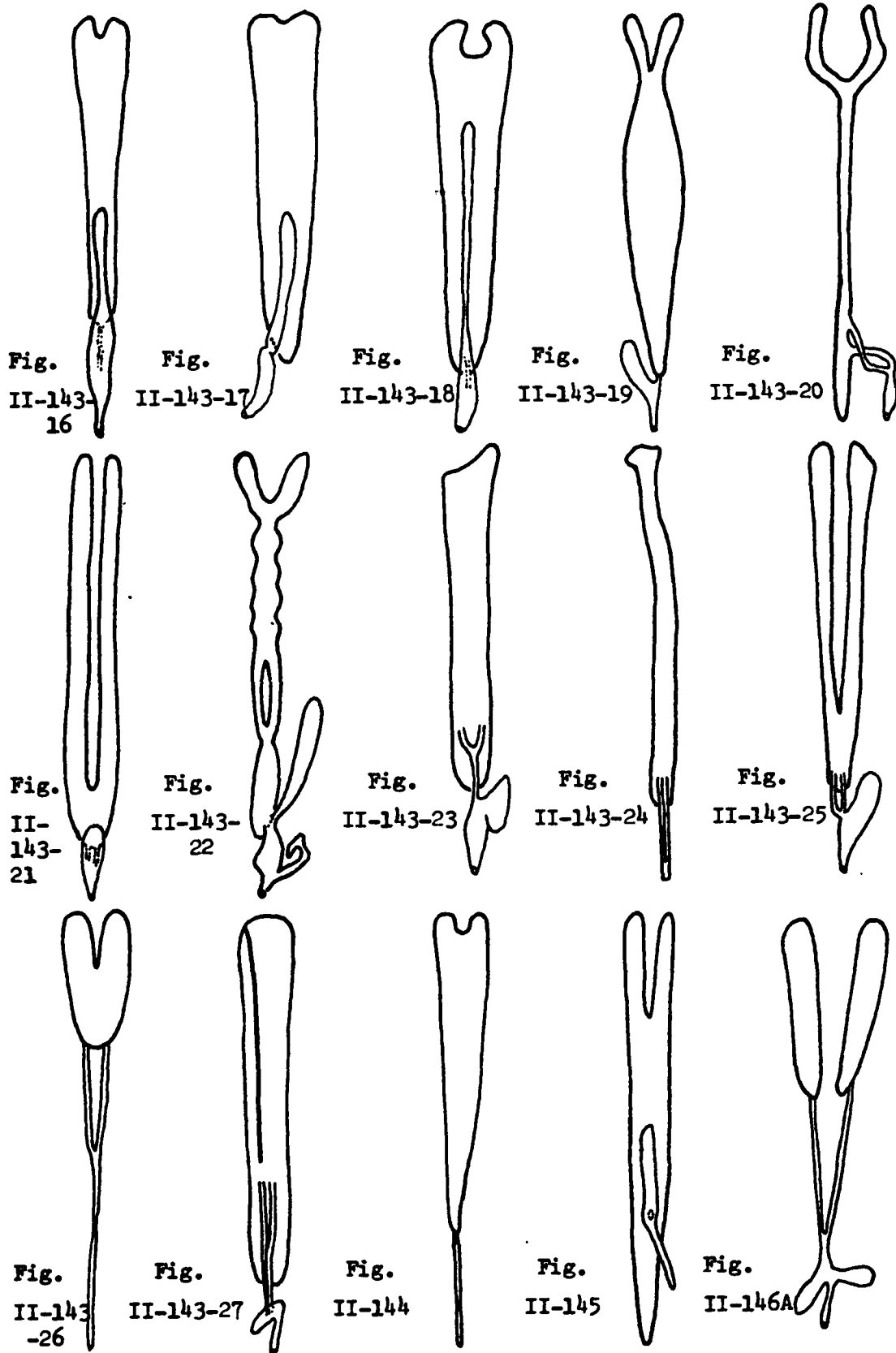


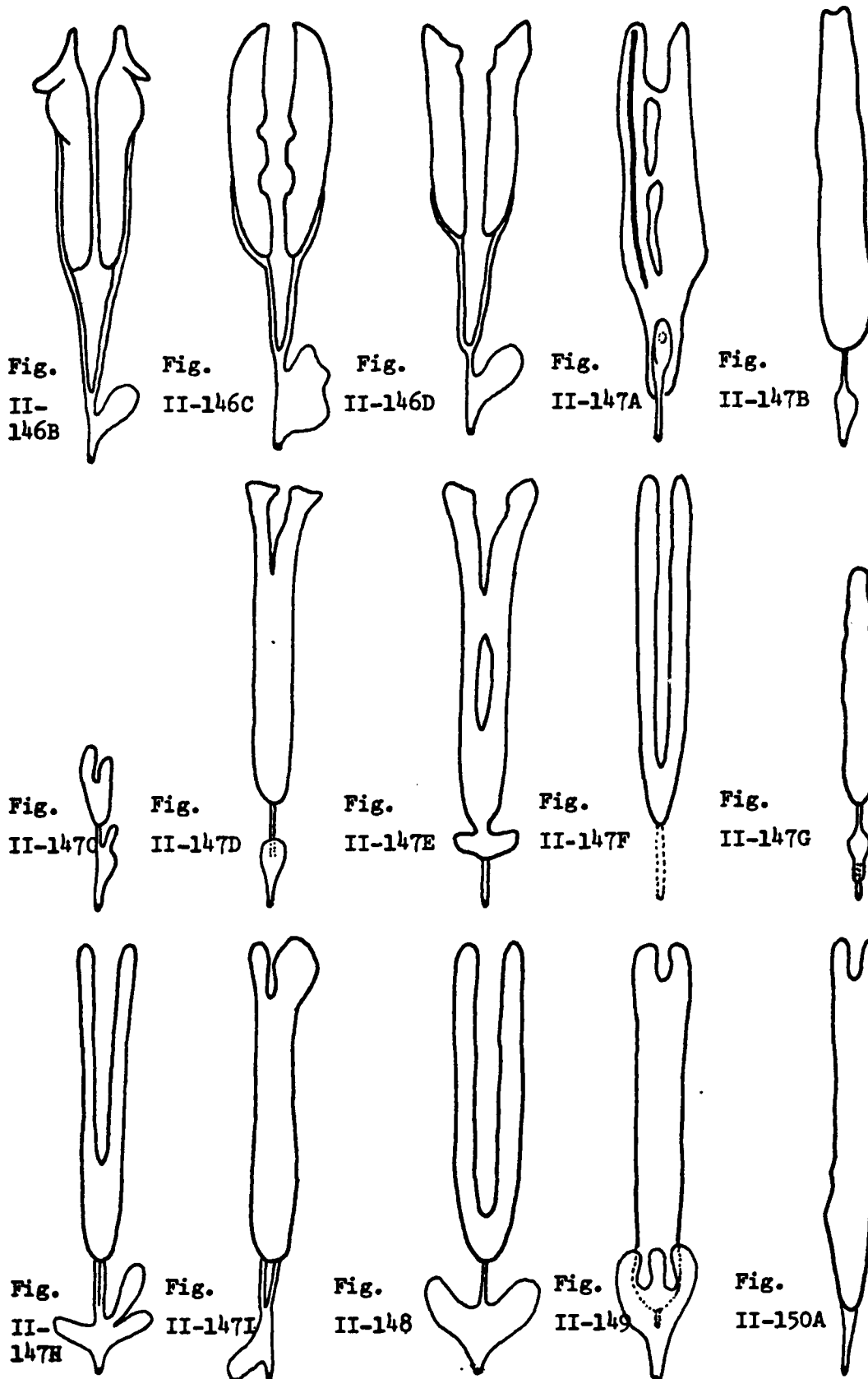


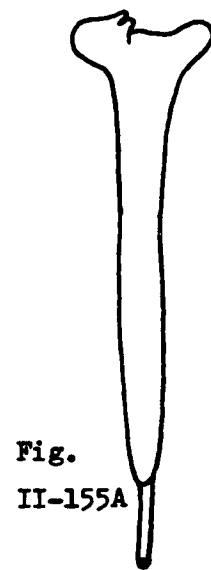
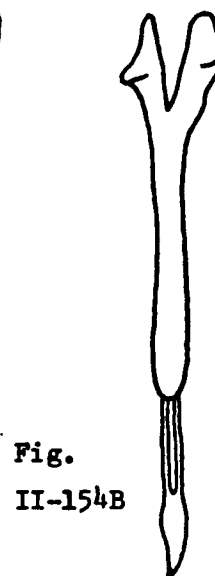
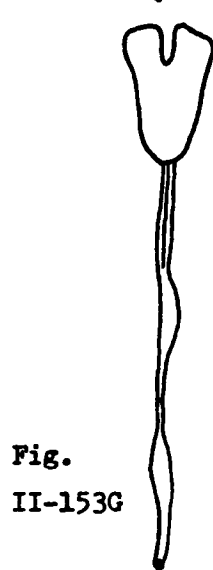
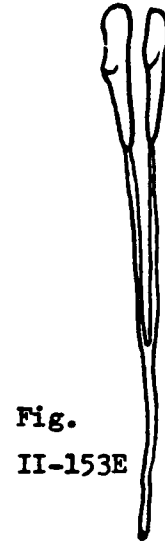
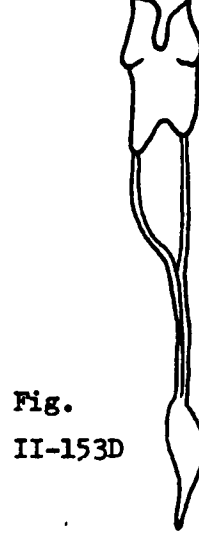
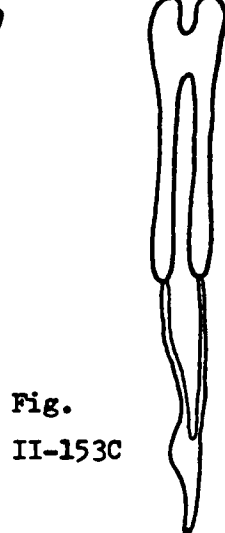
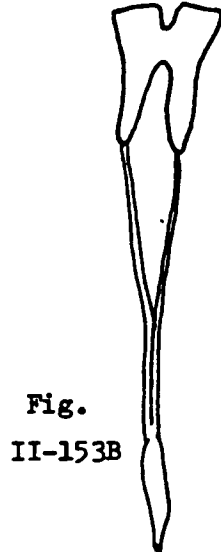
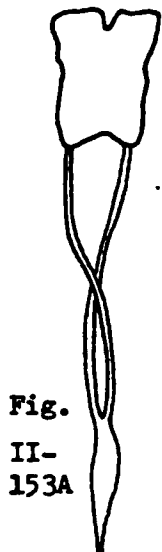
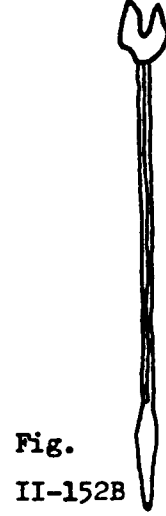
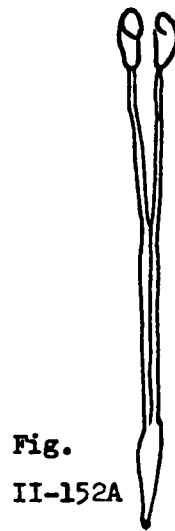
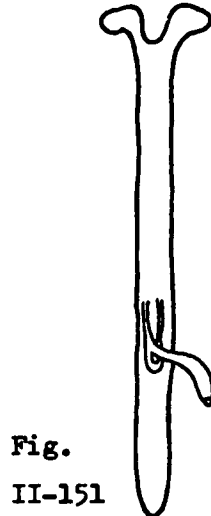
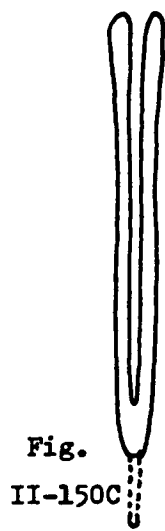


