35¢

HAMMERMILL
EYE-EASE®

ROBT. BEHNKE
~~JOHN PARKER~~
NAME

~~1540 BENVENUE~~
ADDRESS

Engl. 138
~~[illegible]~~ 1-A
SUBJECT

50 SHEETS
NARROW RULED
MARGIN

NATIONAL
Made in U.S.A.
No. 33-881

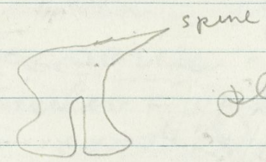
ok

Backus, R.H. 1957 Fishes of Labrador
Am. Mus. Nat. Hist. Bull. 113 273-338

4-6 7-11

Scales Placoid - extinct - dermal denticle in Chond.
Ganoid
Cosmoid
Cycloid - Ctenoid

Scales are dermal

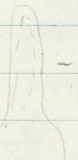


placoid - dentine scale - homologous with mammalian teeth

Ganonine enamal differs from placoid.

- Cosmoid found in Dipnoi - similiar to dentine.

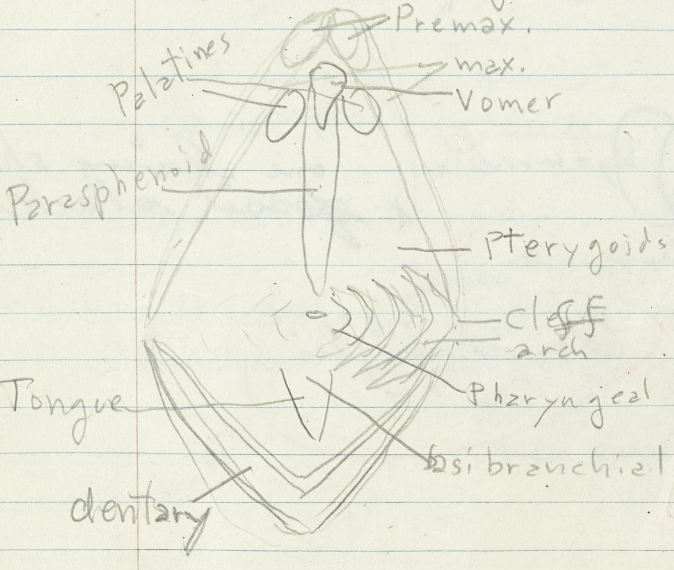
Ceratotrichia - conective tissue for fin support.

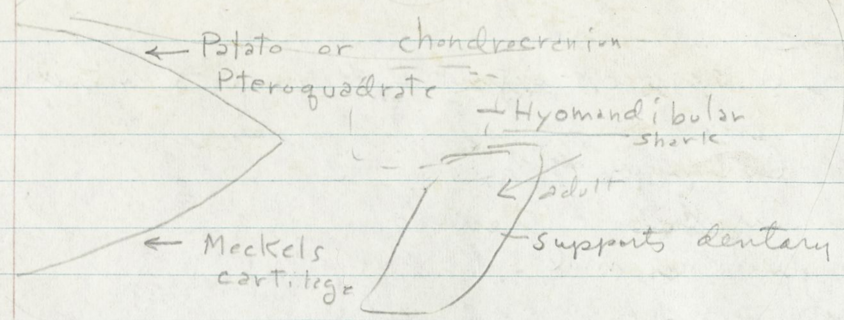


- fin rays of higher fish from scales origin
Lepidotrichia

5 gill bars
- holobranch = 2 pr. gill lamellae
hemibranch = 1/2 holobranch

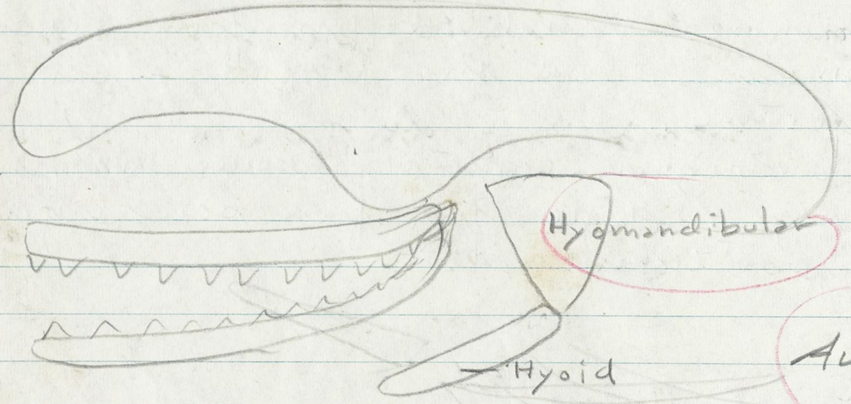
Psuedobranch in chondrichthes spiracle
(hemibranch of 2nd arch (Hyoid)





1st visceral arch (above cyclostomes)

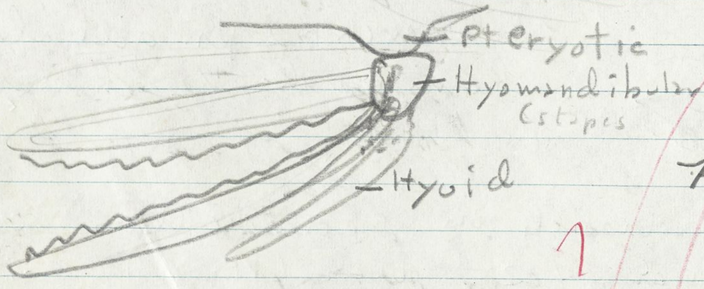
upper jaw teleost not chondrocranium but of new dermal bone -



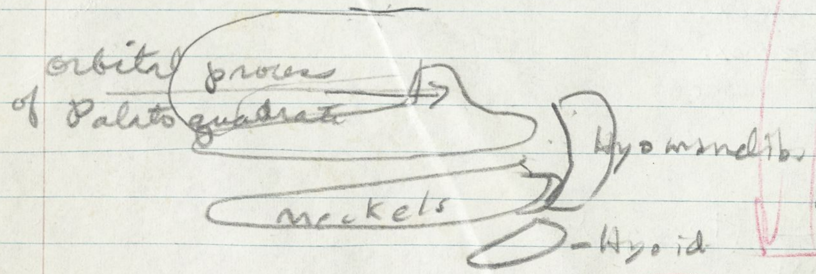
Evolution of
* I - backbone
* II - jaws

[illegible]

Autostylic
(lungfish)



Holostylic
(teleosts)



one living shark
& fossil sharks.

Amphistylic

-- Romer Vert. body - jaw development.

I Cartilage replacement bones.

II ~~Cho~~ Dermal bone.

lower teleosts ~~have~~ still have much cartilage – Dermal (membrane) bones do not have cartilage precursor. – probably modified scales. - frontals, parietals nasal, vomer palatine, max. dentary, angular operculum, orbitals – all dermal –

otic series – cartilage bones – quadrate – articular – ~~sphenotic~~ – branchials – hyoid all cartilage.

pyloric valve – between pylorus – intestine duodenum.

pyloric caeca – on duodenum. – function perhaps to secrete enzymes.

Spleen – compact; ~~gl~~ lobulated, manufacture c destroy blood cells (red)

Pancreas – imbedded in liver. – prob. same as mammal – in sugar ~~s~~combustion.

2 body cavities – cardiac & peritoneum coelom

1 – sinus venosus – 2 atrium 3 ventricle

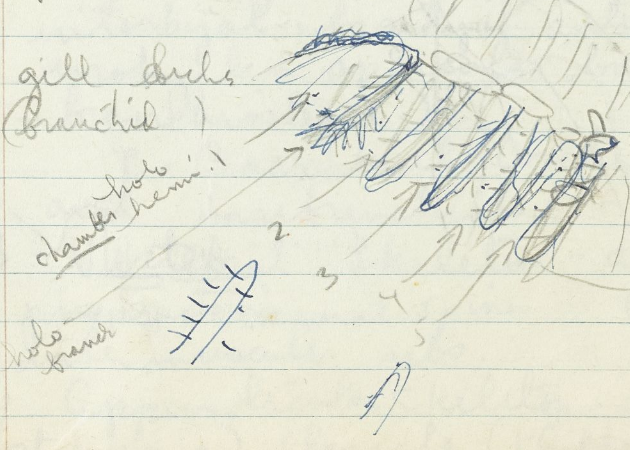
~~Conus~~ a Conus arteriosus – dorsal aorta. – blood from conus arteriosus thru gills.

Air bladder – functions as hydrostatic, respiratory, and sound.

– hyoid – meckels – quadrate . pterygoid ~~angular~~, articular all cart. repla.

palatines ? palatoquad. – max, dentary ? ; angular – derm – p. 258 Romer

– Spiral valve in Teleost (231)



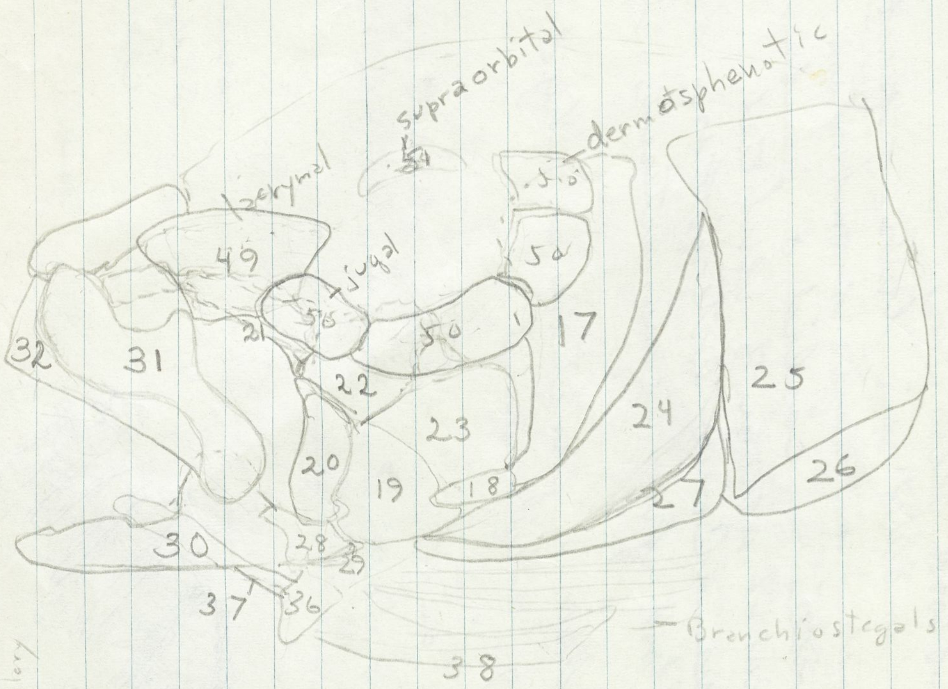
– coracoid

scapula

clavicle – clith

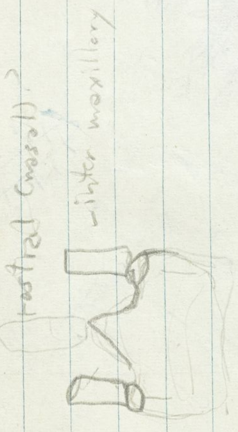
Classification - Wm Gosline, Copeia - Dec. 1949 #4

dermal - cartilage
homologies -



17. Hyomandibular
18. Symplectic
19. Quadrate
20. Pterygoid
21. Palatines
22. Mesopterygoid
23. Metapterygoid
24. Preopercle
25 Opercle
26 Subopercle
27 Interopercle
28 Articular
29 Angular
30 Dentary
31 Maxillary
32 Premaxillary
33-35 - Inter, Epi, ~~Cerato~~-hyal
36 - Basihyal
37. Glossohyal
38. Interhyal

49 - lacrymal
50 - suborbitals



Cerato - horn like
uro - tail
Pter - fern like
opis - behind
ali - wing-like
para - along side of.

Skeletal System

A. Physiology
1. Framework for muscle attachment
2. Physical support,
3. protective structures - scales, scutes
4. defensive mechanisms - spines.
5. reproductive structures - claspers.

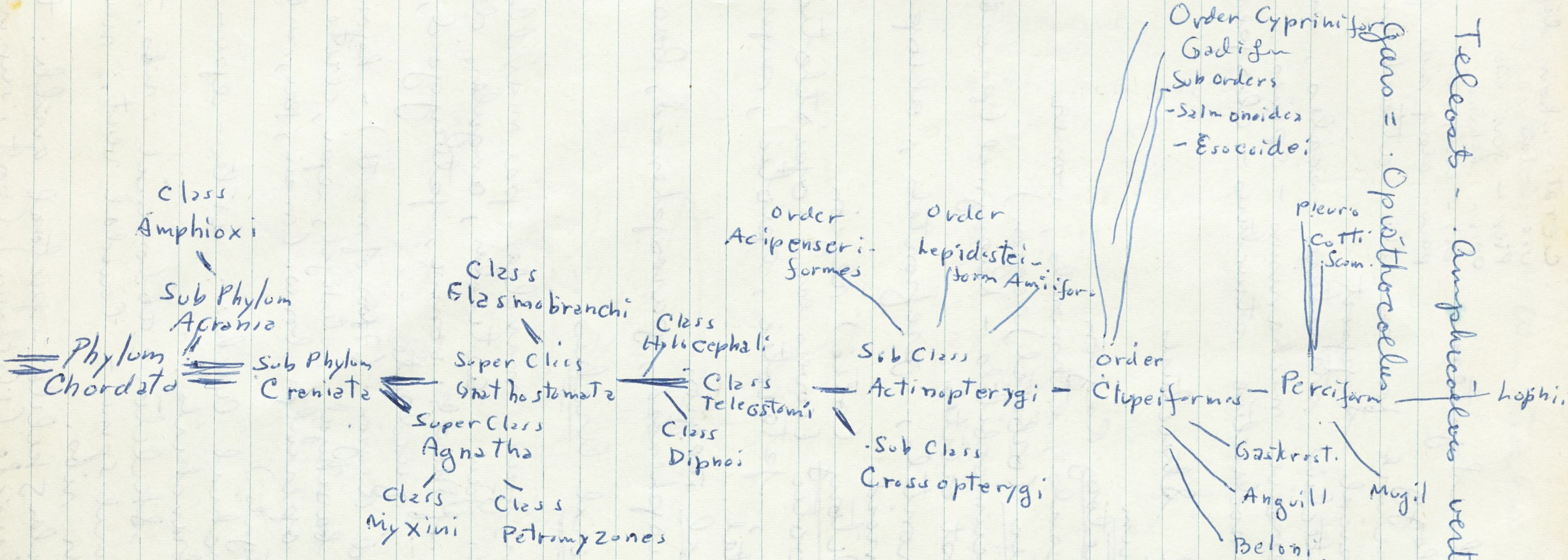
B. Skeletal Structures
1. Cranium
a. Olfactory Region
1. Nasals, ethmoids, vomer
b. Optic (orbital) region)
1. Circumorbitals - Lacrymal (preorbital), sub- & post orbitals.
2. Frontals, prefrontals, alisphenoid, parasphenoid.
C. Auditory (otic) region
1. Prootic (covers ear) opisthotic, sphenotic, pterotic, epiotic, supraoccipital, exoccipital.
d. Basal region
1. basisphenoid, parasphenoid, basioccipital.

2. Visceral Arches

a. Upper Jaw - maxilla - premaxilla
b. Lower Jaw - articular, angular, dentary.
c. Roof of Mouth: vomer, pterygoid, palatines, quadrate ...
d. Hyoid Region: (Floor of mouth) - hyomandibular, interhyal; basihyal, interhyal, epi, cerato - glosso - urohyal - opercular bones - (main, pre, sub, inter, & branchiostegals.)
e. Branchial Arches: inter - epi - cerato - hypo and basibranchials. +

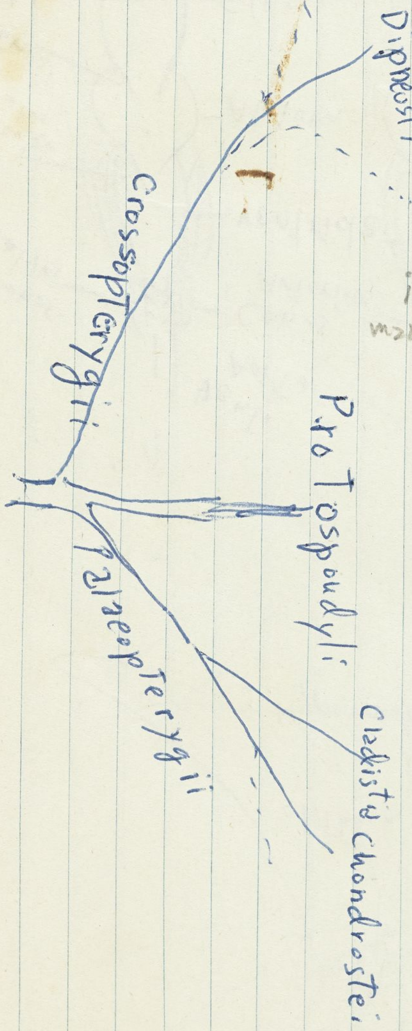
3 - Vertebral Skeleton - abdominal: ribs. transverse processes; neural spines - Caudal vert.: neurals haemal inter muscular ribs.

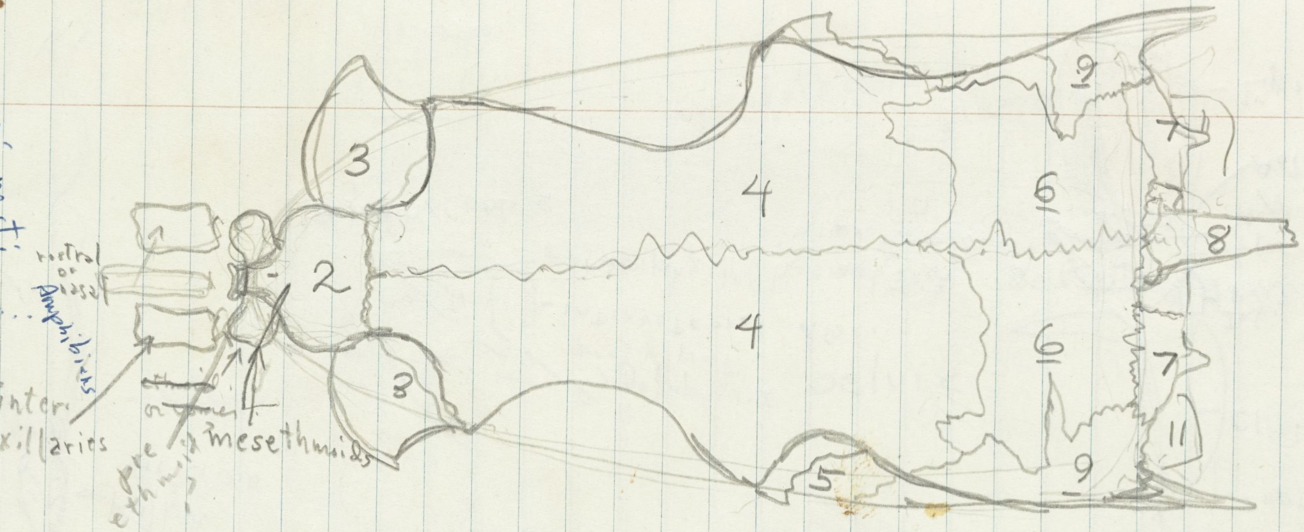
4 Appendicular Skeleton - pectoral girdle: temporals (post - supra) clavicle (clithorum) (post & sup.cl) coracoid
actinosts at base fin rays - — 4-Pelvic —

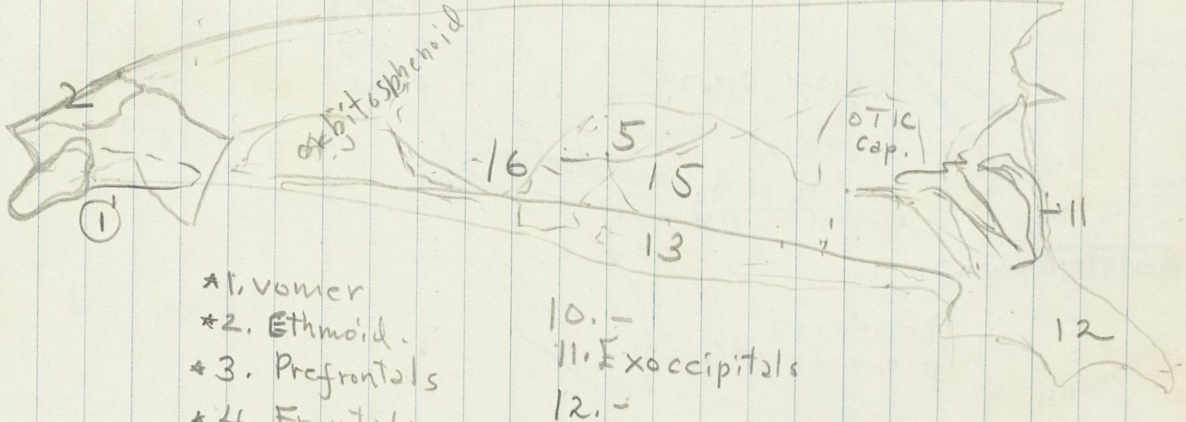


Teleost - amphicoelous vertebrae centrum

Gano = Opisthocoelus



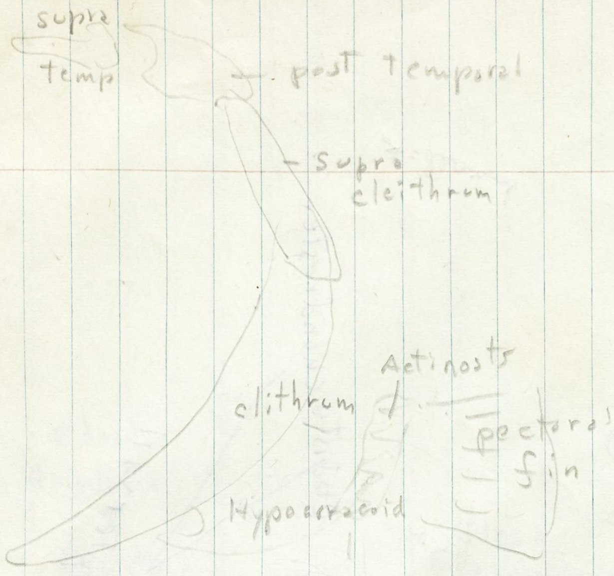




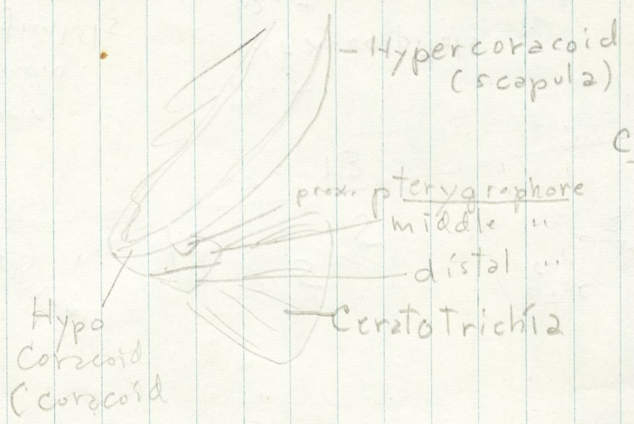
*1. vomer
*2. Ethmoid.
*3. Prefrontals
*4. Frontals
*5. Sphenotics
*6. Paraietals
7. Epiotic
8. Supraoccipital
9. Pterotic

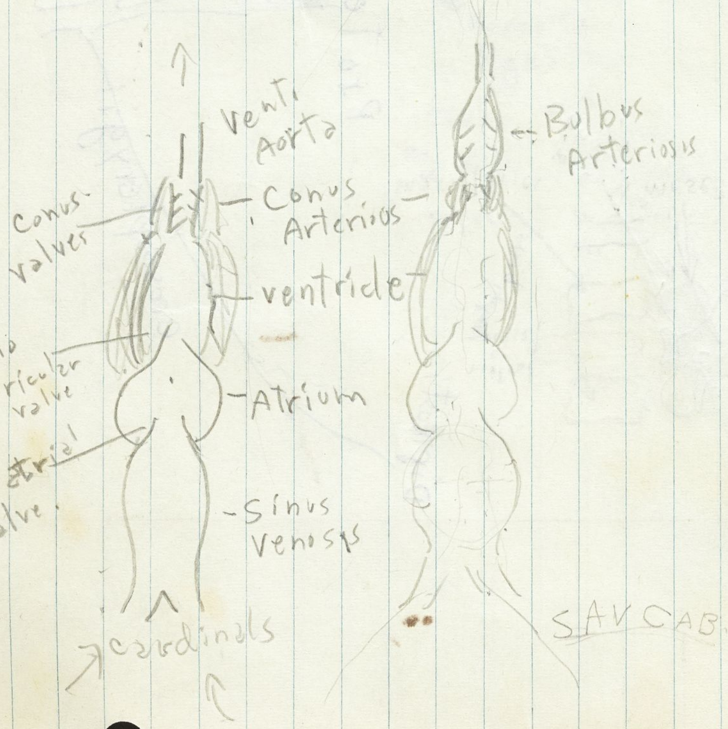
10. –
11. Exoccipitals
12. –
13. parasphenoid
14.
15. Prootic
16. Alisphenoid

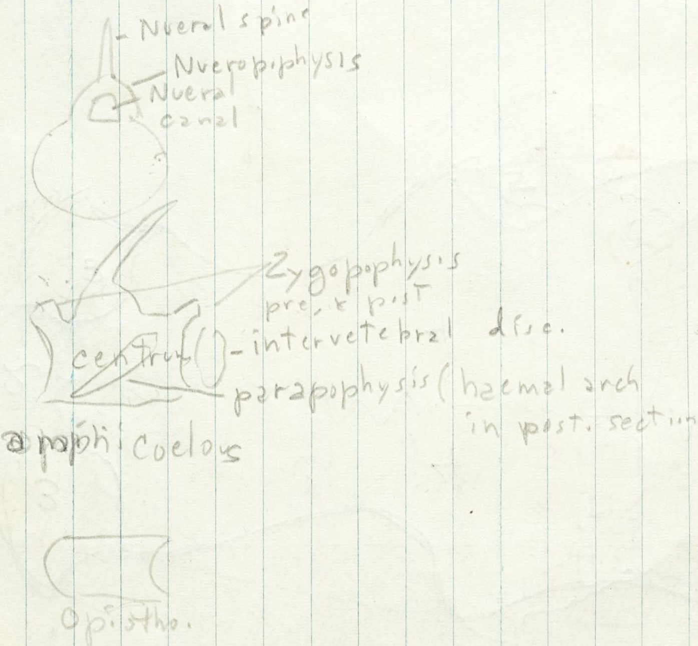
*=dermal

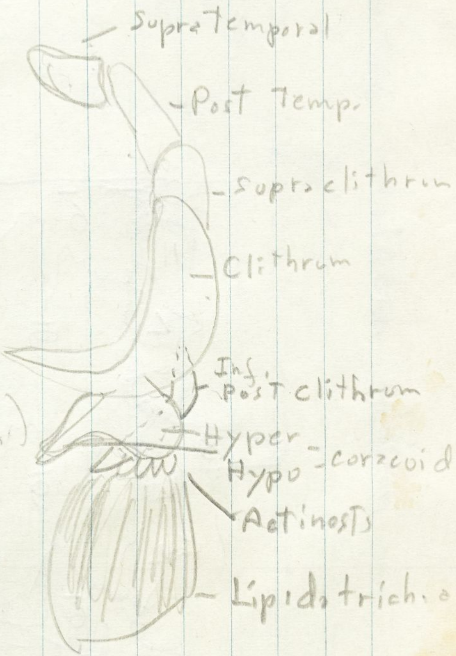


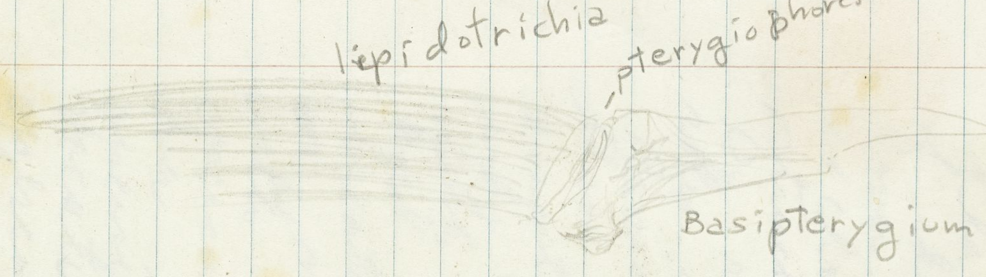
Chondriichthyes



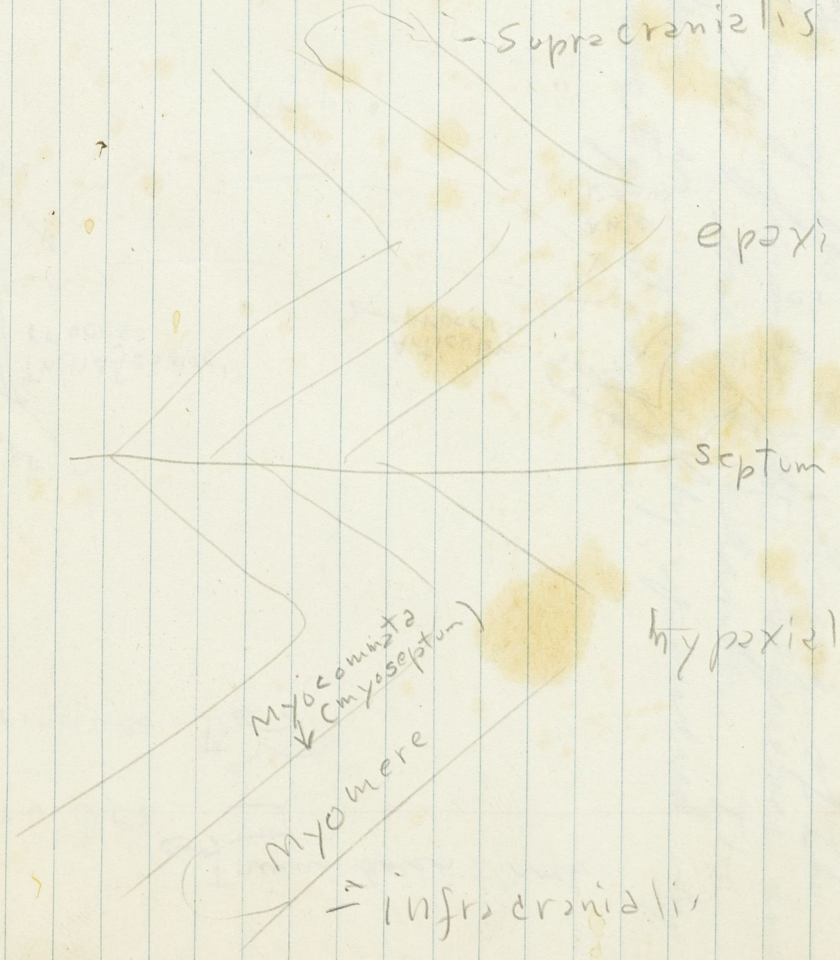


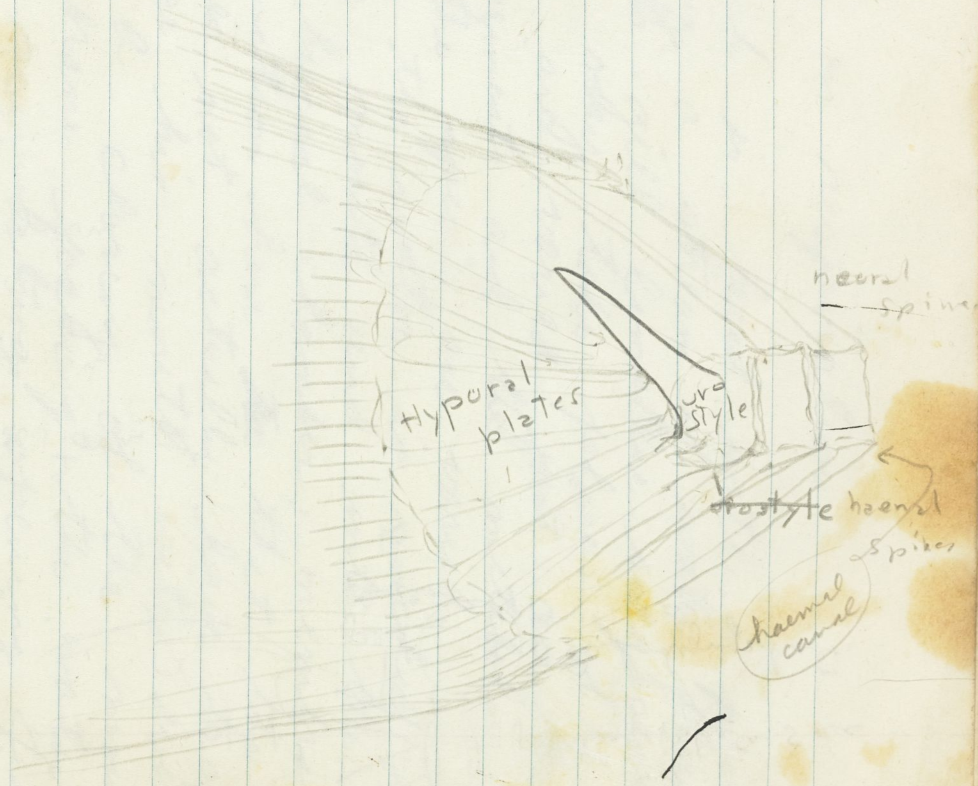


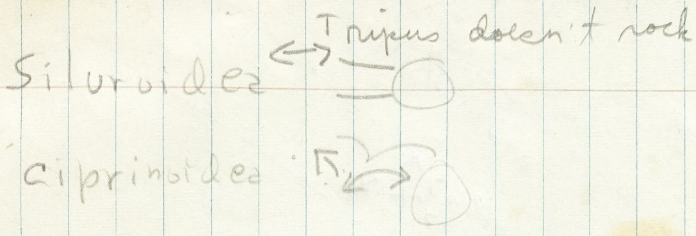


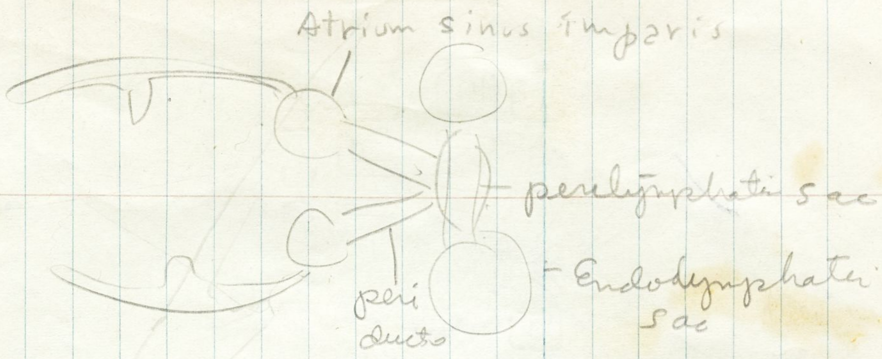

lepidotrichia
pterygiophores
Basipterygium

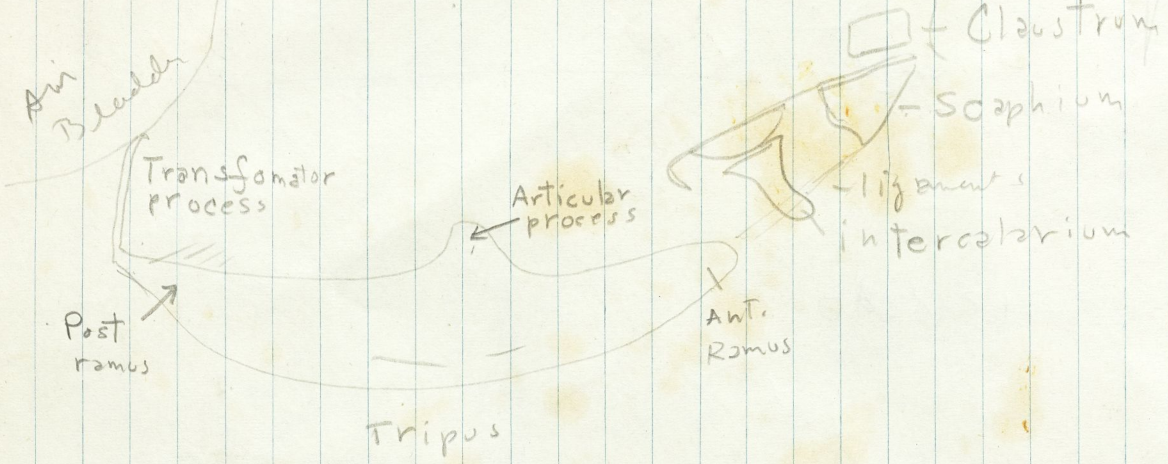
pelvic


Supracranialis
epaxial
septum
hypaxial
Myocommata (myoseptum)
Myomere
infracranialis


neural spines
Hypural plates
uro style
~~urostyle~~
haemal spines
haemal canal


Tripus doesn't rock
Siluroidea
Ciprinoidea


Atrium sinus Imparis
perilymphati sac
Endolymphati sac
peri ducts

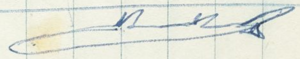
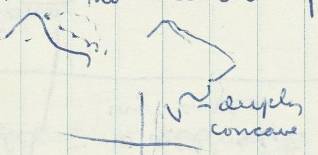
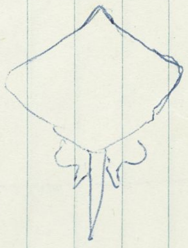
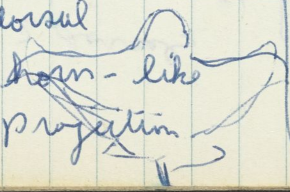

