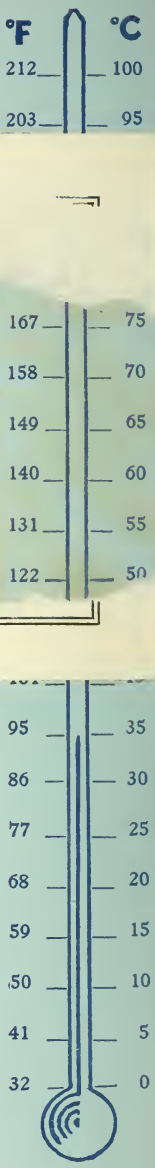
A Guide to the Study of Fresh-water Biology

James G. Needham

and

Paul R. Needham

LIST OF PLATES



A Guide To The Study of Fresh-Water Biology

With Special Reference to Aquatic Insects and Other Invertebrate Animals and Phyto-Plancton

By

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Preface

The plan and purpose of this little book in this its fourth revision are the same as in the earlier ones: to facilitate the recognition of freshwater organisms in the field and in the laboratory. It offers for the purpose keys and tables and figures illustrating genera. Only things commonly found in fresh waters are included. Inhabitants of salt and alkaline waters and of caves are omitted. Vertebrate animals and vascular plants are also omitted because they are better known, and because aids to their recognition are commonly available. The larger invertebrates are more fully treated than are the microscopic ones. Genera and not species are illustrated; and generic names are applied in an inclusive sense to groups of species that a beginner may be able to recognize by external differences. To provide him with a tool that he can use has been our aim, and we trust that that will explain our disregard of some of the much subdivided genera of systematic specialists. The keys have been expanded to include genera whose immature aquatic stages were formerly unknown.

The program of 25 practical exercises for use by classes stands as before, these having yielded satisfactory results in practical acquaintance with water life. A good background of field experience is needed for proper appreciation and enjoyment of the world we live in. Knowledge of the place and rôle that these organisms fill in that world is the best basis for further and more technical work with them.

James G. Needham
Paul R. Needham

Ithaca, New York
March 1, 1938

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Group Finding List

PLANTS

(Algæ only; higher groups not treated.)

ANIMALS

AIDS

See also List of Plates inside front cover.

PART I

AIDS TO RECOGNITION OF FRESH-WATER ORGANISMS

KEY TO THE ORDERS OF AQUATIC INSECT LARVAE

1—Larvæ with wings developing externally (called *nymphs* in this book) and no quiescent pupal stage.....2
Larvæ proper, with wings developing internally, and invisible till the assumption of a quiescent pupal stage: form more worm like.....5

2—With biting mouth parts.....3
—Mouth parts combined into a jointed sucking beak, which is directed beneath the head backward between the forelegs. (Bugs; see page 20).....**Hemiptera**

3—With long, slender tails; labium not longer than the head, and not folded on itself like a hinge.....4
—Tails represented by three broad, leaf-like respiratory plates traversed by tracheæ, or by small spinous appendages; labium when extended much longer than the head; at rest, folded like a hinge, extending between the bases of the forelegs. (Dragonflies and damselflies; see page 14).....**Odonata**

4—Gills mainly under the thorax; tarsal claws two; tails two. (Stone flies; see page 7).....**Plecoptera**
—Gills mainly on the sides of the abdomen; tarsal claws single; tails generally three. (Mayflies; see page 8).....**Ephemerida**

5—With jointed thoracic legs.....6
—Without jointed thoracic legs; with abdominal prolegs, or entirely legless. (Flies, etc.; see page 28).....**Diptera**

6—With slender, decurved, piercing mouth parts, half as long as the body; small larvæ, living on fresh-water sponges. Family HEMEROBIIDAE (see page 30) of..**Neuroptera**
—With biting mouth parts.....7

7—With a pair of prolegs on the last segment only (except in Sialis, plate 13, which has a single long median tail-like process at the end of the abdomen) these directed backward, and armed each with one or two strong hooks or claws.....8
—Prolegs, when present, on more than one abdominal segment; if present on the last segment, then not armed with single or double claws (except in gyrinid beetle larvæ, which have paired lateral abdominal filaments), often entirely wanting..9

8—Abdominal segments each with a pair of long, lateral filaments. Family SIALIDIDAE (see page 30) of.....**Neuroptera**
—Abdominal segments without long, muscular, lateral filaments, often with minute gill filaments; cylindric larvæ, generally living in portable cases. (Caddisflies; see page 24).....**Trichoptera**

9—With five pairs of prolegs, and with no spiracles at the apex of the abdomen. (Moths; see plate 13).....**Lepidoptera**
—Generally without prolegs; never with five pairs of them; usually with terminal spiracles; long, lateral filaments sometimes present on the abdominal segments. (Beetles; see page 26).....**Coleoptera**