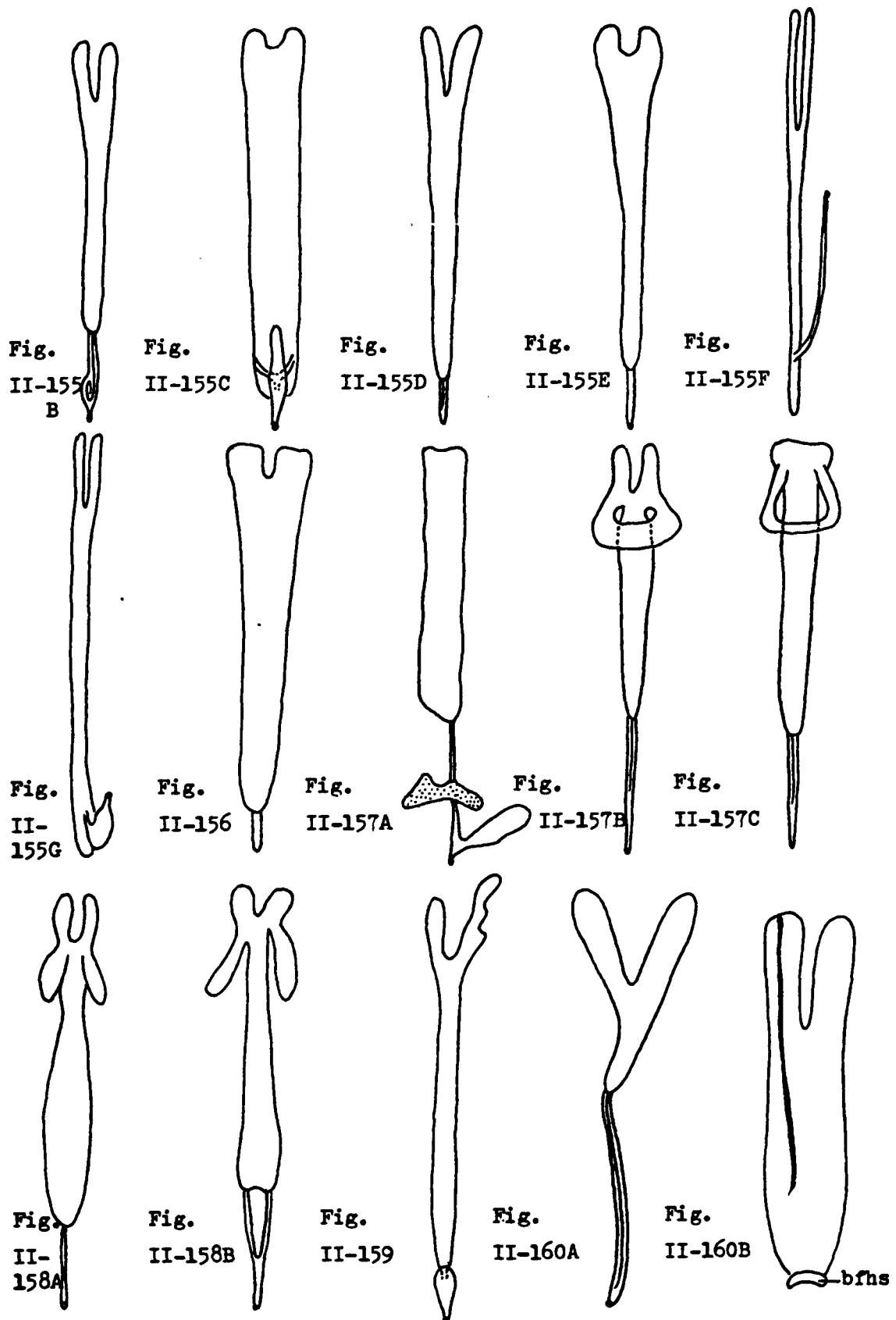


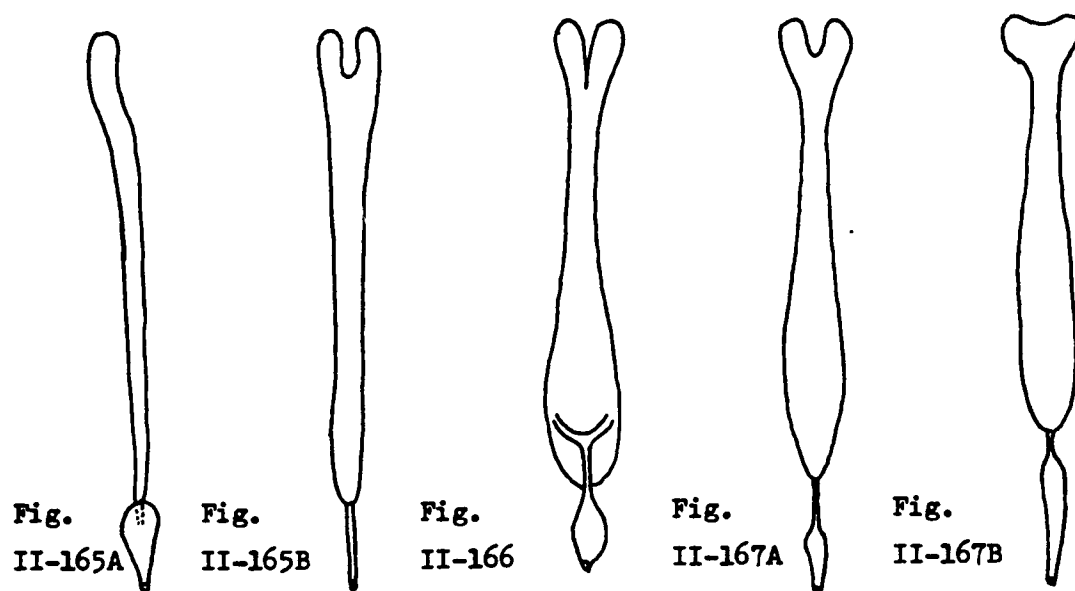
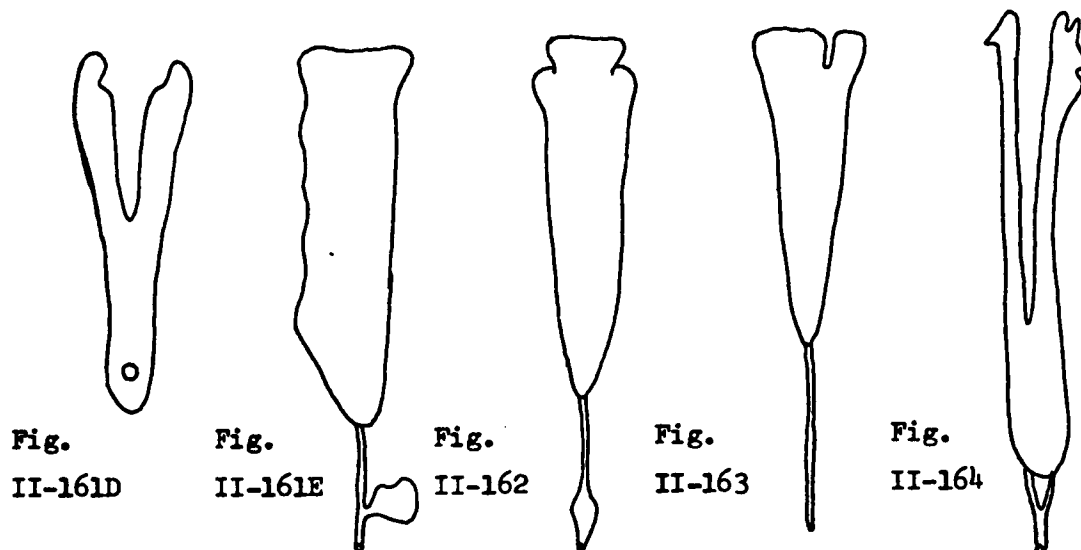
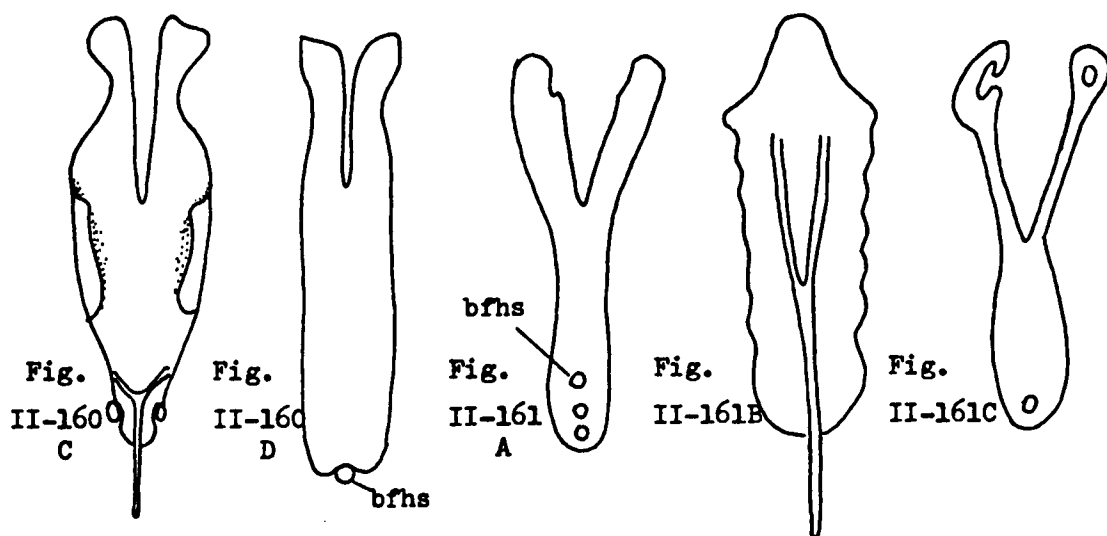












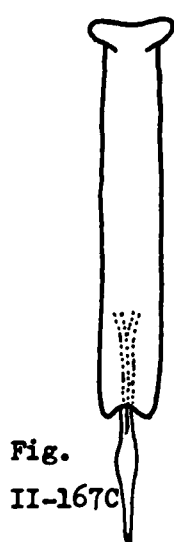


Fig.
II-167C



Fig.
II-167D

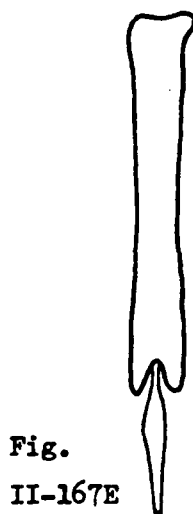


Fig.
II-167E



Fig.
II-167F



Fig.
II-167G



Fig.
II-167H

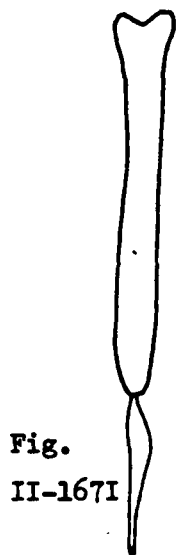


Fig.
II-167I

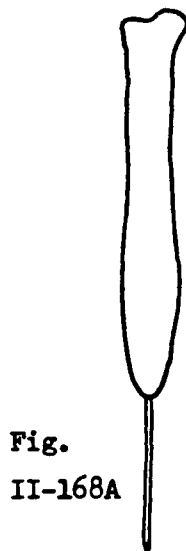


Fig.
II-168A

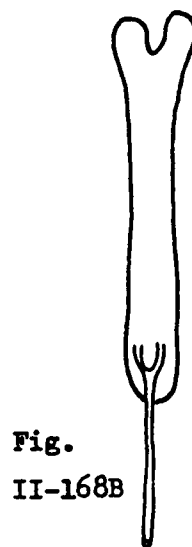


Fig.
II-168B

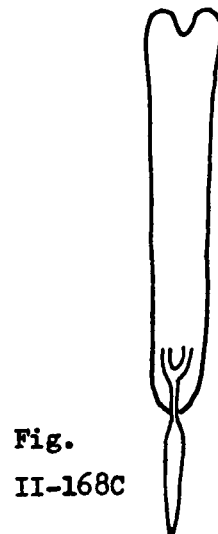


Fig.
II-168C

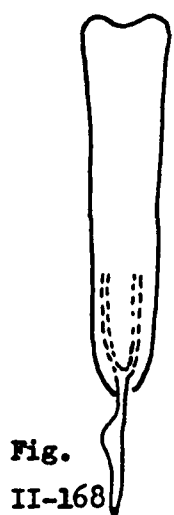


Fig.
II-168
D

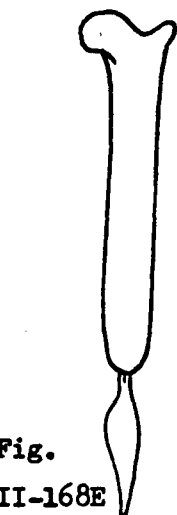


Fig.
II-168E

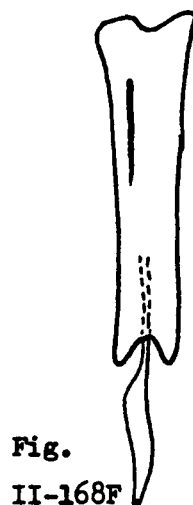


Fig.
II-168F

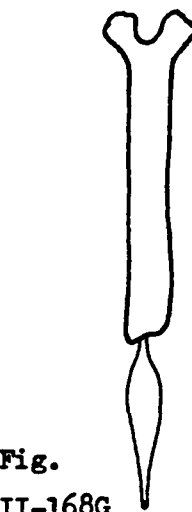
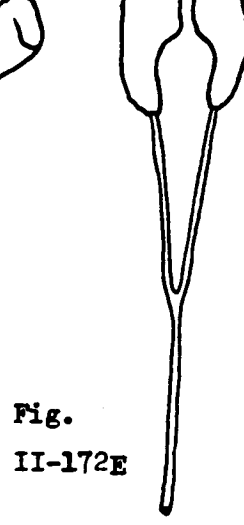
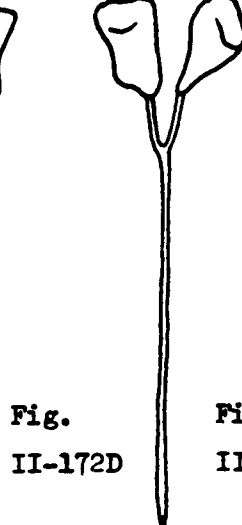
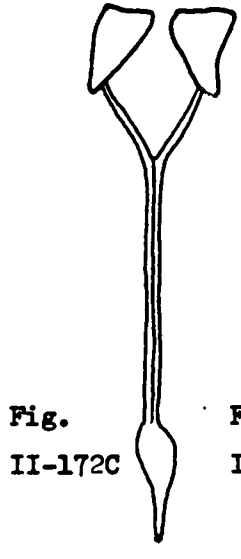
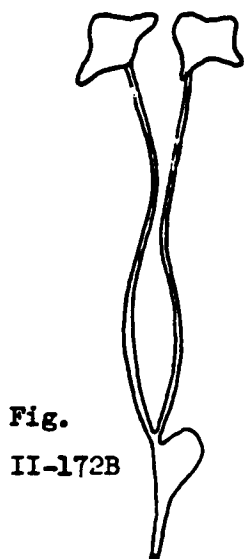
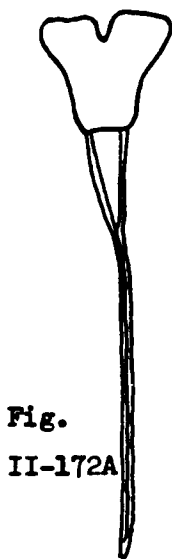
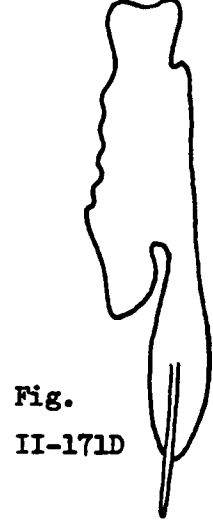
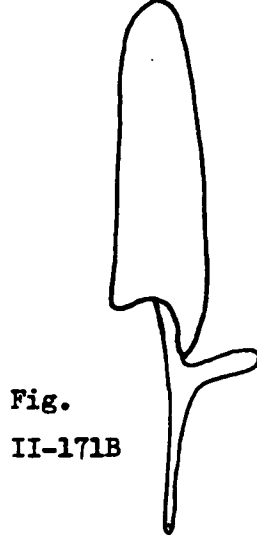
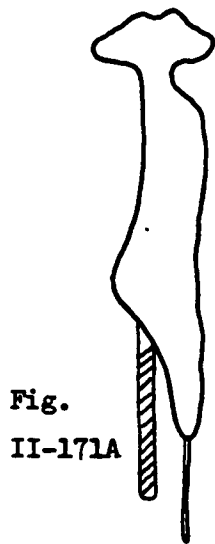
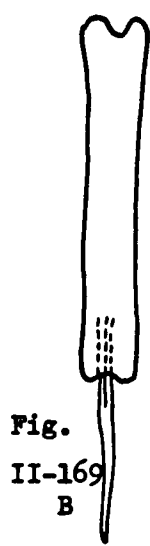
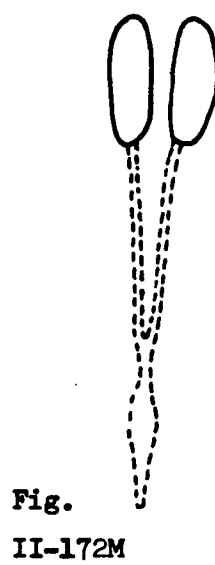
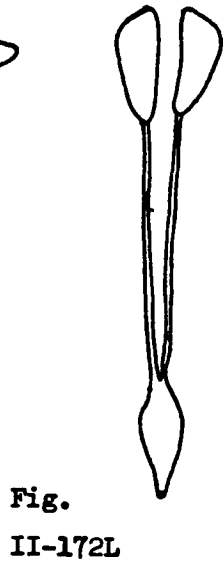
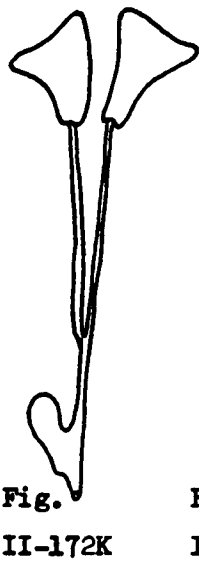
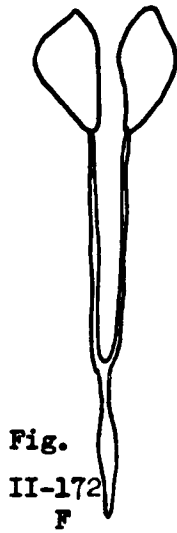