Claustrum
Air Bladder
Scaphium
ligaments
intercalarium
Transfomator process
Articular process
Post ramus
Ant. Ramus
Tripus

CSIT

Comments on respiration

The fish is faced with a problem of keeping a stream of water flowing over its gill lamellae so gaseous exchange may take place. The structures are varied just as the O_2 requirements and the metabolic rates of the species are varied.

Basically the water is sucked in thru the mouth and into the empty buccal chamber, membranes may function here ~~so~~ that the fish does not actually have to open and close his mouth with every breath. A closing of the mouth or membrane forcing the water back with a simultaneous opening of the operculum allows the water to pass over the gills. A closing of the operculum finishes the sequence and vacates the buccal chamber. The operculum is generally powered by branchiostegal rays.

Name Scientific & common	order	family	Distinguishing characters	Range	Habitat	Ecological Importance
Sphyrna Tiburo Bonnethead 	Selachi		External gill openings 5-[illegible] anal fin present head spade shaped			
"Dogfish Squalus acanthias	"		no anal fin spines in both dorsals			
Calif. Skate Raja inornata	Batoidea		2 - dorsals  Skin rough Tail - not well developed  			
Stingray Urobatis halleri	"		spine - no dorsal fin 			
Angel & Shark Squatina Californica	Selachi		- 2 dorsals - pectorals not attached! gills in notch 			
Holorhinus Californicus Bat-Ray	Batoidea		- 1 dorsal no horn - like projection 			

Electric ray Torpedo Californica	Batoidea		- 2 dorsals - skin smooth 	
Ratfish Hydrolagus Colliei	Chimera			
Hagfish	Hyper.	Entrapetradae	- no gill slits no eyes	nasal open. ?

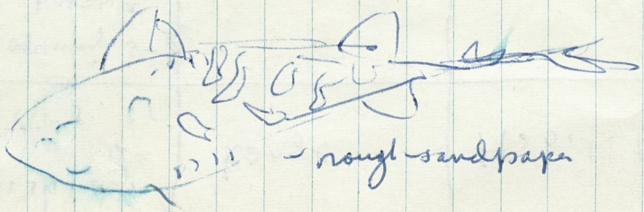
Amphioxus

Lamprey ammocoets

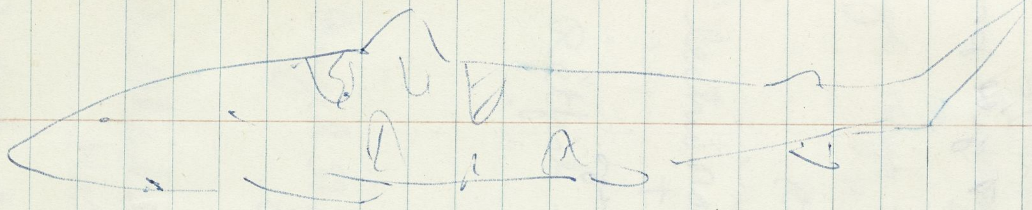
Pacific lamprey

Cephaloscyllium venter Selachi

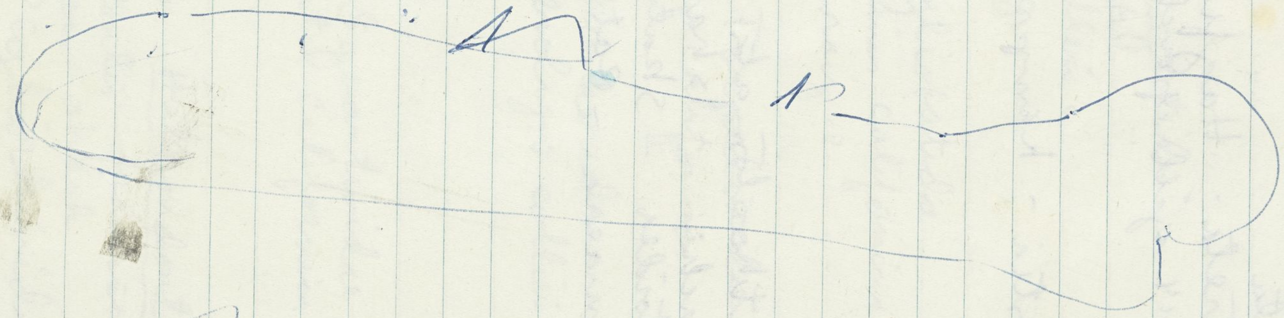
Swell shark



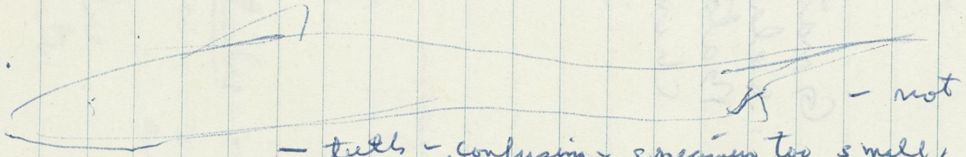
Leopard Shark
Triakis
semifasciata



Horn Shark
Heterodontus
francisci



Soup fin
Galeorhinus
zyopterus



— not crescent shape

— teeth —. confusing — specimens too small.

Sub Phylum - Cephalochordata =
Class Leptocardii   Amphioxus

Super class Agnatha -
Class Cyclostomata
order Hyperotreta - Hagfish - barbels - nasal to pharynx - 12-14 gill pouches no rasping device

order Hyperoartii - Lamprey 7 gill pouches - rasping device

- Super Class Gnathostomata
- order Selachii - sharks.
order Batoidea - Skates rays
order Chimaera - Ratfish

Dog Fishes - Squalidae anal fin absent
- Squalus acanthias spines dorsal

.. - <u>Chondrichthyes</u>

Family & Characteristics

Skates = Rajidae
Raja inornata
<u>Calif, skate</u>

Sting rays: Dasyatidae
~~Raja inornata~~
Urobatis halleri
Sting ray

Eagle rays: Myliobatidae
Holorhinus californicus
Bat ray

Electric rays: Torpedinidae
Torpedo californica

Ratfish: Chimaeridae
Hydrolagus colliei

Angel Shark: Squatinidae - ray-like c ~~no spiracle~~
Squatina californica no anal fin

Bullhead Sharks: <u>Heterodontidae</u>: - ~~teeth not in bands, bladelike~~
Heterodontus francisci - spine in front dorsals
Horn shark anal fin present.

Cat shark: Scyliorhinidae
Cēphaloscyllium uter
Soup fin

Smoothound: <u>Triakidae</u>
Triakis semifasciata
(Leopard shark)

Hammerhead = Sphyrnidae - head expanded.
Bonnet head Sphyrna tiburo (

Class Osteichthyes

Order Dipnoi - Neoceratodus -
Lepidosiren - Protopterus

- Chondrostei - Acipenseridae
Cladistia Polydontidae
Polypteridae

- Ginglymodi - Lepidosteidae
- ~~Am~~
- Halecomorphi - Amiidae

- Isospondyli

both premaxillary and maxillary form margin of upper jaw - no modified ant. vertebrae - Opercular bones well developed. - homocercal tail - Physostomous - Abdominal pelvic fins.

- Clupeidae: herrings, sardines, shad.
- lat. line traversing 2-5' ant. scales
- scales large
- teeth reduced or absent - abundant gill rakers
- Pseudobranchiae
- no adipose fin
- pelvic appendage

- Engraulidae: anchovies
- sub term. mouth - long max.
- no lat. line.

- Salmonidae
- adipose fin
- pelvic appendage
- strong well armed mouth.

Coregonidae
- fewer scales (less than 100 in l. l.)
- small mouth - few or no teeth
- pelvic appendage present
-

Thymallidae:
- parietals meet in middle - parietals prevent supra occipital from touching frontals. as in Salmonidae.
- gill rakers as in trout

- Osmeridae:
- teeth well developed
- pelvic appendage lacking
- fewer 100 scales

+ Isospondyli - (Clupeiformes)
- Elopidae - see (gular plate)
- Chanidae - milk fish
- Engraulidae - Anchovy.
- Sub order Salmonoidea

Salmonoidei - Sub order

Salmonidae (Salmonidae + Coregonidae)
last vert. upturned - an orbitosphenoid.
An opisthotic (intercalary)
Salmonini - A basisphenoid. No hypethmoid
(an unpaired bone below dermal ethmoid)
A supraopercular. - No dermosphenotic
I (1) - Otic region of Chondrocranium dorsally w/
pair large foramina roofed by post.
ends of frontals. - Salmo, Salvelinus,
Hucho, Salmothymus, Brachymystax
(2) - No foramina in Chondrocranium Onchorhynchus.

II Coregonini - hypethmoid present,
basisphenoid present or absent. no supra
opercular - foramina in chondrocranium.
A dermosphenotic

Thymallidae - Thaumaturidae extinct
Plecoglossidae - last vert. not upturned

Osmeridae - last vert. not upturned

Argentinidae - last not upturned

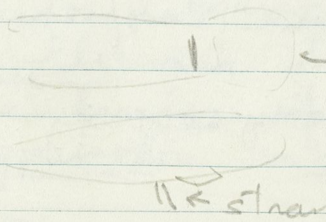
- Check scales on Brachymystax
- X-ray - brachy - look for up turned vert. ✓

order Haplomi
Esocidae, Umbridae, Dallidae

order Iniomi
Myctophidae (C&W)

order Ostariophysi
sub order Cyprinoidei - Characinidae
- Gasteropelecidae - True flying fish.
~~sub order~~ Electrophoridae (Gymnotus)
Cyprinidae
Catostomidae
Cobitidae
sub order Siluroidea
Ictaluridae
Pygidiidae
Doridae (Callichthyidae)
Corydoridae
Loricariidae
Malapteruridae

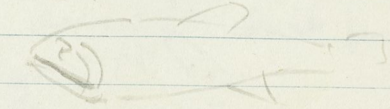
Ex. on display - Esox americanus - Barred Pickerel



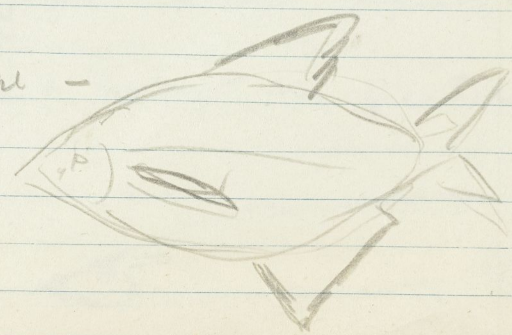
- Umbra limi - mud minnow
- Dallia pectoralis

strand for pelvics

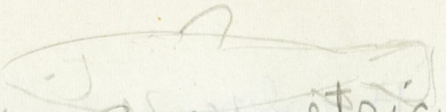
- Iniomi - ex. of - (lanthern fish)
- pearl organs - resembles
small anchovy



- Characinidae -



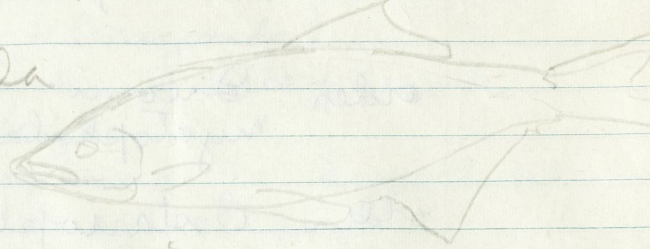
Ctenobrycon
spilurus



Hesperoleucas symmetricus
Venus Roach

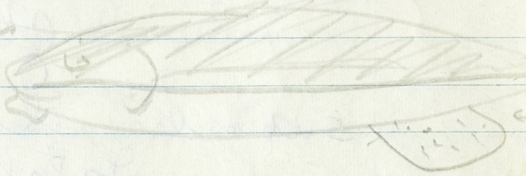
Lavinia exilicauda

Hitch



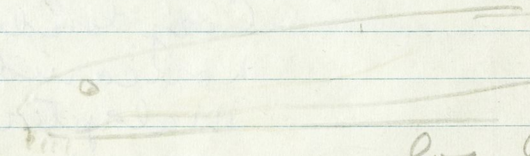
Catostomus commersoni

Catostomus tahoensis



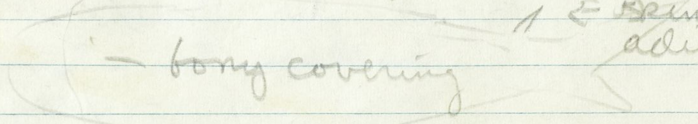
Cobitus taenia

Cobitidae



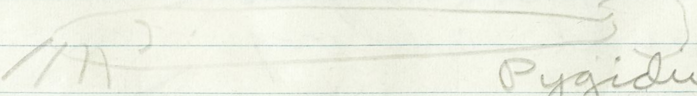
loach

Placostomus - S. Am. catfish



Loricariidae

Ictalurus nebulosus
Brown Bullhead



Pygidium

Pygiidae

order Apodes
  Anguillidae - Freshwater eel - scale patches
  Congridae - Congers - scales absent
  Muraenidae - Morays - minute - no pectorals?

order Synentognathi
  - Sub order - Scombersocidea
    Scombersocidae - (Sauries)
    Belonidae - needle fish
  Suborder - Exococtoidea
    Exococitae - flying fish
    Hemorhamphidae - half beaks.

order: Microcyprini - tooth carps.
  Cyprinodontidae - egg layers
  Poecilidae - live Bearers

order Salmopercae
  Percopsidae - trout perch - adipose fin
  Aphrerododeridae - pirate perch.

examples

Microcyprini - Molliensia latipinna - Poecilidae
- Gambusia affinis
- Cyprinodon macularis - (Saltaser) } Cyprinodontidae

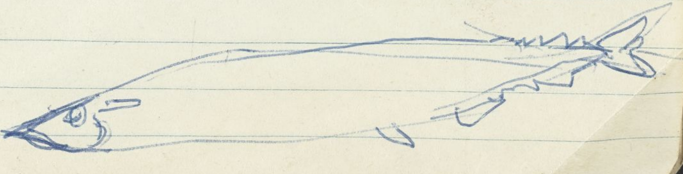
Salmoperca - - ~~Op.~~ Percopsis omiscomaycus - trout perch - adip. - fin
- Aphrodederus sayanus - Pirate perch

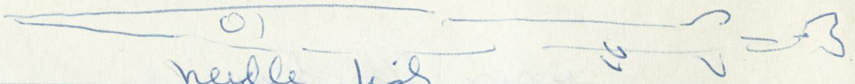
Apodes - Angiulla rostrata - dorsal fin. back from pectoral

- Conger cinareus -  - dorsal originates over pectoral

- Gymnothorax meleagris + moray - no pectorals

Synentognathi - Scomberesocidae
- Cololabis - saria





1 Belonidae needle fish

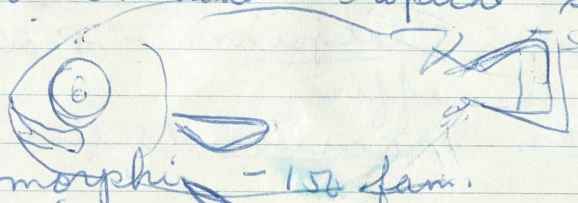
Suborder. Exocoetoidea -
- Exocoetidae - flying fish.

pipe fish
Order Solenichthys
fam. Syngnathidae - pipe fishes, sea horses
together jaw
pelvics absent - physoclisti
no teeth - bony plat

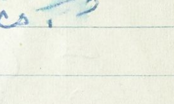
fam. Aulostomidae - scales - Trumpet fish

Order - Anacanthini - cycloid scales,
without spines
- jugular pelvics
Gadidae physoclisti.

Beryomorphi - good ctenoid scales
Holocentridae - tropical soldier fish.
★ squirrel fish



Percomorphi - 150 fam.
Sciaenidae - covered psuedobranch
Serranidae - free psuedobranch, serrated pre opercle
Centrarchidae -
Percidae
Cichlidae
Embiotocidae
Acanthuridae - surgeon fish
Gobidae - pelvics into sucking discs.



Percomorphi (cont.)

- Chichlidae (Mouth breeders)
- Toxotidae (Archer fish)
- Xiphisteridae
- Blennidae (Blennies)
- Stichaeidae (Pricklebacks)
- Pholidae (Gunnels)
- Cebidichthyidae (Monkey faced)
- Clinidae - (Kelp fish)
- Mullidae - (Goat fish)
- Mugilidae - (Mullet)
- Sphyraenidae - (Barracuda)
- Carangidae - (Scud-Jacks)
- Scomberidae - (Mackerel)
- Thunnidae - (Tunas)
- Anarrhichadidae - (Wolf eels)
- Atherinidae - (Silversides)
- Chaetodontidae (Butterfly fish)

- Key to Blennoids -

1. Dorsal spiny to lite touch - Xiphisteridae
 - not - 2

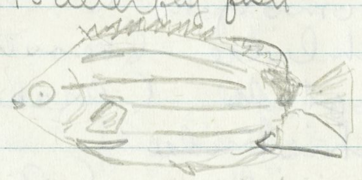
2. Pelvics present. Blennidae
 not - 3

3. Pectorals much reduced - Stichaeidae
 - normal - 4

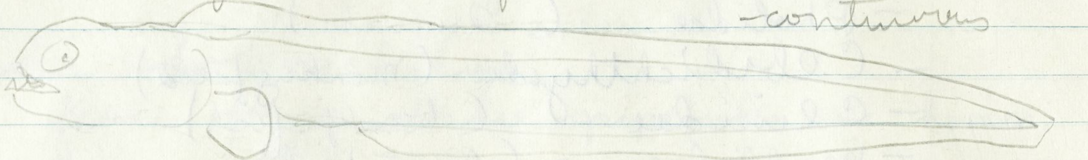
4. Caudal continuous w/ dorsal & ventral - Pholidae

5 Caudal separated by dorsal & ventral notch.
Cebidichthyidae

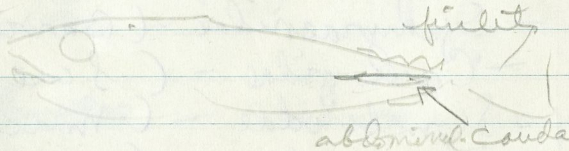
- Chaetodontidae — Butterfly fish



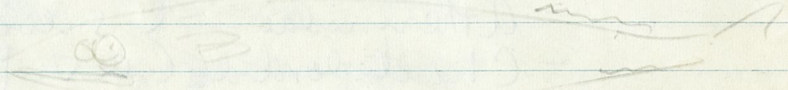
Anarrichthyidae — Wolf eel



Carangidae —



Scomberidae —

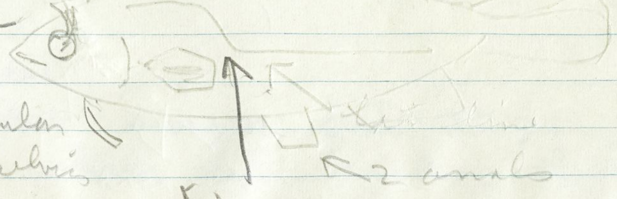


Mugilidae — inf. - sup. mouth —
- 2 dorsals spiny - Spiny anal

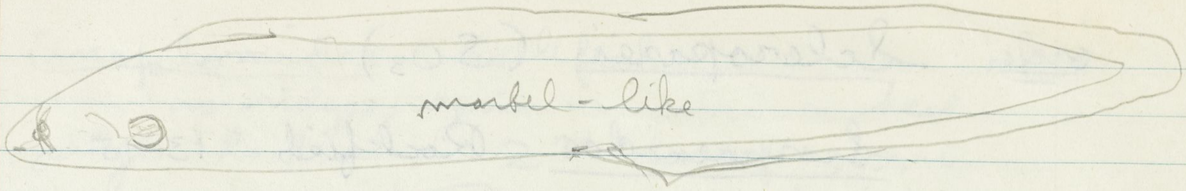
- Mullidae
- goat fish
- no anal spine
- chin barbels

Cebidichthyidae —
eel-like

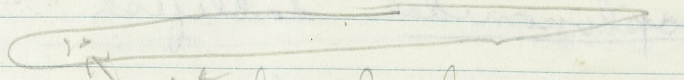
Clinidae —



somewhat – spiny to touch – but not!



~~Xiphisteridae~~ – ~~Pol~~ Pholidae



pectorals reduced –

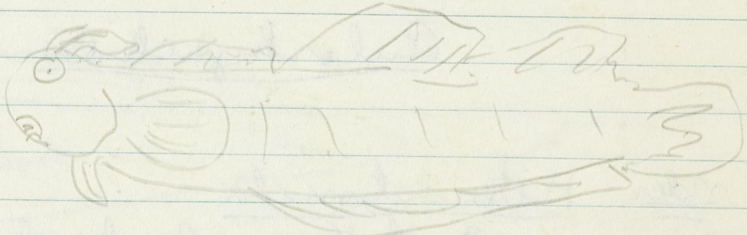
STichaeidae

spiny to touch –

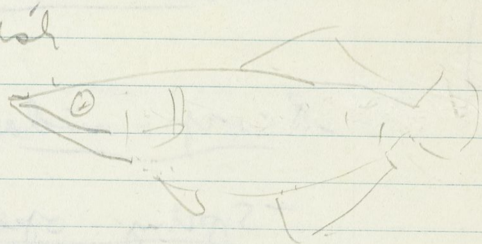
reduced pectorals

Xiphisteridae

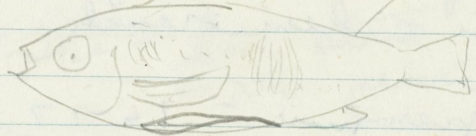
– Blennidae



– Toxotidae – archer fish



– Cichlidae – mouth breeder



pelvics reach base of anal

order Scleroparei (SO_3)

Scorpaenidae Rockfish 13-15

Hexagrammidae Greenling 16-27

Anoplopomidae Sablefish

Cottidae Sculpins

Liparidae Snail Fish

Gasterosteidae

Aulorhynchidae Tube fishes (bony plates)

order Heterostomata

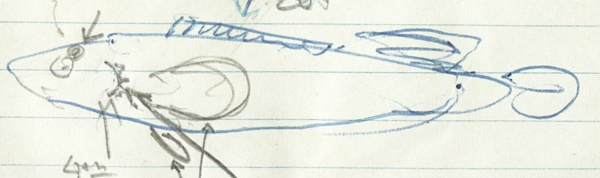
1. Bothidae l. hand asymetrical pelvics
2. Pleuronectidae R. hand symetrical pelvics

- Scorpaenidae - Rockfishes - Sebastoides
- Dendochirus

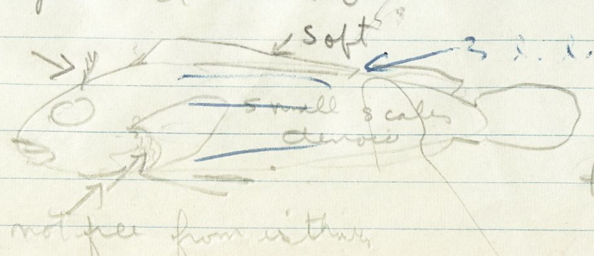
- Spiny opercle. 3 anal spines - 13-15 dorsal spines
large pseudobranch 4th gill arch attached
and is a hemibranch
- Ro

- Hexagrammid - 16-27 dorsal Spines

Ling Cods -
Ophiodon -



gill arch holobranch but top fused.

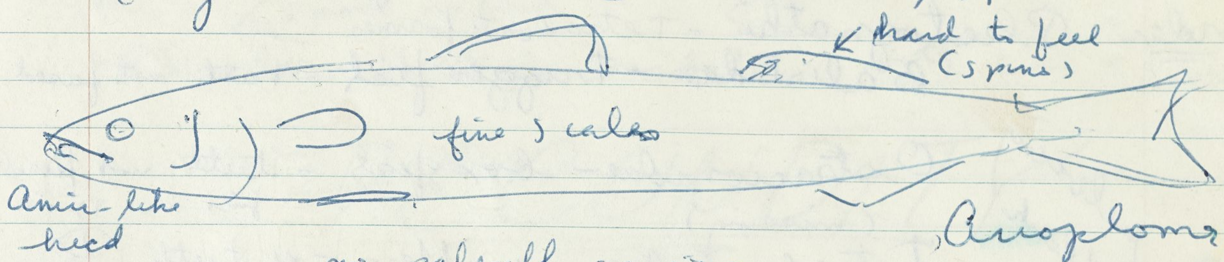


Hexagrammus

Anoplomidae Sablefish

no ridges, spines or cirri on head

single l. l. 2nd dorsal w/ spine

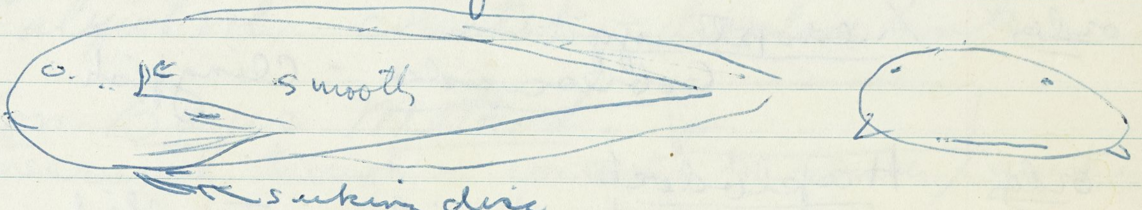


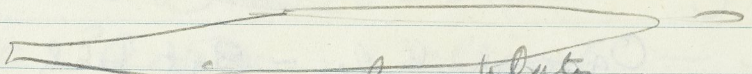
no palpable spines

7-8 branchiostegals fused to isthmus

4th holobranch

Liparidae – Snail fish.





Aulorhynchidae – tube fish

– like pipe & trumpet fish

order **Discocephali**

Echeneidae - Remora (Shark Sucker)

- dorsal modifeid to sucking disc.

order Plectognathi - Tetradontiformes

Balistidae - Trigger fish - teeth not fused

no pelvis
poisonous flesh

Ostracionidae - box fish - teeth not fused
- fins no spines

(missing)

Tetradontidae - puffers - 4 teeth 

Diodontidae - porcupine fish -  - no teeth separation

Molidae - ocean sunfish

order Xenopterygii

Gobiesocidae - Clingfish

order Haplodoci

Batrachioidae Toadfish

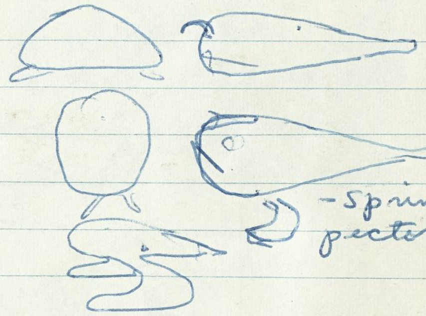
- care of young

order Pediculati (missing)

Lophiidae - Angler fish

Antennaridae - Frog fish

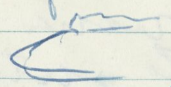
Ogocephalidae - Bat fish



- Springing pectorals

581 gm. 5
30.5

- Carangidae - teeth on max. - 2 spines front of anal
Acanthuridae c surgeon fish - spines missing



M
spines on head

- Clinidae - Hexagrammidae - both cirri c similar

FECUNDITY

E
7819 1. Gravimetric: Aliquot portion - weigh - count deduct 5% for ovarian tissue - ratio of sample wt. to whole wt.

6885 2. Volumetric: - same as gravimetric except volume instead of wt. used. - aliquot vol. counted. - displace water

5981 3. Von Bayer Method. (5% correction) measuring trough - converts to number/quart.

7330 4. Direct Count.

Sample - total wt. total volume

~~[illegible].4 gm~~ ~~581.~~ 581 gm. 565 ml = 6885

sample = 30.5 gm. aliquot - 32 ml = 389

581 gm = 7819 eggs. 6885 total ~~4190~~ eggs

size of egg. .187 in. 16 = 3.0 in. = 10,348/qt.
.578 qt. = 5981 eggs

300 ml H₂O + eggs + 280 = 1 liter 420 ml of eggs.
+ 145

690
+ 550 ml
140 ml

total ovary = 565 ml of eggs

B

Comments on Fecundity.

The ovaries used were large - too large to utilize a grad. cylinder. 2 separate wheighings & volumes were necessary - thus introducing twice the errors of one measuring. 5% was subtracted from total volume for Von Bayer method. (estimated ovarian tissue) - A 15% difference exists between Grav. & vol. estimates.

A direct count yielded 7330 almost intermediate between the gravimetric & vol. method. The Von Bayer method may have been most in error due to a biased selection of larger eggs which were not a true sample of the population of eggs.