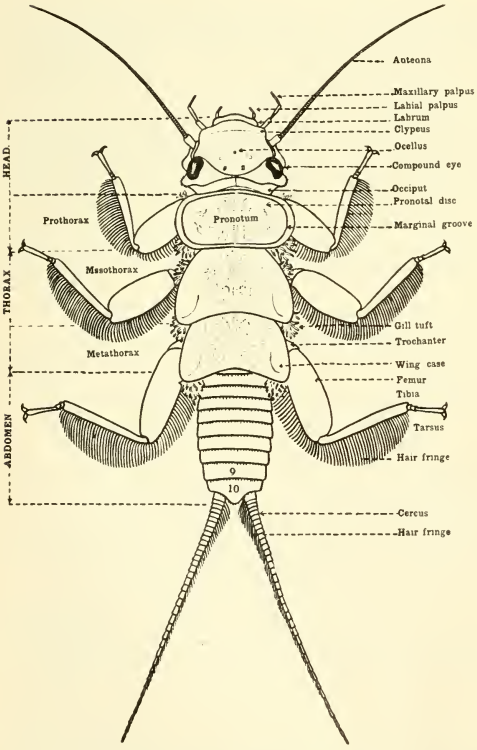
The General Plan of Part I

The names of the genera that are included in the keys and illustrated in the plates are set down in alphabetic order in small foot-tables facing the plates to which they correspond. The Arabic numerals in the next column of the tables refer to corresponding figures in the plate opposite: sub-numbers (as 12a) represent details, or variants within the genus. Numerals within parentheses are used when no whole figure of the genus is given, and indicate the whole figure of another genus that is similar in form.

The length given in the next column is that of grown specimens, and is given in millimeters (one mm. equals 1/25 inch approximately). Maturity of nymphs of insects may be judged by length of wing cases. The figures are for length of body without antennæ and tails.

The capital letters of the next column indicate continental distribution in a very general way: N, E, S, and W; G, general; C, central.

The last column gives habitat in terms of water movement: static (or lenitic) and lotic.



From Claassen, with alterations

In order to use the keys which follow, choose between the alternatives offered and follow the numerals in the margin on to the name of the genus. Verify by reference to figures in the plate.

If terms in keys are unfamiliar, use any good English dictionary.

Recent studies have added greatly to our knowledge of the immature stages in the lower orders of insects, and the keys in this edition have been correspondingly expanded. Too recent for incorporation here is the new and very important work on aquatic dipterous larvae by Dr. O. A. Johannsen (*Aquatic Diptera*, in 5 Parts, 1934–1938 in *Memoirs of the Cornell University Experiment Station*) completed as this left our hands for the printer.

For methods of caring for and rearing aquatic animals consult *Culture Methods for Invertebrate Animals*, 590 pages, illustrated (Comstock Publishing Co. Inc., Price $4.00).

KEY TO THE GENERA OF STONEFLIES (PLECOPTERA)*

1—With gills on a number of segments of the abdomen....2
—With no gills (except anal gills) on the abdomen....4

2—With large single lateral gills on abdominal segments 1 to 7....**Oroperla**
—With small tufted ventral gills on the basal segments only....3

3—These gills on segments 1 and 2 only....**Pteronarcys**
—These gills on segments 1, 2 and 3....**Pteronarcella**

4—Body depressed, roach-like in form; head bent under....**Peltoperla**
—Body elongate, head directed forward....5

5—First and second tarsal segments very short, together less than half as long as the third segment....6
—First and second segments more than half as long as the third....19

6—With 2 ocelli: copious gill tufts under the thorax....7
—With 3 ocelli: gill tufts various or wanting....8

7—Ocelli close together; anal gills present....**Neoperla**
—Ocelli far apart (several diameters of one of them)....**Atoperla**

8—With branched gill tufts at the base of the legs....9
—With gills if present minute unbranched and inconspicuous....12

9—Eyes set far forward, before the middle of the head....**Perlinella**
—Eyes not before the middle of the head....10

10—Body freckled with small brown dots: length 10 mm....**Perlesta**
—Body not so freckled; size much larger....11

11—With distinct occipital ridge, continuous across the head....**Perla**
—Generally with this ridge not continued across the middle....**Acroneuria**

12—With minute fingerlike gills at the throat....13
—Without gills....14

13—These gills very minute (fig. 15)....**Hydroperla**
—These gills larger, and generally more numerous....**Perlodes**

14—Head squarish with the small eyes set far forward....15
—Head more convex at sides with the eyes more prominent laterally....16

15—Pronotal disc heavily fringed with coarse hairs: tails 8 mm....**Kathroperla**
—Pronotal disc not heavily fringed: tails 6 mm. long....**Paraperla**

16—Outer margin of wing buds when grown incurving only at the ends: tails longer than either abdomen or antennæ....17
—Outer margin of wing buds broadly and regularly rounded: tails shorter than either abdomen or antennæ....18

17—Maxillae very large, their projecting "elbows" visible from above the head..**Isogenus**
—Maxillae not visible from above the head....**Isoperla**