Fig.
II-168G



Fig.
II-169A





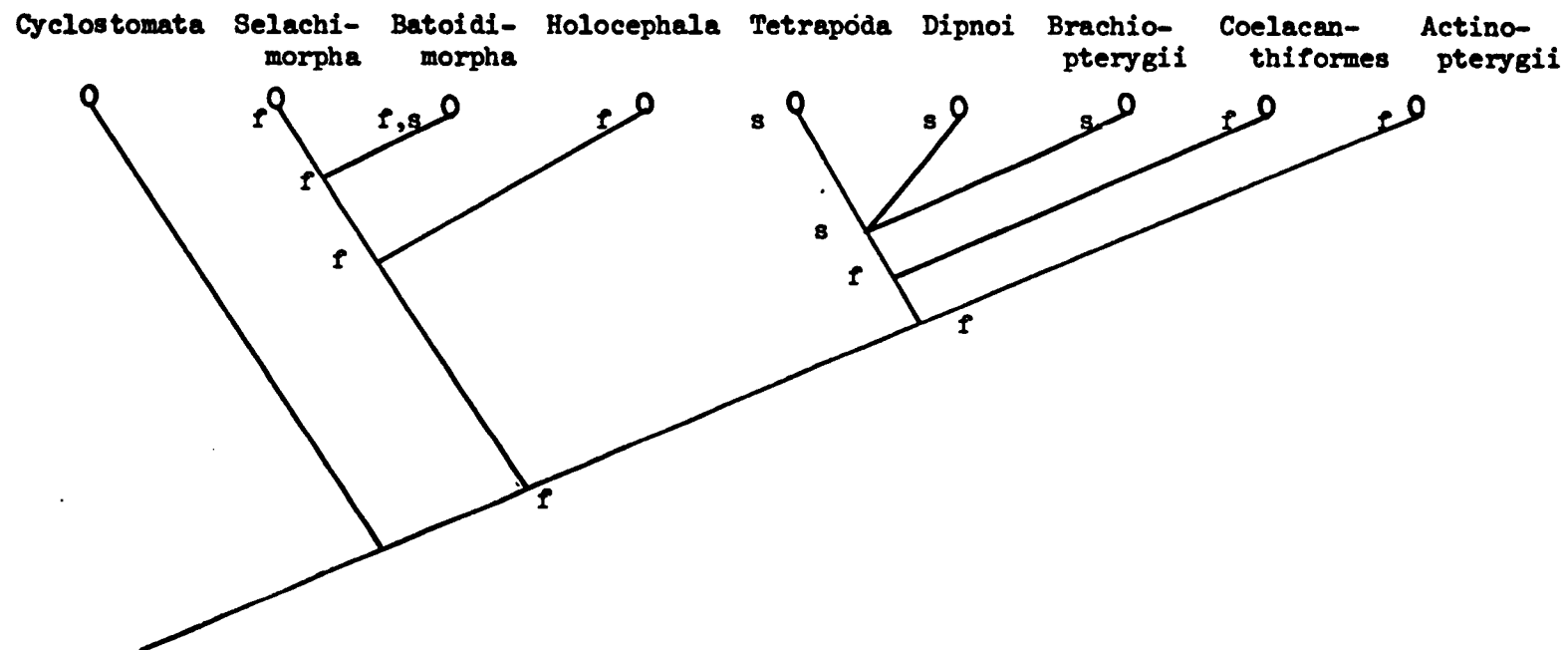


FIG.11-173

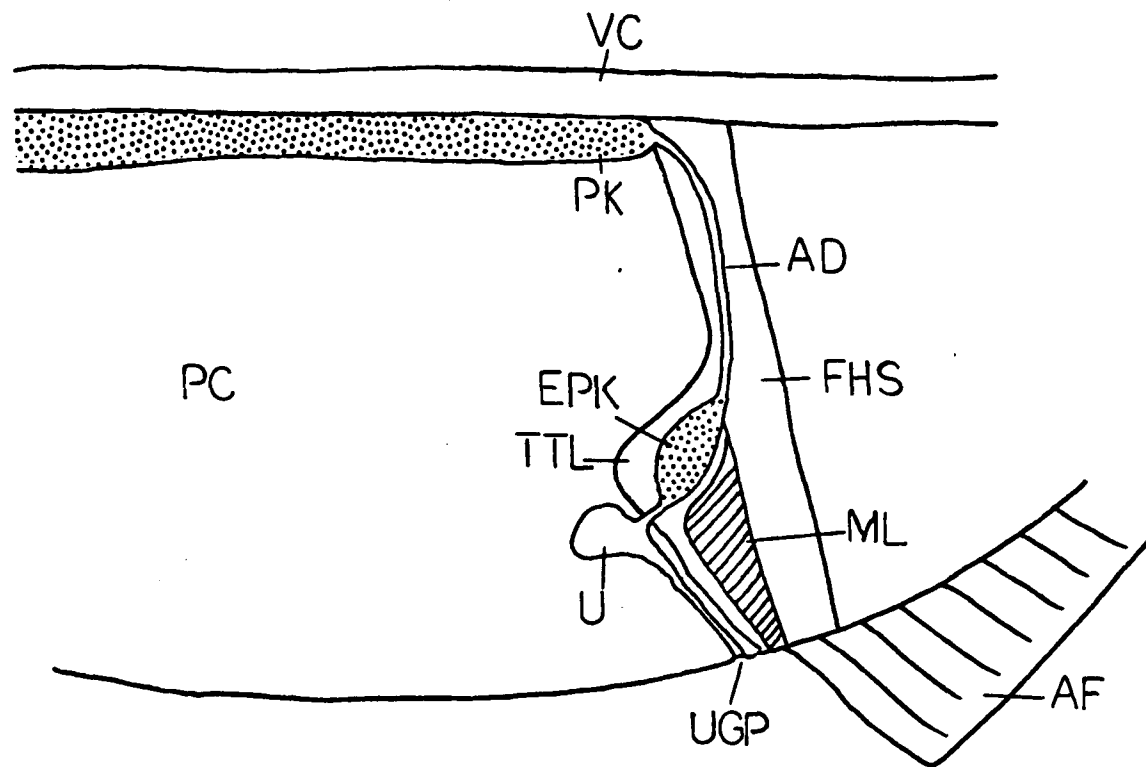
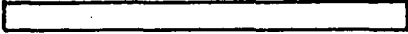


FIG.II-174

Pomoxis	Centrarchus	Archoplites	Acantharchus	Ambloplites	Erneacanthus	Lepomis	Micropterus	Elassoma
								
								
								
								

Fusion of extreme anterior kidneys occurs.

Fusion of posterior kidneys occurs only behind the base of the first haemal spine.

Existence of extreme posterior kidney.

Existence of direct connection between the posterior and extreme posterior kidneys.

FIG.11-175

FIG. 11-176

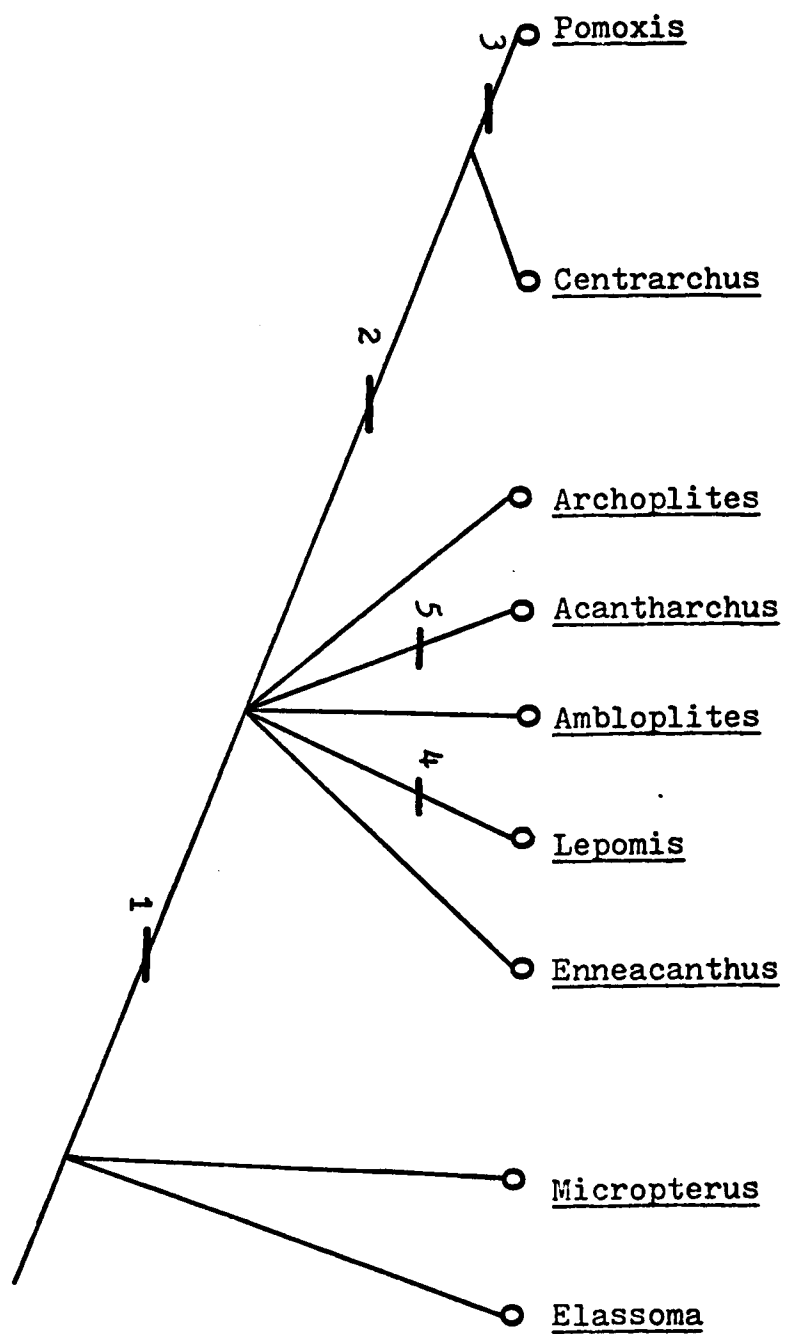
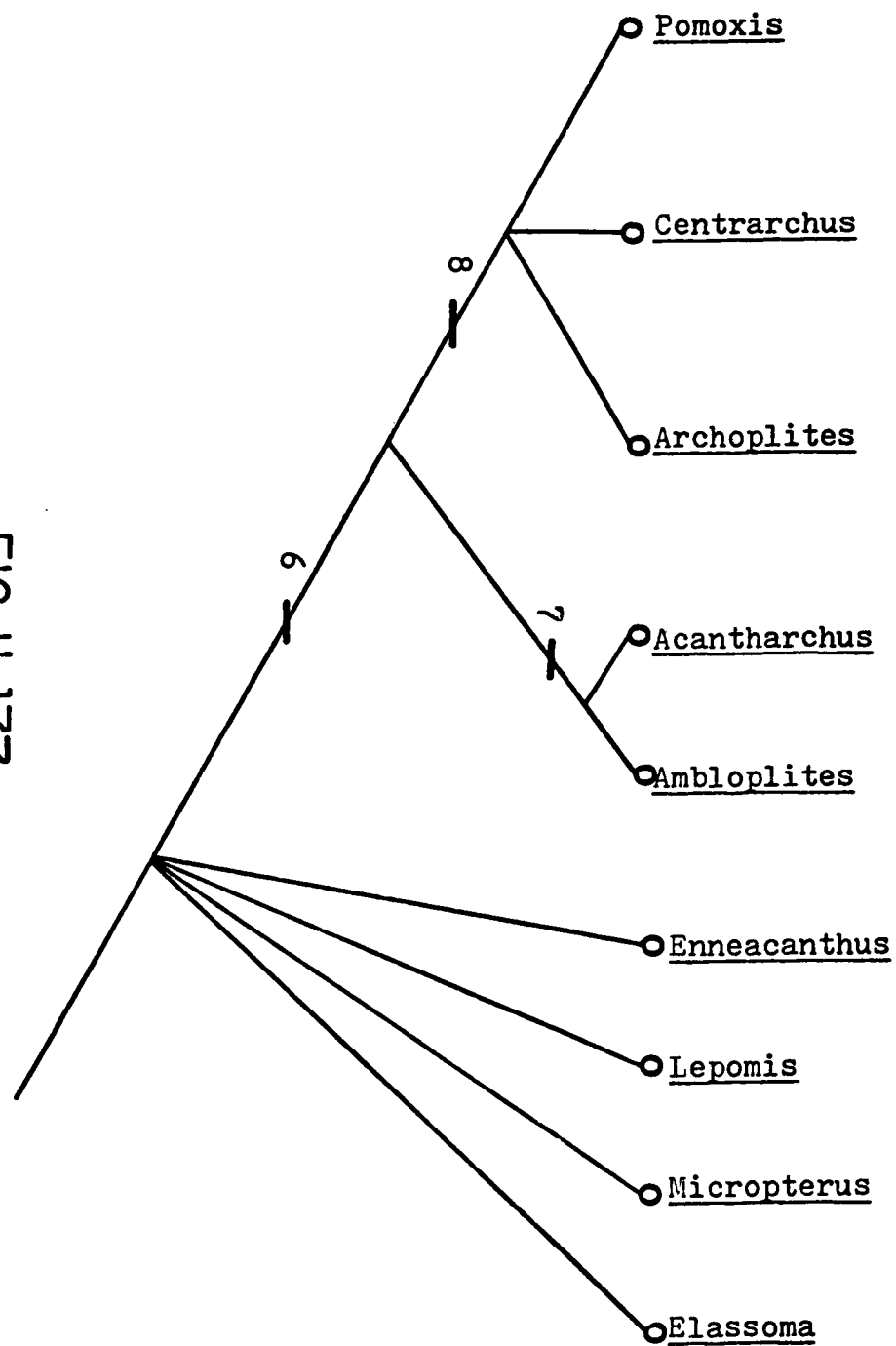