Scale Count on Hitch

range : 59-66

$\bar{X}$ = 62 N = 18

σ^2 = 5.6

σ = $\sqrt{5.6}$ = 2.36

S.E.m = .556

C.V. = 3.81

5.6
17)95
85
100

Scale count on Blackfish

range : 95-119

$\bar{X}$ = 105 N = 18

σ^2 = 39

σ = $\sqrt{39}$ = 6.25

S.E.m. = 1.47

C.V. = 1.10

38.1
617|665
51
155
153
20

1.09
105|685
105
200
945
55

CV is a % of the $\bar{X}$ - (a σ of 2 is great if $\bar{X}$ is 5 but small if $\bar{X}$ is 150)

$$\sigma^2 = \frac{\Sigma d^2}{N} \qquad \sigma = \sqrt{\frac{\Sigma d^2}{N}}$$

$$C.V. = \frac{\sigma \times 100}{m}$$

$$S.E._m = \frac{\sigma}{\sqrt{N}}$$ this is for comparison of $\bar{X}$'s

indicats closeness of sample $\bar{X}$ to real but unknown $\bar{X}$ - depends on size of sample.

- This is similar to σ in that 68% of sample means would be expected (in normal distibution) to be within ±1 S.E.m., 95.5% within ±2 S.E.m.

~~Two~~ two pop. can be considered different if the difference between their $\bar{X}$'s ($M_1 - M_2$) is more than twice the sum of their S.E.M. ($S.E_{M_1} + S.E._{M_2}$)

to see if difference between 2 $\bar{X}$'s is significant use $S.E.d. = \sqrt{(S.E._{m_1})^2 + (S.E._{m_2})^2}$ if difference is more than 3 x dif. between $\bar{X}$'s - than it is significant.

5.56
1.470
2.026
4.052

Hitch and Blackfish Scale count. The graph shows at a glance that the differences between $\bar{x}$'s are significant to a high degree. The difference between $\bar{x}$s = 105 - 62 = 43 while twice the sum of their S.E.m is 2(.556 + 1.47) = 4.052 - More than ten times the difference to be statistically significant.

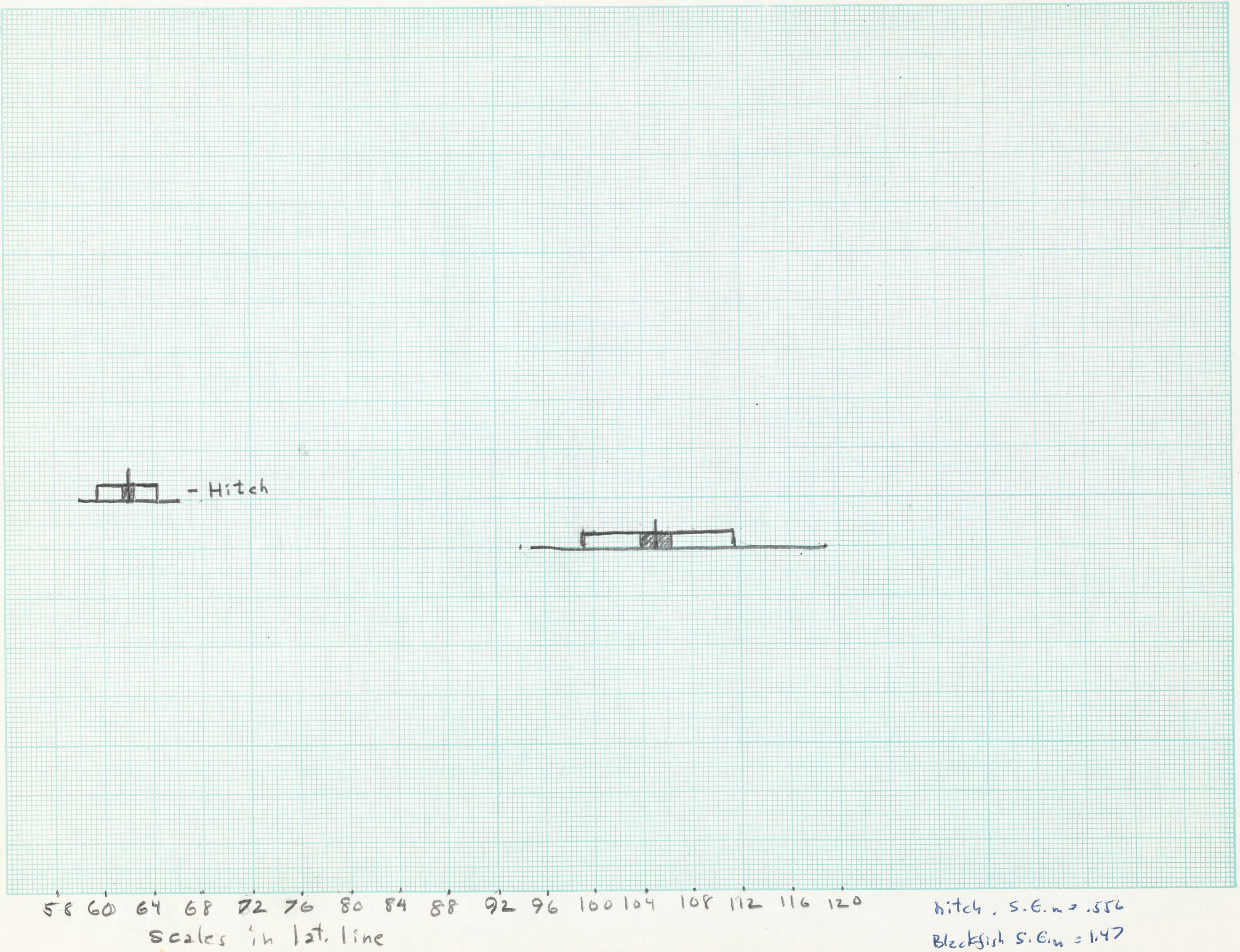
Rainbow Trout

Branchiostegal rays show five distinct populations and Scale Counts show four that are statistically significant.

But one would be on dangerous grounds to name subspecies merely on the basis of what statistics has proved. - It may demonstrate that the means of two populations are significantly different, perhaps the possibility that it is due to chance is one in a million. Yet statistics tells us nothing of the biology of the populations! - What is the environment? What was the temperatures during development? How much influence does the environmental conditions have on the character being analyzed? All of these questions must be faced and here is where biological knowledge must be used.

It would be a fine idea that before a new species ~~of~~ or sub species be named on the evidence of statistically significant ~~between~~ differences between populations, these differences must be demonstrated to be genetic, i.e. the degree of difference not being able to be produced by environmental influences.

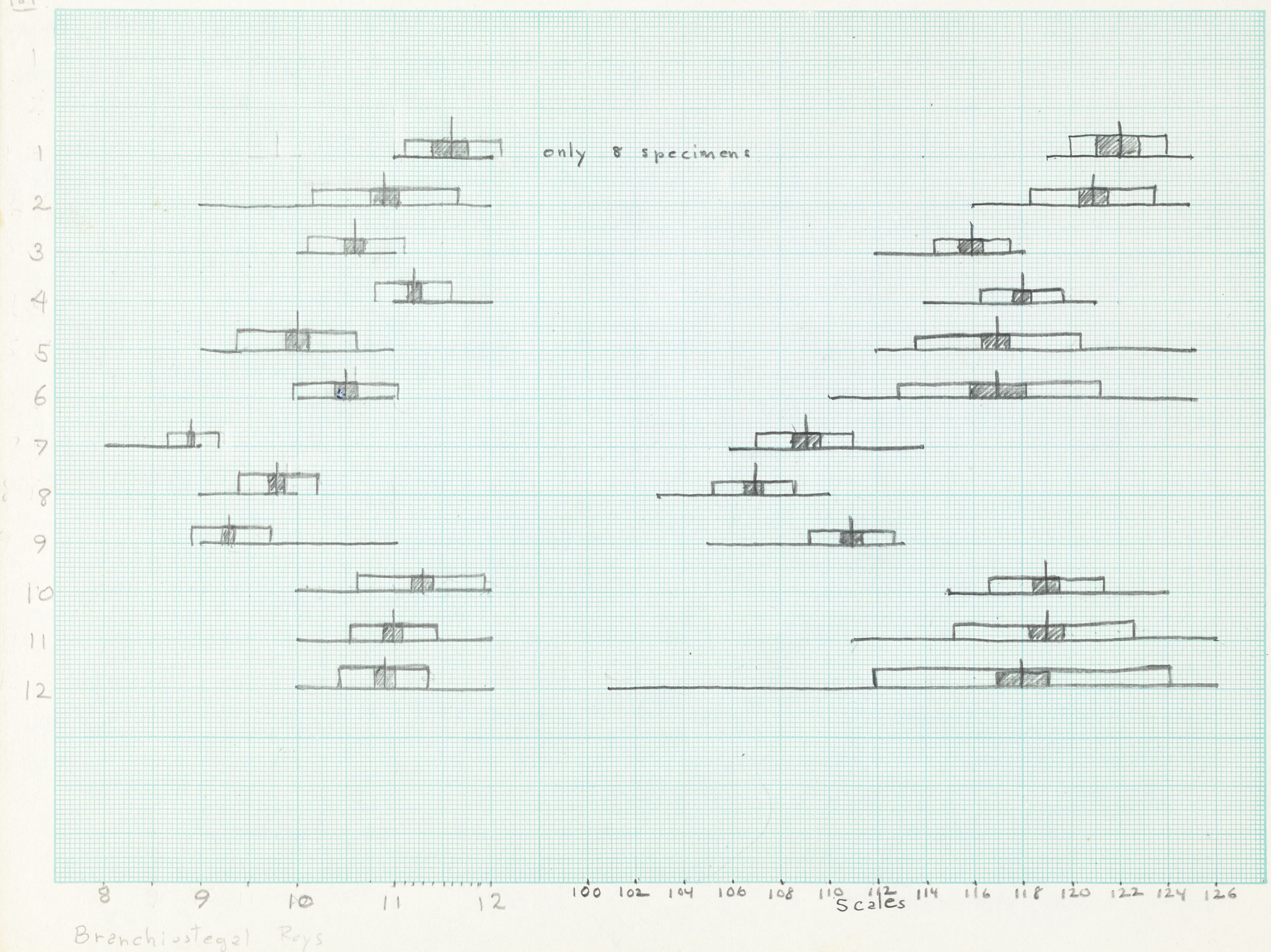
Comparison of Scales on Hitch & Blackfish



hitch. S.E.m = .556

Blackfish S.E.m = 1.47

Rainbow Trout {see pg 70 in lab manual)



Hitch and Blackfish scale count. The graph shows at a glance that the difference between $\bar{X}$'s is significant to a high degree. The difference between $\bar{X}$'s = 105 - 62 = 43 while twice the sum of their S.E.s is 2(.556 + 1.472) = 4.052 - More than ten times the difference to be statistically significant.

.556
1.470
2.026
4.052

Ecological Trait

Zoogeographical maps show five distinct populations and scale counts also show that they are statistically significant.

But one would be in dangerous grounds to name subspecies merely on the basis of what statistics has proved.

It may demonstrate that the means of two populations are significantly different; perhaps the possibility that it is due to chance is one in a million, yet statistics tells us nothing of the biology of these populations. What is the environment? What were the temperatures during development? How much influence does the environmental condition have on the character being analyzed? All of these questions must be found out before a biological hierarchy must be made.

It would be a fine idea that before a new species or a subspecies be named on the evidence of statistically significant ~~between~~ differences between populations, these differences must be demonstrated to be genetic, i.e. the degree of differences not being able to be produced by environmental influences.

Expiriment on the mark and recapture method of population estimation.

- A package of beans put in pan one hundred (100) taken out and marked on both sides for easy discrimination.
- this marked sample was placed back into total population and then put into a sack and shaken, a handful was withdrawn and computed, the marked specimen recorded. This was done 4 times and 4 estimated population figures resulted which varied somewhat but the overall average was close to the true population as counted individually.

	(Pop.)	Sample	(in sample)	
Trail No.	No. marked	No. Removed	No. Marked	Estimated Pop.
1	100	242	17	1482 (replaced)
2	100	296	26	1139 (replaced)
3	100	298	16	1863 (replaced)
4	100	527	35	1506

$\overline{X}$ of 4 estimations = 1503

Actual pop. (as counted) = 1445

an error of 58

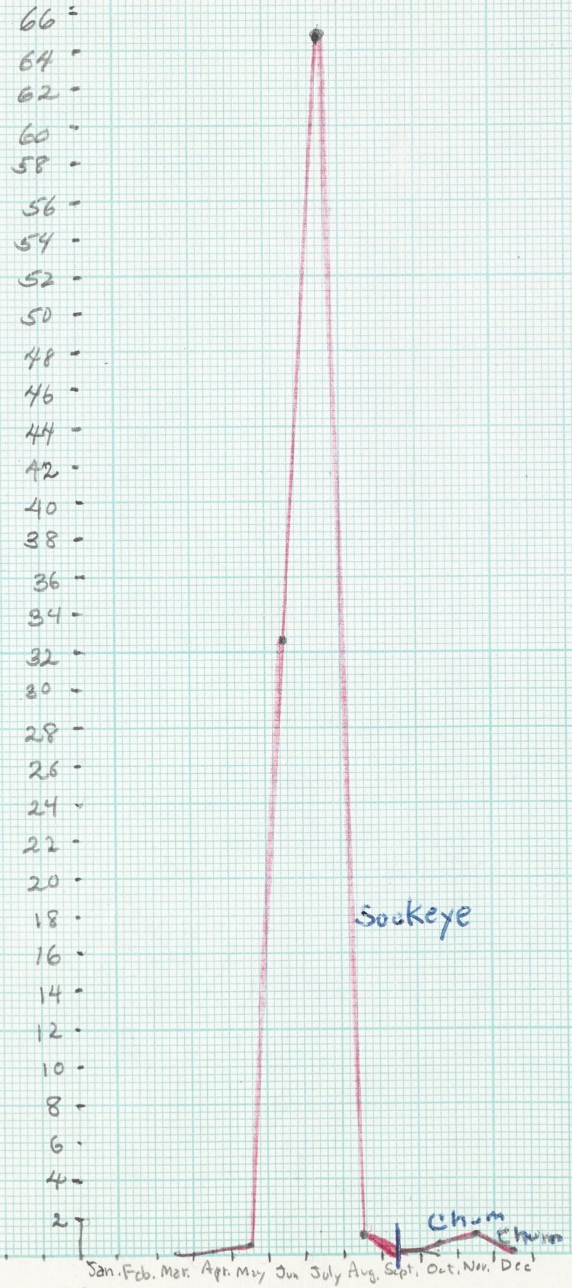
or of 3.8% - this is accurate enough for most purposes - but also demonstrates that a large sample is needed to be confident of any degree of accuracy.

Graphs of Steelhead and Salmon ascending Columbia River:

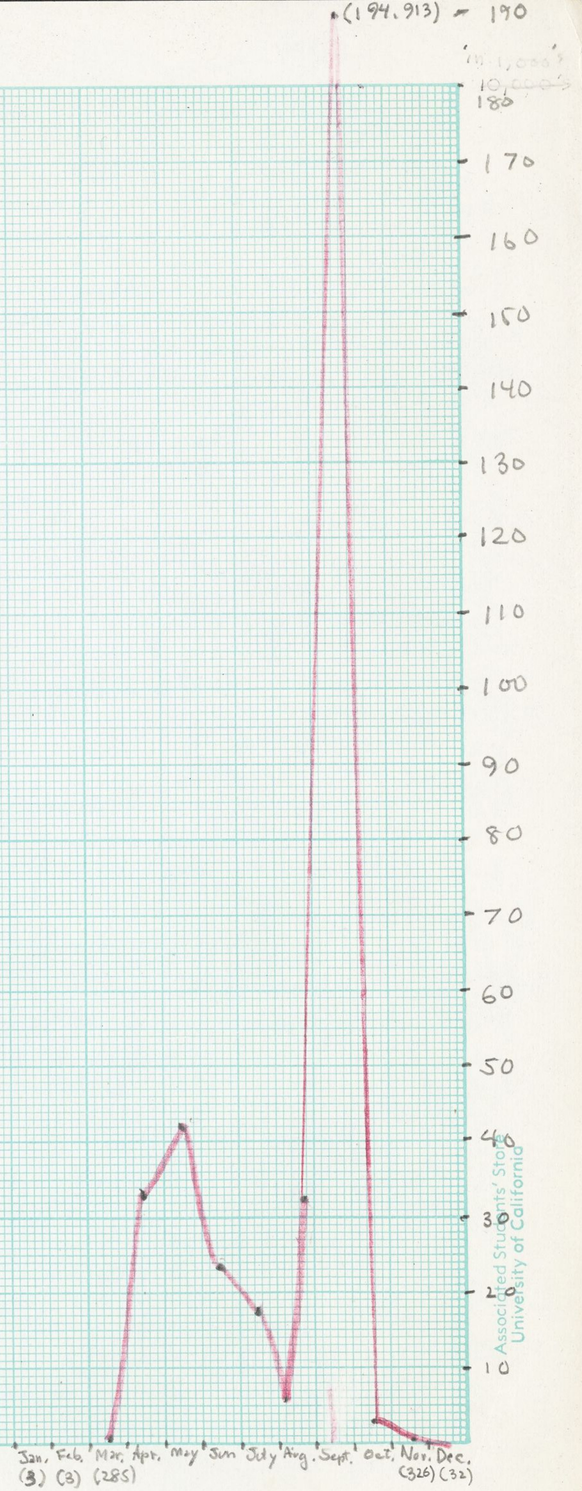
#4- Peaks and valleys in daily Steelhead count could most likely be correlated to flow and temp. which influence upstream migration.

#5- McNary Dam has a lower count than Bonneville due to ~~the~~ some of the fish ascending tributaries in between the two dams ~~and~~ plus natural mortality. Perhaps also the lake behind Bonneville lacks enough current to sufficiently guide the migrating fish quickly upstream, this would cause a maturation before reaching their home spawning beds.

#1=17 yr. Av. (1938-54) no. of steelhead per Month.
over Bonneville Dam.



Chum Salmon & Sockeye Counts
Monthly Average 1938-54
in 1000's of fish



(Chinook salmon count (monthly average)
over Bonneville Dam 1938-54.
in 1000's of fish


3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
SEPTEMBER
Steelhead & Silver Salmon Daily Counts
Bonneville Dam
Silver's
Steelhead
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 24 28 31
OCTOBER
Silver Salmon
Bonneville & McNary Counts
Bonneville
McNary

the harvest from 20% growth

#4 Pond A
20% mortality

Pond B 80% harvest

year		lbs.	% increase	Total		lbs.	% increase	
1	200	400 ×	1.00 =	400	800	1600 ×	100 =	1600
2	160	320 ×	1.20 =	384	160	320 ×	1.20 =	385
3	128	256 ×	1.44 =	369	32	64 ×	1.44 =	95
4	102	204 ×	1.73 =	350	6	12 ×	1.73 =	23
5	82	164 ×	2.18 =	345	2	4 ×	2.18 =	8
6	65	130 ×	2.61 =	339	0			
7	53	106 ×	3.13 =	330				
8	42	84 ×	3.75 =	315				
9	33	66 ×	4.50 =	297				
10	27	54 ×	5.40 =	242				
	892 fish	=		3371 lbs. of fish	~~2000~~ 1000 fish			2111 lbs. of fish.

20% removes less fish but gives higher weight

#5 1000 fish & 1000 added yearly

year	25% harvest	50% harvest	75% harvest
1	250	500	750
2	437	750	940
3	628	870	990
4	720	935	1000
5	795	967	1000
6	850	987	1000
7	880	991	1000
8	910	995	1600
	5410 Total catch	6995 Total catch	7755 Total catch

assume death at 8 years

9	930	997
10	950	998
11	962	999
12	972	999
	⋮	
24^{yrs} –	999-1000	

If fish lives 8 yrs. then by all of these methods all of the fish will eventually be removed by fishing only the 75% harvest removes them the quickest, but the standing crop will necessarily have to be greater for the lighter harve (1000 fish at 25% harvest from 4000 standing crop) while 75% needs only stock of 1333.

Mortality Rates

Instataneous Mortality Rate

total mortality = i
due to fishing = p so $p + q = i$ = Instantaneous Mortality Rate
natural causes = q

Annual Mortality Rate

total = a $a = 1 - e^{i}$
fishing = m $m = 1 - e^{-p}$ = Annual Mortality
natural = n $n = 1 - e^{-q}$
$a = m + n - mn$

Annual Expectations of death

total = a
fishing (rate ~~fex~~ of exploitation = u $u + v = a$
natural causes = v

problem ③ 4000 fish - ~~harvest~~ recruitment 1000
if fishing mortality 25% - then - no change
if. 50% then 2000 fish removed 1000 added.

		removed	recruitment	remaining
yr. 1	4000	2000	1000	3000
2	3000	1500	1000	2500
3	2500	1250	1000	2250
4	2250	1125	1000	2125
5	2125	1063	1000	2063 - then level

④ 2 ponds 1000 fish each - average 2 lb.
pond one = 20% removal pond 2 = 80% removal
fish live 10 yrs. - ~~remove~~ recruitment = 20% by wt.

⑤ 1000 fish add 1000/yr. 25% removed | annually
50% removed
matures 8 yrs. 75% removed
which intensity yield greatest number? - weight?

Mortality Rate

Instantaneous Mortality Rate

total mortality rate

due to fishing = p p + q = z

natural causes = q

Annual Mortality Rate

total = a a = 1-e^-z

fishing = m m = 1-e^-p = Annual mortality

natural = n n = 1-e^-q

a = n + m - nm

Annual expectation of death

total = a

fishing (natural) of any [illegible] u + v = a

natural causes = v

Problem ③ [illegible] Fish — harvest 1000

if fishing mortality 25% [illegible]

yr. 1 [illegible]	2000	[illegible]	[illegible]
2 [illegible]	1320	1440	2390
3 2507	1257	1250	2248
4 [illegible]	1126	1270	2126
5 2125	1065	1020	2063

④ 2 years 1000 fish [illegible] 2 [illegible]

[illegible] = 20% [illegible] 2 = 52% [illegible]

[illegible] = 20% [illegible]

⑤ 1000 fish [illegible] 25% [illegible]

50% [illegible]

mortality [illegible] 75% [illegible]

[illegible]

Field Trips

-Redwood Creek-

A typical coastal stream, small and not draining a large area, but with a steady flow of cool water it is a fine stream for anadromous salmonids who put on most of their growth at sea. - Both steelhead-rainbows and silver salmon utilize Redwood Creek for spawning and as a nursery stream. - Sculpins abound in the salmonid zone and may be predators on the eggs and young. - Dr. Eddy was along and added much to the trip. - Sticklebacks not present in riffles but were extremely abundant in slow brackish water below. 3 age groups of gairdneri collected, and 2 of kisutch.

Clear Lake

I Siegler Creek: immense numbers of hitch in stream for spawning. ♀ were larger (up to 11 in.) many ♂ would attend one ♀ - thrashing, nudging, and vibrating. The eggs are shed without nest building. The site selected is not very specific - gravel, rubble, larger rock, usually near shore. This is a good adaptation for the whole stream may be used instead of just a few restricted areas. Thus not being such a limiting factor. The eggs are non adhesive, quickly swell on being exuded. The streams are subject to floods and dessication. many eggs seen above receded water level, but since such tremendous numbers are a few hitch and Hesperoleucus collected,

suckers were sighted.

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FISH COLLECTIONS

State or Country Calif. Field No. 4

County Lake Map , 1

Locality Kelsey Cr. trib. of Clear Lake (4 mi. above Lake)

Lat ° ′ N., Long ° ′ W. , 1

Water glacial colored

Vegetation no aquatic

Bottom gravel - sand - bed rock

Cover deep pools Temp. water 55° air 68°

Shore cliffs Current swift

Dist. offshore Stream width 30-50 ft.

Depth of capture 1-5 ft. Depth of water 1-6 ft.

Collected by 138 class

Tide Date 4-13-58

Method of capture seine

Orig. preserv Time 10:30 A.M.

1m-3,'58(3171)9112

Carp and hitch
collected, but released.

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FISH COLLECTIONS

State or Country Calif. Field No. 3

County Lake Map , 1

Locality Clear Lake, - beach between Lucerne and Clear Lake Oaks.

Lat ° ′ N., Long. ° ′ W. , 1

Water turbid

Vegetation none

Bottom sand - gravel - mud

Cover none Temp. water 57° air apprx. 65°

Shore sand - gravel Current

Dist. offshore 100-200 ft. Stream width

Depth of capture 3-5 ft. Depth of water

Collected by 138 class

Tide Date 4-12-58

Method of capture beach seine (200 ft.)

Orig. preserv. not preserved Time 4 P.M.

1m-3,'58(3171)9112

Hitch spawning
in tremendous numbers.
Also few carp sighted.

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FISH COLLECTIONS

State or Country Calif.
Field No. 2
County Lake Co.
Map , 1.
Locality Siegler Cr. 1/4 mi. above Cache Cr. - Clear Lake

Lat. ° ′ N., Long. ° ′ W. , 1.
Water clear -
Vegetation no aquatic vegetation.

Bottom gravel, sand, rock
Cover not great
Temp. 65°F water 74° air
Shore
Current moderate - swift
Dist. offshore
Stream width 15-30 ft.
Depth of capture
Depth of water 1-3 ft.
Collected by 138 class
Tide
Date 4-12-56
Method of capture seine
Orig. preserv. formalin
Time 2 P.M.

1m-3,'58(3171)9112

-hitch - also hitch bullheads, and bass collected in gill net set overnight.

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FISH COLLECTIONS

State or Country Calif. Field No. 1

County Lake Map , 1.

Locality Grandview motel beach on Clear Lake - Nice

Lat. ° ' N., Long. ° ' W. , 1.

Water - turbid

Vegetation flooded shrubery.

Bottom gravel

Cover brush Temp. 57° water - air 72°

Shore Current

Dist. offshore 10-20 ft. Stream width

Depth of capture 2-4 ft. Depth of water

Collected by 138 class

Tide Date

Method of capture seine

Orig. preserv. formalin Time 7 P.M.

1m-3,'58(3171)9112

2 young steelhead trout - smolt stage

sticklebacks *Gasterosteus aculeatus* predominate

1 pacific herring

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FISH COLLECTIONS

State or Country Calif. Field No. #2

County Marin Map , 1

Locality Redwood Cr. - Mouth in tidewater zone

Lat. ° ′ N., Long. ° ′ W. , 1

Water brackish

Vegetation none

Bottom sand

Cover none Temp. water 48° air 62°F 3 p.m.

Shore barren Current slow

Dist. offshore Stream width ~~25f~~ 50ft.

Depth of capture Depth of water 1-5ft.

Collected by 138 class

Tide low Date 5 MAR. 58

Method of capture seine

Orig. preserv. 10% formalin Time 3 p.m.

1m-3,'58(3171)9112

above tidewater influence a typical small coastal (southern) salmonid stream. - Silver salmon fingerlings & yearlings, pre seaward migrant rainbows, ~~fingerlings~~ yearlings and 2 yr. olds. Sculpins (2) Cottus asper and Cottus ______.

No Sticklebacks found this far upstream.

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FISH COLLECTIONS

State or Country Marin Co. Calif.

Field No. #1

County

Map , 1

Locality Redwood Creek - East Boundary - Muir Nat. Park

Lat. ° ′ N., Long. ° ′ W. , 1

Water - clear - brown

Vegetation none

Bottom gravel, sand small rock

Cover shore, banks, pools

Temp. 48° F water - 60° air 2 P.M.

Shore brush, trees

Current mod. swift

Dist. offshore

Stream width 15 ft.

Depth of capture

Depth of water 1 - 4 ft.

Collected by 138 class

Tide

Date 3-5-58

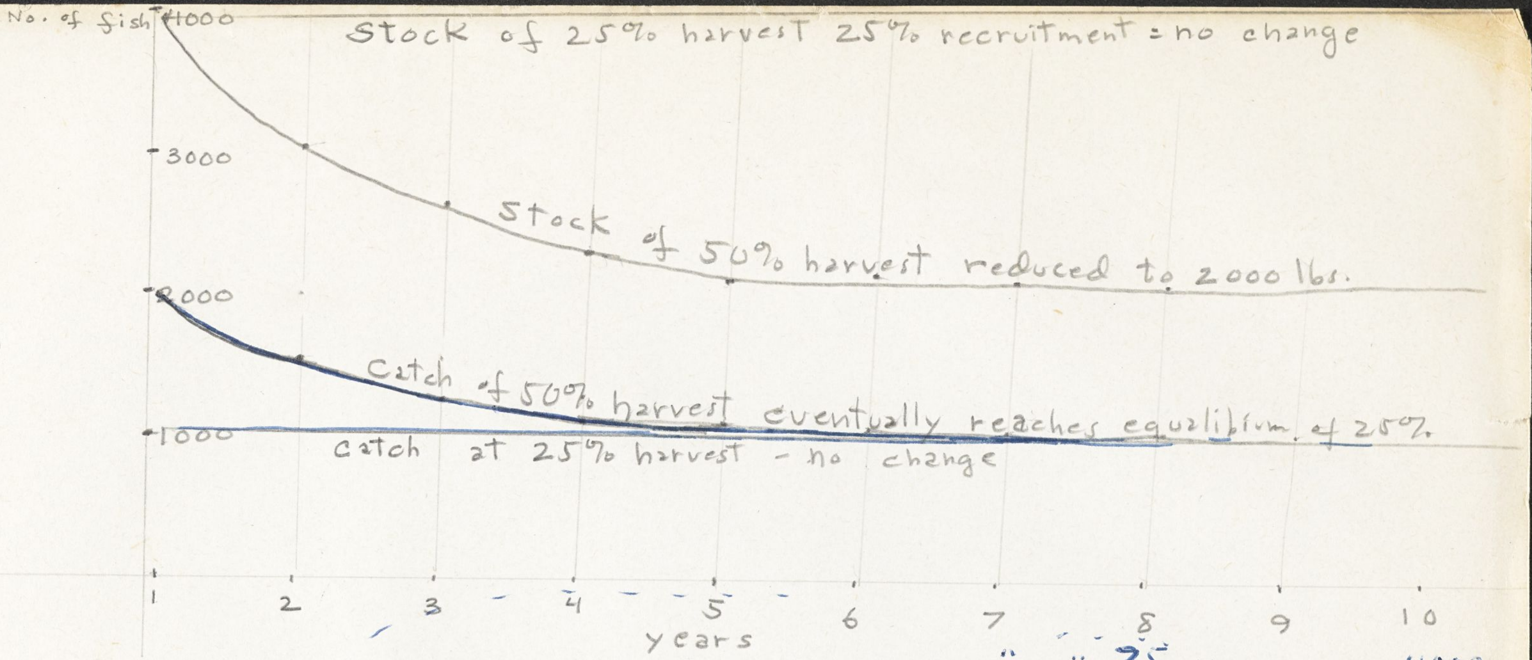
Method of capture seine

Orig. preserv. ~~alive~~ in 4% formalin

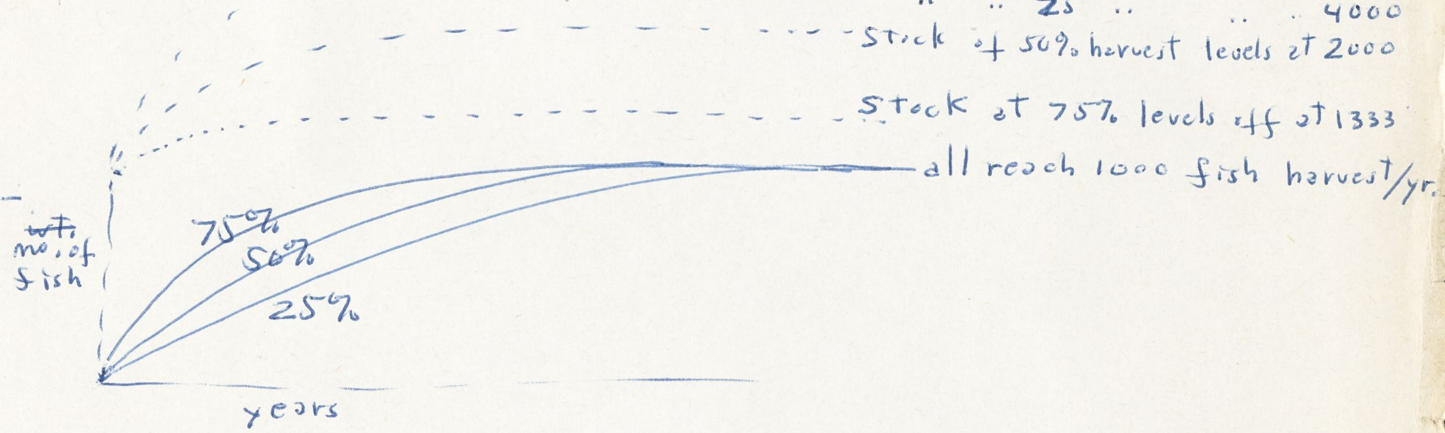
Time afternoon - 2 p.m.

1m–7,'52(A2342s)9112

#3



#5 –



- What intensity greatest wt. of fish? – 75% ~~should~~ be cropping fish off rapidly before they have grown. 25% cropping will take more older and thus larger fish so this rate of harvesting should yield best results in weight.

deposited the loss is not serious. The erratic flow of the streams and the sight of hitch seeming to attempt to spawn in the flooded city park at Lakeport - causes speculation over possibility that they will not spawn in lake. Three successive dry years with no stream flow would exterminate population. This has probably occurred at some previous time.