FIG. 11-177



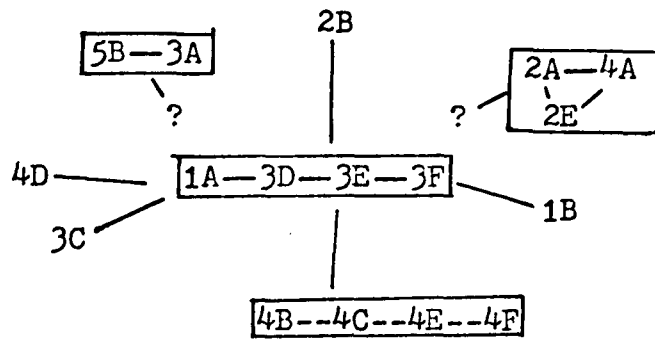


FIG.II-178

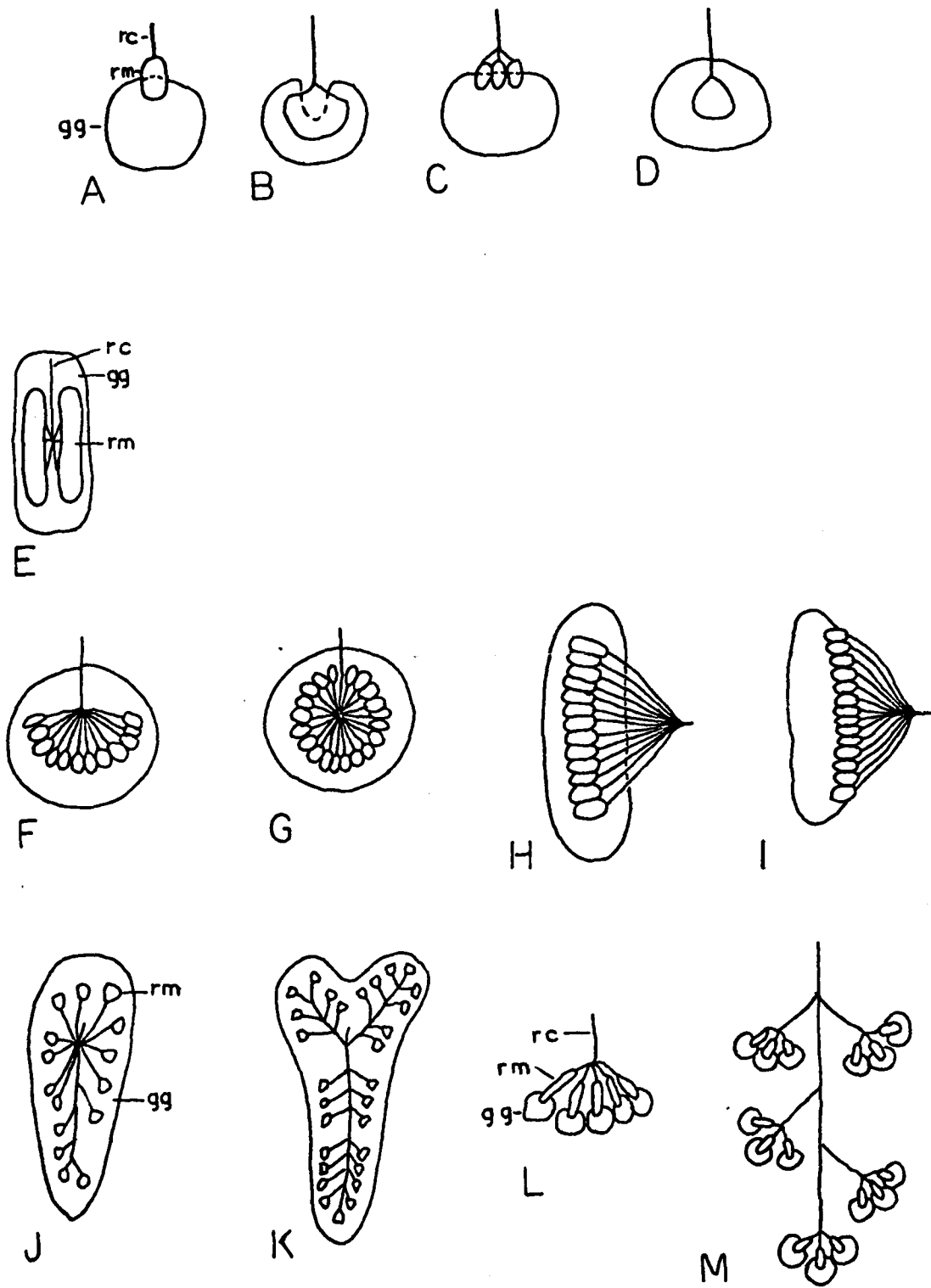


FIG. III-1

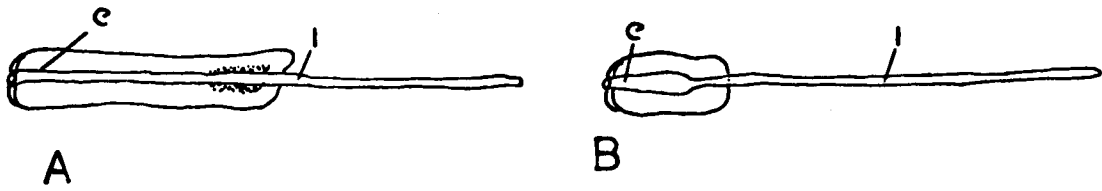


FIG. IV-1

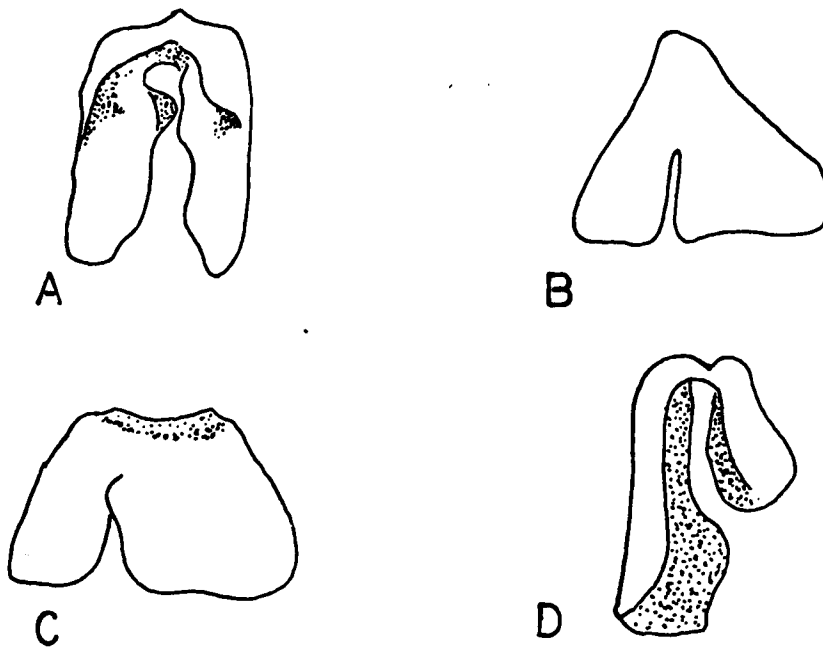


FIG. IV-2

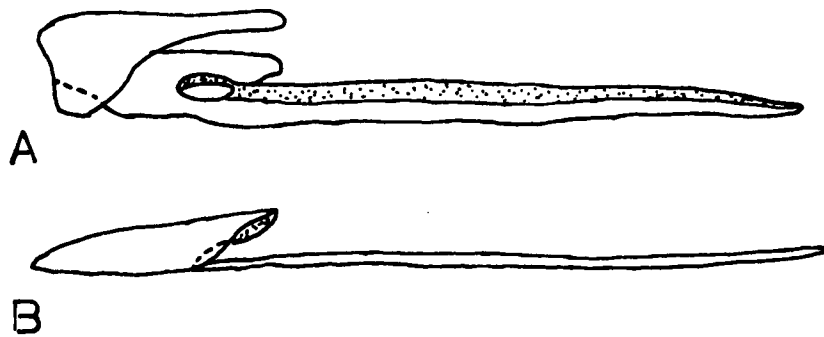


FIG. IV-3

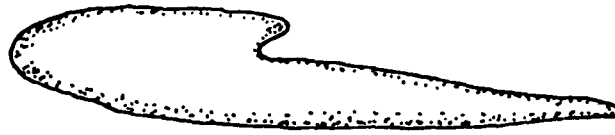


FIG. IV-4

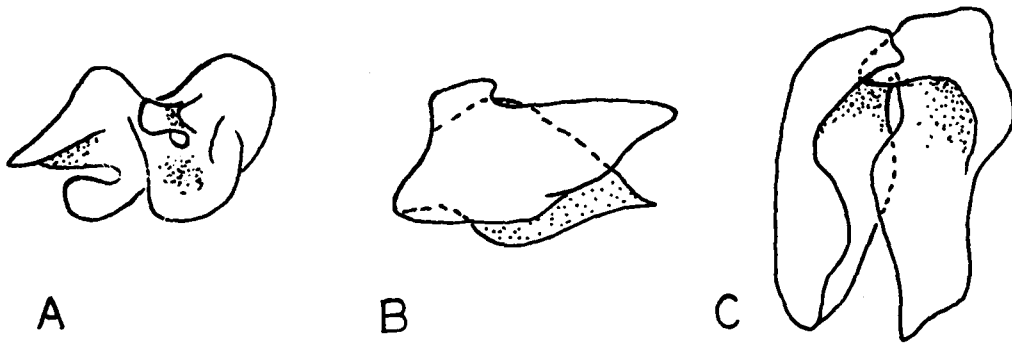


FIG. IV-5

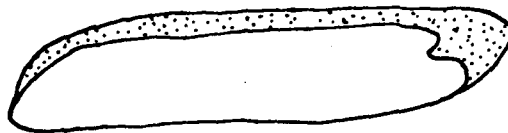


FIG. IV-6

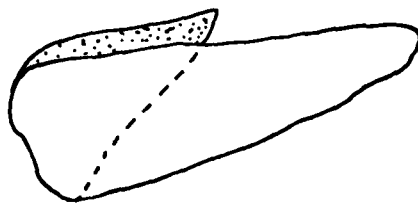


FIG. IV-7

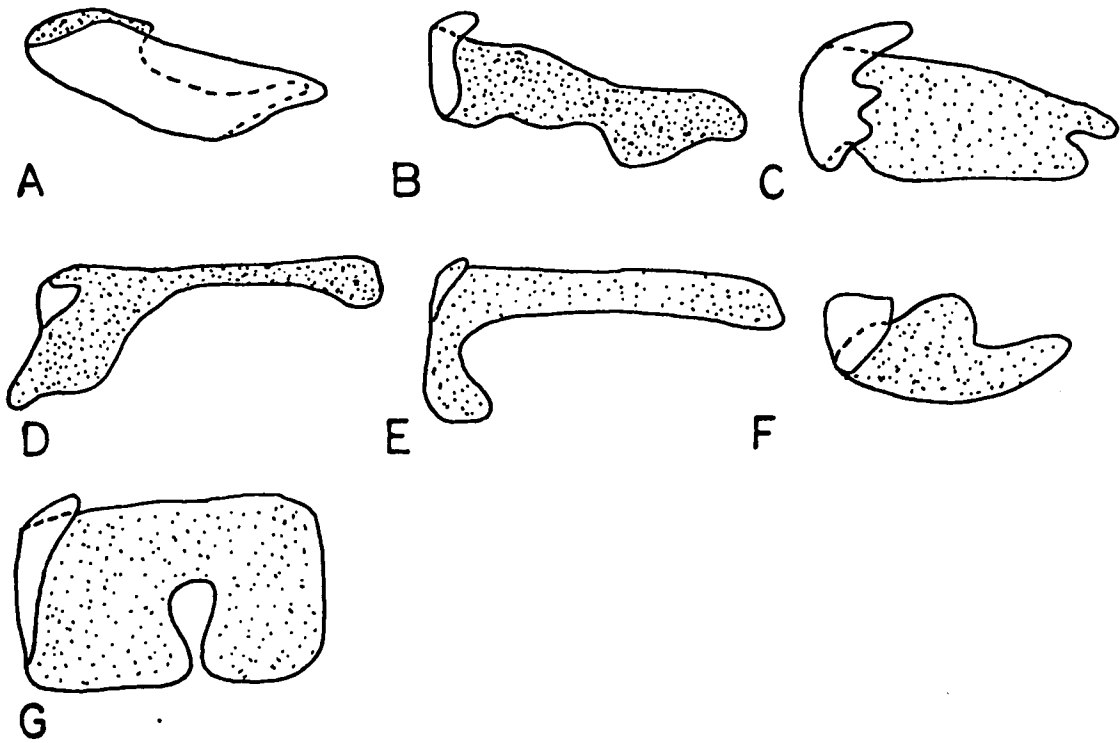