Stone flies, may flies and dobson flies larvae found in creek. but after hatching the young hitch probably soon migrate to lake, for they are plankton feeders. The hitch have benefited by the changes wrought in the ecology of Clear Lake by man. The lake is now richer and plankton production higher.

- Nice - Gill net - Blackfish, hitch, carp, bluegill, catfish. - bass and catfish in morning. indicated nocturnal movements. - One rainbow trout yearling taken in seine this may be due to local stocking either in lake or in streams flowing into lake. The lake is definitely not a trout lake in the summer with its uniform temp. of 80°F.

- Kelsey Creek - cold stream flowing from mountains water 55° - few hitch found, probably due to low temp. which may not be conducive to hitch spawning.

Tomales Bay - Duxbury Reef.

- Fortunate to have Mr. Follet along.
- Many types of fish from many habitats collected. - tide pools, bay, brackish, streams and brooks.

-Rotenone in tide pools took about 20 min. to work - fish showed differential tolerance: the Embiotocids most suceptible the blennies the least. The tide pools have an amazing abundance of life. At first they appear barren to the causual observer, but every niche is utilized. Many of the inhabitants are herbivores utilizing the abundant algal growths.

The table on the next page lists all of the fish collected and where they were collected.

The list shows 2 classes 9 orders and 38 species collected. All this in a two day trip indicates the richness of the area.

-

Layfayette Creek. Although almost no sign of life was found, - When the seining and bottom samples was done, The lesson demonstrated here was the effects of mans interaction with the environment - The effects of flooding and flood control measures, the heavy silt load in the stream. Layfayette Creek is a good example of a bad example of effects of civilization.

Only Hesperleucas (Venus Roach) and 3 spinned sticklebacks were collected. Evidence of flooding and erosion, unstable banks and much silting. Food seems poor, 1 Surber sample yielded no organisms. ~~[illegible]~~ Example of flood control measures and deleterious effects on stream life. Two other stops were made - observation of San Pablo Cr. and a test netting of upper San Leandro Cr. near Moraga town line which was abortive.

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FISH COLLECTIONS

State or Country Calif. Field No.

County Contra Costa Co. Map , 1

Locality Lafayette Cr.; Bridge at Rolies Sta. Rd.
Lafayette (From Bridge to 1/4 mi downstream)

Lat. ° ′ N., Long. ° ′ W. , 1

Water

Vegetation algae, moss no rooted aquatics

Bottom bedrock, silt, beercans, rubble - stones

Cover abundant - trees, brush Temp. air 76°F water 65°F

Shore steep banks, trees, brush, Current gentle to moderate

Dist. offshore Stream width 6 - 20 ft.

Depth of capture all depths Depth of water 1/2 - 5 ft.

Collected by Zool. 138 class

Tide Date 5-5-58

Method of capture 6 ft. seine

Orig. preserv. Time 2:45 P.M.

1m-3,'58(3171)9112

- a good steelhead and silver salmon spawning stream.
- 2 yr. groups of steelheads collected
- 1 yr. class of *O. kisutch*
- many Hesperoleucas in breeding colors.

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FISH COLLECTIONS

State or Country Calif. Field No. 4

County Marin Map , 1

Locality Papermill Cr. - Taylor St. Park

Lat. ° ′ N., Long. ° ′ W. , 1

Water Clear

Vegetation none

Bottom rock- gravel

Cover rock - trees Temp. water 52° air 65°

Shore Current moderate

Dist. offshore Stream width 15-30 ft.

Depth of capture Depth of water 1-3 ft.

Collected by 138 class

Tide Date 4-27-58

Method of capture seine

Orig. preserv. formalin Time 11 Am

1m-3,'58(3171)9112

- Clevelands goby
Surf smelt
top smelt
shiner perch
staghorn sculpin
- sticklebacks in
a lagoon
- steelhead fingerlings
in small brook.

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FISH COLLECTIONS

State or Country Calif. Field No. 3

County Marin Co. Map , 1.

Locality Francis Beach

Lat. ° ′ N., Long. ° ′ W. , 1.

Water calm, clear salinity 18 ppt.

Vegetation algae

Bottom sand-gravel

Cover none Temp. water 61°F air 53°F (brook 53°)

Shore gravel Current -

Dist. offshore 100 ft. Stream width

Depth of capture 1-3 ft. Depth of water 1-3 ft.

Collected by 138 class

Tide receding Date 4-27-58

Method of capture beach seine

Orig. preserv. formalin Time 10 AM

1m-3,'58(3171)9112

- ~~top~~ ss
- jack smelt
- Walleye perch

Pile perch
black perch
shiner perch
curl fin turbot
spotted sand dab
herring (pacific)
midshipman
leopard shark
eagle bat ray.

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FISH COLLECTIONS

State or Country Calif.

Field No. 2

County Marin

Map , 1

Locality Tamales Bay - Spengers landing

Lat ° ′ N., Long ° ′ W. , 1

Water - clear (moderately so)

Vegetation none

Bottom sand - mud

Cover

Temp. water 61° F air 59°

Shore sand

Current

Dist. offshore 100-300 ft.

Stream width

Depth of capture 4-6 ft.

Depth of water 6 ft.

Collected by Spenger

Tide out going

Date 4-26-58

Method of capture 600 ft. beach seine

Orig. preserv. formalin

Time 4-5 pm

1m-3,'58(3171)9112

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FISH COLLECTIONS

State or Country Calif. Field No. 1

County Marin Co. Map , 1.

Locality Duxbury Reef - Tide Pool #1

Lat. ° ′ N., Long. ° ′ W. , 1.

Water - Tide pools - murky.

Vegetation kelp, other marine algae

Bottom rock, some silt

Cover rocky crevices Temp. water 54° - air 56° F.

Shore cliffs Current

Dist. offshore ~~Stream width~~ pool 500 sq. ft.

Depth of capture Depth of water 2-6 ft.

Collected by 138 students

Tide low Date 4-26-58

Method of capture rotenone

Orig. preserv. formalin Time 11 A.M.

1m-3,'58(3171)9112

	Duxbury Reef	Tomales Bay	Franes Beach	Paper Mill Cr.
Class Chondrichthyes				
order Selachi				
fam Triakidae				
Triakis semifasciata		✓		
order Batoidea				
fam Myliobatidae		✓		
Class Osteichthys				
order Isospondyli				
fam Clupeidae				
Clupea pallasi		✓		
fam Osmeridae				
Hypomesus pretiosus			✓	~~✓~~
fam Salmonidae			✓	✓
Salmo gairdneri			✓	✓
Oncorhynchus kisutch				✓
order Ostariophyci				
fam. Cyprinidae				
Hesperoleucus symetricus				✓
order Percomorphi				
fam. Serranidae				
Roccus saxatilus	✓			
fam. Embiotocidae		also Embiotica j.		
Damalichthys vacca	✓	~~Cymatogaster~~ a. Hyperprosopon	✓	
Micrometrus minimus	✓	Phanerodon furcatus	✓	
sub order Blenoidea				
Cebidichthys violaceus	✓			
Apodichthys flavidium	✓			
Epigeichthys atropurpureus	✓			
fam. Cottidae (order Scleroparei)				
Scorpaenichthys marmoratus	✓			
Enophrys bison	✓			
Artedius notaspilotus	✓			
Oligocottus snyderi	✓			
Artedius lateralis	✓			
fam. Atherinidae				
Atherinops affinis	✓	✓	✓	
Atherinopsis califoriensis	✓	✓	✓	

	Duxbury	Tomales	Francis	Paper Mill
fam. Gobidae				
Clevlandii osi			✓	
fam Gasterosteidae {order scleroperoi}				
Gasterosteus aculeatus			✓	
fam Clinidae				
Gibbonsia metzi	✓			
order Sclaleroparei				
fam. Scorpaenidae				
Sebastodes melanops	✓			
Sebastodes	✓			
fam. Hexagramididae				
Hexagrammos decagrammus	✓			
order ~~f~~ Heterosomata				
fam Bothridae				
fam. Pleuronectidae				
order Xenopterygii				
fam Gobiescocidae				
Gobiesox meandricus	✓			
order Haplodoci				
fam. Batrachoididae				
Porichthys notatus	✓			

1

AMS 3, 4, 5, 66 & 67

ICHTHYOLOGY LABORATORY MANUAL
ZOOLOGY 138

by
Paul R. Needham
and
Albert C. Jones

Berkeley, Calif. January, 1956

ICHTHYOLOGY LABORATORY MANUAL

ZOOLOGY 138

INTRODUCTION

There are, perhaps, 25,000 or more species of fish in existence. Species are grouped into progressively larger categories; genera, families, orders and classes. Theoretically, modern classification reflects phylogeny and relationships. The basis for classification can be considered an inquiry into the origin of species. The evolutionary and biological approach to classification is often referred to as systematics, as opposed to old fashioned taxonomy which merely "pigeon holes" museum specimens, and may not reveal the true nature of relationships.

Fishes inhabit almost every conceivable aquatic habitat from tiny pools in the desert to the greatest depths of the ocean. The array of adaptations of various species to specific environments produces diversity allowing unlimited possibilities for systematic, ecological and physiological research.

Fossil records of fishes go back approximately 400 million years. The great bulk of living species, however, belong to the super order Teleostei which are comparatively modern; radiating contemporarily with the evolution of birds and mammals.

Research for Term Papers

Rather than assign a term paper of the usual type that entails only library work on some specific topic, each student is expected to do a small piece of original research. Suitable materials are often collected on the field trips, though some students select a laboratory or field problem of special interest to them. The main caution here is that the research problem adopted must be small, well rounded, clearly defined, and one that will not require an unfair amount of student time for its completion over the four steps involved, i.e. (1) library research to ascertain what has already been done, (2) doing the work, (3) analysis of results, and (4) writing it up in proper scientific style to turn in at the last regular laboratory period in the term. The only restrictions imposed in the selection of a subject are that it must be on some subject dealing with fish or fishes and your selection must be approved by your instructors. Lastly, each student will be expected to make a brief oral report on his research at the last regular laboratory meeting. Term papers will not be returned and will become part of the course files for reference purposes for future students.

A Soft-rayed Bony Fish
Carp (Cyprinus carpio)

External Anatomy

Examine the general body shape. Most streamlined fish exhibit a teardrop or fusiform body shape with the deepest part of the body somewhat anterior to the midpoint. Comparisons should be made of structural peculiarities, such as body shape in different species in relation to habits. The student should think of each structure studied in terms of adaptation to a specific environment.

Nasal Apparatus: Nostrils are paired in all teleosts. Each is a sac more or less completely enclosed in a cartilaginous or bony investment and divided into anterior and posterior portions by a fold of skin.

Is there a passage from the nostril into the mouth of the carp? no

Barbels in many species of fish are principally gustatory organs and, to a lesser extent, tactile organs. The gustatory function is shown by the fact that when tasty? substances are brought in contact with the barbels, the fish will immediately snap with avidity. When the same regions are touched by tasteless substances no snapping will occur.

Where are the barbels located in the carp? maxillary How many are present? 2

Fins. Median fins in the carp include the dorsal, anal, and caudal. Paired fins are the pectorals and pelvics. Note in the carp the long dorsal fin and the short anal fin, and the number of spines anteriorly in each. Numerous soft-rayed fishes have developed single dorsal and anal spines, but these fishes are not considered spiny-rayed since the spines are not consecutive. Examine the fin rays to see how they branch distally, are segmented, and are actually paired structures, each being made up of two halves. ?

Pelvic fins are described for taxonomic purposes as abdominal when located between the anus and the middle of the pectoral and thoracic when located between the insertion and middle of the pectoral. The position of the pelvic fins is jugular when these are located anterior to the insertion of the pectoral.

Notice in the trout the fleshy adipose fin and the pelvic ? appendage at the base of each pelvic fin.

Refer to Clemens and Wilby (1946) or Hubbs and Lagler (1947) for methods of making fin ray counts. Make such counts for the carp.

The integument consists of a thin outermost epidermis and a thicker inner dermis. Mucuous cells scattered among the epidermal cells provide an osmotic barrier, lubrication to increase streamlining, and protection against bacteria. The dermis is made up principally of connective tissue plus nerves, blood vessels, muscles, and pigment cells. The scales lie in pockets in the dermis and are usually covered by the epidermis. Note how the scales are arranged in diagonal rows. The majority of each scale is covered by other scales.

Does the epidermis cover the scales in the carp? What portions of the body are devoid of scales?

Remove a scale from the region between the anterior end of the dorsal fin and the lateral line, place in water under the dissecting microscope and locate the following structures: 1) focus, 2) radii, 3) circuli, and 4) exposed and unexposed portions.

Sketch and label the carp scale as an example of the cycloid type. Observe and sketch the ganoid, placoid, and ctenoid scales on demonstration. What are the distinguishing characteristics of each type? What is the special characteristic of the scales in the lateral line series? Make scale counts for the carp.

pores

Color in fish is due to chromatophores present in the dermis. Principal types are melanophores and lipophores which contain melanin and carotenoid pigments respectively and guanophores which secrete guanine crystals. These three types of cells are distributed in two layers of skin, two outside the scales in the epidermis and one, the guanophores, on the inner surface of the scales between the latter and the underlying muscles.

Detach a carp scale and observe the distribution of the different types of chromatophores.

Mouth: Examine the jaws of the carp by extending them forward. Correlate the subterminal mouth with this fish's mode of life. Compare the jaws of the trout and the carp.

Identify the premaxillary, maxillary, and dentary bones in the carp. Examine the maxillary membrane, a fleshy fold of tissue just inside the mouth.

Is there a like membrane on the dentary? How might such a membrane function in respiration? Close mouth when water → gills

Teeth: In teleosts the teeth are both epidermal and dermal in origin. There are four groups of tooth-bearing bones in fish. These are: 1) maxillary and premaxillary, 2) vomer, palatine, and pterygoid, 3) parasphenoid, and 4) dentary. In addition there are pharyngeal teeth found on the inner margin of the last gill arch in the pharynx in certain groups offish such as catfish, minnows and suckers. It is a general rule that the development of the pharyngeal dentition is in inverse proportion to the degree of development of the jaw teeth.

Tooth development indicates feeding habits and the environment in which the fish lives. The usual tooth shape in bony fish is conical (canine), but specializations to an incisor form in herbivores ? and a molar form in herbivores and shellfish-feeders are present.

Opercular Apparatus: Between the head and shoulders of the fish is a series of opercular bones lying in the flap of skin covering the gill region. Locate the large posterior plate, the operculum, on either side behind the cheek region of the skull. Ventral to this is the subopercle. Ventral and anterior to this is the small interopercle. Anterior to the opercle is the preopercle.

Is the preopercle a support of the operculum or is it a member of the cheek bone series?

The ventral portion of the opercular region is produced into a thin membranous extension, the branchiostegal membrane, supported by the brachiostegal rays.

The branchiostegal membrane joins the operculum and facial bones to the medial fleshy septum (isthmus) that lies between the gills, connects the throat area with the lower jaw, and supports the gill arches. The posterior border of the membrane is unsupported.

Are the branchiostegal membranes broadly or narrowly joined to the isthmus in the carp?

Gills and Branchial Chamber: Lift the operculum to observe the branchial chamber. Count the number of gill slits and gill arches. These are the common numbers for teleosts; deviations occur by reduction in number or size or both. Dissect out a gill arch from the carp. The anterior and posterior gill filaments (lamellae) of each arch constitute the holobranch. Either set of filaments is referred to as a hemibranch. Notice that the gill filaments project freely into the branchial chamber. In sharks the filaments of each hemibranch are joined to a gill septum and do not project freely into the branchial chamber.

Observe the gill rakers, protuberances on each gill arch opposite the gill filaments. What is the function of these? Compare the gill rakers in the carp, anchovy, and trout. Does this tell you anything further about the nutritional habits of these species? The gill rakers, including all rudiments, are always counted on the first gill arch; those on the upper half of the arch are given first, followed by those on the lower half of the arch, as 8 + 13.

Study the demonstration of a pseudobranch. The pseudobranch in all teleosts is considered a remnant of the spiracular gill. It is located on the inner side of the operculum anteriorly. It may or may not retain the gill-like structure. All other gills except the pseudobranch receive blood for aeration directly from the heart by way of the aortic arches. However, in the pseudobranch, as in the hemibranch present in the spiracles of the sharks and sturgeons, blood is received that has been oxygenated by passage through gills behind it. It is, therefore, named a "pseudo" branch.

Is a pseudobranch present in the carp, the trout, or the anchovy?

Draw a lateral view of the carp. Label fully the following parts: eye, mouth, nasal openings, opercle, preopercle, subopercle, interopercle, head, maxillary, premaxillary, dentary, barbels, caudal peduncle, lateral line, branchiostegal membranes and rays, anus and dorsal, anal, caudal, pectoral, and pelvic fins.

Internal Anatomy

Trunk Musculature: Midway along the length of the carp carefully remove the skin on one side between the dorsal and the mid-ventral line. Care must be taken not to remove any of the muscle. This will expose the great lateral muscle. Observe the transverse septum indicated by the connective tissue band lying immediately under the lateral line. It extends fromthe under surface of the skin directly down to the lateral ventral surfaces of the centre of the vertebral column. This septum completely divides the great lateral muscle into dorsal (epaxial) and ventral (hypaxial) portions. The extreme dorsal portion of the epaxial muscle on each side has become further differentiated by the separation of a definite cylindrical bundle, the supracarinalis. Similarly, the extreme ventral portion of the hypaxial muscle is differentiated into the infracarinalis muscle. What are the functions of each of these muscles?

The lateral muscle mass is subdivided into vertical segments (myomeres) which are separated by connective tissue septa (myocommata). The form of the myomere and of the septum varies somewhat in different regions of the body but is always complex and intricate. In the myomeres of the entire side of the carp, the surface markings have the general outline of the letter "W" with the bottom of the letter turned towards the tail.

Make a ventral incision beginning medially between the pectoral fins back between the pelvic fins and almost to the anus. So as not to damage the urogenital and intestinal opeinings, continue the incision to the side of the anus and shallow enough not to damage underlying structures.

Reproductive System: In the male note the long, white, enlarged testes. Trace out the vas deferens to the genito-urinary pore. In the female note the enormous egg mass which indicates the fish was approaching the spawning period when captured. Locate the oviduct. Observe both male and female structures. Would you judge that this species has a high reproductive potential?

Note the peritoneum. Do not damage the urinary and genital ducts. Locate the external opening for these ducts and for the rectum. Which is the most anterior, the urogenital papilla or the anal opening?

Alimentary Canal: In order to study the digestive organs and structures dorsal to them, carefully cut the intestine and stomach free from the mesenteries and also the diffuse yellowish structure, taking care not to break this latter structure. The intestinal tract can now be pulled out of the body cavity for inspection, but do not cut any of its connections. Locate the oesophagus, stomach (cardiac and pyloric ends), the liver, gall bladder, spleen. Can you locate the pancreas? How many pyloric caeca are there (these are finger-like outpocketings of the stomach in the pyloric region)? Note the large air bladder, its constriction, and its pneumatic duct. Trace the connections of this duct. The term describing the condition when the pneumatic duct is not present or does not connect with the alimentary canal is physoclistic, that for when the pneumatic duct does connect is physostomous, the primitive condition. The teleosts are the only group of fishes of the class Osteichthyes which have the air-bladder, though not all of them possess it as adults. All teleosts are phystomous in the embryonic stage. The air-bladder may be quite alveolar internally (Lepisosteus) or very smooth, or it may act as a functional lung as in the Dipnoi. Also it may have other differences such as caecal outgrowths, be adapted for sound production (Sciaenidae) or have a connection with the auditory organ as occurs in the carp, which condition will be taken up later. It may even extend into the tail region in some groups of fishes by penetrating for a short distance into the expanded haemal canal of the anterior caudal vertebrae (order Gadiformes) or bifurcate into two lobes, one on each side of the haemal spine (family Embiotocidae). The most important function of the airbladder for teleosts is as a mechanism for detecting changes in water pressures encountered by changes of depths.

Circulatory Organs: Below and behind branchial arches, locate the heart. Locate the sinus venous, auricle or atrium, ventricle, bulbus arteriosus, and ventral aorta.

Locate the kidneys, the urinary duct, urinary bladder and the urogenital sinus. The kidney of all fishes above cyclostomes is an opisthonephros in the adult.

Sketch and label the organs studied, showing their positions and relationships.

Skeletal Structures

Pelvic Fin: Remove and discard the digestive and associated organs but leave the air bladder in place. The pelvic fin is situated in the body wall below the tips of the ribs. Cut around the base of the pelvic fin skeleton so as to remove it from the body wall. Remove as much of the flesh as possible from the fin skeleton, then hold the fin in boiling water for about one minute. Remove remaining flesh, but take care to keep the fin elements together so as not to lose their relationship. It is seen that the pelvic fin has no girdle, but instead has a large triangular, flat bone, the basipterygium, probably representing fused proximal pterygiophores. To the posterior border of the basipterygium are three partly ossified pieces, the distal pterygiophores. It is on these that the dermal, jointed, fin rays (lipidotrichia) are articulated. The dermal rays are believed to have been derived from long rows of scales that covered the fins of primitive fishes. The horny dermal ray-like fibers, unjointed, of the elasmobranch and chimaeras are termed ceratotrichia. The term dermotrichia (a broad term that includes both lipidotrichia and ceratotrichia) refers to dermal fin rays of all cartilaginous and bony fishes. Sketch the pelvic fin and label parts.

Caudal Fin: Beginning on the caudal fin, fillet off on each side of the body the flesh for about 3" back towards the end of the dorsal and anal fins. Then cut it off here so that you have the caudal fin and about one inch of caudal vertebrae. Remove as much of the flesh as possible, then hold the fin and vertebrae in boiling water for about 3/4 minute. Do not leave in longer because the bones will come loose and fall apart. Carefully remove the cooked flesh and scales. Holding under a stream of cold water and using the fingers to remove the smaller particles of flesh is a good procedure. This dissection of the caudal fin shows how modified the posterior end of the vertebral column is for the support of the caudal fin. Observe and describe the modifications. The rod-like extension of the last distinct vertebra is the urostyle. The broad, expanded plates attached to the urostyle are the hypural plates. The ventral spine on each distinct vertebra is a haemal spine through which the haemal canal passes. The dorsal spine is the neural spine. Notice how the dermal fin rays articulate on the hypural plates. Sketch and label the caudal end of the vertebral column, showing its modifications for support of the caudal fin. Look up the definition of heterocercal and diphycercal caudal fins and be able to give several examples of each.

Dorsal Fin, Anal Fin, and Vertebral Column: To study these structures, fillet off the flesh from each side, beginning where the tail was cut off and fillet up to about an inch anterior to the front end of the dorsal fin. Cut through the vertebral column at this point, taking care not to remove the air bladder from its connection at the posterior part of the skull. What you now have is one section with the head and the attached air-bladder and a second section, the trunk with the dorsal and anal fins and vertebral column. Remove as much of the remaining flesh as possible. Then place this vertebral and fin section in boiling water for 3/4 minute, no longer; then remove the rest of the flesh. Lay the section flat and pick off the flesh from one side, exposing the skeleton of the vertebral column. Time does not allow a study of the musculature of these structures, but notice that there are broad plates for attachment of muscles and tendons connecting the dorsal and anal fins to the trunk and vertebral column. Study the relationships between vertebral column and the median fin skeletons. Each dorsal fin ray has its two halves separated at the base. A small bone, the distal pterygiophore, fits in between the two basal ends of each ray and articulates with a small oblong bone, the middle pterygiophore, which is partly ossified onto the proximal pyerygiophore (also called an interneural bone). Sketch a front view of one dermal ray and its pterygiophores. The anal fin structure is similar to that for the dorsal fin, consisting of dermal rays, distal and middle pterygiophores and proximal pterygiophores (interhaemal bones).

Vertebral Column: The vertebral column in the teleosts, unlike the vertebral column of the cyclostomes, sharks, rays and chimaeras, is differentiated into distinct, complete bony vertebrae (except in the chondrosteans - sturgeons, paddlefish). Boil the carp's vertebral column in water for ten minutes. Remove the flesh. Note that the column is divisible into two distinct portions, the trunk and caudal regions. It is sometimes necessary to count the number of vertebrae in each of these regions in the classification and identification of fish.

Abdominal and Haemal Vertebrae: The abdominal vertebrae are identified by the fact that they have a nerual canal only and no haemal or ventral canal. Notice the remains of the notochord in the biconvex space between the spool-shaped centra of two vertebrae. On the anterior dorsal surface of the centrum are two processes, the neuropophyses, which join above to give the neural spine, and the neural canal. In contact with the anterior end of each neuropophysis are the paired pre-zygapophyses which articulates with the paired post-zygapophyses of the preceding centrum. From the ventral sides of the centrum there are paired processes, the parapophyses, on which the ribs loosely articulate. The parapophyses remain unjoined below in the abdominal region. In the caudal region these processes unite to enclose a canal, the haemal canal, and are called haemapophyses and extend ventrally as the haemal spine. Vertebrae with both a neural and a haemal spine are haemal or caudal vertebrae. Both ends of the centrum are concave, a condition called amphicoelous. The vertebrae of all teleosts are amphicoelous except those of the gar pike (Lepidosteus) which has vertebrae with a convex anterior and a concave posterior surface, a condition known as opisthocoelous, a ball and socket type articulation.

Ribs: Dorsal and ventral (Pleural) ribs are present in fishes. The dorsal ribs or intermuscular bones lie between the septa separating the epaxial and hypaxial muscles. These ribs in the carp were removed when the epaxial muscles were filleted off. The ventral or pleural ribs are located internally to the muscles, first outside the peritoneum. In some species of fish the ventral ribs may have one or more secondary branches, the epipleurals.

For the next period: Wrap up the carp head with attached air bladder. Put your name on the outside and return it to your instructor.

Pectoral Girdle: In existing sharks, rays, and chimaeras, the pectoral girdle is in the form of a cartilaginous U-shaped bar incomplete dorsally. It is imbedded in the muscles of the body wall close behind the last gill arch. The upper or dorsal portion is called the hypercoracoid (scapula) and the ventral the hypocoracoid (coracoid). Between these two portions is an area with articular surfaces for the basal cartilages of the pectoral fin.

There are notable differences in the pectoral girdle of the teleosts over the condition in the cartilaginous fishes. The teleosts retain the "primary" girdle of the elasmobranchs, that is, the hypocoracoid (coracoid) and hypercoracoid (scapula), which are both replacement bones, but add a number of dermal bones to these. The scapula and coracoid of Teleostomi may or may not be homologous with similarly names bones in other vertebrates. These latter bones evolved from modified scales, develop on the outer surface of the primary girdle and are called the secondary girdle. Beginning dorsally and passing ventrally the following bones form each half of the secondary pectoral girdle: (1) The post-temporal usually present, being a forked bone articulating with the epiotic and opisthotic or exoccipital bones of the skull; (2) the supracleithrum, a bone dorsally in contact with the post-temporal and venterally in contact with the (3) cleithrum, a bone laterally and anteriorly in contact with the hypercoracoid and hypocoracoid; in cyprinoids and ganoids the supracleithra (post-temporal and supracleithrum) may also connect by ligaments, which are sometimes ossified, with the first vertebral centrum; (4) one or two post-cleithra may articulate on the posterior side of the cleithrum.

Other bones may also be present in addition to those bones in the pectoral girdle of other groups of fishes. All chondrosteans (sturgeons, paddlefishes) and all known crossopterygians and lungfishes have a *clavicle* which extends from the cleithrum to the mid-ventral region where it has a union by a symphysis with the clavicle of the opposite side. In some species the coracoids may expand ventrally and unite medially. In some groups of fishes (salmon, trout) there is present a third bone of the primary shoulder girdle, the mesocoracoid. In teleosts the scapula and coracoid are small bones which lie on the inner side of the cleithrum with the scapula dorsal to the coracoid. This primary girdle (cartilaginous in origin) in teleosts is much reduced in most species compared with the extent and size of the bones of the secondary girdle.

Notice that the pectoral girdle forms the posterior wall of the gill chamber; the anterior face of the cleithrum is the most prominent bone here.

Sketch and label the bones of the pectoral girdle and fin of the carp and trout.

Pectoral Fin: Most teleosts have only a few radials (*actinosts*), four is the common number but sometimes only 2 or 3, rarely more than 5, in the pectoral fin. They articulate or even unite with the pectoral girdle near the junction of the hypocoracoid (coracoid) and hypercoracoid (scapula). Distally they articulate with the *dermal fin rays*. Usually the first dermal ray articulates directly with the hypercoracoid.

Two Cephalic Muscles: A series of bones, the *infraorbitals* or *circumorbitals*, forms a ring around the anterior ventral and posterior part of the eye. Immediately ventral to these is a large muscle, the *adductor mandibularis*, covered by skin. Carefully remove this skin and expose the muscle. It is long and large, the largest muscle in the head. Its main origin is in the angle of the preopercle. Anteriorly it narrows to a tendon which is inserted on the dorsal arc of the mandible. Carefully loosen the circumorbital bones by cutting some of the skin connecting them. A muscle that is seen to spread out from the postorbital region of the skull continues under these bones. It is the *levator arcus palatini*. Its origin is from the external surface of the *sphenotic* bone of the cranium (to be studied later) and it fills the space just posterior to the eye. It radiates to its insertion on the autero-lateral face of the hyomandibular.

The *Skull*, *Facial*, and *Branchial Skeleton:* Before proceeding to a dissection of the cephalic skeleton, study the plates available in the laboratory on the cranium, facial bones and branchial arches of *Roccus saxatilis*. Study also the assembled skulls of *Roccus saxatilis*. Except for a few differences, these bones in Roccus will be readily recognizable in the carp. In the classification and study of fishes it is necessary to transfer what one has learned about one fish to a new species that is taken up for examination. The student should be able to transfer his knowledge of the skull, facial, branchial, girdle and all bones studied in *Roccus* to these bones in the carp. Also, the student may be required to identify these bones on other species of fish that may be presented to them. To acquaint yourselves with the appearance of fish bones in other groups and species of fish, the student should spend some time looking at the places in Gregory, W. K., *Evolution Emerging*, and Gregory, W. K., *Fish Skulls*.

Dissection and Study of the Weberian Apparatus of the Carp, Cyprinus carpio

Discussion: In the order of teleosteous fishes Ostariophysi, there is a unique modification of the anterior vertebrae called the weberian apparatus. This apparatus, one of the distinctive characters for the order, consists of 4 ossicles in close association with the first four modified vertebrae. They form a series on each side of the vertebral column that connect the anterior end of the air-bladder and the internal ears.

The internal ears, each of which consists of three semi-cicular canals, a sacculus, and a utriculus, are connected by the endolymphatic sac in the posterior part of the cranium. This sac meets the perilymphatic sac medially, which extends a short distance posteriorly and then divides, each half leaving the cranium on both sides through a lateral foramen. Just anterior to the first vertebra each branch of the perilymphatic sac enlarges to form the atrium sinus imparis. The wall of each atrium is partly membranous and is in part formed by the two cup-shaped ossicles, the claustrum and scaphium. Continuing in the anterior-posterior direction is the intercalarium, a thin, forked bone whose two processes rest on the second vertebra. An interossicular ligament connects this ossicle with the next posterior one, the tripus, a much larger trianular bone with a long anterior process and a long thin medially curving posterior process, the transformator. The tripus has a central process that extends into the second vertebra. This process acts as a fulcrum in its articulation on the second vertebra. The transformator process of each tripus is imbedded in the tendonous outer layer of the anterior portion of the air-bladder. The end of each transformator process is attached anteriorly to the ossa suspensoria by a small triangular muscle consisting of unstriated fibres, the tensor tripodis muscle. The tripus and intercalarium lie in a cavity, the saccus paravertebralis which is membranous and filled with a semi-gelatinous fluid. In the more generalized members of the order this sac communicates anteriorly with the atrium sinus imparis, a condition present in the carp but a careful dissection is necessary to show it.

Development of the weberian apparatus: The neural arches and spines of the compound vertebra (the fused second the third centra) are formed from the basidorsals of the second, third, and fourth vertebrae fused with the first three interspinous bones and possibly also the neural spine of the first vertebra.

The transverse processes of the first and second vertebrae are dorsal ribs. The ossa suspensoria are modified haemapophyses. The claustrum arises as an ossification of the connective tissue forming the wall of the atrium sinus imparis. The scaphium arises partly from the basidorsal of the first vertebra and partly from an independent mesenchymatous rudiment. The intercalarium is also dual in origin, deriving partly from an ossification in the interossicular ligament and partly from the second basidorsal. The tripus arises from three sources, from the third basidorsal, from an independent mesenchymatous rudiment and from a small ossification in the outer coat of the air-bladder. These conclusions on the embryonic origin of the weberian ossicles and anterior vertebrae are those given by Watson (Ref. 8) for the goldfish. Some of these may be in conflict with the findings of earlier workers but these conflicts may be due to the less complete observations of the earlier workers.

Evolution in weberian structure: In the suborder Siluroidea (catfishes) of the order Ostariophysi, the apparatus is direct, that is, the intercalarium does not articulate with the vertebral column and the tripus does not possess a transformator process which reverses the direction of motion of the ossicular chain as it does in the suborder Cyprinoidea where the system is termed indirect. Since the embryonic condition of the weberian chain in the goldfish (Carassius auratus) is so similar to the adult condition in the catfishes, it is assumed that most likely the indirect cyprinoid system has evolved from the direct siluroidean system.