FIG. IV-8



FIG. IV-9

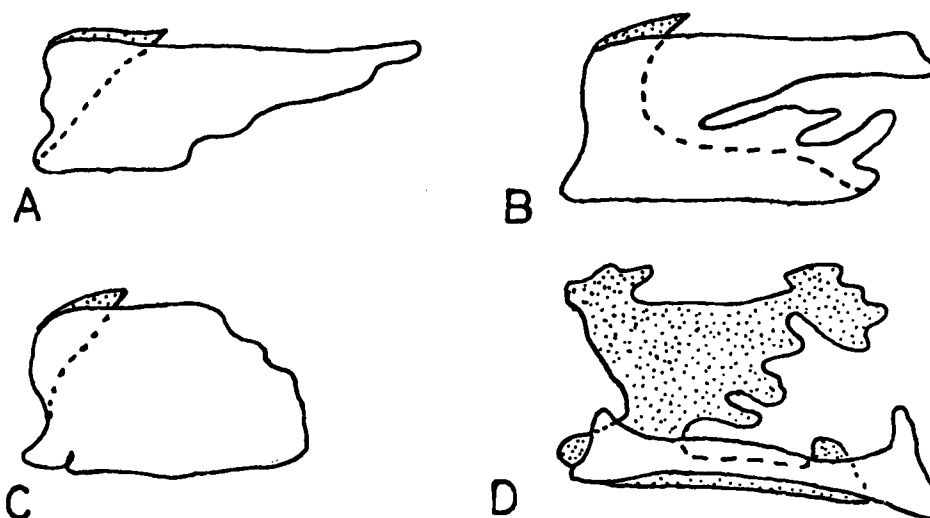


FIG.IV-10

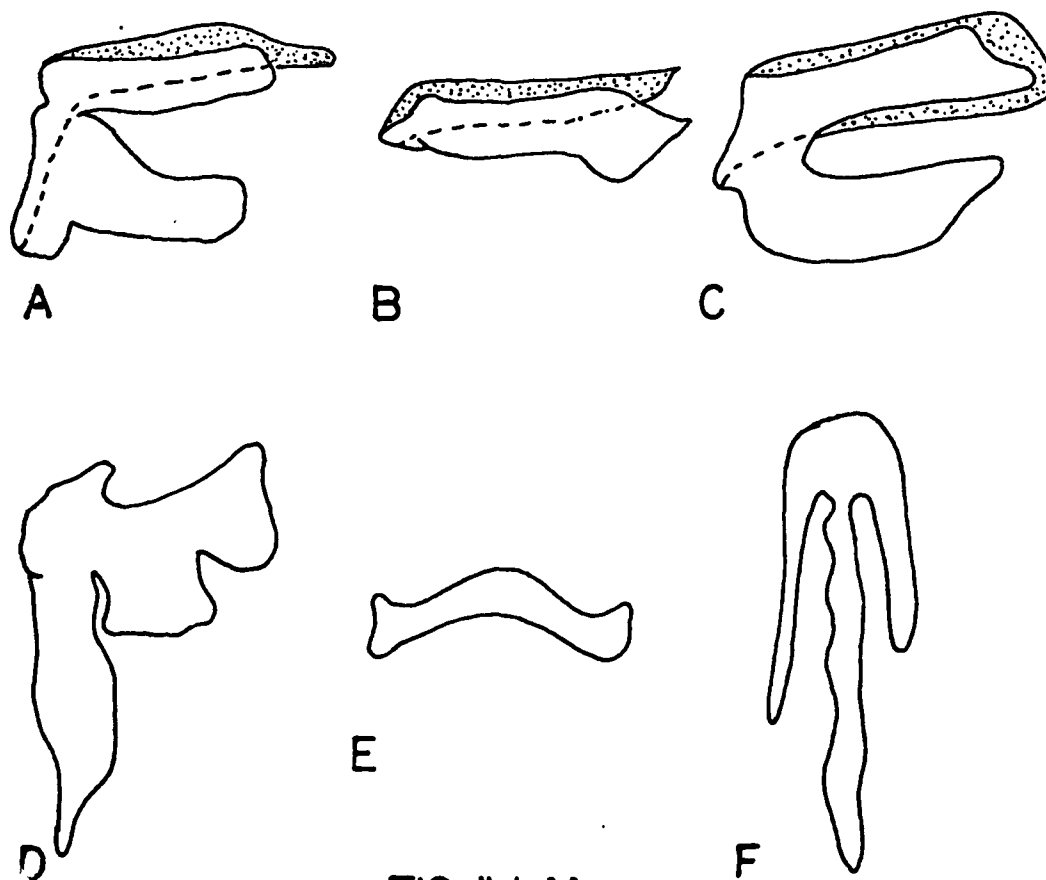


FIG.IV-11

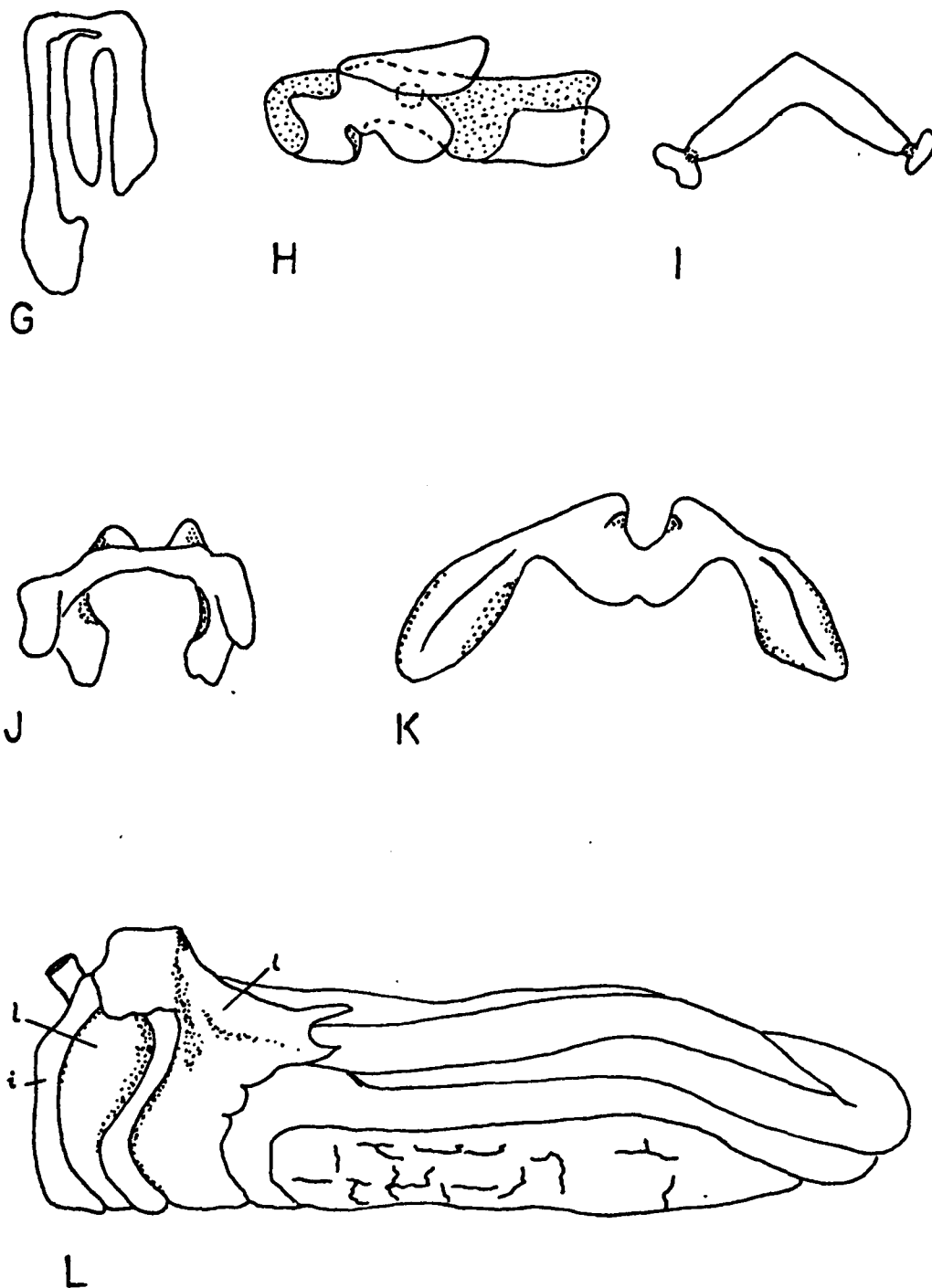


FIG.IV-11

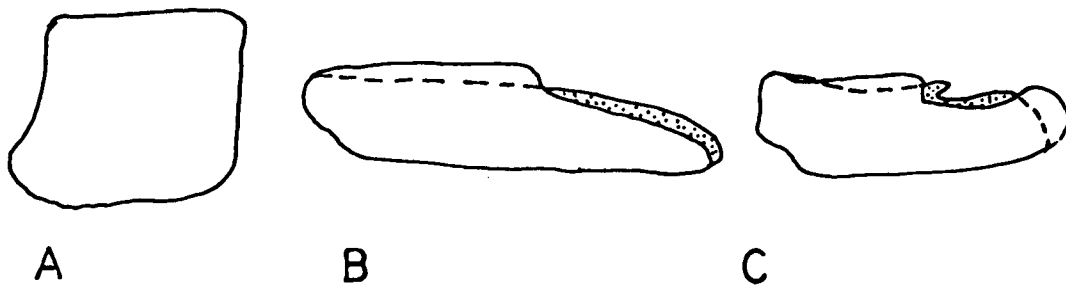


FIG. IV-12

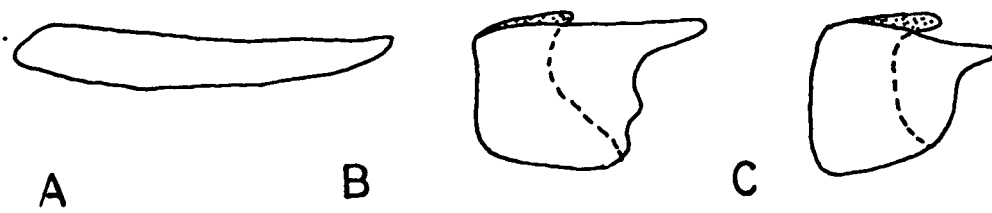


FIG. IV-13



FIG. IV-14

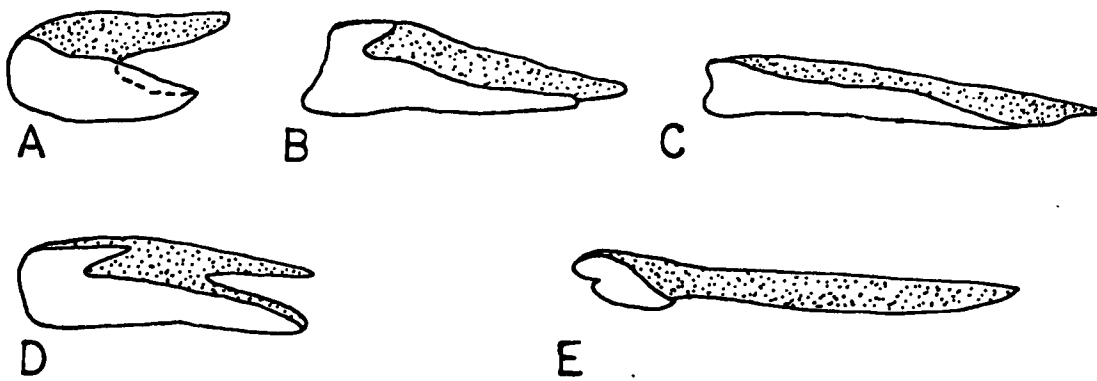


FIG. IV-15

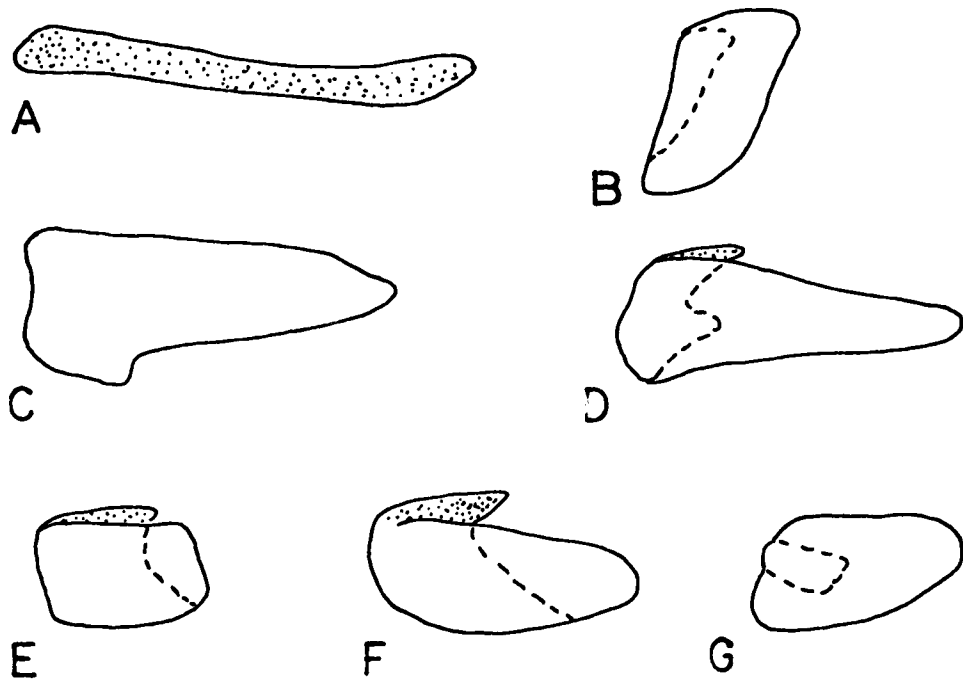


FIG. IV-16

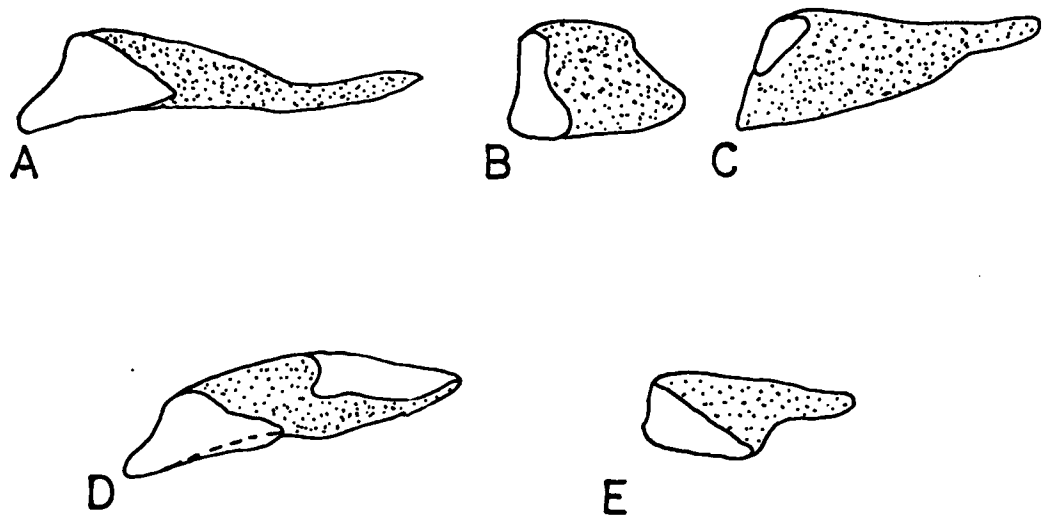


FIG. IV-17

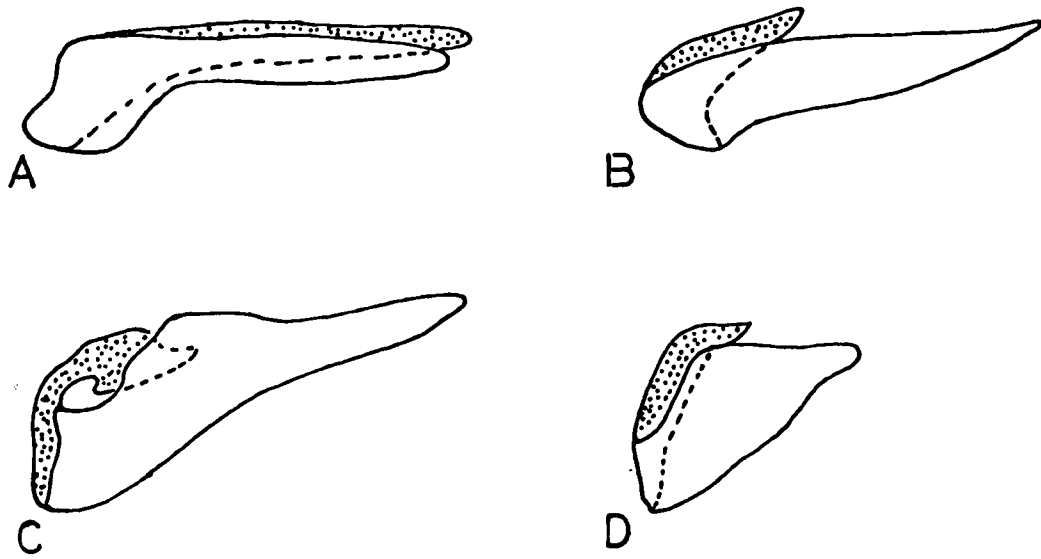