Dissection for weberian apparatus: Carefully remove the musculature from the anterior end of the vertebral column on one side of the carp. If you damage the sacs on one side, you still have the opposite side to dissect after you finish the side on which you are working. Study the structures described in the discussion part of this exercise. Sketch the ossicles *in situ*. Then remove the section of the vertebral column bearing the apparatus, place in boiling water for a minute or two, remove all flesh from the vertebrae, glue the ossicles of one side in place on the vertebrae and keep the ossicles from the other side in a small vial. Sketch and label the cleaned vertebrae with ossicles in place. Sketch the separated ossicles and label.

Function of weberian apparatus: Experimental work definitely shows that it is a mechanism for the transmission of vibrations to the internal ear. The attachment of the air-bladder to the tripus is such as to make the apparatus a very sensitive one for reception of rapid vibrations of small amplitude. It has been shown that the sacculus and lagena in the ear of the *Cyprinidae* and *Siluridae* are especially adapted to receive sound vibrations conveyed to it by the weberian apparatus.

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Suggested Reading

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Cephalic Skeleton

Cephalic Sensory Canal System: The lateral line continues onto the head in the form of sensory canals. It passes by means of the posttemporal from the trunk onto the head where it becomes a tube enclosed in the dermal bones and gives off several branches. This branching takes on a rather constant pattern throughout most of the groups of the Osteichthyes. The Chondrichthyes and Osteichthyes agree in the patterns these canals take. The canals open by means of pores into the surface of the head. The first branch given off upon reaching the head is the occipital or supratemporal canal which runs transversely across the occipital region. The next is the hyomandibular branch which runs down onto the lower jaw as the mandibular canal. The main canal continues forward to just behind the eye where it forks to give the suborbital canal which passes below the eye and forward to the nasal area, and a dorsal branch, the supraorbital canal which runs forward to the nasal region also. Observe what you can of this canal system and sketch. Later, after the flesh has been removed, you will trace the canals and pores on the skull and facial bones.

Tie the carp head in a cloth and place it in boiling water for a few minutes. Then remove all the flesh, taking great care not to lose any of the bones. Some bones will be quite small and are easily missed, so go slowly. Note what muscles fill what spaces as you dissect, even though we are not studying all the muscles. Pay special attention to the removal of the flesh around the pharyngeal teeth area. Frequently an extra set of loose pharyngeal teeth are found. Note under what circumstances this extra set is present. Note also how oily the flesh and bones are. Oil will come out of apparently cleaned bones for some time. Perhaps fish have played a role in the formation of petroleum deposits.

Bones of the Cranium: The cranium is composed of two types of bones, investing (or membrane or dermal) bones and cartilage (or replacement) bones. The former type composes the secondary cranium and the latter type the primary cranium (or neurocranium or chondrocranium). The membrane bones of the cranium are the parietals, frontals, nasals, parasphenoid, and vomer.

The cartilage bones, formed as ossifications in the chondrocranium, are as follows: the basi-occipital, forming most of the occipital condyle and the posterior region of the basis cranii or skull-floor; the ex-occipitals, which form the sides of the foramen magnum and meet above and below it; the supraoccipital forming the occipital crest; the bones of the auditory capsule, which may number as many as five, but usually only three, which are the prootic in the anterior region of the capsule, quite a large bone, which meets with the prootic from the opposite side in the floor of the braincase, just in front of the basi-occipital; the opisthetic is a tiny bone in the posterior part of the capsule external to the ex-occipital; the sphenotic, above the prootic and beneath the frontal and pterotic; the pterotic, at the postlateral corner of the cranium and with a pointed pterotic process; the epiotic, above the exoccipital, medial to the pterotic, lateral to the supraoccipital, with a small, sharp epiotic process; the alisphenoid, in front of the prootic, beneath the sphenotic and frontal; the orbitosphenoid, bordered by the frontal dorsally, the alisphenoid posteriorly, the prefrontal anteriorly, the parasphenoid ventrally.

The Membrane Bones: The mesethmoid is the most anterior of the dorsal bones and is pointed and unpaired. The two separate ossifications that form articulating processes on the anterior part of the mesethmoid are the preethmoids. The large frontals follow the mesethmoid; then the small, paired parietals. The parasphenoid is the narrow ventral bone joining the vomer and basi-occipital. The vomer is the most anterior ventral bone. The prefrontals are lateral bones placed beneath the ethmoid and frontals just posterior to the vomer.

Hold the freshly cleaned cranium up to the light and trace out the sensory canals. Determine how their course is continued on certain of the facial bones. Sketch and label.

In the Ostariophysi the unpaired basisphenoid bone is missing. It forms the interorbital septum found in other orders of fishes. Is the basisphenoid present in the Roccus? List which bones Cyprinus and Roccus do not have in common.

Note the vertebral process of the basioccipital and the horny pad fitting onto it on which the pharyngeal teeth work; the large optic fenestra above the parasphenoid and below the alisphenoid; the foramen for the trigeminis nerve opening between the posterior end of the alisphenoid and the prootic; the foramina for the facialis nerve in the anterior third of the prootic; the large oblong foramen in the anterior lateral part of the exoccipital; the paired foramina for the perilymphatic ducts on the posterior surface of the exoccipitals; the fossa for the hyomandibular bone; the canal for the glossopharyngeal nerve at the posterior border of the prootic, very close to the foramen for the facial nerve; the frontal process.

Using the pens and India ink in the laboratory, number each cranial bone according to the numbers used on the Roccus plates. Sketch and label the cranium.

Facial Bones: Identify and number with India ink the following bones, using the illustrations and demonstrations as aids: the premaxilla and maxilla which enter into the gape anf form the upper jaw; the dentary, the articular which articulates with the quadrate, the remains of Meckel's cartilage, and a small bone, the angular, which three bones together form the lower jaw; the rostral, a small phlange-like bone connecting by ligaments to the premaxillae and mesethmoid; the intermaxillary, a small, disk-like bone between the dorsal end of the maxilla and the pre-ethmoid articulation; the palatine, dorsal to the intermaxillary, articulating posteriorly with the mesopterygoid; along the anterior border of the mesopterygoid and the quadrate bones is the flat pterygoid which overlaps rather broadly the quadrate. The quadrate bone articulates with the articular of the lower jaw and is connected by cartilage for most of its dorsal border with the metapterygoid and to a much smaller extent with the mesopterygoid. The quadrate has a v-shaped cut in its dorsal edge where the symplectic fits. The symplectic runs for a short distance up the posterior border of the metapterygoid. At its posterior end the symplectic is connected by cartilage to the hyomandibular, a large bone, which extends up to the cranium where it articulates on the sphenotic and prootic bones; the circumorbital bones, six in number, beginning anteriorly where the first one is known as the lacrymal, and the second one sometimes as the jugal. The dermosphenotic is the sixth circumorbital. A small bone, the supraorbital articulates on the lateral border of the frontal.

The operculum consists of the preopercle which articulates on the dorsal surface of the hyomandibular, the interopercle located ventral and medial to the preopercle, the opercle which articulates on the hyomandibular dorsally, and the subopercle ventral and medial to the opercle.

Mouth Parts: The protrusible, edentulous mouth of the carp is similar in its structure and mechanical operation to that of the sucker but is considerably different from that of the trout, sunfish, or of a fish like the striped bass. Each of the paired premaxillary bones has in most teleosts a backward projecting spine on its anterior, inner surface which works on the mesethmoid. In the carp and some other cyprinids and in the suckers the premaxillary spine does not come in direct contact with the mesethmoid. Instead a ligament connects from the premaxillary spine posteriorly to a median, unpaired bone, the rostral. The rostral bone moves from a horizontal position to a vertical position at the head of the mesethmoid as the mouth moves from the protruded position to a closed one. The base of the rostral is connected by a short ligament to the mesethmoid. The paired maxillary bone follows behind the premaxillary and has three processes. The median dorsal one has a small cartilage piece between it and the underside of the lacrymal. The ventral process, articulates laterally to and on the premaxillary. The dorsal process of the dentary is connected by a ligament to the ventral process of the maxillary.

Ventral to the anterior end of the palatine and the post-dorsal end of the maxillary lies the intermaxillary bone, ossified in the carp. It is also known as the cartilaginous rod. It is located between the post-dorsal end of the maxillary and the antero-dorsal surface of the pre-ethmoid on which it articulates. From the anterior end of the palatine there is a ligament connecting to the dorsal end of the maxillary. The palatine has an articulating surface about midway along its length. This articulating surface works on the posterior articulating surface with the pre-ethmoid. The palatine also has a process dorsal to its articulation with the pre-ethmoid. This process is connected by a short ligament to the edge of the mesethmoid. The palatine articulates posteriorly with the mesopterygoid. This bone has a ligament connecting it to the prefrontal.

The mouth of the carp is protruded by having the lower jaw depressed by the action of several muscles. The premaxillae are then protruded because the lowering of the dentary increases the tension of the ligaments and membranes connecting the upper and lower jaws at the angle of the mouth.

The upper jaw of the shark, the palato-quadrate (or palato-pterygo-quadrate) is carried over into the bony fishes but in these it is much modified in the adult. It has lost most or all of its cartilage and has been broken up into five cartilage bones none of which enter into the gape of the mouth though some may bear teeth. The bones of the primary upper jaw in bony fish are the palatine, pterygoid, mesoterygoid, quadrate, and metapterygoid. These bones, however, are not referred to as forming the upper jaw. Two dermal bones have appeared in bony fish ancestry to form the upper jaw proper, the premaxilla and maxilla. In the lower jaw a similar modification has taken place. The primary jaw consisting of Meckel's cartilage in the embryo practically disappears except for a small rod of cartilage and an ossified cartilage, the articular. The angular and dentary are dermal bones.

Jaw Suspension: In most modern fishes the upper jaw has no direct connection with the brain case except by the hyomandibular. In this type of suspension the thrust of the jaws is transmitted from the quadrate to the brain case by way of the symplectic and metapterygoid to the hyomandibular which relays it to the brain case. Such a type of jaw suspension is called *hyostylic* or *holostylic*. Elasmobranch fishes have support for the jaws in two ways; in one the hyomandibular articulates with the brain case and in the other the upper jaw also articulates with the brain case. This type where the hyomandibular takes only part of the jaw support is called *amphistylic*. A third type of jaw suspension is that in which the hyomandibular takes no part in the support of the jaw. The upper jaw functions as the sole support for both jaws. This type is called *autostylic* and is found in the living chimaeras and lung fishes. Land vertebrates all have an autostylic jaw suspension. There are a number of modifications of these three types almost each modification being given the name of a new bype but only the three preceding terms will be used here.

Identify and reassemble the bones of the hyoid arch and branchial apparatus.

The *hyoid* or *second arch* consists of the *hyomandibular*, the *interhyal*, a small bone located at its articulation point in the cartilage between the symplectic and hyomandibular, *andepihyal*, a *ceratohyal* below, and then a small *hypohyal*. The right and left hyoid arches are connected by an unpaired median bone, the double *basihyal* which supports the base of the tongue. Running forward from on top of the basihyals is the *glossohyal* which supports the tongue.

Along the posterior border of the epi-and cerato-hyals are the attached *branchiostegal rays*. Below the basihyal is an unpaired bone, the *urohyal*.

Next come the four branchial arches decreasing in size posteriorly. The dorsal most segment of each arch is the *pharyngobranchial*, then the *epibranchial*, next the *ceratobranchial*, and most ventrally the *hypobranchial*. The hypobranchials from each side are joined by an unpaired basibranchial. All bones of the hyoid and branchial arches are cartilage bones.

Sketch and label the facial bones, hyoid and branchial arches.

SELECTED ANNOTATED SYNONYMY OF TELEOST SKULL BONES

Angular, A, (e.t. of de Beer, 1937; Devillers, 1947; Lekander, 1949; dermarticular of Goodrich, 1930), the ectosteal (membranous) component of the compound bone known conventionally as "articular". Histology (Haines, 1937) and embryology (Lekander, 1949:83) confirm the invasion of Meckel's cartilage by the angular to the partial or total suppression of the true articular, although Berg (1940: 416) preferred to retain the old name, "articular."

Articular, AR, ("true articular" of Haines, 1937), the endochondral and/or perichondral (i.e. endosteal) ossification of the penultimate, posterior segment of Meckel's cartilage. The angular replaces the articular in the more differentiated fishes, but it is often hard to determine whether one, the other, or both angular and articular are present in the compound "articular" (Lekander, 1949: 83).

Autopalatine, P, (e.g. of Goodrich, 1930: 284; Gregory, 1933; Ramaswami, 1948: 526), the anteriormost bone of the pterygoquadrate arch, as distinct from the sometimes associated dentigerous,membranous component (dermopalatine).

Autopterotic, PTO, (e.g. of Devillers, 1947: 29; pterotic of Gregory, 1933; and of der Beer, 1937), the cartilage bone component of the "pterotic," in contact with the lateral semicircular canal. The autopterotic is called opisthotic by Holmgren and Stensio (1936: 482, 486, 490) and Lekander (1949), who considered it to be the homologue of the dorsal half of the opisthotic of *Polypterus*.

Autosphenotic, SPH, (e.g. of Holmgren and Stensio, 1936: 490, 494; Lekander, 1949; sphenotic of Gregory, 1933; der Beer, 1937; Ramaswami, 1948), the cartilage bone occupying the postorbital (sphenotic) process, as distinct from the dermosphenotic (see below). Without this distinction much confusion has arisen from the difference.

Basisphenoid, (e.g. of Gregory, 1933: 89; suprasphenoid of Kindred, 1919: 37, 73), phylogenetically a cartilage bone but ossifying ontogenetically without cartilage preformation (de Beer, 1937: 129, 140). Lacking in Cypriniformes (Ostariophysi) according to Sagemehl (1891: 496) and Berg (1940: 442); but according to Holmgren and Stensio (1936: 489) present in cyprinoids, the pedicel only developing, and often fused to the parasphenoid, e.g. in *Abramis*. According to Kindred (1919) and de Beer (1937), present also in *Amelurus*. Absent in *Carassius* (Koh, 1931, "basioccipital") and in homalopterids (Ramaswami, 1948: 522).

Coronomeckelian, SA, (e.g. of de Beer, 1937; Lekander, 1949: 80; sesamoid articular of Ridewood, 1904a; Starks, 1916; Haines, 1937; sesamoid angular of Ramaswami, 1948: 528; *Os Meckeli* of Berg, 1940: 427 and fig. 129). Although classified by de Beer and Berg as a cartilage bone, Haines (1937) found it to be a detached portion of the teleost angular (as named here), invariably concerning the insertion of the fibers of the adductor mandibulae, but having no necessary connection with the perichondrium. Coronomeckelian is preferred here to avoid further use of the names articular and angular, although Ramaswami's name is perhaps more apt.

Dentary, D, (dental), the largest dermal bone of the mandible, a part of the bone complex, dental-splenial-mentomandibular, according to Holmgren and Stensio (1936), Pehrson (1944), Lekander (1949). The objection of de Beer (1937: 125) to the name dentalo-splenial is overcome with the demonstration by Lekander (1949: 125) that splenials in cyprinids may arise separately, either fusing later with the dental or remaining free. The anterior third of the dentary is typically fused with the ossified tip of Meckel's cartilage, known as the mentomeckelian (de Beer, 1937) or mentomandibular ossification (Holmgren and Stensio, 1936; Lekander, 1949).

Dermosphenotic, DSPH, (e.g. of Gregory, 1933: 88; Holmgren and Stensio, 1936: 494; Devillers, 1947: 47; Tretiakov, 1946; Ber, 1940, figs. 58, 72, 92, 98, 111, 122, etc.; the triradiate "post orbital 2" of Ramaswami, 1948), the dermal representative of the autosphenotic, bearing part of the suborbital latero-sensory canal (sometimes the conjunction of temporal, supra- and suborbital canals), contributing by its anteroventral corner to the margin of the orbit, and in its maximum development roofing the lateral temporal fossa. In more active cyprinids, dermosphenotic and adjacent suborbitals tend toward regression and disappearance in connection with the protraction of the lateral temporal fossa to accommodate a more robust adductor mandibulae (Tretiakov, 1946). The name sphenotic has been used for either or both the dermo- and autosphenotic. The names postfrontal and intertemporal are wrongly synonymous with dermosphenotic. De Beer (1937: 498) correctly asserted that the postfrontal never was the dermal representative of the sphenotic, since the tetrapod postfrontal was mistakenly homologized with the fish 'sphenotic' before the distinction between membrane and cartilage bones, so that with the distinction, the membrane bone became wrongly named postfrontal. However, he erroneously identified the intertemporal as "the representative of the sphenotic" and the postfrontal as "the uppermost bone in the postorbital series," His intertemporal can be accepted as an intertemporal, but is not the equivalent of the dermosphenotic! It is the dermosphenotic which is the uppermost bone of the postorbital series, whereas the tetrapod postfrontals are represented in fishes by the supraorbitals (Gregory, 1933; 88). In *Tarpon* (Gregory, 1933, fig. 31), the postfrontal is contiguous anterodorsally with the dermosphenotic. In the figure of *Osteolepis* (Goodrich, 1930: 286) alluded to by de Beer (1937: 498), if dermosphenotic is read for postfrontal the discrepancy vanishes. In cyprinids (Tretiakiv, 1946), the apparent uppermost bone in the suborbital series may be either dermosphenotic (SO_6), suborbital 5, or suborbital 4. In *Salmo*, a dermosphenotic is figured by Gregory (1951: 201, fig. 9.33D), although Berg (1940: 425) denied its occurrence in the Salmonini. Tretiakov's dermosphenotic is the same as Gregory's and the penultimate bone in Tretiakov's series (our SO_5) seems to be de Beer's postfrontal, the presumption being that the dermosphenotic was lacking in de Beer's as in Berg's specimens of *Salmo*. That a bone in this position may upon occasion represent at least in part the postfrontal is shown by the paleoniscoid, *Coccocephalus* (Gregory, 1951: 179, fig. 9. 6C), in which the penultimate suborbital and hindmost supraorbital series, i.e. through suppression of the dermosphenotic. In *Leptolepis bronni* (Berg, 1940: 418, and figs. 111 and 113, after Rayner), two supraorbitals, a dermosphenotic, and a supratemporal-intertemporal are present, so that dermosphenotic and intertemporal can not be regarded as valid synonyms either.

Dermosupraoccipital, DSOC?, the dermocranial covering of the endocranial supraoccipital (tectum synoticum) according to Gregory (1933: 89), who does not equate it with the extrascapulars. Goodrich (1930: 283) is less explicit as to its use: "postparietal (dermosupraoccipital) which with (sic) the tabulars may form a transverse row of bones sometimes called supratemporals." Berg (1940, figs. 66 and 68) used the names postparietal and dermosupraoccipital interchangeably for superficial bones of the occipito-parietal region apart from the extraxcapulars (tabulars) and not enclosing the transverse occipital lateral line canal.

Ethmoid, E, the bone ossifying in and around the nasal septum. The name mesethmoid should be rejected because of implications of homology with the mammalian mesethmoid (Gregory, 1933: 88; de Beer, 1937: 442), and because of its application to a dorsally contiguous dermal element (e.g. by Starks, 1926).

Extrascapular, PP, one of a series of from two to eight bones of the teleost skull, known variously as cervicals, extrascapulars, nuchalia, postparietals, scale bones, supratemporals, or tabulars (cf. review by Tretiakov, 1945:52). Their relations to adjacent bones are diverse and their homologies are not well established. The logical name (supratemporal) of each element of the series is preempted by its application to the dermal (tube bone) representative of the autopterotic, as Tretiakov notes in perferring the name tabular. He identifies them by their connection with the supratemporal commissure (transverse occipital tatero-sensory canal), and infers from their frequently reduced number mutual fusion or growth to subjacent bones. According to him the lateral extrascapular (tabular) retains its independence more often than the others, and may be recognized by the conjunction within it of temporal (postorbital), supratemporal, and posttemporal canals. In cyprinids, the lateral extrascapular has often been called the postparietal, but de Beer (1937) applied the name postparietal in a less restricted sense to the several members of the series, and postparietal seems also to be the synonym of dermosupraoccipital (see above). The names most frequently and unequivocally employed are extrascapular and tabular. Most commonly there are two such bones on either side of the skull, a mesial (or median) extrascapular (middle tabular), and a lateral extrascapular (lateral tabular), such a condition occurring widely, e. g. in *Acentrophorus*, *Chanos* and *Cyprinus*. Among cyprinids, Tretiakov found tube bones free and separate, mutually fused, or fused with parietals or adjacent bones. Ontogenetic studies (Devillers, 1947: 31; Lekander, 1949: 87) show, moreover, that the extrascapulars often arise *ab initio* as discrete entities, only later fusing with other bones. Thus the old dilemma (cf. Allis, 1904: 437; de Beer, 1937: 495, 506, 513) concerning the homologies of the components of the "parieto-extrascapular" is resolved.

Intertemporal, (see supratemporal-intertemporal).

Jugal, may be represented by suborbital 2 (SO_2) according to Gregory (1933: 88) and de Beer (1937: 124). An anatomical criterion is the attachment to the mesial surface of the bone, in conjunction with a ligament from the hyomandibular, of the M. adductor maxillaris, a division of the M. adductor mandibulae (Chabanaud, 1945: 570).

Lachrymal (lachrimal, lacrimal, lacrymal, preorbital, SO_1), L, usually the foremost bone in the suborbital series in teleosts, and the homologue of the lachrymal of *Cheirolepis* and of tetrapods, but not of the antorbital of *Amia* (Gregory, 1933: 89, 93). The foremost bone in this series in *Salmo* is called lachrymal-antorbital by Holmgren and Stensio (1936: 494), but Devillers (1947: 11) objected to this, asserting that it has none of the characteristics of the latter element. On the other hand, Lekander (1949) used the name antorbital for the bone in cyprinids called lachrymal here and by Devillers. Among homalopterids, Ramaswami (1948) described a lachrymal-jugal present simultaneously with an antorbital.

Lateral ethmoid, LE, (parethmoid, ectethmoid, erroneously called prefrontal), the bone arising on each side in relation to the cartilage of the lamina orbitonasalis, according to de Beer (1937: 107), who reserved the name extethmoid for the ossification at the same locus independently evolved in birds. Berg (1940: 446) mistakenly equated the prefrontal (membrane bone) and lateral ethmoid (cartilage bone).

Membranopterotic, (see under supratemporal-intertemporal).

Mentomeckelian (mentomandibular), M, (see under dentary).

Opisthotic (intercalary), OPIS, phylogenetically a cartilage bone, often all that remains of it being an ossified ligamentous extension completely excluded from the auditory capsule according to de Beer (1937: 130), who accepted the interpretation of Sagemehl (1891: 558), who described this condition among cyprinoids. Holmgren, Stensio, and Lekander applied to it the name intercalary, but reserved the name opisthotic for the autopterotic as named here (see under autopterotic). Berg (1940) used the names opisthotic and intercalary both as synonyms (pp. 419, 434) and not as synonyms (pp. 412, 414).

Parasphenoid, PS, homologue of the mammalian vomer (Gregory, 1933: 89).

Postfrontal, (see under dermosphenotic).

Posttemporal, PTT, the bone articulating with the epiotic, suspending the pectoral girdle, and traversed by the posttemporal lateral line canal. De Beer (1937: 125) called such a bone "suprascapular (supracleithrum)" in *Salmo*, "posttemporal" in *Ameiurus* (p. 139), and "posttemporal (supracleithrum)" in *Amia*

(p. 105). This confusion stems perhaps from the nomenclature of Haller (1905), in which the upper of the two bones traversed by the posttemporal canal was called the second supracleithrum, and the lower, the first supracleithrum. Haller's first supracleithrum articulates with the cleithrum and should be called simply the supracleithrum; his second supracleithrum is known to most authors as the posttemporal, as named here.

Preethmoid, PE, (e.g. of Starks, 1926; and cf. Ramaswami, 1948: 516), the bone called septomaxillary by Sagemehl (1891) but renamed by Swinnerton (1902: 530) in view of the dubious homology of these bones with the tetrapod septomaxillaries.

Prefrontal, PF, the membrane bone extending laterad from the lamina orbitonasalis (cartilaginous precursor of the lateral ethmoid) of each side, and which in teleosts may be absent, separate, fused from the beginning with, or developed as an extension of, the lateral ethmoid (de Berr, 1937: 500).

Prevomer, PV, the homologue of the parasphenoid rather being the teleostean homologue of the mammalian vomer.

Pterosphenoid (pleurosphenoid), PTS, for the so-called "alisphenoid" of teleosts (cf. Gregory, 1933: 98). With the recognition of the non-homology of the mammalian alisphenoid with the "alisphenoids" of either teleosts or birds and reptiles, the reptilian "alisphenoid" became known as the pleurosphenoid. De Beer at first (1926: 366) used the name pterosphenoid for the teleost "alisphenoid" presumably agreeing with Goodrich (1930: 380) that the fish bone was not the exact homologue of that of birds and reptiles. Later (1937: 439) he reverted inexplicably to the use of pleurosphenoid for the fish bone merely with the statement that "the bone in question in these forms has occasionally been known as the pterosphenoid pending the demonstration of its homology with the pleurosphenoid." Unfortunately the name alisphenoid is still often applied to this bone in fishes.

Retroarticular, RA, (e.g. of Boker, 1913: 387; Haines, 1937; de Beer, 1937: 128; Ramaswami 1948; dermarticular of Holmgren and Stensio, 1936: 496 and fig. 373; dermarticular plus retroarticular? of Lekander, 1949), the bone conventionally known as the angular. The retroarticular is a mixed ossification, with a core of endochondral bone formed in the ultimate, posterior segment (retroarticular process) of Meckel's cartilage overlain by dermal bone (the latter probably the equivalent of Lekander's dermarticular).

"Rostral," RO, (e.g. of Sagemehl, 1884; Starks, 1926; supraethmoid of Koh, 1931; preethmoid of Edwards, 1926), the sesamoid bone typical of cyprinoids and involved in the mechanism for the protrusion of the premaxillaries (cf. Gregory, 1933: 185; Easton, 1935). All names so far used for this bone are preempted by their applications to other bones. The name "kinethmoid" (Gr. *kinein*, to move, plus ethmoid) is therefore proposed here for the cyprinoid "rostral," a movable bone of the ethmoid region.

Squamosal, the name used by Sagemehl (1891: 506) for the "pterotic" complex of cyprinoids, and unfortunately still applied occasionally to the teleost skull, alth2 although Westoll (1937) and others have shown that the true squamosal is absent from the Actinopterygian skull, having disappeared with the retirement of the jugal canal from the status of lateral-line canal to that of pit line.

Suborbital, SO, (e.g. of Gregory, 1933; de Beer, 1937; Ramaswami, 1948; infraorbital of Holmgren and Stensio, 1936; Moy-Thomas, 1938: 307; Lekander, 1949; Devillers, 1947), any one of the series of bones (lachrymal, jugal, postorbital, dermosphenotic, etc) associated with the suborbital (infraorbital) lateral-line canal. Among teleosts, the most usual number in this series is six bones, although departures from this number, even within the same fish, render homologization of individual bones uncertain.

Supracleithrum, SCL, (see under posttemporal).

Supraethmoid, SE, (e.g. of de Beer, 1937; Ramaswami, 1948; dermal ethmoid, dermethmoid, dermal mesethmoid, mesethmoid of various authors). Berg (1940, fig. 127) retained the name mesethmoid for the dermal ethmoid, and used hypethmoid for the "unpaired bone below the dermal mesethmoid" (p. 425), but the name mesethmoid should only be applied to the mammalian skull (see under ethmoid), and hypethmoid appears to be a synonym for ethmoid as defined above.

Supraorbital, SPO, one of the one or more bones along the upper margin of the teleost orbit, not traversed by a laterosensory canal, and according to Gregory (1933: 88) including the postfrontal. The confusion of postfrontal and dermosphenotic becomes understandable from an examination of such skulls as those of *Cheirolepis* and *Coccocephalus* (Berg, 1940, fig. 52; Gregory, 1951, fig. 9.6), in which the hindmost supraorbital (postfrontal) seems to be confluent in the one case with the uppermost bone of the suborbital series (dermosphenotic) and in the other, with the bone just beneath the dermosphenotic. Supraorbitals apparently only thus come to acquire relationships with the laterosensory system.

Suprapreopercular, (e.g. of Allis, 1910: 152; Holmgren and Stensio, 1936: 495; Ber, 1940: 403, 413, 423, 428, fig. 146, "s. pr. op."; Tretiakov, 1945; Devillers, 1947: 11, 36, 38; Lekander, 1949: 69, 102; supraopercular of Bruch, 1861: 12; supratemporal of Parker, 1873: 99; "subtemporal or supraopercular" of Ridewood, 1904b: 485; subtemporal of Kindred, 1919: 94; and of de Beer, 1937: 125; "subtemporal" of Gregory, 1933: 166, supratemporal, p. 165, "sbtm," fig. 59). The name suprapreopercular is applied to any of from one to several usually small tube bones conducting the dorsal extension of the preopercular laterosensory canal across the gap between the preopercular bone and the supratemporal canal above. These bones are considered to represent vestiges of the upper half of the bipartite preopercular (suprapreopercular plus infrapreopercular) of, e.g., Paleoniscoids, Bobasatraniidae, Pycnodontiformes, Phractolaemoidei and Chanoidei (Stensio, 1932, 1947: 184; Tretiakov, 1945: 49), the infrapreopercular being represented by the preopercular as usually understood. Among salmonoids and cyprinoids, suprapreopercular elements tend to be absent or vestigial, and when present in cyprinids, exist as free tube bones or may fuse with the anterodorsal corner of the operculum the latter condition being peculiar to cyprinids, according to Tretiakov. The skull of *Notemigonus c. crysoleucas* has such an opercular, and the same condition is recorded for a few other cyprinids (Allis, 1904: 437, fig. 17; Devillers, 1944; Tretiakov, 1945).

Supratemporal-intertemporal, ST, (e.g. of Holmgren and Stensio, 1936: 490, 494; Berg, 1940: figs. 92, 97, 111; Bamford, 1941; Devillers, 1947: 29; Lekander, 1949: 69, 71, 85, 103; supratemporal and/or intertemporal of de Beer, 1937: 132, 139; "pterotic" or supratemporal of Gregory, 1933: 92; squamosal in part of Kindred, 1919; in part, the dermosquamosal of other authors). In cyprinids, the pterotic complex or pteroticum (squamosal of older authors), in addition to the cartilage-preformed autosphenotic (as named here), consists according to Devillers and Lekander of (1) a flat membranous bone (membranopterotic or dermopterotic), which may be fused from the beginning with the autopterotic or may fuse to it later; and (2) several tubular canal bones (one or two intertemporals and one supratemporal), which either remain free or fuse with the membranopterotic. The extosteal complex might thus be called a supratemporal-intertemporal-membranopterotic but is usually referred to as the supratemporal-intertemporal, as here. The entire pterotlcum may therefore be designated the supratemporal-intertemporal-autopterotic. Except for their relation to the temporal laterosensory canal and for the more anterior position of the intertemporal, the intertemporal and supratemporal bones have often been only vaguely characterized. The confusion of intertemporal and dermosphenotic has been noted (see under dermosphenotic). Ramaswami (1948: 518) identified the intertemporal as the canal bone opposite the sphenotic gap, asserting (p. 520) that in the majority of cases the intertemporal is associated with the sphenotic and the supratemporal either fused with the "pterotic" or located above it. Devillers (1947: 30) recalled that phylogenetically the line of demarcation between the two bones was the junction point of preopercular and horizontal canals. In cyprinids, the intertemporal portion of the temporal canal is associated with two neuromasts innervated by the ramus oticus facialis, whereas the supratemporal portion is associated with two neuromasts innervated by the glossopharyngeal (Devillers, 1947; Lekander, 1949). (From: Harrington, R. W. 1955. Copeia No. 4)

REMARKS ON TERMINOLOGY OF FISH BONES

The terminology of teleost fish bones adopted here is mostly based on current usage and does not necessarily imply homology with similarly named bones of tetrapods or even other groups of fishes. As Romer (1947) has pointed out, the determination of precise homologies between the skull bones of different groups of fishes presents great difficulties. The homology of many teleost skull bones is in question. For example, according to Westoll (1944, p. 67) the frontals of teleosts may be roughly equivalent to the parietals of tetrapods; however, this did not cause Westoll to propose a change in the name of the bone currently called frontals in teleosts and other fishes. Pending absolute proof that the frontals of teleosts are equivalent to the parietals of tetrapods, it would seem better to retain the old nomenclature for stability's sake. Also, Westoll (1937, p. 570; 1944, p. 76) believed that the premaxillary of teleosts cannot be homologous with that of tetrapods. Even though an old commonly used name may not be used in a strict homologous sense this is no reason to propose a new name until a definite homology can be established. Since accurate homologies have not been determined in many instances, a more or less conventional terminology, based largely, but not completely, on topographic regions is utilized here for the sake of consistency and ease of usage. Where it has been adequately demonstrated that the conventional term is improper or misleading, a substitute term has been accepted and used.