FIG. IV-18

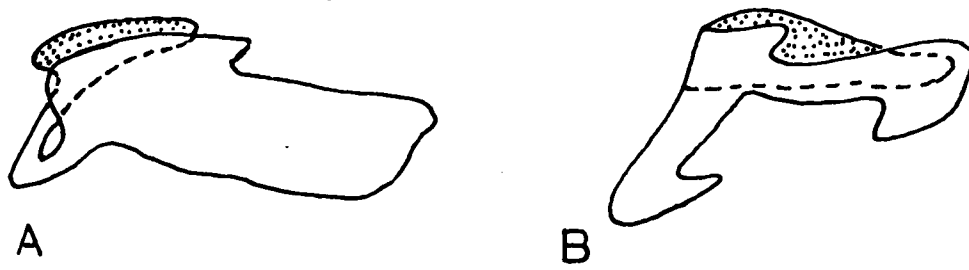


FIG. IV-19



FIG. IV-20

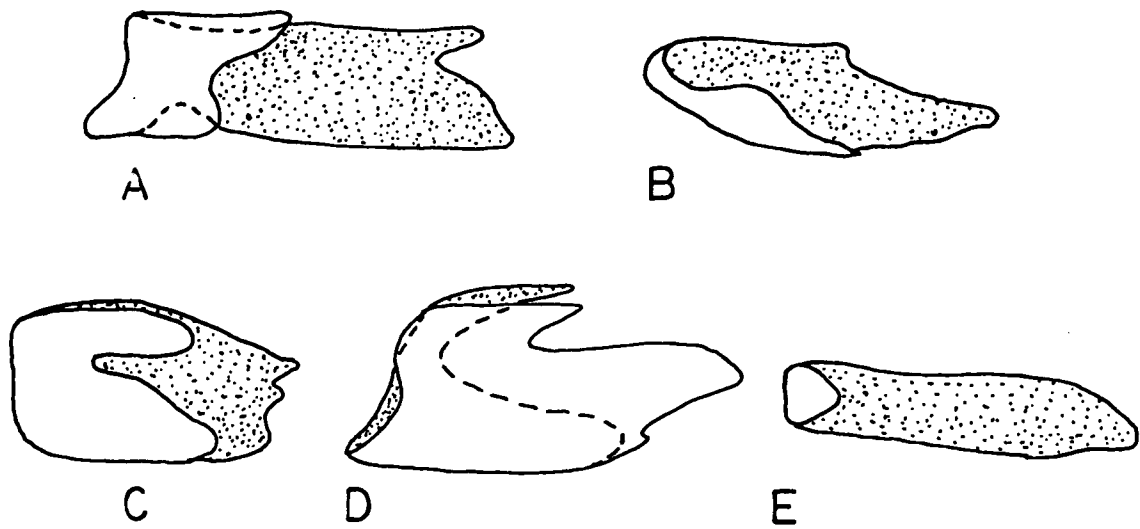


FIG. IV-21

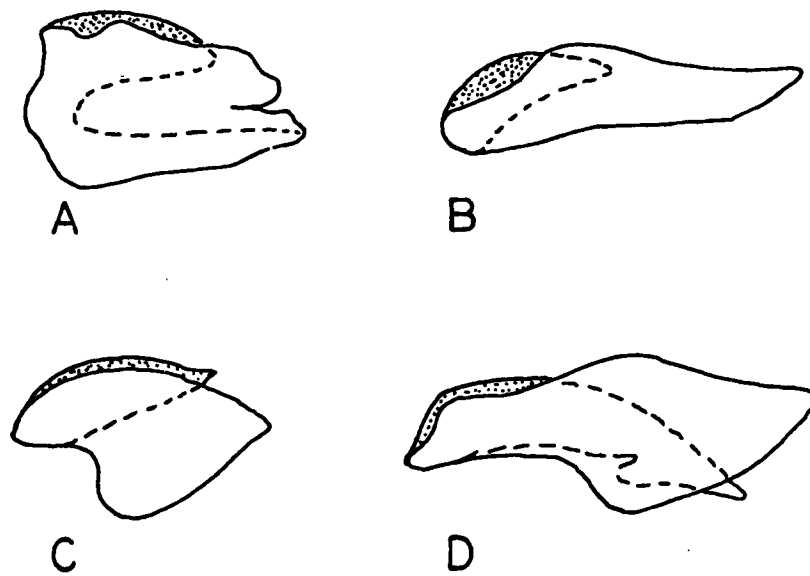


FIG. IV-22

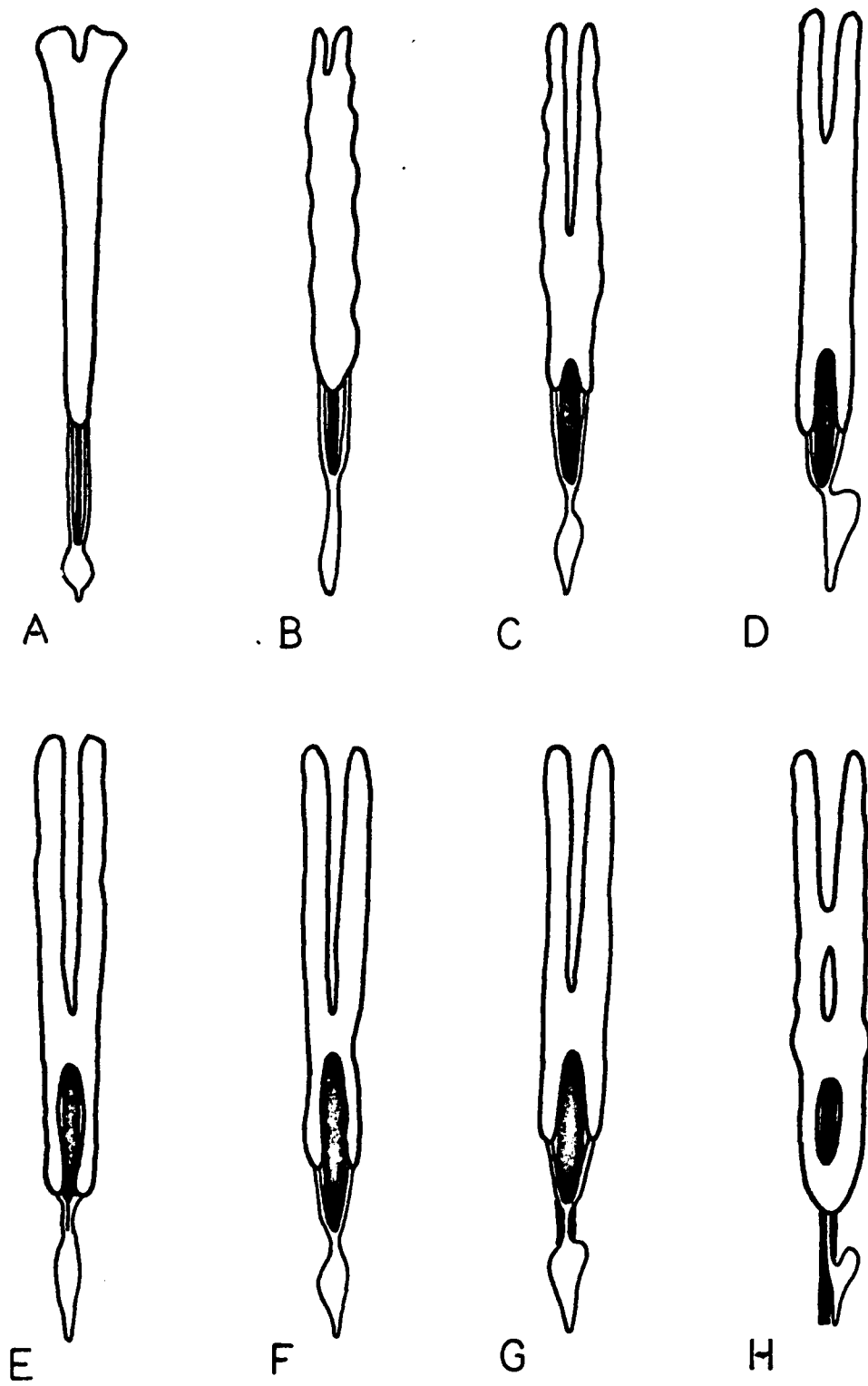
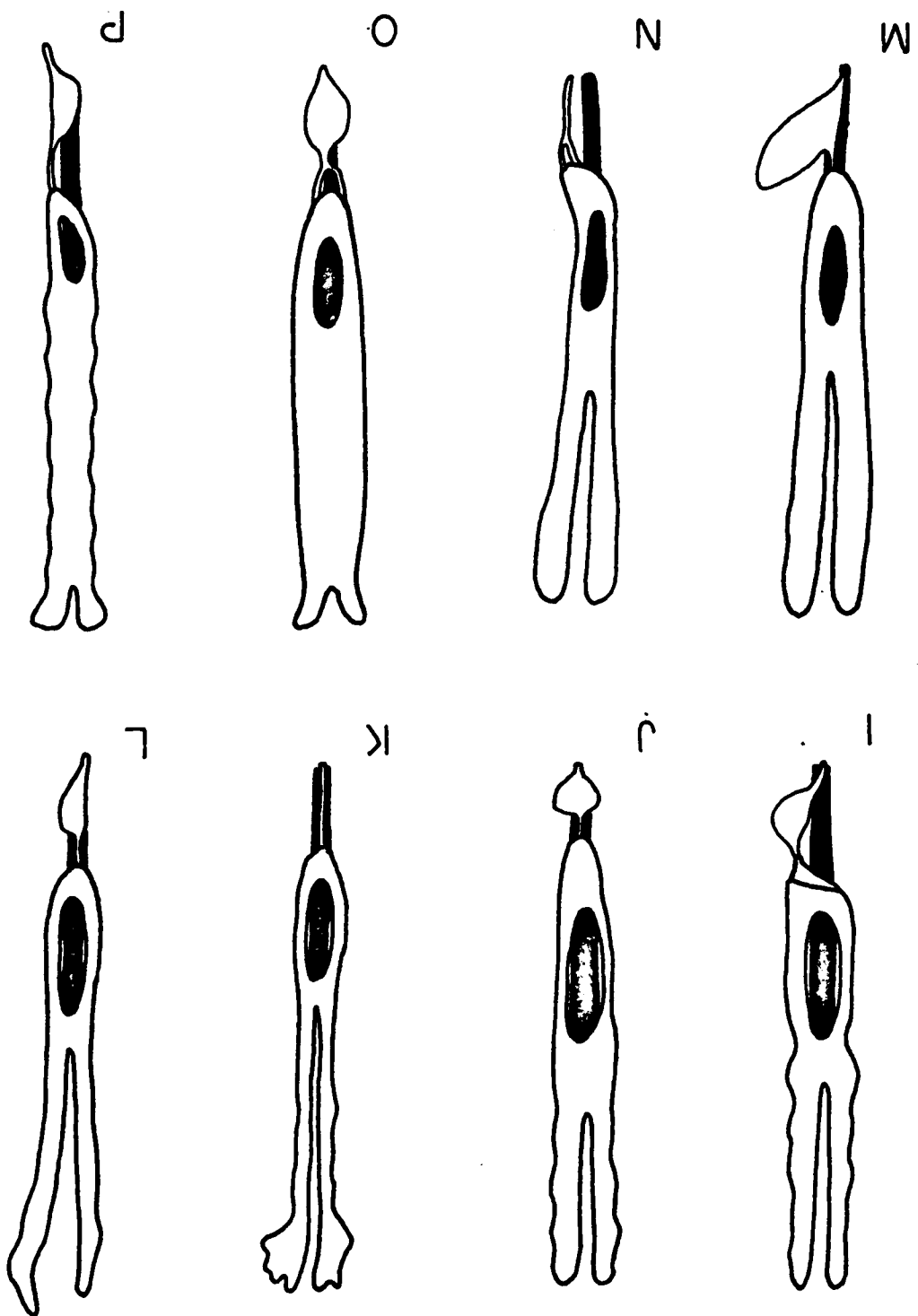


FIG. V-1

FIG. V-1



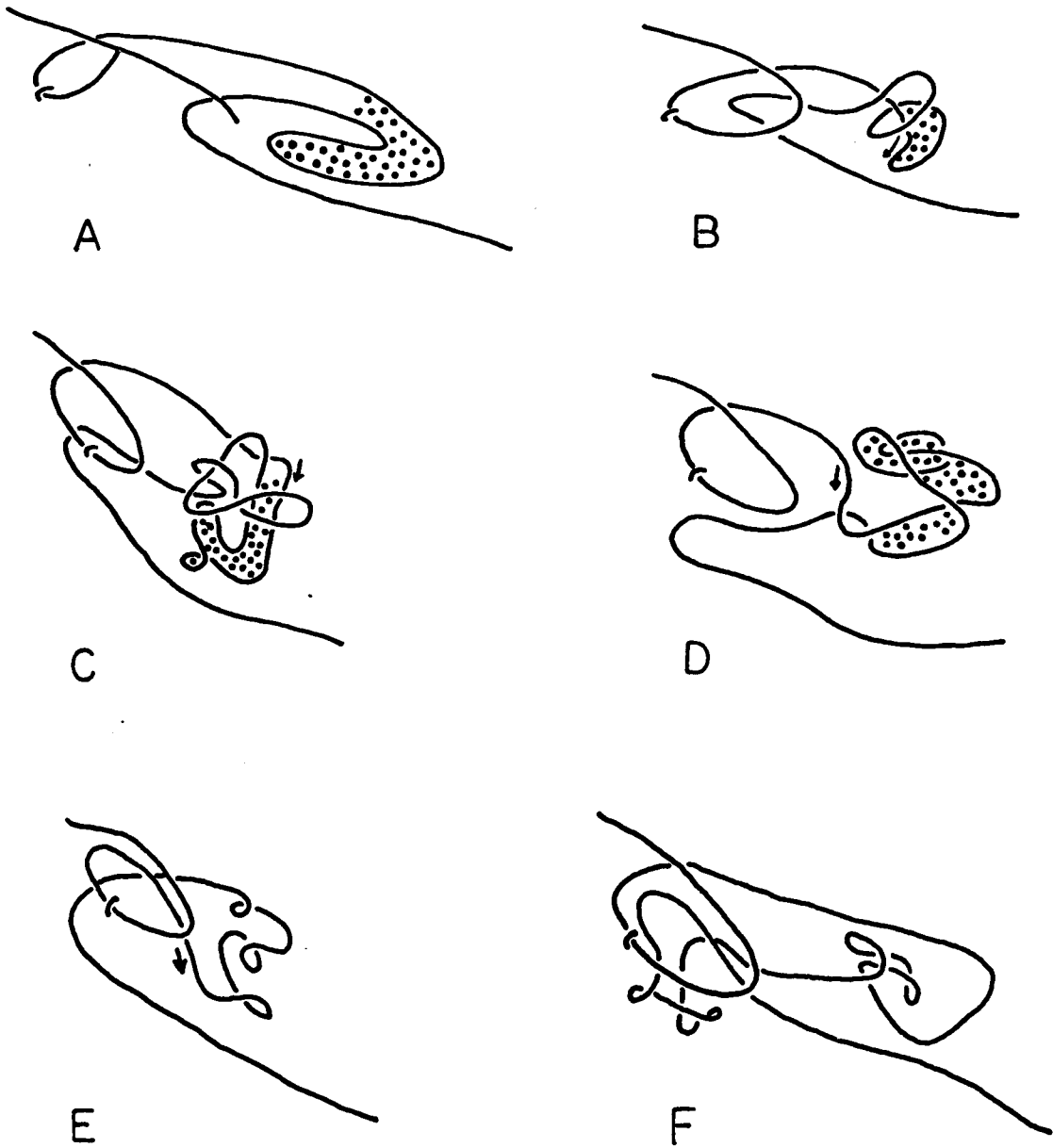


FIG.V-2

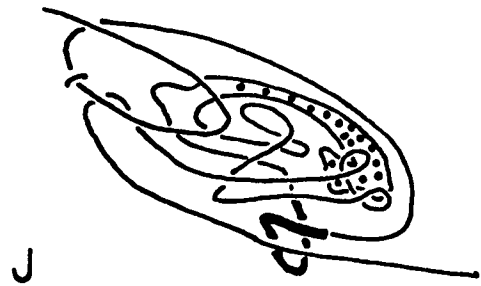
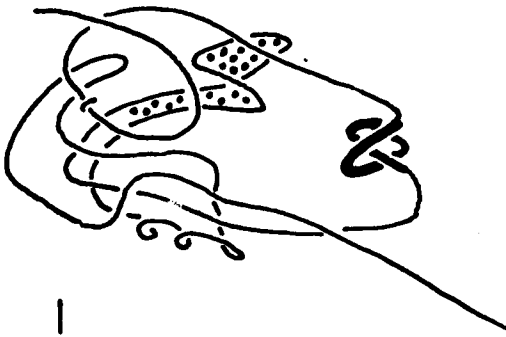
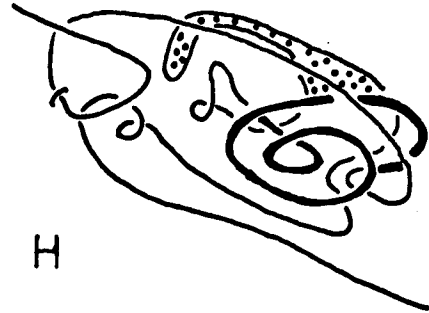
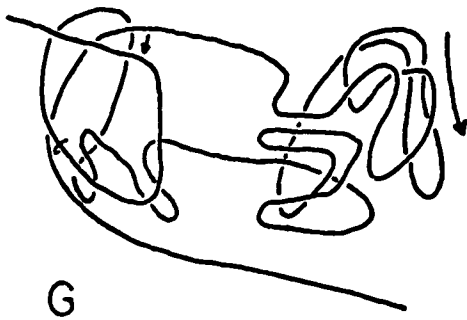