I cannot subscribe to the terminology employed by Harrington (1955) wherein a single bone in the adult is described as though it were composed of two bones simply because developmentally two bone primordia may have contributed to its formation. For example, the bone called lateral ethmoid in this paper may actually be the result of the fusion of two bone Anlagen, the intramembranous prefrontal and the endochondral lateral ethmoid. Definite proof would require study of developmental stages Calling areas of this bone by two different names, i.e., referring to this bone as though it were two bones, serves no useful purpose and unnecessarily complicates the nomenclature of fish bones. Even if it was definitely established that two bones have contributed to the lateral ethmoid of a certain characid, the complications of using such nomenclature must be considered. If this system of nomenclature is used for all bones of a fish, it would become both difficult and verbose to refer to any of several bones in the adult fish skeleton. Although I firmly believe that, wherever possible and applicable, the developmental origins of bones should be studied and then indicated in the text discussion, especially where they have phylogenetic significance, use of the term "os dentale-mento-mandibulare-spleniale" by Lekander (1949, p. 82) for the dentary of fishes is far too cumbersome. I believe that the advantage such a name has in pointing out developmental origins and possible phylogenetic descent is more than nullified by the loss of brevity. Some writers forget that a name is merely a name, not a description.

There are several systems and variations of terminology in current use for the various parts of the laterosensory system of the head in fishes. Many of these systems were derived irrespective of the associated bony or nervous structures, and often the limits of the various named portions of the continuous canals of the head have been treated very subjectively. For example, the infraorbital canal in the Cyprinidae was described by Illick (1956, p. 209) as extending posteriorly along the side of the head to the supratemporal canal. Robins and Miller (1957, pp. 216-217) more correctly described this canal as the lateral canal of the head. They defined this as that portion of the laterosensory canal between the attachment of the gill membrane forward to the orbit.

In general, the terminology employed here follows that utilized by Allis (1889 and 1904), Illick (1956) and Robins and Miller (1957). However, in order to maintain a nomenclature more consistent with the osterological description, I have chosen to define the extent of the various canals in relation to the bones and thus have slightly modified the system. It would probably be more logical to attempt to define the limits of these canals by their innervation. However, the following designations work well for members of the Characidae. See Figure 9 for diagram of head canals.

The supraorbital canal is that portion of the laterosensory canal within or in relation to the dorsal surface of the frontal bone. In characids it has an epiphyseal branch over the epiphyseal bar and a posterior branch which extends posteriorly and is continuous with the parietal canal that lies within the parietal bone. A nasal laterosensory canal lies within the nasal bone and above the nasal capsule. The infraorbital canal lies within or over the six infraorbital bones and rarely over or partially within the adnasal bone. The lateral canal of the head, here called the dermopterotic canal, lies within the dermal portion of the pterotic bone. The supratemporal canal lies within the posterior portion of the parietal bone. The Y-shaped extrascapular canal lies within or over the bone of the same name and the posttemporal canal passes through the posttemporal bone. The supracleithral canal lies within the supracleithrum and the preopercular-mandibular canal extends from the dermopterotic canal across the suprapreopercular region and downward into the suprapreopercular portion of the preoperculum. It continues into the preoperculum, across the mandibularquadrate joint into the ventrolateral border of the dentary almost to the symphysis of the lower jaw.

It should be pointed out that the branches of the main laterosensory canals on the headoof *Brycon meeki* are far more extensive than the bony distribution here given. I Also, as the size of the specimen increases, the branches of the canals that overlie ;the bones of the head become more complex and extensive.

(From: Weitzman, S. 1962. Stanford Ichthyol. Bull. 8 (1)).

BONES OF THE FISH SKULL AND THEIR EMBRYONIC ORIGINS*

1. vomer (d)
2. metaethmoid (and preethmoid) (d)
3. prefrontals (d)
4. frontals (d)
5. sphenotic (c)
6. parietal (d)
7. epiotic (c)
8. supraoccipital (c)
9. pterotic (c)
10. opisthotic (c)
11. exoccipital (c)
12. basioccipital (c)
13. parasphenoid (c and d)
14. basisphenoid (c)
15. prootic (c)
16. alisphenoid (c)
17. hyomandibular (c)
18. symplectic (c)
19. quadrate (c)
20. pterygoid (c)
21. palatine (c and d)
22. mesopterygoid (d)
23. metapterygoid (c)
24. preopercle (d)
25. opercle (d)
26. subopercle (d)
27. interopercle (d)
28. articular (c)
29. angular (d)
30. dentary (d)
31. maxillary (d)
32. premaxillary (d)
33. interhyal (c)
34. epihyal (c)
35. ceratohyal (c)
36. basihyal (c)
37. glossohyal (c)
38. urohyal (c)
39. branchiostegal (d)
40. basibranchial (c)
41. hypobranchial (c)
42. certobranchial (c)
43. epibranchial (c)
49. preorbital (d)
50. suborbital (d)
51. nasal (d)
52. supratemporal (d)
53. posttemporal (d)
54. supracleithrum (d)
55. cleithrum (d)
56. postcleithrum (d)
57. hypercoracoid (scapula) (c)
58. hypocoracoid (coracoid) (c)
59. mesocoracoid (c)
60. actinosts (c)

* d = dermal
c = cartilaginous

Numbering System from Jordan and modified by D.W. Seegrist.

SECTION II
SYSTEMATIC ARRANGEMENT OF FISHES

Systematics performs two major tasks: The definition, description and naming of animals and plants and organization of the various kinds into a logical system of classification. It is constructed on the fundamental fields of ecology, genetics, morphology, and physiology. Systematics as practiced today is far different from that of the 19th century when almost the entire emphasis was on the description of new species of plants and animals as a static or fixed concept. The "new systematics" of Huxley (1940) abandons completely the idea of fixity of species and instead of a morphological basis, a broad biological definition is used to cover all internal and external factors which may account for differences. The "population" or a "series" are the units with which modern systematist deals.For a better understanding of modern systematics, students are referred to Huxley (1940), Mayr (1963), Dobzhansky (1951), Mayr, Linsley, and Usinger (1953) and Simpson (1961).

It should be stated here that the taxonomy of fishes is still in a primitive state as apparently no two ichthyologists can agree on a single system of classification. While upwards of 40,000 species of fishes have been described, many of these are but poorly known and often the descriptions have been based on single specimens. Often, too, many of them have been described two or more times by different workers under different names. This has caused endless confusion by erecting an enormous number of synonyms.

PHYLUM CHORDATA

Characters: Animals with an internal skeleton, including at some point in their life history a dorsal supporting notochord, gill clefts, and dorsal, tubular nerve cord. These features are all formed in the early embryo and they may persist or be altered or disappear in the adult stage.

CLASS AGNATHA

Characters: The Agnatha includes both armored fossil forms which were widely distributed in Europe and America in the Silurian. There is only one living subclass, the Cyclostomi. In this group the body is eel-shaped and lacks scales. The notochord is persistent and the skeleton is cartilaginous and ribless. Paired fins and limb girdles are absent. There are no jaws and the mouth is surrounded by a sucking disk. The absence of jaws and fins is regarded as a primitive feature of Cyclostomes. However, the absence of a bony skeleton is a degenerate character since the ostracoderms were covered by a bony armor and some had a well-developed internal bony skeleton.

ORDER PETROMYZONTIFORMES

FAMILY PETROMYZONIDAE (lampreys) (Gr. petra, rock; myzo, to suck)

Characters: Lampreys have a single median nostril which does not communicate with the pharynx. There are seven pairs of spherical gill pouches. Each pouch is connected by a narrow opening to the exterior and opens internally to a common branchial basket. The circular mouth is surrounded by horny teeth, the number and arrangement of which is characteristic for the species. The tongue is also fitted with horny teeth. Usually two dorsal fins are present. The vertebral column is represented by a notochord and rudimentary cartilaginous neural arches.

Ecology: Adults of some lampreys, such as the local Pacific lamprey, Entosphenus tridentatus, are parasitic on fish. They attach to the sides or ventral surfaces of fish by means of the sucking disk, rasp on opening in the flesh with the tongue, and suck the body fluids. A well-developed musculature which constricts and expands the gill pouches serves to circulate water over the gills when the mouth is attached to the prey. Recovery of living fish bearing lamprey scars shows that such attacks are not always fatal. The lamprey, Petromyzon marinus, has become a serious economic pest in the Great Lakes because of its attacks on lake trout. Other species, such as the brook lamprey, Lampetra planeri, possess a degenerate alimentary tract and do not feed after becoming adults. Adult lampreys spawn in streams where they excavate stones to form a shallow nest. During the spawning act the female attaches by means of the mouth to a stone and the male attaches to the head of the female. All lampreys die shortly after spawning. The eggs are numerous and small, approximately 1 mm. in diameter. Larval lampreys (ammocoetes) possess rudimentary eyes, an oral hood, a single dorsal fin, and lack teeth. Ammocoetes bury themselves in mud and feed on small particles of organic debris. After several years in this stage, metamorphosis occurs. Theeyes become functional, teeth appear, and the oral hood is lost.

Pacific lampreys are anadromous. On their spawning migrations they can often be seen by the thousands attached to rocks and walls of falls or dams over which they work their way by the aid of their suctorial mouths. Their only commercial value is for reduction into meal and each year large numbers are trapped for that purpose.

Distribution: Freshwater and anadromous. Temperate parts of both hemispheres.

References: Parker and Haswell, Textbook of zoology, Vol. II, pp. 119-139.
Hydrostatics of the suctional mouth of the lamprey, University of Calif., Publ. Zool., Vol. 37, No. 2.

CLASS CHONDRICHTHYES (sharks, rays, and chimaeras)
(Gr. chondros, cartilage: ichthys, fish)

Characters: These primitive fishes are distinguished by a cartilaginous skeleton in which the notochord is partially replaced by centra. The placoid scales are derived from epidermis. The teeth, which are modified scales, have an enamel-like covering and are attached to the jaw only by fibrous connective tissue. The mouth consists of true jaws, modified from the first visceral arch, and is ventral in position. The tail, except in the chimaeras, is heterocercal. Cartilaginous fishes resemble the class of true bony fishes in having jaws, paired nasal organs, gill arches, and paired fins. They differ from the bony fishes in lacking an air bladder, pyloric caecae, a true operculum and a double nostril.

Ecology: The chondrichthyes are the most primitive of the fishes, remnants of vast groups which once dominated ancient seas. The spiral valve of the intestine, which increases absorptive area, is best developed in this group, although it is also present in lampreys, sturgeons, bowfins, gars, and lungfish. Primitively this consists of an outgrowth of a flap of mucous membrane along the dorsal margin of the alimentary canal. In modern forms this flap is coiled many times upon itself to produce a complicated, highly-variable structure.

Fertilization in all living forms is internal. Adult males can be recognized by the myxopterygia or claspers, modifications of the inner margins of the pelvic fins. Embryo development is oviparous, ovoviviparous, or viviparous. In oviparous forms, for example the skates and ratfish, the eggs develop externally after being laid in horny cases. These cases are spindle-shaped or rectangular and often bear tendrils at the corners which attach them to weeds or stones. In ovoviviparous forms the eggs develop within the body of the mother, but the embryos are not connected directly with the body of the mother. The large egg yolk provides food. In viviparous forms, the young are connected to the mother by a placenta-like structure through which they draw nourishment. Due to the increased protection afforded by internal development, fecundities in this group are low and if a population is reduced by fishing or for any other reason, a long time is required for them to build back to former levels.

SUBCLASS ELASMOBRANCHII

ORDER SQUALIFORMES (sharks)

Characters: Sharks have a body which is elongate and round in cross-section and 5-7 slit-like lateral gill openings. The margin of the eyeball is free from the skin for some distance all the way around (on the rays the upper margin is adnate to the skin). The caudal is heterocercal. A cloaca is present. A spiracle (vestigal gill slit) is usually present. The pectoral fins have narrow bases and are not attached to the head anteriorally or to the pelvic fins posteriorally, as in the rays. In sharks, as well as rays and most bony fish, the jaw suspension is hyostylic. The jaw structure here has no direct connection with the braincase and the jaw joint is braced entirely by the hyomandibular. Sharks are a difficult taxonomic group due to the relatively few external features on which distinction may be based.

Ecology: Most sharks live along coasts in relatively shallow water, although some forms are found at very great depths and in the open ocean. They are primarily scavengers, the sense of smell being especially well developed. Vision is not especially keen, except in the pelagic forms. The largest fish is found among this group. It is the whale shark, Rhineodon typus, which reaches a length of 70 feet. Shark fins are used by the Chinese in cooking. Shagreen, used for polishing, is the skin of those species with small, close-set denticles. The vitamin-rich liver oil previously supported a commercial fishery for two Pacific Coast species, the soupfin shark (Galeorhinus zyopterus) and the dogfish (Squalus suckleyi)but the manufacture of synthetic vitamins has largely replaced marine sources.

Distribution: Marine, cosmopolitan. A few species occasionally enter fresh water and Carcharhinus has become landlocked in a freshwater lake, Lake Nicaragua. The greatest number of species occur in tropical and subtropical waters.

Common California Families: Heterodontidae (bullhead sharks), Scyliorhinidae (cat sharks), Triakidae (smoothhounds), Carcharhinidae (blue sharks), Sphyrinidae (hammerhead sharks), Squalidae (dogfishes), and Squatinidae (angel sharks).

ORDER RAJIFORMES (rays)

Characters: Rays have five gill openings on the under surface of a depressed body. The anterior margin of the enlarged pectoral fin is joined to the side of the body or head to provide a continuous flat surface and the anal fin is absent. The spiracles, through which water is taken in for respiration, are located dorsally.

Ecology: Rays are bottom dwellers of shallow and moderate depths. They are well protected from potential enemies. Poison glands are associated with the spines of stingrays which can inflict severe wounds on unwary waders. The large organs derived from muscle tissue and located on each side of the head of electric rays are capable of voluntarily emitting shocks up to 220 volts. Many forms are equipped with pavement teeth (hexagonal plates) which are adapted for feeding on shellfish. "Ray" is a general term which refers to members of the order; the term "skate" is restricted to members of the family Rajidae.

Distribution: Marine, cosmopolitan.

Common California Families: Rajidae (skates), Dasyatidae (stingrays), Myliobatidae (eagle rays), and Torpedinidae (electric rays).

Procedure: Observe other adaptations of this group for a bottom-living existence. te the special characters of the angel sharks which are intermediate between the sharks and the rays.

SUBCLASS HOLOCEPHALI
ORDER CHIMAERIFORMES (chimaeras)
(Gr. chimaira, the fabulous monster with the head of a lion, the body of a goat, and the tail of a serpent)

Characters: Chimaeras have five gill arches and four gill openings protected by a gill cover which is a flap of skin without membrane bones. Thus there is only one external gill opening on each side, in contrast to multiple gill openings of the preceding groups. The teeth, at least partially, are in the form of grinding plates and there may also be prominent incisor-like teeth. The teeth lack enamel, which is present in the other orders. The tail is diphycercal. The jaw suspension, in common with the lungfish, is autostylic, since the upper jaw is fused to the braincase. There are no cloaca, ribs, or spiracle. On males there is a cephalic holder or frontal hook, possibly useful in copulation.

This order is intermediate between the elasmobranchs and the teleosts. It is like the former in lacking an air bladder, and possessing a spiral valve and cartilaginous skeleton. It resembles the latter in the single external gill opening, and lack of spiracle and cloaca.

Ecology: The local Hydrolagus colliei is a relatively shallow water form compared to other members of the family and is taken in night beach seine hauls in Puget ound. The uniting of the teeth into bony plates is responsible for the common name ratfish". The eggs are laid in elongate, rigid, brown cases. This fish is little utilized although the liver oil is rich in vitamins and the flesh is said to be palatable.

Distribution: Marine, cosmopolitan, principally in deep water. A single family, Chimaeridae.

CLASS OSTEICHTHYES (bony fishes)
(Gr. osteon, bone; ichthyes, fish)

Characters: In this class are included the vast majority of fishes. The bony fishes have many structural features which distinguish them from the lampreys, sharks, and rays. The endoskeleton and vertebral column are wholly or partly ossified. Neural and haemal arches are present. Membrane bones are present. The jaw is well developed with premaxillary, maxillary, and dentary elements. A bony operculum covers the gill clefts and either gular plates or branchiostegal rays are present. There is an air bladder present, except in certain specialized groups. The well-developed secondary pectoral girdle is connected dorsally with the posterior part of the skull (except in many eel-like fishes). The external opeining of each nasal sac usually is divided into two external openings and is not connected internally with the mouth cavity. The exoskeleton is of rhomboid plates, cycloid or ctenoid scales, bony plates, or naked skin. There are typically four gill arches and the gill filaments project beyond the greatly reduced interbranchial septa.

SUBCLASS SARCOPTERYGII
ORDER DIPTERIFORMES (lungfishes)
(Gr. dipnoos, with two breathing apertures)

Characters: In the lungfishes the paired fins are lobate with a jointed median axis. The scales are overlapping and cycloid in shape, but not true cycloid. An operculum is present but the opercular elements are not differentiated. Internal nares, a cloaca, and a spiral valve are present. The air bladder possesses a duct opening to the ventral side of the esophagus and is lung-like and cellular. All of these forms must secure air at the surface of the water even during periods when the water is not stagnant. Peculiar grinding teeth are present. In all living forms the median fins are confluent to form a continuous symmetrical diphycercal tail. Anatomical features which resemble those of amphibians include the internal nares associated with lung breathing and the fleshy, lobed fins which are suitable for development into terrestrial limbs. Living lungfishes are survivors of a fossil group which was moderately abundant in the late Paleozoic and Triassic. There are three genera living, one each in tropical regions of Australia, South America, and Africa.

FAMILY CERATODONTIDAE (Australian lungfish) (Gr. keras, horn; odous, tooth)

Characters: In Neoceratodus the air bladder is an unpaired sac, divided into right and left lobes by a band of connective tissue.

Ecology: The Australian lungfish, unlike the lungfishes of Africa and South America, does not build a cocoon in the mud. If the pool in which it is living dries up, it cannot survive. However, the air-breathing habit enables it to live in the mud during periods of drought in shallow ponds polluted by decaying organic matter and deficient in oxygen. It is a sluggish fish, feeding on aquatic vegetation and small invertebrates. Eyesight is poor and food is located principally by means of the sense of smell. Spawning occurs in the spring months (Aug-Oct.) Each egg, placed among aquatic vegetation, is surrounded by a heavy gelatinous coat. The embryological development has many amphibian characteristics. In swimming all lungfishes undulate their whole body in a salamander-like fashion. These fish are the only true freshwater fishes in Australia. All the others present reinvaded freshwater from the sea.

Distribution: Northern Queensland, Australia. Freshwater.

FAMILY LEPIDOSIRENIDAE (South American and African lungfishes) (Gr. lepis, scale; seiren, siren, a group of eel-shaped amphibians)

Characters: In Lepidosiren the endocranium is largely membranous. The paired fins are reduced. The air bladder is paired. The pelvic fins are fringed.

Ecology: This fish lives in swamps along rivers but never in the rivers themselves. The nest burrow is in the muddy bottom and the male guards the eggs. Separate burrows for aestivation are constructed in impervious clay. These burrows are mucous-lined and are closed at the surface with a loose clay plug. It is a carnivorous fish and feeds mainly on snails.

Distribution: Amazon basin, South America. Freshwater.

GENUS PROTOPTERUS (African lungfishes) (Gr. protos, first; pteron, wing)

Characters: The African lungfishes are similar to the South American form with the exception that the pelvic fin is elongated into a barbel-like structure.

Ecology: Protopterus builds an aestivation chamber which is lined with mucous. The entrance of the chamber is not closed as in Lepidosiren. Special nest burrows are built which are lined with leaves and sticks. The male guards the eggs. The larvae have four pairs of plume-like external gills and are equipped with ventral suckers in order to attach to rootlets in the burrow.

Distribution: Central West Africa. Freshwater.

SUBCLASS ACTINOPTERYGII
SUPERORDER CHONDROSTEI
ORDER ACIPENSERIFORMES

Characters: The primitive chondrosteans possess characters which closely resemble those of sharks and rays. The caudal is heterocercal. The endocranium is cartilaginous, never ossifying as a complete box. Spiracles are present in most forms. The opercular apparatus is only partially developed, with the subopercle, interopercle, and preopercle absent. The notochord is not replaced by vertebral centra and the otoliths are not calcified. The fins have numberous close-set rays, and these rays outnumber the radials. This group also has certain unique characters, such as an elongate snout and a body naked or covered with 5 rows of bony scutes.

FAMILY ACIPENSERIDAE (sturgeons) (L. acipenser, sturgeon)

Characters: The body is covered with five rows of bony scutes which form a partial armor. The mouth is ventral and protractile. Teeth are present only in very young fish. There are four gills. The gill membranes are joined to the isthmus and there are no branchiostegal rays. The dorsal and anal fins are inserted far back on the body.

Ecology: Sturgeons are sluggish fishes which feed on aquatic insects, crustaceans, and molluscs. In the Columbia River part of the diet consists of salmon, smelt, and lamprey carcasses. Theyare long-lived; ages up to 50 years have been determined by study of cross-sections of the first pectoral fin rays. Growth of the fish is extremely slow. Females reach maturity at an age of between 15 and 20 years. Males become ripe somewhat earlier. Individuals up to 20 feet in length and 1800 pounds in weight have been taken in the Columbia River basin. Sturgeon spawn in fresh water in the spring an d early summer. Fecundity is high with up to four million eggs being produced by a 50 year old female. Only a few species of sturgeon remain as degenerate representatives of a large group of primitive bony fishes. The flesh is esteemed as food and caviar is prepared from the eggs. A high quality isinglass is prepared from the air bladders.

Distribution: Anadromous and freshwater. Temperate parts of North America and Eurasia.

FAMILY POLYDONTIDAE (paddlefishes) (Gr. poly, many; odontos, teeth)

Characters: In paddlefishes the snout is prolonged into a thin, flexible projection whose length may be one-third of the body length. The inner portion of the paddle is formed by produced nasal bones and it is surrounded by a reticulate bony framework. The jaws have small teeth. The body is naked except for a few small scales at the base of the upper lobe of the caudal fin. The caudal fin is heterocercal, although the lower lobe is well developed so that the fin is nearly equally forked. There is one pair of broad branchiostegal rays. The air bladder is cellular and is connected by a duct with the esophagus. The gills are covered by a large soft operculum which extends far posteriorly to a point above the base of the ventral fins.

Ecology: Paddlefishes feed by stirring up the mud with their snouts and by straining plankton from the water through the sieve-like gill rakers. They have been called "animated plankton nets". Adults spawn in the spring when they are found associated in schools along sandy lake shores. As in the sturgeons, eggs are small and numerous. The newly-hatched young do not possess the paddle-shaped snout.

Paddlefishes have been greatly reduced by overfishing in North America. The palatable flesh is marketed as "boneless cat".

Distribution: Freshwater. Polydon, eastern North America; *Psephurus*, China.

SUPERORDER HOLOSTEI
ORDER LEPISOSTEIFORMES

FAMILY LEPISOSTEIDAE (gars) L. lepidus, graceful; Gr. osteon, bone)

Characters: Gars are characterized by the thick, diamond-shaped *ganoid* scales that cover the body. The jaws are extremely elongate with sharp teeth and the nostrils are located at the end of the upper jaw. There are also teeth on the palatines and the paired vomer bones. Three branchiostegal rays are present. The caudal fin is abbreviate heterocercal, although it may appear superficially symmetrical. The dorsal and anal fins are located opposite each other towards the posterior end of the body. The air bladder is cellular, connected with the esophagus, and may be used as a lung. The gill rakers are very short. Pseudobranchia are present. There are no spiracles or gular plate.

Ecology: Gars are a remnant of an ancient and numberous family. Fossil gars are known from Europe. Gars and the bowfin, discussed below, are probably the most predatory fishes in freshwater, consuming large quantities of game and forage fishes. They often bask lazily at the water surface but are capable of swift movements to capture prey. They are warm-water fishes and inhabit sloughs and quiet backwaters. Their armor protects them from the attacks of most other animals. The tough skin was used by early settlers to cover wooden plowshares.

Distribution: Fresh waters of eastern North America, Central America, and Cuba.

ORDER AMIIFORMES

FAMILY AMIIDAE (bowfins)

Characters: In the bowfin the head is covered with smooth plates. The jaws have an outer series of conical teeth and an inner band of rasp-like teeth. There are also teeth on the vomer, palatines, and pterygoids. The tail, as in the gars, is abbreviate heterocercal. There is a gular plate and 10-12 branchiostegal rays. The dorsal fin is long and low. The median fins have equal numbers of dermal rays and endoskeletal supports in contrast to the sturgeons and paddlefishes where the number of dermal rays is greater than the number of endoskeletal supports. The scales are cycloid. The gill rakers are short and stout. There are no pseudobranchiae.

Ecology: There is only one living species, *Amia calva*, in this order which has many fossil representatives. This is a predacious fish which feeds on crayfish and small fish. The males are smaller than the females and can be distinguished from the latter by the ocellus rimmed with orange-yellow located at the base of the caudal fin. Bowfins can live a long time out of water, breathing air with their lung-like air bladders. Spawning occurs in the late spring in streams or shallow bays. The eggs are laid in a shallow depression prepared by the parents. On hatching the young adhere to roots on the bottom of the nest by an adhesive organ on the snout. The young are guarded for a time after hatching by the male.

Distribution: Freshwater. North America. Mississippi River and Great Lakes, south to Florida.

Clupeomorpha

SUPER
SUPERORDER TELEOSTEI
ORDER CLUPEIFORMES (Isospondyli)

Characters: Isospondylids are herring-like and salmon-like fishes. In this group both the premaxillary and maxillary bones form the margin of the upper jaw. In contrast to the order Ostariophysi, the anterior vertebrae are unmodified and without auditory ossicles. Opercular bones are well developed. The caudal fin is homocercal and the tail is usually forked. Physostomous. The pelvic fins are abdominal. The fins have soft rays only and there are no barbels. This order comprises most of the marine soft-rayed fishes, excepting those found in the deep sea (Iniomi). It represents an artificial assemblage since the separate members differ greatly from one another. In time the Isospondyli will doubtless be divided into several orders. Members of the order probably sprang from a Ganoid stock, since the tarpons (Elopidae) and the lady-fishes (Albulidae) show relationships to the bowfins (Amiidae). The gular plates of the tarpons and bowfins may be of similar homology.

FAMILY CLUPEIDAE (herrings, sardines, shad)

Characters: These are silvery, compressed fishes with the lateral line traversing only the anterior 2-5 scales. The scales are large, deciduous, and of the striated cycloid type. The head is not covered by scales. The mouth is large but the teeth are small or absent. The gill rakers are long and fine. Gill membranes are free from the isthmus. Pseudobranchiae are present. The single dorsal fin is situated at about the middle of the body; there is no adipose fin. The caudal fin is usually forked. The pelvic fins are abdominal in position. There is a pelvic appendage and frequently keeled ventral scutes.

Ecology: Most members of this family are schooling fishes. Herring, sardines, menhaden, and similar species are the most important in volume of all the varieties of fish making up the world's commercial production. They are also of inestimable importance as food for larger fish, birds, and mammals. Clupeids feed on phytoplankton and zooplankton and thus serve as primary converters in the food chain. Northern and freshwater species, as in many other families, differ from tropical forms in having a larger number of vertebrae. The eggs are generally pelagic, although those of the herring are demersal and adhesive.

Distribution: Cosmopolitan. Principally marine; some anadromous and freshwater forms. No deep sea forms. The group is best developed in tropical waters, but some approach Polar seas.

FAMILY ENGRAULIDAE (anchovies) (Gr. engraulis, a small fish)

Characters: Anchovies have a subterminal mouth and the extremely long maxillary extends posterior to the large eye. There is no lateral line. Otherwise the characters are similar to those of the Clupeidae.

Ecology: Anchovies are carnivorous shore fishes, usually swimming in large schools. The wide gape of the mouth makes these fish very efficient plankton feeders. Eggs are oval in shape and pelagic.

Distribution: Marine. Tropical and subtropical, partly temperate seas. Most abundant in tropics. Some forms in brackish water.

FAMILY SALMONIDAE

Subfamily Salmoninae

Characters: Body fairly stout covered with cycloid scales of the circulus type. Adipose prominent and the pelvic appendage is large. Fresh, returning, sea-run forms silvery below, and bright, steely blue to green above. Juvenile stages usually with strong, dark vertical parr marks. Mouth strong with many teeth on premaxillaries and maxillaries in contrast to the weak mouths and lack of teeth in the herrings, smelts, and white fishes.

Economic Value: This group of fishes is the most valuable of inland species from a monetary standpoint. Millions of dollars are spent annually in search of them by anglers. For this reason, the great bulk of funds available for hatchery operations are expended on rearing and planting salmon and trout. For the same reason much of the money available for fisheries research is expended on solving problems dealing with the members of this group.

Taxonomy of the salmonids, except for the five species of Pacific Salmon comprising the Genus Onchorynchus, is in a badly confused state. Over forty species of trout alone have been described, many of which are poorly defined and of doubtful status. Further complications have been added by fish culturists who have crossed many strains or races and stocked both streams or lakes with the resultant hybrids. The transfer of fishes from one drainage to another plus the planting of non-native forms of the same or closely allied species, has likewise caused a considerable amount of genetic masking of original stocks. The trout series apparently is in an incipient stage of speciation and enormously plastic which, in turn, has resulted in considerable taxonomic confusion. It will be less confusing to the student if he considers the rainbow trout as a single species, Salmo gairdneri, but having many subspecies which have developed through geographic or climatic isolation in numerous separated drainages. This viewpoint can well be applied to the age-old controversy as to whether or not steelhead and rainbow are the same or different species. Each of the above series has both sea-run and resident forms and in each the same controversy exists as to whether they are the same or defferent species or subspecies. Trewavas (1953) concluded that the sea-trout of Europe (sea-run brown trout) and the "burn" trout (resident brown trout) were all one species and gives excellent arguments in support of this view.

Ecology: Most of the members of this sub family are carnivorous, boreal fishes and are the principal predators in the cold waters of the Northern Hemisphere. In warm waters they are replaced by such fishes as the basses, pikes, perch, bowfins, and gars as the main predators. All spawn in fresh water but many are anadromous, making cyclic migrations between the sea for feeding and freshwater streams for breeding. Two types of cycles are illustrated in this family, (1) mixed age group cycle and (2)year class cycles. The mixed age group type of cycle is illustrated by most mammals, birds, and fishes. In this case the offspring of several different brood years may be present in the population at the same time because (1) individuals may live for several years, (2) they may produce more than one brood per year, or (3) interbreeding may occur among individuals of the different age groups present. In contrast, in the year class type of life cycle, only a single age-group is present at any given time because of the short period in maturing and dying. Pink salmon, O. gorbuscha, are a good example of this type of life cycle since they always mature at two years of age and only a single age group is present in any given run. In this type of cycle there is no interaction, competition or predation between cycles. Other salmonids such as the chum, silver, king, and sockeye salmon, Atlantic salmon, steelhead, and trout generally do not have such a rigid life span and, hence varying age groups are present in their feeding and breeding grounds. Age at maturity varies with all other species of salmon and trout but with pink salmon it is always two years. Other organisms that display the year class type of cycle are various crustaceans such as waterfleas and shrimp and insects such as the 17 year cicada.

Sea-run salmonids spend from a few months to eight years in salt water before returning to freshwater to spawn. All go through an elaborate courtship procedure.

Once the fish are fully mature, breeding occurs over gravel bed areas in shallow water, usually at the lower ends of pools. Here the females dig their "redds" or nests and deposit the eggs. Fertilization of the eggs is external by the males and occurs as the eggs fall to the bottom of the nests. After each spawning the females cover the eggs with gravel by vigorous digging movements, using their caudal fins. A completed redd can be easily recognized following spawning for it will appear as a mound of clean gravel, well rounded, and will lack any silt covering its surface. In observations of spawning beds from airplanes, it is easy to count or to photograph the completed redds as they are clearly visible when the water is clear.

Non-sea-run trout and landlocked salmon usually migrate only short distances to suitable spawning areas. Most salmonids are stream spawners ~~and only two~~, the eastern book trout (<u>Salvelinus fontinalis</u>) and the Landlocked sockeye salmon (<u>Oncorhynchus nerka kennerlyi</u>)spawn to any extent in gravelly lake shores. Even these two species seem to prefer streams in which to spawn if they are available.

(Salvelinus

Except in hatchery stocks, most trout females mature at either three or four years of age. The males, however, usually mature at the end of their second year although it is not uncommon to find male fish mature at the end of their first year. Grilse salmon are usually males that mature after only one year in the ocean. Trout may survive several annual spawning periods but all Pacific salmon die after spawning once.

One of the most unusual and important habits of most salmonids is that they will "home" to their parent streams. All Pacific salmon display this instinct as well as the steelhead and in other trouts similar tendencies have been noted.

All Pacific salmon, brown trout (<u>Salmo trutta</u>), chars, and the Atlantic salmon (<u>Salmo salar</u>) are fall spawners. Spring spawners include all members of the rainbow and cutthroat series.

<u>Distribution</u>: Circumpolar in the northern hemisphere in cold waters. South to the vicinity of Durango, Mexico, in Pacific drainage streams. On the east coast they are found south into Georgia. In Europe they occur in Spain and in cold mountain streams generally. Introduced widely into South America, India, Australia, and New Zealand.

SUBFAMILY COREGONINAE (whitefishes)

no teeth in max. - double nostril

<u>Characters</u>: The whitefish group is distinguished from the Salmoninae by the larger scales (fewer than 100 in the lateral line). Whitefishes are silvery in color with blue-green backs. They have small mouths with few or no teeth. Most species have long, slender gill-rakers. There is a single dorsal fin with soft rays and an adipose fin. A pelvic appendage is present. Characters of individual species are extremely variable.

<u>Ecology</u>: Whitefishes are cold-water fishes. In lakes they are found to depths of 700 feet. Lake species spawn in the autumn above the bottom in shallow areas. Stream species may make spawning migrations into the smaller tributaries. The eggs are generally smaller than those of salmonids. Whitefishes are one of the most valuable food fishes in the Great Lakes.

<u>Distribution</u>: Freshwater lakes and streams of North America and Eurasia.

SUBFAMILY THYMALLINAE (grayling)

Dorsal fin, mouth like coregonus

<u>Characters</u>: Grayling differ from salmon and trout in that the parietal bones of the skull meet in the middle and thus the frontals are not touched by the supraoccipital. They also have epipleural spines on the anterior ribs. Grayling

may be easily distinguished by the enlraged flag-like dorsal fin with more than 15 soft rays (fewer in salmon and trout). The dorsal fin has red or organge and blue spots. The mouth is small and the teeth are sparse. The gill rakers are short and stiff. Pseudobranchiae are present.

__Ecology:__ Grayling are highly regarded as sport fish. They are found only in clear, cold, unpolluted streams and most often in deep pools of gravel-bottom streams. They feed chiefly on insects. Grayling spawn in the spring and dig redds similar to those made by salmonids. They have been reduced to extinction in much of their native habitat due to destructive logging operations, over-fishing, pollution, and other factors.

__Distribution:__ Freshwater. Holarctic Cold clear ~~northern~~ streams and lakes of Europe, North America, and ~~Asia~~. Siberia

FAMILY OSMERIDAE (smelts) (Gr. Osmeres, emitting an odor)

__Characters:__ Osmerids are small fishes which resemble salmonids in body shape and in the presence of an adipose fin but differ in having fewer than 100 scales along the lateral line. They also lack pelvic appendages. The head is long and pointed. Gill rakers are elongated and slender. The teeth and the lateral line are well developed.

__Ecology:__ Smelts are carnivorous and even cannibalistic. Their role in freshwater ecology is not as yet completely understood. The flesh is delicious and many are caught on their spawning migrations. The flesh is so oily that the eulachon was used for candles in early days. Pacific Coast marine and anadromous species spawn on sandy ocean beaches, over eelgrass beds, or over silt bottoms in freshwater streams. The Eulachon or Pacific smelt, __Thaleichthys pacificus__ (also called Columbia River smelt) migrates intermittently into the Sandy River near Portland, Oregon from the Columbia River in enormous numbers at times. The senior author has seen solid schools of these fish moving upstream, containing literally millions of fish that filled the stream from bank to bank. Dip-netting is permitted at such times and a daily limit of 25 pounds per person is allowed on a special license selling for fifty cents per person. There is a regularity in the timing of the runs. Good runs may occur for three years in succession but more often blank years will occur when no fish will be seen. The runs usually arrive in March or April. In years of heavy runs, many tons will be taken commercially as well as by sport fishermen. They are best if eaten fresh though they are almost as palatable if frozen in water. The "wealth of the sea" is nowhere better reflected than in the enormous abundance of these small fishes in years of heavy runs.

__Distribution:__ Arctic and North Temperate regions. Circumpolar. Marine, anadromous, and freshwater.

SUBORDER ESOCOIDEI (blackfish, mud minnows, and pikes)

Characters: Soft-rayed fishes with cycloid scales and the mesocoracoid missing. Mouth with teeth. Physostomous. Ventral fins abdominal. No adipose fin. Chiefly freshwater species. An order intermediate between the Isospondyli and Percomorphi. Includes some of the most predacious of freshwater forms in the pickerels, pikes and muskellunge.

FAMILY ESOCIDAE (pikes) (L. esox, pike)

Characters: These fish are characterized by a long, slender body with the dorsal and anal fins located near the tail and opposite each other. The snout is depressed and duck-bill shaped when viewed from above. The long jaws are armed with sharp canine teeth. There are also teeth on the vomer, palatines, and tongue. The maxillaries are toothless. The scales are small and there are scales on the cheek and opercle. Gill membranes are free from the isthmus. The pectoral fins are inserted very low on the body. The caudal fin is forked. Pikes may be distinguished from gars, which they superficially resembele, by the rounded snout and the homocercal, forked caudal fin.

Ecology: Pikes are predacious, feeding on fish and to a smaller extent on other aquatic vertebrate forms. They are strongly piscivorous and noted for their greediness and voracity and have been called "mere machines for the assimilation of other organisms." These fish prefer the cooler waters of lakes, ponds and the larger streams. All are spring spawners, casting their eggs over weeds in shallow water or marshy areas.

In the Great Lakes Region these fishes are of great importance both commercially and for sports fishing. The northern pike, Esox lucius, is taken widely by commercial fishermen while "muskie" (E. masquinongy) fishing provides anglers with fish up to over 60 pounds in weight and famous for their fighting ability. Baits most commonly used are flashy spoons or live minnows. To all the members of this group, shelter is an important factor. Submerged stumps or logs, cut-banks, and root mats form the most suitable shelters and anglers usually catch them near such types of cover. Pikes depend on large minnow populations for forage.

Distribution: Freshwater. Europe, Asia, and North America. There is a single genus, Esox. Jordan and Evermann (1920) list seven species, one of them, E. lucius, cosmopolitan and the rest confined to North America. Three species have been introduced into California.

ORDER CYPRINIFORMES (OSTARIOPHYSI) (minnows, suckers, catfishes, and allied forms)

Characters: This order consists of the largest group of chiefly freshwater fishes. It is second only to the order Percomorphi in number of species. Its members have in common a Weberian apparatus and an air bladder which is usually divided into two parts. They are physostomous and the fins are usually without spines.

SUBORDER CYPRINOIDEI
(Gr. kyprinos, a kind of carp)

Cypriniform (Ostariophysi in part)

Characters: This suborder contains the minnows and their allies. There is no duct between the two compartments of the air bladder. The subopercle and parietal bones are present. There is no adipose fin. The body generally is covered with cycloid scales and is never naked or covered by bony plates as in the catfishes.

FAMILY CATOSTOMIDAE (suckers) (Gr. kata, downward; stoma, mouth)

Characters: Suckers are characterized by a subterminal mouth which can be protruded for feeding on the bottom. The lips are usually fleshy and sucking. There are no teeth in the jaws, but pharyngeal teeth are present. The pharyngeal teeth are in a single series and often numerous. There are three branchiostegal rays. Pseudobranchiae are present and the gill membranes are more or less united to the isthmus. The alimentary canal is long and the stomach is simple with no appendages. The dorsal fin contains 10 - 30 soft rays.

Small suckers are some times difficult to distinguish from minnows. In minnows the distance from the front of the anal fin to the base of the tail fin is contained less than two and one-half times in the distance from the front of the anal fin to the tip of the snout. In the suckers this proportion is contained more than two and one-half times. This is also true for the carp but this fish can always be recognized from all other native minnows and suckers by the stout, spinous first dorsal and first anal rays.

Ecology: Suckers are sluggish fishes, feeding on bottom plants and animals. Their ability to find food by the senses of touch and taste enables them to survive where fishes that feed by sight could not exist. Most species prefer relatively quiet waters over sand and gravel bottoms. The young are eaten by predatory fish.

Distribution: Freshwater. Widely distributed in North America; at least two species in China and Siberia. Nearly 100 species occur in North America, a few of which such as the common white sucker, redhorse and buffalo, are taken commercially in gill nets, trap nets and by dipping on spawning migrations.

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FAMILY CYPRINIDAE (minnows)

Characters: Minnows are characterized by well-developed pharyngeal teeth, which are in 1 - 3 rows. North American minnows have these teeth in one or two rows but with never more than seven in the main row. The introduced carp and goldfish have three rows. The mouth is terminal and is without teeth. The margin of the upper jaw is formed by the premaxillaries alone. There are three branchiostegals. The dorsal fin is short in all the American species with less than ten soft rays, but it is elongate in many Old World forms. The stomach is a simple enlargement of the alimentary canal.

Due to the uniformity in size, form, and coloration, this is a difficult taxonomic group. The genera are best distinguished by the pharyngeal teeth patterns.

Ecology: This is the largest family of all fishes, including about 200 genera. There are over two thousand species distributed throughout the entire north temperate zone alone. The family is most diverse in Asia. Hubbs and Cooper (1936) attribute this abundance to three factors: minnows as a group occupy a great variety of habitats and eat many types of foods; most species of minnows require a relatively short time to reach sexual maturity; and a large number of minnows can occupy a small space and find sufficient food and shelter because they are usually small fishes.

Although most minnows are small fishes, a few grow to a large size and are marketed in considerable quantities, especially in Europe. Minnows are of great ecological importance as food for predacious fishes. During the spring spawning season, males develop epidermal outgrowths or tubercles on various parts of the body, which are similar to those of the suckers, and red markings on the first and lower body parts. Some species build nests. Minnows feed on insects, crustaceans, vegetation, and organic mud.

The term "minnow" often is applied incorrectly to any small fish superficially resembling members of this family.

Distribution: Fresh waters of Europe, Africa, Asia, North and Central America. Absent from South America, Madagascar, and Australia.

SUBORDER SILUROIDEA (catfishes)
(L. silurus, a kind of river fish)

Characters: Catfishes are scaleless except for some forms covered with bony plates. Their heads and mouths are broad. The two compartments of the air bladder are connected by a duct. The maxillary is rudimentary, serving only as a support for the barbel. The subopercle is absent. There is usually an adipose fin and the first ray in the dorsal and pectoral fins is spinous.

Ecology: This large group is composed chiefly of freshwater fishes distributed cosmopolitanly. They are especially common in warm rivers in Africa and the Amazon region of South America. However, the families Ariidae and Plotosidae are chiefly marine. This is a habit which has been derived secondarily. The marine habit has enabled both these families to reach the rivers of New Guinea and tropical Australia and to give rise in them to a number of freshwater genera and species.

FAMILY ICTALURIDAE (North American freshwater catfishes)

Characters: The dorsal and pectoral fins each have a sharp serrated spine. The body is naked and there are four pairs of barbels. The small teeth are in broad bands on the premaxillaries and dentaries.

Ecology: Most catfishes inhabit the shallow silty water of ponds, creeks, and sloughs although several mid-west forms occupy the colder, flowing waters of large rivers. Catfishes are omnivorous and feed principally on invertebrates. They are nocturnal in habits. Most species utilize holes in the banks of streams for nests and guard the eggs and young. The channel catfishes (*Ictalurus*) are large active fishes of rivers, with a forked caudal fin. Other ameiurids are stouter in form and have a rounded or truncate caudal fin. The mad-toms (*Schilbeodoes*) have poison glands at the base of the pectoral fin spines. When the pectoral spine is folded against the body, it is in contact with a poison pore. Thus the spine is bathed with poison when it makes a puncture. Catfishes are little eaten by other species, presumably because of this defensive apparatus. These fish are important both commercially and for sport fishing. Introduced into California, these forms provide much anglingin the upper bay sloughs, in Clear Lake, and the lower courses of the Sacramento and San Joaquin rivers. The white catfish, *Ictalurus catus*, is the dominant species taken.

Distribution: Canada into Guatemala. Fewer than 50 species. South American and Asiatic groups contain many more species and show much greater diversity than the North American forms.

ORDER ANGUILLIFORMES (eels) (APODA)
(Gr. a, without; pous, foot)

Characters: Eels are soft-ryaed physostomous fishes, with no pelvic fins. The pectoral fins, if present, are small. The body is elongate and the long dorsal and anal fins are usually confluent. The scales, if present, are embedded. The gill openings are narrow and placed well behind the head. The vertebrae are very numerous, up to 260. The true jaws distinguish them from the lamprey "eels."

Ecology: Most eels are marine, carnivorous, and prefer rocky reef habitats. The leptocephalid larvae are transparent and pelagic. The smooth, elongate body with reduced fins represents an adaptation to their mode of existence of living in crevices. Moray eels can inflict serious wounds. Many eels are eaten as food.

Distribution: Mostly marine; tropic and temperate zones.

FAMILY ANGUILLIDAE (freshwater eels) (L. anguis, snake)

Characters: Pectoral fins are present. The rudimentary scales are arranged in small groups, which are placed obliquely at right angles to one another, forming a distinct pattern. Maxillary bones are absent. The teeth are small and in bands on each jaw and on the vomer. The head is small and conical. The lateral line is well developed.

Ecology: Freshwater eels are catadromous, returning to the sea to spawn after five or more years in freshwater. Both the adults and the elvers (young eels) are hardy and will even travel over wet ground on their migrations. Adults are voracious and carnivorous, although they do not feed after beginning the spawning migration. Eels are extremely prolific; a female may produce up to ten million eggs. Both the males and the females die after spawning. The eggs and larvae drift with the ocean currents. They metamorphose into small elvers which migrate upstream into freshwater. Here they spend several years before returning to the sea to spawn. Females grow to a larger size than the males.

Distribution: Tropical and temperate seas. Absent from the South Atlantic and the Pacific coasts of America. Introduced unsuccessfully into California.

ORDER CYPRINODONTIFORMES (toothcarps or topminnows)

Characters: Tooth carps have a single dorsal and a single anal fin, usually placed far back on the body, opposite and equal to each other, and rounded. They may be distinguished from cyprinids by the projecting lower jaw and the presence of teeth on the jaws. The gill membranes are free fromthe isthmus and the gill rakers are short. The pelvic fins are abdominal in position. The caudal fin is not forked. There are scales on the head. Physoclistic. The sexes are usually unlike, with the males having larger fins or the females being larger in size.

FAMILY CYPRINODONTIDAE (killifishes) (Gr. kyprinos, carp; odontos, tooth)

Charcters: These are egg-laying toothcarps. Males lack an intromittent anal fin. In most species, as in the following family, the head is flattened on top and the mouth is dorsal-oblique.

Ecology: These fishes often swim among vegetation near the water surface. They are popular aquarium fishes.

Distribution: Freshwater. Temperate and tropical North and South America, Africa, Spain, southern Asia, and the East Indies. The group is best developed in Africa and in South America.

FAMILY POECILIIDAE (livebearers) (Gr. poikilos, variegated)

Characters: These are live-bearing toothcarps. Males have an intromittent organ, the gonopodium which is formed from the first three rays of the anal fin.

Ecology: These fishes, especially Gambusia, are important in the control of mosquitoes. Tropical species are popular aquarium fishes.

Distribution: Freshwater. North and South America. Introduced into California.

FAMILY GADIDAE (cods) (Gr. gados, a kind of fish)

Characters: Cods have an elongate body which is deep anteriorly. The long dorsal fin may be divided into two or three separate fins. The pelvic fins are jugular in position. There is often a barbel at the tip of the dower jaw. The mouth is terminal or subterminal. There are no pseudobranchiae. The air bladder generally is well developed. This order shows both the primitive features of cycloid scales and soft-rayed fins without spines in addition to the specialized characters of jugular pelvics and physoclistic condition. Several fishes which do not belong to this family are commonly misnamed "cod," such as the rock-fishes (rock cods) Scorpaenidae, the greenlings (Tommy cod) and lingcod (cutius cod) Hexagrammidae, and the sable-fish (black cod) Anoplopomidae. All these fishes belong to the Order Scleroparei, not to the Order Anacanthini.

Ecology: Cods are fishes ofcolder waters. Some species are found in the abyssal zone of the ocean. They are gregarious and often occur in large schools of equal sized individuals. Eggs and larvae are pelagic. They feed on bottom invertebrates and such fishes as herring and smelt. They are fishes of great economic importance and include such forms as the cod, whiting, tomcod, and long-finned cod in the Pacific as well as the haddock and pollack of the North Atlantic.

Distribution: Chefly marine in the northern hemisphere. One genus, Lota (ling, burbot, lawyer or loche) is confined to fresh water in North America, Asia, and Europe.

ORDER PERCIFORMES

Characters: The percomorphs are a vast and diverse order of chiefly marine fishes. There are usually two dorsal fins, the first spinous, the second soft-rayed. These may be separate or confluent but not widely separate. The plevics are usually thoracic with one spine and not more than five rays. The caudal has no more than 17 principal rays with the outer ones unbranched. Percomorphs are physoclistic and the premaxillaries are protractile. Many specialized groups lack some or all of these general characters but are connected to the order by transitional forms. This order has been the "dumping" ground for many diverse families of fishes. Taxonomists not knowing precisely the proper order in which to place any given family, often have placed them here. The order encompasses some fifteen or more suborders and doubtless future work will eventually separate this group into several separate and distinct orders.

FAMILY SERRANIDAE (sea-basses) (L. serra, saw, referring to the preopercular margin)

Characters: Serranids have a large mouth with small teeth in bands on the jaws, vomer, and palatines. Often there are enlarged canine teeth present in front. Scales are small and ctenoid. The preopercle margin is normally serrate. The opercle usually ends in one or two flat spines. The air bladder is small and adherent to the walls of the abdomen. Pseudobranchiae are large. The dorsal fin is usually deeply notched between the spines and the rays, and in some species it is divided into two well-separated fins. The caudal fin is rounded, truncate, or rarely emarginate. The anal fin has three spines. There is no pelvic appendage. The single lateral line does not have tubules in all the scales.

Ecology: Serranids are unspecialized forms, perhaps the most fish-like of all fishes. The family is large and serranids and their allies probably make up the dominant group of marine fishes today. They are carnivorous and of much importance to sport and commercial fishermen. Such forms as the striped bass (Roccus), white bass (Morone), jewfish, and groupers belong in this group. They generally live at the bottom of the sea near coasts. The jewfish (Stereolepis gigas) attains a weight of close to 1,000 pounds.

Distribution: Widely distributed in temperate and tropical seas, some in fresh water. Serranids probably had their origin in the reefs of tropical waters, where most still abound.

FAMILY CENTRARCHIDAE (sunfishes, freshwater basses) (Gr. kentron, spine; arch, first)

Characters: The body is deep and compressed. The dorsal fin is incompletely divided into two parts with the anterior portion supported by 6-13 spines. There are 3-9 anal spines. The scales are weak to moderately ctenoid, rarely cycloid. There are scales on the cheeks and opercles. Pseudobranchiae are poorly developed in contrast to the white and yellow basses (Serranidae). The teeth on the jaws and palate are villiform; there are no canines.

Ecology: Sunfishes may be divided into three groups: the black basses, the true sunfishes, and the crappies. Coloration is usually brilliant, chiefly greenish. The sexes are similar in appearance. Most species reproduce in the spring months and build nests which they defend with much courage. Parental care is well developed. They are usually carnivorous and voracious and feed partly on young of their own species. Collectively they make up a substantial portion of the game and pan fish population in many lakes and streams. They are of enormous importance to anglers and fill parallel niches in warm waters that salmonids do in cold waters.

Distribution: Freshwater. North America. Introduced widely to most parts of the world. The only centrarchid native to California is the Sacramento perch, Archoplites interruptus, found in Clear Lake and the lower Sacramento River and tributaries.

FAMILY PERCIDAE (perches, darters)

Characters: In this family the body is elongate and the operculum ends in a flat spine. There are two distinct dorsal fins, with the spinous one having 6-15 spines. The anal fin has one or two spines. The scales are moderately to strongly ctenoid. The gill membranes are not connected to the isthmus. The teeth on the jaws, vomer and palatines are villiform and sometimes canine. The darters (Ethiostominae) are small in size, brightly colored, and have large fins. Pseudobranchiae and air bladder are absent. The darters also have six branchiostegal rays while the larger perches have seven.

Ecology: Percids are common inhabitants of lakes (perches) and streams (darters). All are carnivorous. Darters hide among rocks and crevices on the bottoms of streams. Their small size, broad fins, and pointed heads enable them to maintain themselves in swift, shallow waters. Some darters are capable of burying themselves in sand with only the snout and eyes protruding. They feed on insect larvae. Spawning habits of the group are varied. Eggs of the yellow perch, Perca flavescens, are connected by a membrane and form long floating bands attached at one end to weeds. Other perches, such as the sauger and the walleye, spawn their eggs at random over gravel areas. Darters may bury their eggs in the sand, leave them unattended, or deposit the eggs in a nest guarded by the parents.

From the standpoint of freshwater angling, this group is of great importance. Yellow perch are caught in enormous numbers by small boys with rods as well as commercially in the Great Lakes. Yellow pikeperch ("walleyes" of anglers) are likewise taken widely for sport and commercially in the Great Lakes Region. Both yellow perch and yellow pikeperch may be easily taken through the ice in winter. Two closely related forms, the saugers and blue pikeperch, are of little angling importance but contribute materially to the commercial fish production of the Great Lakes area.

Introduced into western waters, the yellow perch, Perca flavescens, often reproduces so rapidly and successfully as to produce stunted populations of little angling value, thus crowding out other more desirable populations of gamefishes. Much money has been expended by conservation groups to destroy such populations in lakds by using rotenone or other chemicals and then restocking later with more desirable forms. Yellow perch should never be introduced into trout waters for there they usually crowd out the trout and soon become completely dominant. Many of Oregon's excellent coastal lakes have been badly hurt by the stocking of yellow perch.

Distribution: Freshwater fishes of the northern hemisphere. Darters are restricted to eastern North America. Perches are indigenous to eastern North America but have been introduced widely to other areas.

FAMILY EMBIOTOCIDAE (surfperches) (Gr. emblos, live; toketos, bearing)

Characters: Surfperches are recognized by the sheath of scales along the base of the single dorsal fin, separated by a furrow from the body scales. The scales are cycloid and there are scales on the cheek and opercle as well as onthe compressed body. The lateral line is well developed. The anal fin has three spines. There are no teeth on the vomer or palatines. Those on thejaw are conical, moderate in size, and in one or two series. The short maxillary slips under the preorbital for most of its length. Pseudobranchiae are present. The gill membranes are free from the isthmus. The caudal fin is forked. The air baldder is well developed. The oviduct opening is distinctly separated from the anterior vent opening.

Ecology: These fishes are viviparous, and the young develop to adult appearance in a sac-like enlargement of the oviduct. Copulation is apparently accomplished by a modification of the anterior portion of the anal fin of the male. Breeding occurs in the spring, but fertilizationmay be delayed until autumn of the following spring. The young, while in the oviducts, have very large median fins with fringed margins which serve as respiratory structures. Males may be distinguished by the glandular-like structure on the anal fin. Most species inhabit shore areas, often in the surf itself. They are often found in schools around wharves, sandy areas, and kelp beds.

Distribution: Marine. Pacific coast of North America, Japan, and Korea. One freshwater species, Hysterocarpus traski, is found in Clear Lake and in the streams of northern and central California. The center of distribution of the marine species is southern and central California. Temperature apparently limits both northward and southward distribution. There are 15 genera and 21 species in California waters.

FAMILY GOBIIDAE (gobies) L. gobius, a fish of small value)

Characters: Gobies are recognized by the sucking disc, which is free from the body and formed by the united pelvic fins. The skull is depressed and the small eyes are close together on top of the head. The mouth is large with small canine teeth. The anal and soft dorsal fins are opposite and similar in shape; the spinous dorsal has no more than eight spines. The lateral line is absent. There is usually no air bladder. The scales are either cycloid or ctenoid. The gill membranes are united to the isthmus.

Ecology: Gobies are small, carnivorous, bottom-dwelling fishes. Many burrow in the mud of estuaries, lining the burrows with hard clay and industriously repairing any damage which may occur. Typhlogobius, the blind goby of California, lives in holes in the tide-swept rocks, generally in company with the Ghost Shrimp, Callianassa. The tropical mudskippers have muscular pectoral fins which are used to skip about on the mud at low tide. The smallest vertebrates known are in this family, the adults of Pandaka pygmea being 7-12 mm. in length.

The Hawaiian climbing goby, Awous guamensis, is noted for its ability to climb high falls. In the Waimea Canyon on the island of Kauai these fishes have been found above falls 60 to 70 feet high and could have gotten there only by climbing over them since they are catadromous, making regular migrations to the sea for spawning. In climbing, this goby uses both its ventral mouth and the sucking disc formed by the fused ventrals. Like lampreys, in climbing they usually move up the smooth surfaces of rocks at the edge of the main flow of water and can often be seen in rows slowly and laboriously working their way upward in short, jerking movements. The Hawaiian goby which grows to a length of ten inches, is highly prized as food but most gobies are too small to be of much value as food.

Distribution: Shore fishes of tropical, subtropical, and temperate seas. Principally marine, some in fresh and brackish waters.

In the suborder Blennioidea, which includes the families Blenniidae, Anarhichadidae, Clinidae, and Pholidae, the ventral fins, if present, are jugular, with one spine and fewer than five rays. The body is elongate or eel-shaped and the dorsal and anal fins are elongate. The caudal fin is usually rounded. Physoclistic. Each radial of the dorsal and anal fins is attached to the corresponding neural or haemal spine. Pseudobranchiae are present.

FAMILY BLENNIIDAE (blennies) (Gr. blennos, slime)

Characters: In blennies the body is usually scaleless. The dorsal fin extends along most of the back and the spines are flexible. The mouth is small and the teeth are slender and close-set in a single series. The pelvic fins are well developed, usually I, 3. The lateral line is incomplete and is usually high anteriorly.

Ecology: These are small fishes which are usually abundant in shallow, intertidal, reef areas. In many cases the parents guard the eggs until they hatch. Some tropical species have two extremely long canines in the lower jaw with which they impale their prey.

Distribution: Principally tropical and temperate seas. Marine and euryhaline. Some species are found in freshwater lakes of northern Italy. No members of this family occur in Northern California.

FAMILY ANARHICHADIDAE (wolf-fishes or wolf "eels")
(Gr. anarrhichaomai, to clamber up)

Characters: In wolf-fishes the body is moderately elongate. Pelvic fins are absent. The dorsal fin is composed of flexible spines only. There is no lateral line. The gill membranes are broadly attached to the isthmus. The scales are rudimentary. The mouth is wide and oblique. The jaws have strong canine teeth anteriorly and molar teeth laterally. The vomer and palatines are equipped with molar teeth.

Ecology: Wolf-fishes are large fishes of northern seas. Their unusual dentition enables them to feed both on other large fish and on invertebrates, such as sea-urchins and sand-dollars.

Distribution: North Atlantic and North Pacific. Marine.

FAMILY CLINIDAE (klipfishes) (Gr. Klino, to recline)

Characters: The klipfishes are somewhat perch-like in appearance. They have minute scales on the body and a protractile mouth with conical teeth. The dorsal fin is elevated at the anterior and posterior regions and has both spinous and soft-rayed portions. The vertical fins are not confluent with the caudal. The pelvic fins are well developed, usually I, 3. The lateral line is arched high over the pectoral fins. The gill membranes are united and free from the isthmus. These small fishes are characterized by an upturned hook-like projection on the inner margin of the pectoral girdle, visible when the operculum is lifted.

Ecology: These fishes are found mainly in shallow water. Many are intertidal forms, living among seaweed and under stones. They are viviparous and the males have an intromittent organ. The limb-like pelvic fins may be used to crawl over the rocks. One of the commonest forms in local tide-pools is the weed klipfish, Gibbonsia metzi.

Distribution: Tropical and temperate seas. Marine.

FAMILY PHOLIDAE (gunnels) (Gr. pholas, lurking in a hole)

Characters: The body is eel-shaped and usually covered by scales. The low dorsal fin is composed of spines only. The pelvic fins are rudimentary or wanting. If present, they consist of one spine and one or four rays. The vertical fins are confluent with the caudal. The gill membranes are united and free from the isthmus. Ther lateral line is short or absent.

Ecology: These are most abundant in rocky intertidal areas. They assume the color of the environment, the same species being bright green when found in eel grass and brownish when found beneath stones or on reefs.

Distribution: North Atlantic, North Pacific. Marine.

FAMILY ATHERINIDAE (silversides) (Gr. atherine, a smelt)

Characters: Silversides have two separate dorsal fins, the first composed of weak spines and the second of soft rays. The anal fin has a single spine in contrast to the mullets (Mugilidae) which have 2-3 anal spines. There is a silvery lateral band on the side of the elongate body but no lateral line. The scales are usually cycloid. The gill membranes are free from the isthmus. The opercular bones do not have spines or serrations. Pseudobranchiae and an air bladder are present. The pelvic fins are abdominal. The pectoral fins are inserted high on the body. The anal fin is usually larger than the soft dorsal.

Ecology: These are small, carnivorous fishes, living in schools, and often mistakenly called "smelt." They are preyed on by fishes and birds. All are valued as food. The spawning season of the various species may be either in winter or summer, with individual fish spawning more than once. The grunion, *Leuresthes tenuis*, is noted for depositing its eggs in the sand of the beach. Spawning occurs on those nights immediately after the highest tide of the series (the full of the moon). The eggs remain covered by sand for two weeks until the succeeding series of high tides exposes them, at which time they are ready to hatch.

Distribution: Tropical and temperate coast fishes. Principally marine, some entering bays and rivers. Some freshwater forms.

SUBORDER COTTOIDEI

Characters: In this suborder the second suborbital is united with the preopercle, forming a bony suborbital stay. The head usually is armored with bony plates with spiny projections. The slit behind the fourth gill is reduced or absent. Otherwise the fishes in this group closely resemble the percomorphs.

FAMILY SCORPAENIDAE (rockfishes) (Gr. skorpios, scorpion)

Characters: Rockfishes have a large head with characteristically placed spines and ridges. The fin spines are well developed and the scales are large and ctenoid. There are three anal spines and 13-15 dorsal spines. The dorsal fin is continuous or sometimes deeply notched. The gill openings are wide and the gill membranes are not united with the isthmus. The mouth has villiform teeth on the jaws and vomer. Pseudobranchiae and an air bladder are present.

Ecology: The mucous which coats the body and spines, especially of tropical forms, is toxic and wounds may be intensely painful. Rockfishes live from shallow water to depths of more than 800 fathoms. Color varies with the depth. Deep-water forms are generally red while shallow-water ones are black or green. Some species are erroneously called rock "cods." Local forms are ovoviviparous. The taxonomy of local species is difficult and has been incompletely worked out. At least 54 species of the genus *Sebastodes* have been described from the North Pacific. Several species support important commercial fisheries on both the Atlantic and Pacific coasts of North America.

Distribution: All tropical and temperate seas. Center of abundance in North Pacific. Marine.

FAMILY HEXAGRAMMIDAE (greenlings) (Gr. hex, six: gramme, line)

Characters: In greenlings the head lacks the spines and ridges of the rockfishes but instead possesses cirri. They frequently have multiple lateral lines. The posterior nostril on each side is reduced in size. Scales are small, either cycloid or ctenoid, and are present on the head. Pseudobranchiae are present. The anal fin is long. The anterior part of the dosal fin consists of slender spines and the fin may be continuous or divided.

Ecology: Greenlings live among rocks or seaweed. They are carnivorous fishes and often are called "sea-trout" by sportsmen. The ling "cod", *Ophiodon elongatus*, which enters the commercial catch, spawns adhesive eggs which are guarded by one parent.

Distribution: North Pacific. Marine.

FAMILY ANOPLOPOMIDAE (sablefishes) (Gr. anoplos, unarmed; poma, operculum)

Characters: The head lacks ridges, spines, or cirri. The lateral line is single. There are two well-developed nostrils on each side. The second dorsal fin has one or two anterior spines. The pelvics are I, 5.

Ecology: Fishes of deep waters. The sablefish, Anoplopoma fimbria, is important commercially in the north from Oregon to Alaska where the flesh is more oily than in the southern parts of its range.

Distribution: North Pacific. Marine.

FAMILY COTTIDAE (sculpins) (Gr. kottos, bullhead)

Characters: Sculpins have a large head with the eyes placed high on the head. The dorsal spines are flexible. The pectoral fins are broad and fan-like. The pelvics are I, 5 or less. The spinous dorsal fin has 8-16 slender spines and the soft dorsal is elongate. The anal fin has no spines and is similar in shape to the soft dorsal. Pseudobranchiae are present. The air bladder commonly is absent. The body never is uniformily scaled. Teeth are in villiform bands on the jaws and often on the vomer and palatines. The gill rakers are short or obsolete.

Ecology: Sculpins are bottom-dwelling fishes, sluggish in movement except when capturing prey. This is a highly successful group of fishes. In California, Cottus beldingi is enormously abundant in the Truckee River drainage including Lake Tahoe and furnishes large amounts of food for trout in this basin. On a parallel basis C. asper and C. gulosus occur abundantly in coastal streams. The staghorn sculpin, Leptocottus armatus, is one of the most numerous forms in Bay Area waters and is frequently caught by bait fishermen angling for striped bass. In both genera and species, this group reaches its maximum development in rocky tide pools in shallow marine areas where a large number of very beautiful, highly colored, and generally small forms occur. While most are marine, they also occur in enormous numbers in freshwater streams and lakes such as Lake Tahoe mentioned above. In such waters they are often very abundant, making up in numbers of individuals of a single kind for the diversity of genera and species occurring in salt water. A few descend to great depths in the ocean. These are mostly small fishes except for the local cabezone, Scorpaenichthys marmoratus, which reaches 30 inches in length. The family is extremely varied with almost every species having an individuality of its own. Consequently, there are almost as many genera as species. In the freshwater sculpin Cottus bairdi, the eggs are deposited under stones in swift water and are guarded by the male. These sculpins have been accused of eating trout eggs, but it is probable that any eggs eaten are loose ones that have no chance of hatching. Freshwater sculpins are generally confined to colder waters.