FIG.V -2

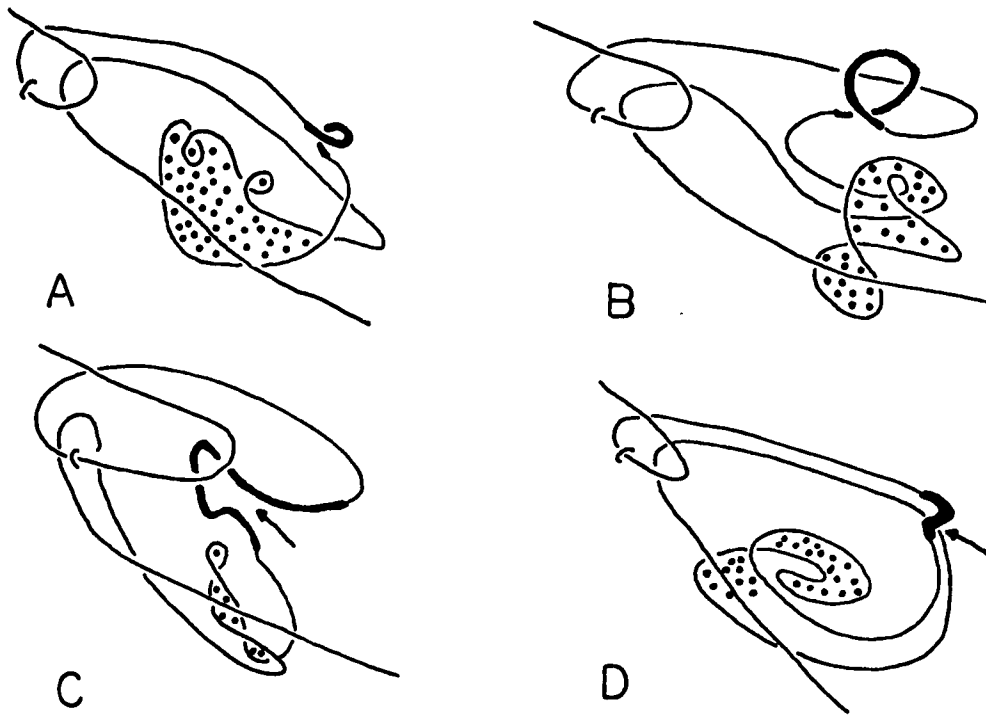


FIG. V-3

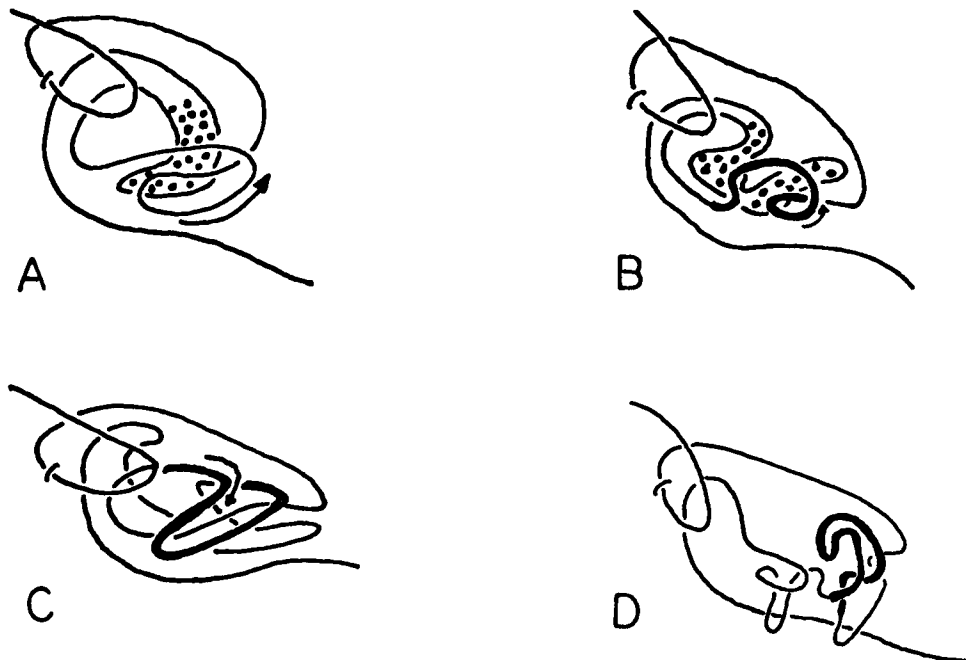


FIG.V-4

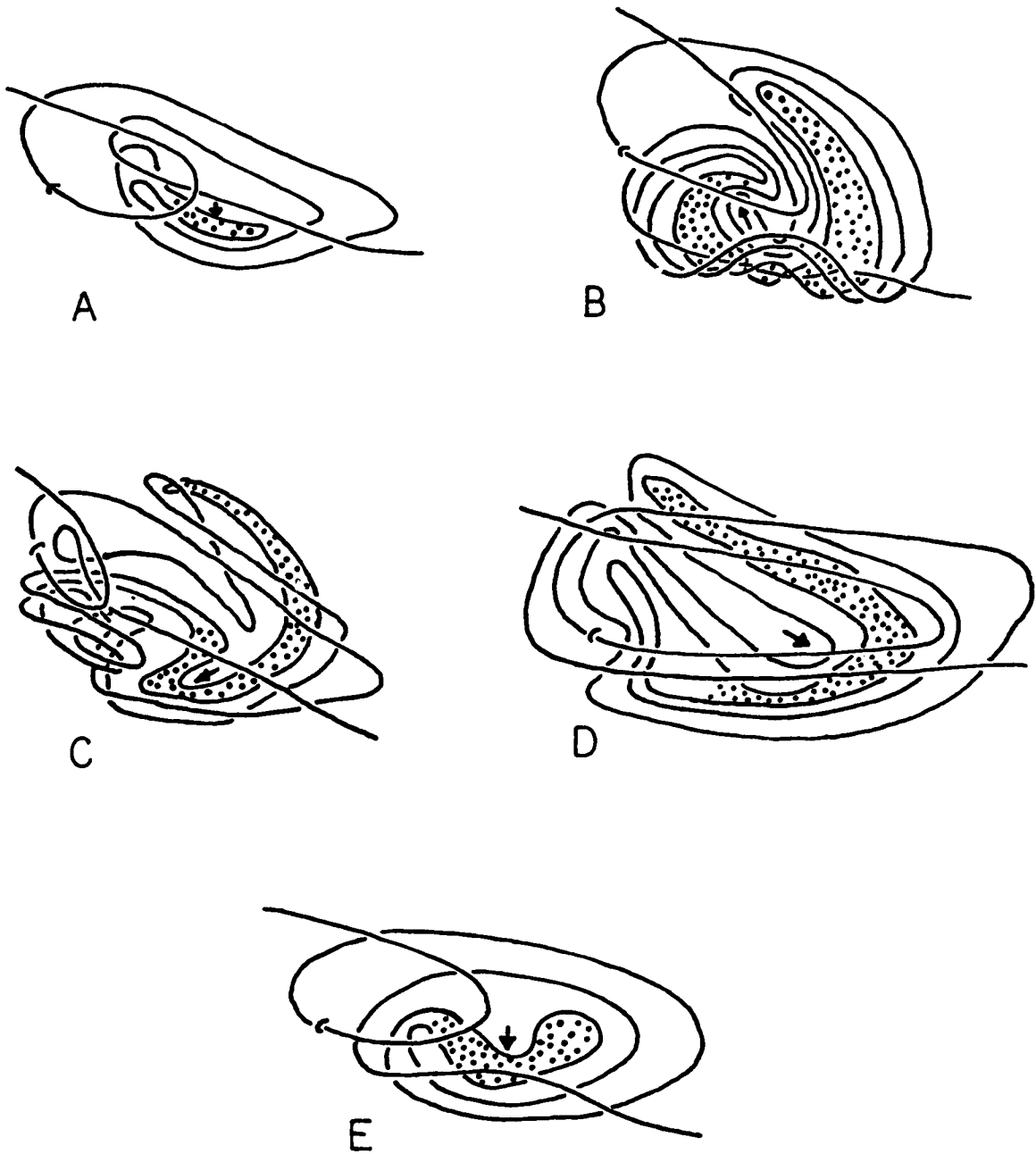


FIG.V-5

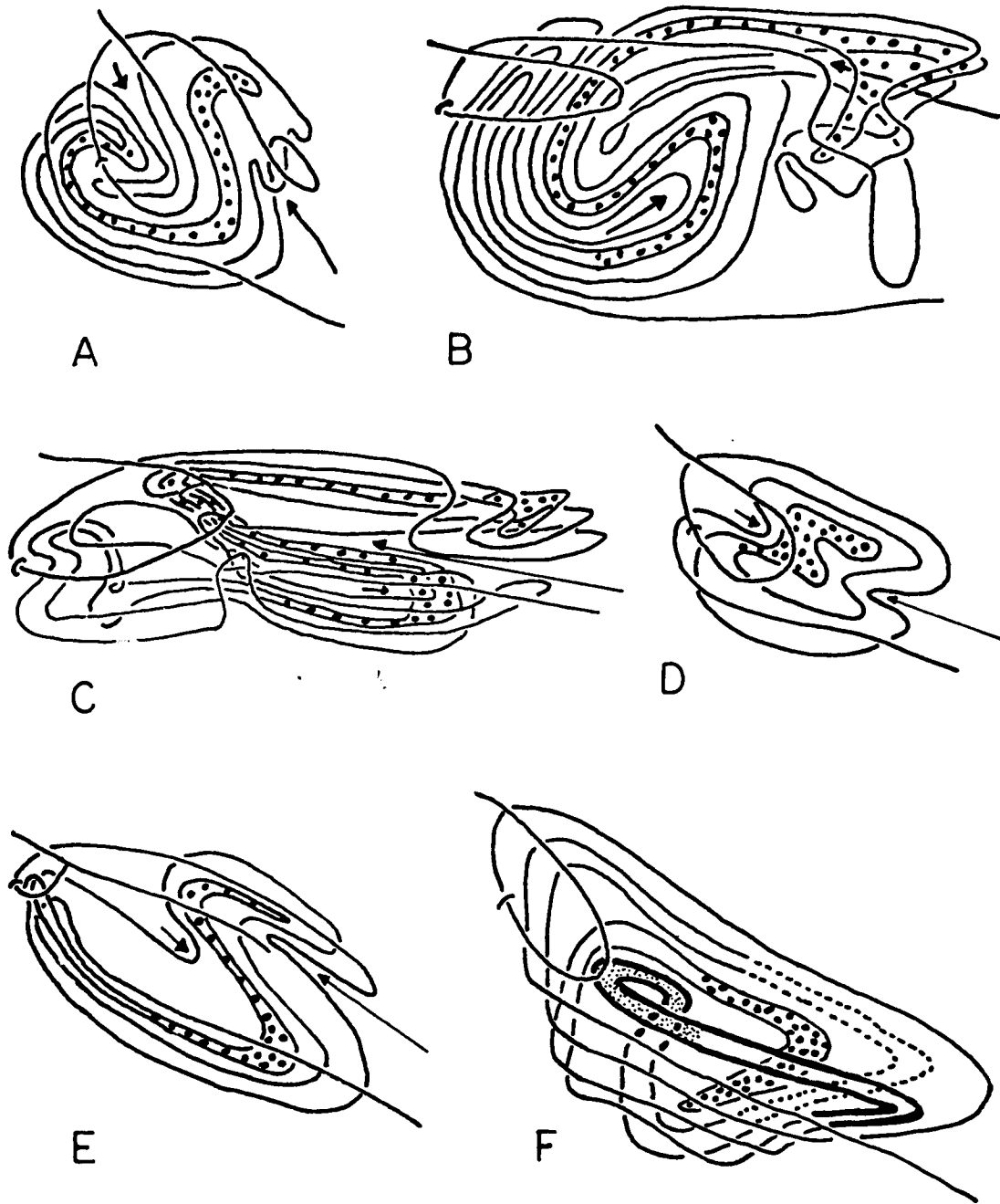


FIG.V-6

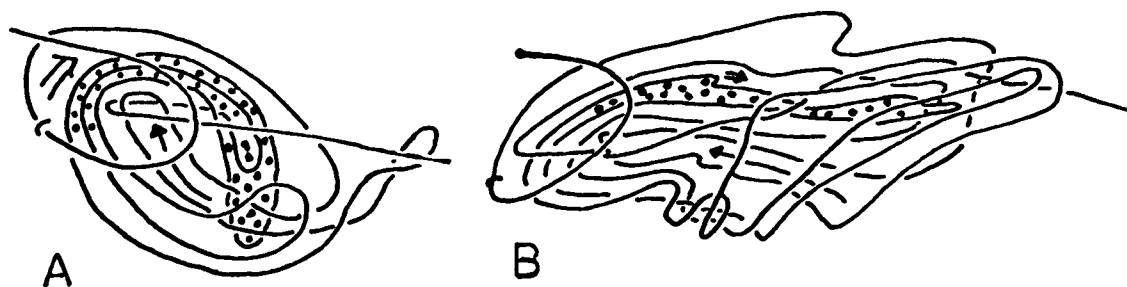


FIG. V-7

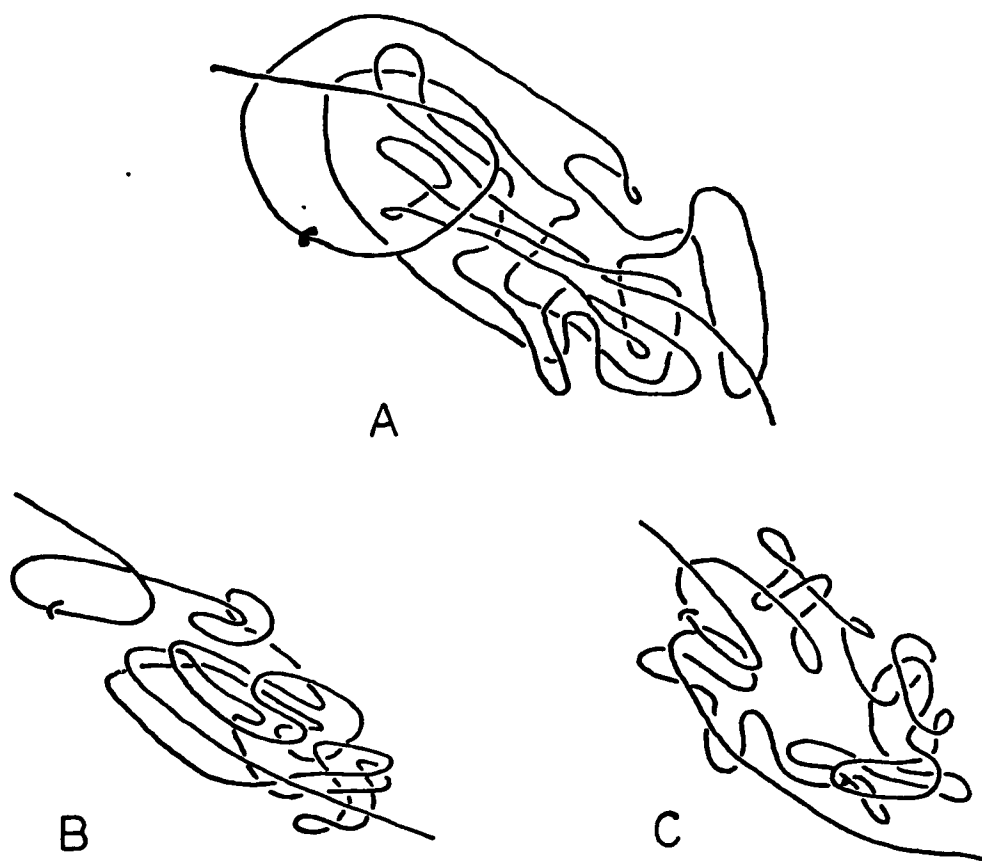


FIG. V-8