Distribution: Northern hemisphere; circumpolar. Mostly marine, some euryhaline and freshwater.

ORDER GASTEROSTEIFORMES

FAMILY SYNGNATHIDAE (Pipefishes and seahorses) (Gr. syn, together; gnathos, jaw)

Characters: In this family the mouth is at the end of a tube-like snout. The elongate body is enclosed in a series of bony rings. Pelvic fins are absent. There is a single dorsal fin without spines. Physoclistic. There are no teeth. In the seahorses the tail is prehensile and the caudal fin is lacking.

Ecology: Protective coloration is well developed in all forms. They swim in an upright or partially upright position and propel themselves by means of the pectoral and caudal fins as well as by wriggling movements of the body. They are commonly found in eelgrass beds or on other marine vegetation. In the seahorses the prehensile tail is used to attach to seaweeds. One syngnathid, Phyllopteryx, from Australia has dermal appendages on the head and body which closely resemble the seaweed among which it lives. These fishes feed on small crustaceans, using the tube snout as a syringe with which to draw in their prey. The females place the fertilized eggs in the brood pouch of the males where they develop. The lining of the pouch is vascular and supplies oxygen to the developing embryos. In the pipefishes the newly-hatched young are released when the flaps of the pouch separate, but in the seahorses theyemerge through the dilated opening of the pouch.

Distribution: Cosmopolitan. Principally marine, some in brackish water.

FAMILY GASTEROSTEIDAE (Sticklebacks) (Gr. gastros, belly; osteon, bone)

Characters: Sticklebacks have dermal plates on the body and two or more free spines in front of the dorsal fin. The pelvic fins each have a stout spine. There are three branchiostegal rays. The caudal peduncle is slender. The preopercle is unarmed. The mouth is bordered by the premaxillaries only. The pair of ventral bony plates anterior to the pelvic fins is responsible for the family name.

Ecology: Sticklebacks are common inhabitants of freshwater, brackish, and marine areas. The pelvic and dorsal spines can be locked in the extended position to form a formidable defense against a potential enemy. The dermal plates are better developed in the marine forms than in the freshwater forms.

Distribution: Northern hemisphere; circumpolar. Marine, euryhaline, and freshwater.

ORDER PLEURONECTIFORMES (flatfishes)

Characters: Flatfishes have a compressed body modified for a bottom existence. The skull is asymmetrical with both eyes on one side of the head. The eyed side of the fish is colored and the blind side is white. The dorsal and anal fins are long. The newly-hatched larvae are symmetrical and physoclistic. They lead a planktonic existence. Larval metamorphosis includes migration of one eye to the opposite side of the head, anterior prolongation of the dorsal fin and loss of the air bladder. The young then become bottom-dwellers for the remainder of their lives. They swim with the eyed side uppermost and the blind side lowermost. The mouth can be either large or small and is often asymmetric. Teeth are always present. The premaxillaries are protractile. Pseudobranchiae are present. The preopercular margin is more or less distinct and not hidden by skin or scales, in contrast to the true soles (Cynoglossidae) of which there is only a single representative on the west coast of North America.

Ecology: Flatfishes are predacious and carnivorous, feeding on other fishes and bottom invertebrates. They often bury themselves in the sand with only the eyes protruding. Eggs are small, pelagic, and produced in great numbers. The local starry flounder, Platichthys stellatus, is often taken in freshwater connected with the ocean and a heavy sports fishery takes place for this species in the Bay Area. Other species form important commercial fisheries locally and in many other parts of the world.

FAMILY BOTHIDAE (dabs)

Characters: The body is sinistral (eyes and colored surface on the left side). e pelvic fin of the eyed side is exactly on the edge of the abdominal ridge. Citharichthys sordidus forms a tenth of the commercial flatfish catch in California.

Distribution: Tropical and temperate seas. Marine.

FAMILY PLEURONECTIDAE (flounders) (Gr. pleura, rib; nektos; swimming)

Characters: The body is dextral (eyes and colored surface on the right side). The pelvic fins are symmetrically arranged, one on each side of the abdominal ridge. The Pacific Halibut (Hippoglossus stenolepis) forms the second most valuable fishery in the North Pacific, second only to salmon. It is caught principally on long lines although some are taken in otter trawls. The fishery is strictly regulated by an international treaty between the United States and Canada. Other flounders form the majority of the flatfish catch in California, Oregon, and Washington.

Distribution: Polar and temperate seas. Marine.

ORDER ECHENEIFORMES

FAMILY ECHENEIDAE (remoras) (Gr. echeneis, remora)

Characters: Remoras have the spinous dorsal fin transformed into an adhesive disk. The flat disk extends forward on the upper surface of the head. The spines of the fin have become divided and flattened to form transverse lamellae. The pelvic fins are thoracic and the pectorals are inserted high on the body. The skull is broad and depressed. There is no air bladder. The second dorsal and al fins have no spines. The body is fusiform, elongate, and covered with small cycloid scales. The opercles are unarmed. The pseudobranchiae are obsolete and the gill rakers are short.

Ecology: Remoras attach to the skin of predacious sharks and large serranids and are transported by these larger fish. Small spines on the posterior margins of the lamellae prevent the remora from sliding backwards on their swift-moving transports. They are facultative commensals since they feed on fragments from the hosts' meals, but in no way do they harm the host.

Distribution: All warm seas. Marine.

ORDER TETRAODONTIFORMES

Characters: These fishes are distinguished from the percomorphs by certain skeletal peculiarities. The pelvic fins are usually absent. The gill opening is reduced in size so that it does not extend below the base of the pectoral fin and the opercular bones are reduced. The body is covered with osseous scales, scutes, or spines; often the body is naked. The few teeth are strong and may be beak-like. This group is found principally in tropical and subtropical seas. Many are poisonous.

FAMILY BALISTIDAE (triggerfishes) (L. balista, a catapult)

Characters: The dorsal fin has one to three spines which can be locked in the ect position. There are eight strong, incisor-like teeth in each jaw. The pelvic fins are represented by a single short spine at the end of a long, movable pelvic bone which helps to expand the abdominal air sac. The scales are enlarged and bony. The lateral line is obscure or absent.

Ecology: Triggerfishes live mainly in shallow water, coral reef areas. The strong teeth are used to crush shells of molluscs on which they feed. They may cause damage to pearl fisheries by eating the pearl oysters. The first dorsal spine can be locked in the erect position by a bony knob at the base of the second and is immovably fixed unless the second is depressed. This second spine has been compared to a trigger. The flesh of some species is poisonous.

Distribution: Atlantic, Indian, and Pacific oceans. Marine.

FAMILY TETRAODONTIDAE (puffers) (Gr. tetra, four; odontos, teeth)

Characters: The teeth are fused into two large plates in each jaw. In contrast to the triggerfishes, the pelvis is fixed. The fins are composed of soft rays only. These are heavy-bodied fishes. The body is naked except for small spines which may be present.

Ecology: Puffers have the capacity of blowing themselves into a spherical shape by distending a large sac, connected with the gullet, either with air or water. When filled with air, they will float upside down at the water surface. The flesh generally is poisonous.

Distribution: Atlantic, Indian, and Pacific oceans. Tropical and subtropical. Principally marine, some in freshwater.

FAMILY DIODONTIDAE (porcupine fishes) (Gr. di, two; odontos, teeth)

Characters: The teeth are fused into a single plate in each jaw. These teeth are sharp at the edge but have broad crushing surfaces inside. The body, which is short, broad, and depressed above, is inflatable and covered with spines. These spines may be short and stout, in which case they are three-rooted or long and movable, in which case they are two-rooted. The dorsal and anal fins are short, similar in shape, and posterior in position. The nostrils on each side form a small tentacle.

Ecology: Porcupine fishes feed on coral and molluscs. Their capacity for inflation is less than that of the puffers.

Distribution: Atlantic, Indian, and Pacific oceans. Tropical and subtropical. Marine.

ORDER GOBIESOCIFORMES

FAMILY GOBIESOCIDAE (clingfishes) (L. gobio, a fish of small value;
Gr. esox, pike)

Characters: Clingfishes are small fishes with a thoracic sucking disc. This disc is modified from the pelvic fins and is also supported by the cleithra and postcleithra. The four rays of each pelvic fin form the lateral edges of the disc with the last ray having a membranous attachment to the lower portion of the pectoral base.

The body is tadpole-shaped, with the anterior part of the head broad and depressed. This is correlated with the loss of some of the skull bones, such as the entopterygoid, metapterygoid, and suborbitals. Scales are absent; however, there is a heavy coat of mucous. The lateral line is present with the pores well developed on the head but small and difficult to locate posteriorly. There is one dorsal and one anal fin, opposite in position. All fin rays are unbranched.

The urogenital papilla, just behind the anus, is larger in the males of many clingfishes than in the females and is generically characteristic. The size, shape, and position of the teeth in the jaws form useful systematic characters at the generic and specific levels.

Ecology: Nearly all species of clingfishes occur in shallow coastal waters, often in the intertidal zone, where the adhesive disc and flattened form enables them to maintain their position in a strong surf. They are weak swimmers and use the sucker to attach to stones and weeds. Their incisor and canine teeth are useful in feeding on small crustaceans and worms. Some forms hide among sea urchins.

In tropical America, species of Gobiesox occur rather widely in small, swift, freshwater coastal streams to which true freshwater fishes cannot gain access. In this respect they are equally as efficient as the Hawaiian climbing goby described above.

Clingfishes may be differentiated from gobies by their single dorsal fin and the widely separated bases of their pelvic fins. In gobies the pelvics are usually united to form a flaring cone free from the body whereas in the clingfishes the disc is formed from a fold of skin which is adhesive to the body.

Distribution: Marine. At no point is the number of species large. A widely distributed group occurring on the warm temperate and tropical coasts of the Atlantic, Indian, and Pacific oceans.

ORDER BATRACHOIDIFORMES

FAMILY BATRACHOIDIDAE (toadfishes) (Gr. batrachos, frog)

Characters: The spinous dorsal fin is reduced, with only two to four spines. The thoracic pelvic fins have one spine and only two or three rays. The soft dorsal and anal fins are long. Scales are usually absent. There are spines on the opercle. These fish have a generally repulsive appearance with a large head with curved canine teeth on the jaws and palate.

Ecology: Some toadfishes have hollow spines which are connected with poison glands. The flesh is tasty but these fish are seldom consumed. The eggs have adhesive disks and the young fry also have an adhesive disk which disappears with growth. The parents guard the eggs and young. The common local species in the Bay Area is the midshipman, Porichthys notatus, which has prominent rows of photophores on the body.

Distribution: Atlantic, Indian, and Pacific oceans. Marine.

An Annotated List of Living Fish Groups, Classified to the Family Level.

The two most widely used systems of fish classification are those of the late C. Tate Regan, and the late Leo S. Berg. Berg's system, with uniform endings for ordinal names, is now more frequently used, especially in non-ichthyological literature. Some of Regan's ordinal names such as Isospondyli, Ostariophysi and Percomorphi are so commonly used that they should be learned along with equivalents in Berg's classification.

The ordinal names are derived from Berg's system. The names in parenthesis are the corresponding names given by Regan. The classification as presented here may be considered as a tentative arrangement based on present knowledge. For several families, suborders and even orders, detailed studies are lacking and the reality of the classification is a matter of speculation. This is not a complete list of all the generally recognized families, but only an indication of the relative number of forms contained in the various orders.

Phylum CHORDATA
Subphylum VERTEBRATA

Class Agnatha (Marsipobranchii) Berg considered Agnatha as a superclass, separating this group from the jawed vertebrates (superclass Gnathostomata).

- Order Petromyzontiformes (Hyperoartia)
  - Family Petromyzontidae - lampreys
- Order Myxiniformes (Hyperotreta)
  - Family Myxinidae - hagfishes

Class CHONDRICHTHYES (cartilaginous fishes)

- Subclass ELASMOBRANCHII (sharks, skates, rays)
  - Borg arranged the cartilaginous fishes into two classes (Elasmobranchii and Holocephali) with two superorders of Elasmobranchii.
- Order Squaliformes (Pleurotremata) the sharks
- Suborder HETERODONTOIDEA
  - HETEODONTIDAE - bull-head sharks
- Suborder NOTICANOIDEA
  - HEXANCHIDAE (NOTIDANIDAE) - cow sharks
- Suborder CHLAMYDOSELACHOIDEA
  - CHLAMYDOSELACHIDAE - frilled sharks
- Suborder GALEOIDEA
  - CARCHARIIDAE - sand sharks
  - SCAPANORHYNCHIDAE - goblin sharks
  - ISURIDAE (LAMNIDAE) - mackerel and man-eater sharks
  - CETORHINIDAE (HALSYDRIDAE) - basking sharks
  - ALOPIIDAE - thresher sharks
  - ORECTOLOSIDAE - carpet and nurse sharks
  - RHINCODONTIDAE - whale sharks
  - PSEUDOTRIAKIDAE - false cat sharks
  - SCYLIORHINIDAE (SCYLLIIDAE) - cat sharks
  - TRIAKIDAE - smooth dogfishes
  - CARCHARHINIDAE - blue sharks, gray sharks
  - SPHYRNIDAE - hammer-head sharks
- Suborder SQUALOIDEA
  - SQUALIDAE - spiny sharks or dog-fishes
  - DALATIIDAE (SCYMNORHINIDAE) - slimesharks
  - ECHINORHINIDAE - bramblesharks
- Suborder PRISTIOPHOROIDEA
  - PRISTOPHORIDAE - saw sharks
- Suborder SQUATINOIDEA
  - SQUATINIDAE (RHINIDAE) - angel sharks
- Order RAJIFORMES (HYPOTREMATA or BATOIDEI) - skates and rays
  - RHINOBATIDAE - sandsharks, shovel nose sharks, guitarfishes
  - PRISTIDAE - sawfishes
  - RAJIDAE - rays or skates
  - PLATYRHINIDAE (DISCOBATIDAE) - thornbacks
  - DASYATIDAE (TRYGONIDAE) - stingrays
  - POTAMOTRYGONIDAE - fluvial in habit, S. America

MYLIOBATIDAE (=AETOBATIDAE) - eagle rays, etc.
MOBULIDAE - devilfish, or devil rays, mantas
TORPEDINIDAE - electric rays

Subclass HOLOCEPHALI
Order CHIMAERIFORMES (CHIMAERAE)
CHIMAERIDAE - Chimaeras, ratfishes
Class Osteichthyes
Subclass Sarcopterygii
Order Coelacanthiformes (Crossopterygii)
Family Coelacanthidae - coelacanths
Order Dipteriformes (Dipneusti; Dipnoi)
Family Ceratodontidae - Australian lungfish
Family Lepidosirenidae - South American and African lungfishes
Subclass Brachiopterygii
Order Polypteriformes
Family Polypteridae - bichirs
Subclass Actinopterygii
Superorder Chondrostei
Order Acipenseriformes
Family Acipenseridae - sturgeons
> Family Polyodontidae - paddlefishes —— Superorder Holostei
Order Amiiformes (Protospondyli or Halecomorphi)
Family Amiidae - bowfin
Order Lepisosteiformes (Ginglymodi)
Family Lepisosteidae - gars
Superorder Teleostei
Order Clupeiformes (Isospondyli)
Suborder Clupeoidei
Family Elopidae - tarpons
Family Albulidae - bonefishes
Family Pterothrissidae - deepsea bonefishes
Family Clupeidae - herrings
Family Engraulidae - anchovies
Family Alepocephalidae - deepsea slickheads
Suborder Chirocentroidei
Family Chirocentridae - wolf herrings
Suborder Chanoidei
Family Chanidae - milkfishes
Suborder Salmonoidei
Osmeridae
Family Salmonidae - salmons, trouts, whitefishes, and graylings
Family Galaxiidae - galaxids
Family Argentinidae - argentines
Family Bathylagidae - deepsea smelts+ Retropinnatidae, Salangidae,
Placoglossidae, Aplochitontidae
Suborder Esocoidei (Haplomi)
Family Esocidae - pikes
Family Umbridae - mudminnows
Family Dalliidae - blackfish
Suborder Stomiatoidei
Family Gonostomidae - deepsea bristlemouths
Family Sternoptychidae - deepsea hatchet fishes
Family Stomiatidae - deepsea scaly dragonfishes
Family Chauliodontidae - deepsea viperfishes
Family Astronesthidae - deepsea snaggletooths
Family Malacosteidae - deepsea loosejaws
Family Melanostomiatidae - deepsea scaleless dragonfishes
Family Idiacanthidae - deepsea stalkeye fishes

- Suborder Notopteroidei
    - Family Hiodontidae - mooneyes
    - Family Notopteridae - featherbacks
- Suborder Osteoglossoidei
    - Family Osteoglossidae - bonytongues
    - Family Heterotidae - African bonytongues
- Suborder Pantodontoidei
    - Family Pantodontidae - African mudskipper
- Order Bathyclupeiformes
    - Family Bathyclupeidae - deepsea herrings
- Order Myctophiformes (Iniomi)
    - Family Synodontidae - lizardfishes
    - Family Scopelarchidae - pearleyes
    - Family Alepisauridae - lancetfishes
    - Family Harpadontidae - Bombay ducks
    - Family Myctophidae - lanternfishes
- Order Ateleopiformes
    - Family Ateleopidae - deepsea ateleopids
- Order Giganturiformes
    - Family Giganturidae - deepsea giganturids
- Order Saccopharyngiformes (Lyomeri)
    - Family Saccopharyngidae - swallowers
    - Family Eurypharyngidae - gulpers
- Order Mormyriformes (Scyphophori)
    - Family Gymnarchidae - gymnarchids
    - Family Mormyridae - mormyrids
- Order Cypriniformes (Ostariophysi)
    - Suborder Characoidei (Heterognathi)
        - Family Characidae - characins (or characids)
        - Family Gasteropelecidae - gasteropelecids
    - Suborder Gymnotoidei
        - Family Rhamphichthyidae -knifefishes
        - Family Gymnotidae - gymnotid eels
        - Family Electrophoridae - electric eels
    - Suborder Cyprinoidei (Eventognathi)
        - Family Cyprinidae - minnows and carps
        - Family Catostomidae - suckers
        - Family Homalopteridae - hillstream loaches
        - Family Gastromyzontidae - suckerbelly loaches
        - Family Cobitidae - loaches
    - Suborder Siluroidei (Nematognathi)
        - Family Diplomystidae - diplomystid catfishes
        - Family Ariidae - sea catfishes
        - Family Doradidae - doradid armored catfishes
        - Family Callichthyidae - callichthyid armored catfishes
        - Family Loricariidae - loricariidae - loricariid armored catfishes
        - Family Aspredinidae - banjo or obstetrical catfishes
        - Family Plotosidae - plotosid sea catfishes
        - Family Siluridae - Eurasian catfishes
        - Family Pimelodidae - pimelodid catfishes
        - Family Bagridae - bagrid catfishes
        - Family Ictaluridae - North American freshwater catfishes
        - Family Saccobranchidae - airsac catfishes
        - Family Clariidae - labyrinthic catfishes
        - Family Mochokidae - upside down catfishes
        - Family Schilbeidae - schilbeid catfishes
        - Family Malapteruridae - electric catfishes

- Family Trichomycteridae - parasitic catfishes
- Order Anguilliformes (Apodes)
  - Suborder Anguilloidei
    - Family Derichthyidae - longneck eels
    - Family Anguillidae - freshwater eels
    - Family Simenchelyidae - snubnose eels
    - Family Muraenidae - morays
    - Family Muraenesocidae - pike eels
    - Family Nettastomidae - duckbill eels
    - Family Congridae - conger eels
    - Family Ophichthidae - snake eels
    - Family Dysommidae - mustard eels
  - Suborder Nemichthyoidei
    - Family Nemichthyidae - snipe eels
- Order Halosauriformes (Lyopomi)
  - Family Halosauridae - halosaurid eels
- Order Notacanthiformes (Heteromi)
  - Family Notacanthidae - spiny eels
- Order Beloniformes (Synentognathi)
  - Family Belonidae - needlefishes
  - Family Scomberesocidae - sauries
  - Family Hemiramphidae - halfbeaks
  - Family Exocoetidae - flying fishes
- Order Gadiformes (Anacanthini)
  - Family Gadidae - codfishes and hakes
  - Family Macrouridae - grenadiers (or rat-tails)
- Order Gasterosteiformes (Thoracostei)
  - Suborder Gasterosteoidei
    - Family Gasterosteidae - sticklebacks
    - Family Aulorhynchidae - tube-snouts
  - Suborder Syngnathoidei (Solenichthtes)
    - Family Aulostomidae - trumpetfishes
    - Family Centriscidae -shrimpfishes
    - Family Macrorhamphosidae - snipefishes
    - Family Fistulariidae - cornetfishes
    - Family Syngnathidae - seahorses and pipefishes
- Order Lampridiformes (Allotriognathi)
  - Family Lamprididae - opahs
  - Family Stylephoridae - tube-eyes
  - Family Lophotidae - crestfishes
  - Family Regalacidae - oarfishes
  - Family Trachipteridae - ribbonfishes
- Order Cyprinodontiformes (Microcyprini or Cyprinodontes)
  - Suborder Cyprinodontoidei
    - Family Cyprinodontidae - killifishes
    - Family Goodeidae - goodeid topminnows
    - Family Jenynsiidae - jenynsiid topminnows
    - Family Anablepidae - four-eyed fishes
    - Family Poiciliidae - livebearers
  - Suborder Amblyopsoidei
    - Family Amblyopsidae - cavefishes
- Order Phallostethiformes
  - Family Neostethidae -neostethid priapiumfishes
  - Family Phallostethidae - phallostethid priapiumfishes

- Order Percopsiformes (Salmopercae)
    - Family Percopsidae - trout-perches
    - Family Aphredoderidae - pirate perches
- Order Stephanoberyciformes (Xenoberyces)
    - Family Stephanoberycidae - deepsea pricklefishes
    - Family Rondeletiidae - rondeletiids
- Order Beryciformes (Berycomorphi)
    - Family Anomalopidae - lanterneye fishes
    - Family Polymyxiidae - beardfishes (barbudos)
    - Family Berycidae - berycids (alfonsinos)
    - Family Monocentridae - pinecone fishes
    - Family Holocentridae - squirrelfishes and soldierfishes
    - Family Gibberichthyidae - givverfishes
    - Family Melamphidae - deepsea bigscale fishes
- Order Zeiformes (Zeomorphi)
    - Family Zeidae - dories
    - Family Caproidae - boarfishes
- Order Ophicephaliformes (Labyrinthici, in part)
    - Family Ophicephalidae - snakeheads
- Order Synbranchiformes (Synbranchii)
    - Family Synbranchidae - swamp eels
    - Family Amphipnopidae - cuchia
- Order Perciformes (Percomorphi)
    - Suborder Percoidei
        - Family Centropomidae - snooks
        - Family Theraponidae - tigerfishes
        - Family Serranidae - sea basses
        - Family Kuhliidae - aholeholes
        - Family Lobotidae - tripletails
        - Family Leiognathidae - slipmouths
        - Family Lutjanidae - snappers
        - Family Priacanthidae - bigeyes
        - Family Apogonidae --cardinalfishes
        - Family Centrarchidae - sunfishes and black basses
        - Family Percidae - perches, walleyes, and darters
        - Family Branchiostegidae - tilefishes
        - Family Pomatomidae - bluefishes
        - Family Rachycentridae - cobias
        - Family Carangidae - jacks, scads, and pompanos
        - Family Coryphaenidae - dolphins
        - Family Bramidae - pomfrets
        - Family Gerridae - mojarras
        - Family Pomadasyidae - grunts
        - Family Sciaenidae - drums
        - Family Mullidae - goatfishes (surmullets)
        - Family Monodactylidae - fingerfishes
        - Family Sparidae - porgies (sea breams)
        - Family Toxotidae - archerfishes
        - Family Pempheridae - sweepers
        - Family Scorpidae - halfmoons
        - Family Ephippidae - spadefishes
        - Family Kyphosidae - sea chubs (rudderfishes)
        - Family Girellidae - nibblers
        - Family Ephippidae - spadefishes
        - Family Scatophagidae - scats
        - Family Chaetodontidae - butterflyfishes
        - Family Nandidae - leaffishes

- Family Cichlidae - cichlids
- Family Embiotocidae - surfperches
- Family Pomacentridae - damselfishes
- Family Labridae - wrasses
- Family Scaridae - parrotfishes
- Family Cirrhitidae - hawkfishes
- Family Trichodontidae - sandfishes
- Family Gadopsidae - river blackfishes
- Family Latridae - trumpeters
- Family Opisthognathidae - jawfishes
- Family Bathymasteridae - ronquils
- Family Mugiloididae - sandperches
- Family Trachinidae - weevers
- Family Trichonotidae sand divers
- Family Percophididae - flatheads
- Family Uranoscopidae - stargazers
- Family Dactyloscopidae - sand stargazers
- Family Chiasmodontidae - deepsea swallowers
- Family Nototheniidae - Antarctic blennies
- Family Chaenichthyidae - icefishes
- Family Bathydraconidae - dragonfishes
- Suborder Siganoidei (Amphacanthini)
  - Family Siganidae - rabbitfishes
- Suborder Acanthuroidei (Teuthidoidea)
  - Family Zanclidae - Moorish idols
  - Family Acanthuridae - surgeonfishes
- Suborder Trichiuroidei
  - Family Gempylidae - snake mackerels
  - Family Trichiuridae - cutlassfishes
- Suborder Scombroidei
  - Family Scombridae - mackerels and tunas
- Suborder Luvaroidei
  - Family Luvaridae - louvars
  - Family Istiophoridae - billfishes (sailfishes, marlins, and spearfishes)
  - Family Xiphiidae - swordfishes
- Suborder Gobioidei
  - Family Eleotridae - sleepers
  - Family Gobiidae - gobies
  - Family Periophthalmidae - mudskippers
- Suborder Cottoidei (Cataphracti; Scleroparei; Loricati)
  - Family Scorpaenidae- scorpionfishes and rockfishes
  - Family Triglidae - searobins
  - Family Anoplopomatidae - sablefishes
  - Family Hexagrammidae - greenlings
  - Family Zaniolepidae - combfishes
  - Family Cottidae - sculpins
  - Family Agonidae - poachers and alligatorfishes
  - Family Cyclopteridae - lumpfishes and snailfishes
- Suborder Dactylopteroidei
  - Family Dactylopteridae - flying gurnards
- Suborder Callionymoidei
  - Family Callionymidae - dragonets

- Suborder Blennioidei (Jugulares, in part)
  - Family Blenniidae - combtooth blennies
  - Family Clinidae - clinids (klipfishes)
  - Family Anarhichadidae - wolffishes
  - Family Pholidae - gunnels
  - Family Stichaeidae - pricklebacks
  - Family Ptilichthyidae - quillfishes
  - Family Microdesmidae - wormfishes
  - Family Zoarcidae - eelpouts
  - Family Scytalinidae - graveldivers
  - Family Zaproridae - prowfishes
- Suborder Ophidioidei
  - Family Brotulidae - brotulas
  - Family Ophidiidae - cusk-eels
  - Family Carapidae - pearlfishes
- Suborder Ammodytoidei
  - Family Ammodytidae - sand lances
- Suborder Stromatoidei
  - Family Stromateidae - butterfishes
  - Family Nomeidae - shepherdfishes
- Suborder Anabantoidei (Labyrinthici, in part)
  - Family Anabantidae - climbing perches (labyrinthfishes)
- Suborder Kurtoidei
  - Family Kurtidae - forehead brooders
- Suborder Luciocephaloidei (Labyrinthici, in part)
  - Family Luciocephalidae - pikeheads
- Suborder Tetragonuroidei
  - Family Tetragonuridae -squaretails
  - Family Icosteidae - ragfishes
- Suborder Sphyraenoidei
  - Family Sphyraenidae - barracudas
- Suborder Mugiloidei
  - Family Mugilidae - mullets
  - Family Atherinidae - silversides
- Suborder Polynemoidei
  - Family Polynemidae - threadfins

Order Pleuronectiformes (Heterosomata)

- Family Bothidae - lefteye flounders
- Family Pleuronectidae - righteye flounders
- Family Soleidae - soles
- Family Cynoglossidae - tonguefishes

Order Mastacembeliformes (Opisthomi)

- Family Mastacembelidae - mastacembelid eels

Order Echeneiformes (Discocephali)

- Family Echeneidae - remoras (sharksuckers)

Order Tetraodontiformes (Plectognathi)

- Family Triacanthodidae - spikefishes
- Family Balistidae - triggerfishes and filefishes
- Family Ostraciidae - trunkfishes
- Family Tetraodontidae - puffers
- Family Diodontidae - porcupinefishes
- Family Molidae - molas (ocean sunfishes)

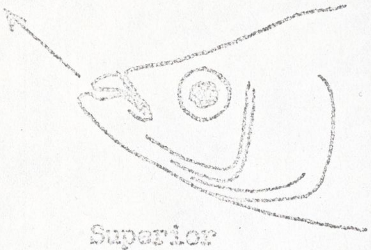
Order Gobiesociformes (Xenopteri)

- Family Gobiesocidae - clingfishes

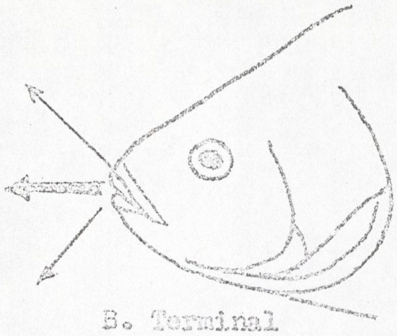
- Order Batrachoidiformes (Haplodoci)
  - Family Batrachoididae - toadfishes
- Order Lophiiformes (Pediculati)
  - Family Lophiidae - goosefishes (anglerfishes)
  - Family Antennariidae - frogfishes
  - Family Ogcocephalidae - batfishes
  - Family Ceratiidae - deepsea anglerfishes
- Order Pegasiformes (Hypostomides)
  - Family Pegasidae - sea moths

FISH MORPHOLOGY

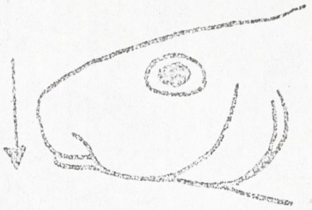
Mouth position --- indicates where a fish feeds --- surface, mid-water, or bottom.



A. Superior ~~Terminal~~
Fish represented here is the mosquitofish; a surface feeder on mosquito larvae.

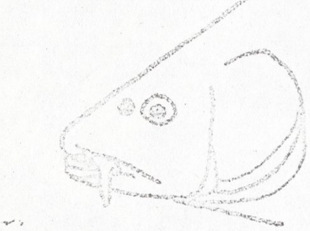


B. Terminal
This type is the most flexible in use --- primarily mid-water, but also surface and b ottom.

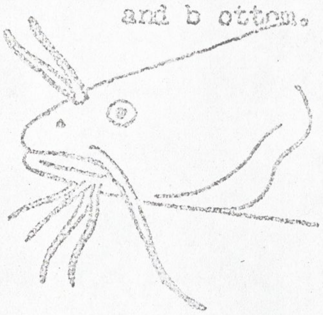


C. Subterminal
Adapted for bottom feeding; includes the sucker and sucker-like minnows.

Oral appendages:



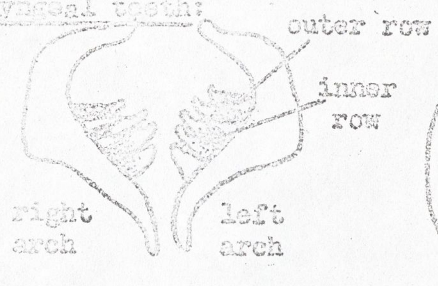
A. Maxillary barbel of the carp.



B. Maxillary and chin barbels of a cat-fish.

C. Fleshy lips of a sucker; bear sensory papillae.

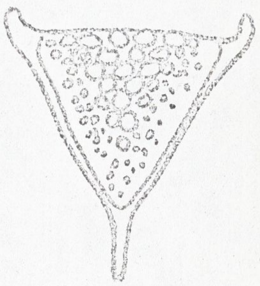
Pharyngeal teeth:



A. Pharyngeal archesof a minnow; tooth formula 2,5--4,2; teeth may be highly variable in shape.

B. Pharyngeal teeth of a sucker; note only 1 row, with teeth of a uniform shape.

C. Unfused, lower pharyngeal arches of a predatory fish(perch)



D. Fused lower pharyngeals of a surf perch; note molariform teeth.

Dentary teeth are absent in minnows and suckers; in these two groups, the pharyngeal teeth are the functional teeth. Molariform teeth crush the carapaces of crustaceans and various invertebrates. In the vast majority of fishes, the lowere pharyngeals are unfused, narrow and elongate, and covered with villiform(hair-like) teeth.

Gill rakers:

Gill rakers are tooth-like projections on the anterior surface of the gill arches. In fish that feed on phytoplankton, the ~~teeth~~ rakers are wedge-shaped and possess a brush-like surface. In fish that feed on zooplankton, the rakers are many in number, closely spaced, and extremely long. Predatory fish have small or reduced rakers which sometimes are transformed into tooth-bearing plates. Differences in gill raker number between two species or subspecies often reflect differences in feeding habits and general ecology.

JDH --- XI:6:62

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