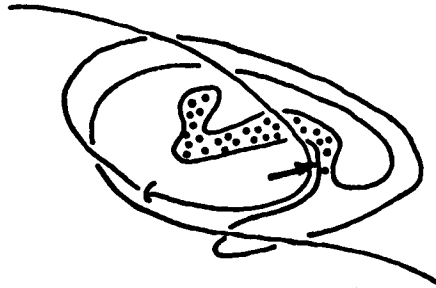


FIG. V-9

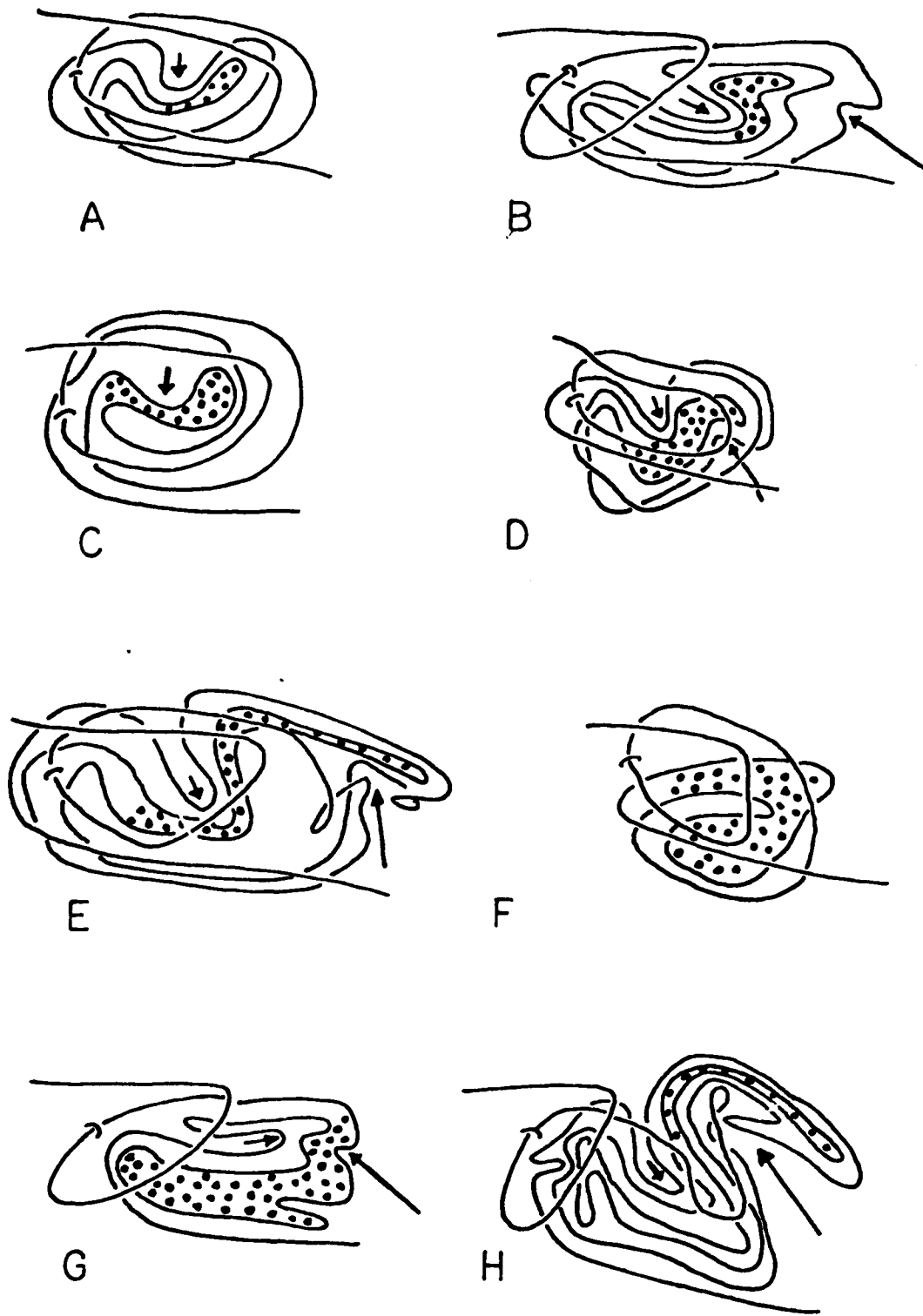


FIG. V-10

FIG. V-11A

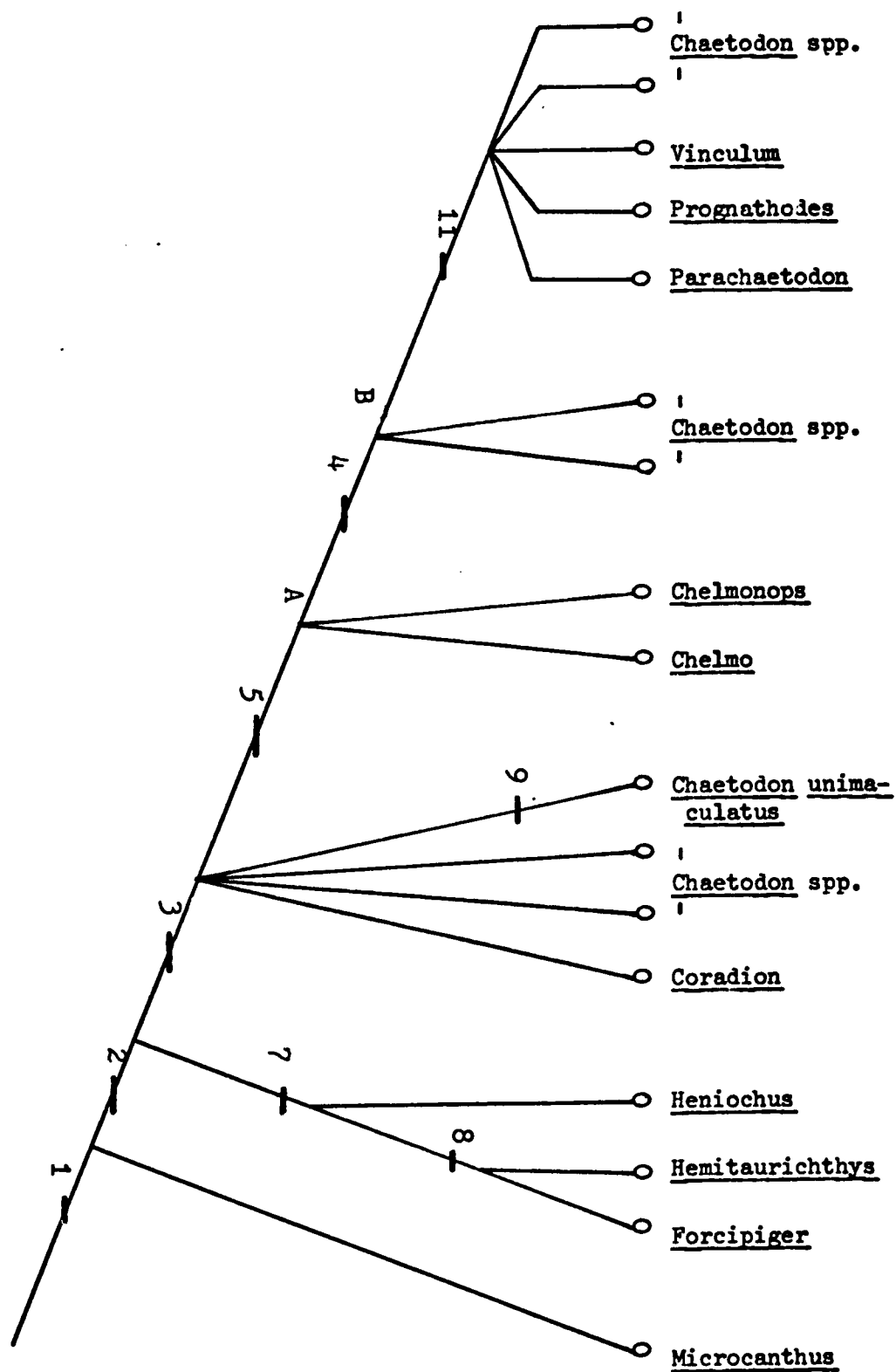


FIG. V-11B

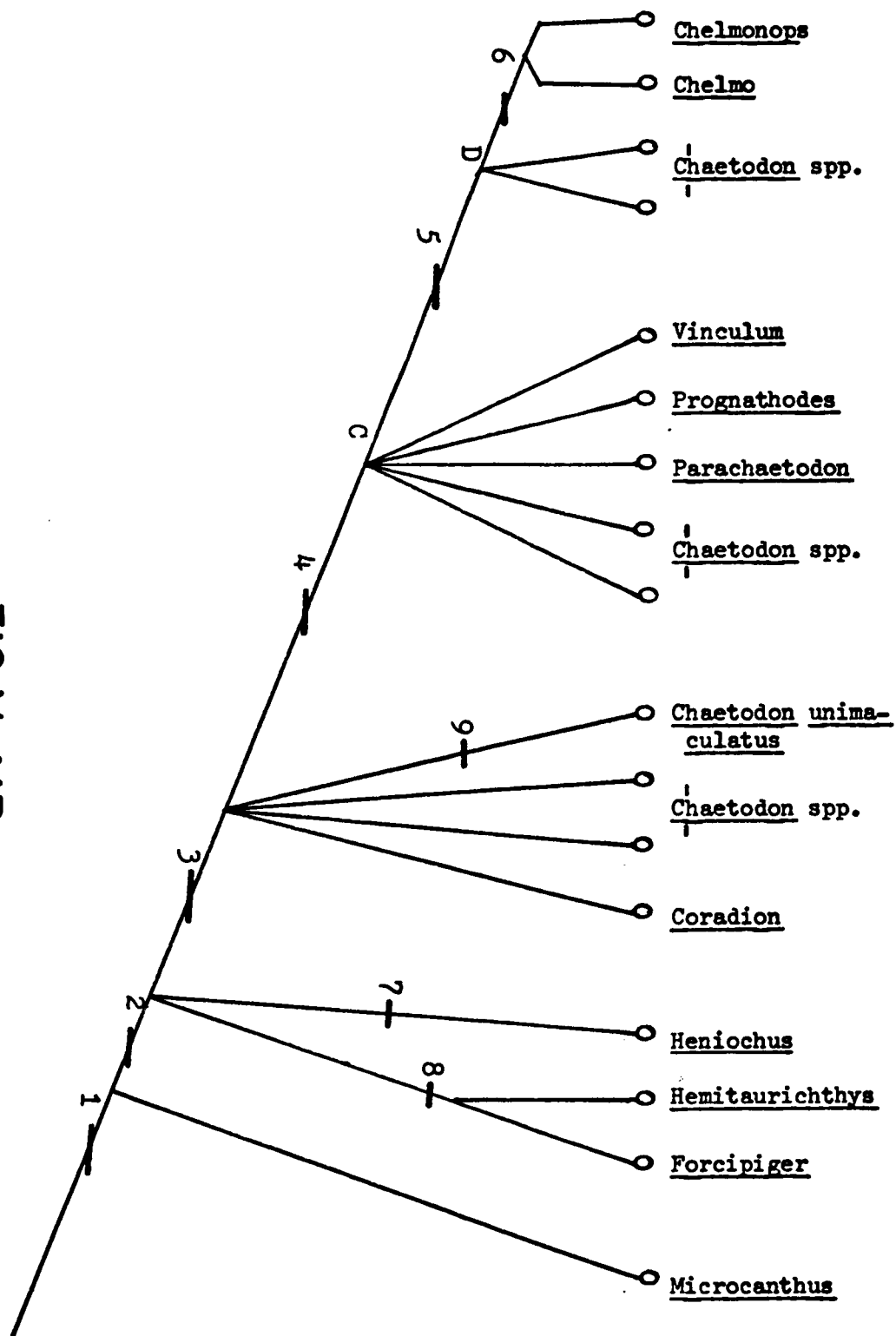
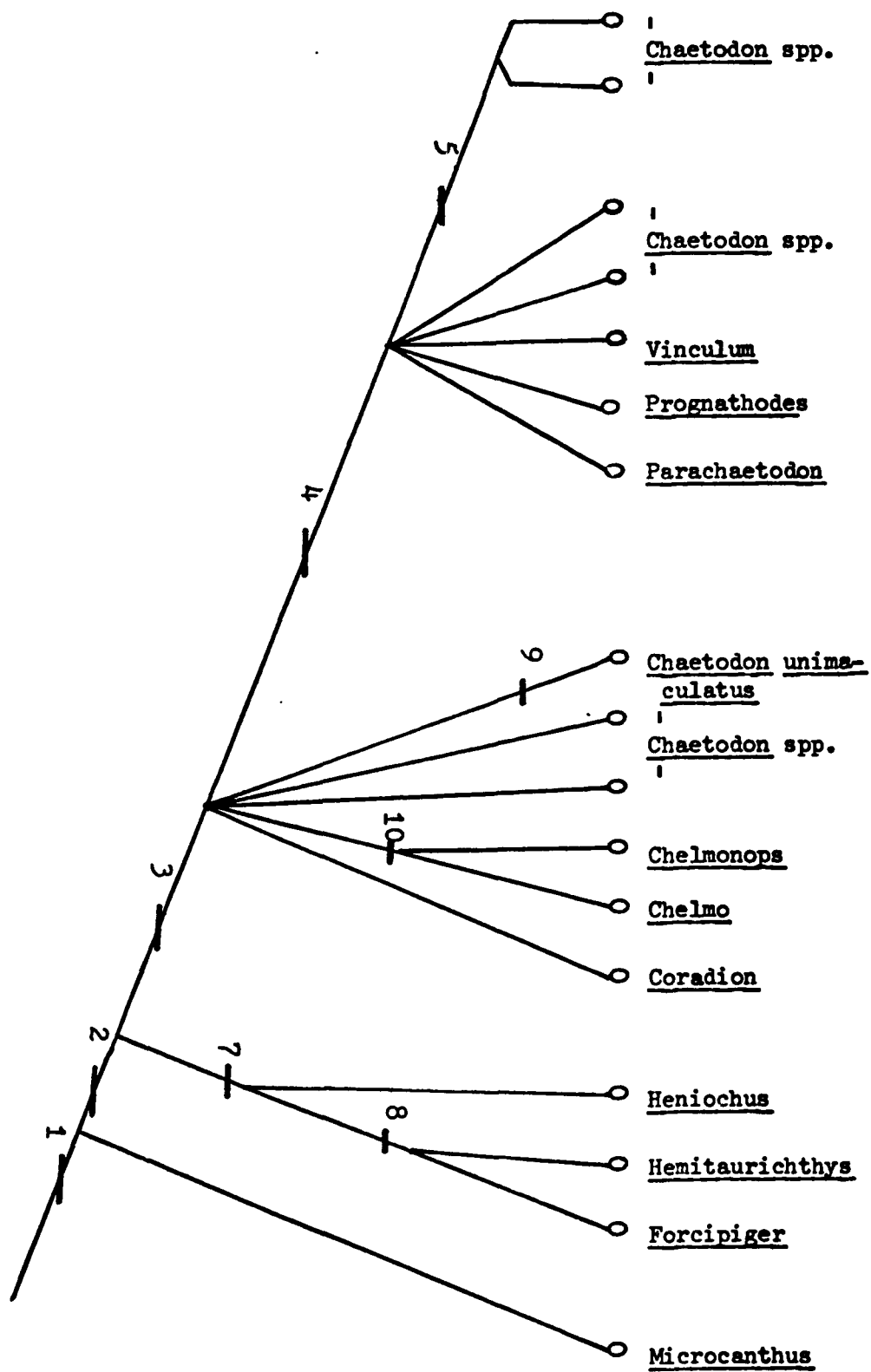


FIG. V-11C



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