18—Dorsum of thorax bare except for a few long hairs....**Chloroperla**
—Dorsum clothed with short scurfy pubescence....**Alloperla**

19—Second tarsal segment as long as the first....**Taeniopteryx**
—Second tarsal segment shorter than the first....20

20—Hind wing cases much more widely divergent than the fore....**Nemoura**
—Hind wing cases parallel with those of the fore wings....21

21—Pale and slender: middle abdominal segments longer than wide....**Leuctra**
—Dark colored: middle abdominal segments wider than long....**Capnia**

* A standard reference work for this order is Claassen's *Plecoptera Nymphs of North America*, issued by the Thomas Say Foundation, Dr. J. J. Davis, treasurer, Lafayette, Indiana (price $4.00). One for adult stoneflies is Needham and Claassen's *The Plecoptera of North America*, obtainable from the same source (price $5.00) Frison's *Plecoptera of Illinois* (Ill. Nat. Hist. Survey 20: 281–471, 1935) treats more fully both nymphs and adults of a more limited area.

KEY TO THE GENERA OF MAYFLY NYMPHS: EPHEMEROPTERA*

1—Mandibles with a tusk projecting forward and visible from above the head.....2
—Mandibles with no such tusk.....9

2—Tusk flattened, blunt-tipped, and bare (certain Western).....**Paraleptophlebia**
—Tusk sharp pointed and more or less hairy.....3

3—Fore tibiæ longer than the hind ones.....4
—Fore tibiæ shorter than the hind ones.....5

4—Mandibular tusks hairy to their tips.....**Euthyplocia**
—Mandibular tusks hairy only at their base.....**Potamanthus**

5—Front of head with an elevated process.....6
—Front of head rounded.....9

6—Frontal process rounded.....7
—Frontal process bifid at the tip.....8

7—Mandibular tusks serrate on the sides.....**Ephoron**
—Mandibular tusks smooth on the sides.....**Hexagenia**

8—Mandibular tusks minutely toothed on the sides.....**Pentagenia**
—Mandibular tusks smooth on the sides.....**Ephemera**

9—Head strongly depressed: eyes dorsal: gills plate like.....10
—Head not strongly depressed: eyes lateral: gills various.....19

10—Gill plates simple, bare.....**Arthroplea**
—Gill plates with clustered gill filaments at the base.....11

11—Tails 2.....12
—Tails 3.....15

12—With a pair of small dorsal spines on each abdominal segment.....**Ironodes**
—With no such spines.....13

13—With a middorsal line of hairs on the abdomen.....**Ironopsis**
—With no middorsal line of hairs on the abdomen.....14

14—Gill plates of first and last pairs directed laterally.....**Epeorus**
—Gill plates of first and last pairs convergent ventrally.....**Iron**

15—Gills of segment 7 reduced to tapered filaments.....**Stenonema**
—Gills of segment 7 flat like the other gills.....19

* A standard illustrated reference work for this order covering both adults and nymphs is *The Biology of Mayflies* by Needham, Traver and Hsu, 759 pages, 1937 (Comstock Publishing Co., Inc., price $7.50).

Unfortunately there are a number of name changes required by the rule of priority, that the users of former editions of this *Guide* will need to know about:

Isonychia replaces *Chirotonetes*.

Paraleptophlebia replaces *Leptophlebia* in part.

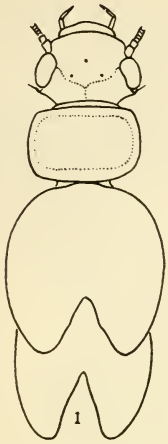
Heptagenia replaces *Ecdyonurus*, and is itself replaced by *Stenonema*. There now appears to be general concurrence and agreement in the use of EPHEMEROPTERA instead of EPHEMERIDA as the name of the Order.

(*Continued on page* 10)

PLATE I. STONEFLY NYMPHS

Genera	*Figs.*	*Length*	*Distr.*	*Waters*	*Genera*	*Figs.*	*Length*	*Distr.*	*Waters*
Acroneuria	(5)	20	G	lotic	Neoperla	(5)	19	F, S	lotic
Alloperla	(5)	12	G	lotic	Paraperla	8	9	W	lotic
Atoperla	(5)	8	W, C	lotic	Peltoperla	2	11	G	lotic
Capnia	(13)	5	N	lotic	Perla	(5)	10–26	G	lotic
Chloroperla	1,(5)	6	G	lotic	Perlesta	(5)	12	G	lotic
Hydroperla	15	17	G	lotic	Perlinella	7,(5)	16	F	lotic
Isogenus	(5)	20	N, W	lotic	Perlodes	(5)	21	G	lotic
Isoperla	4	13	G	lotic	Pteronarcella	11,(5)	18	W	lotic
Kathroperla	(8)	18	NW	lotic	Pteronarcys	(5)	30	G	lotic
Leuctra	6,14	10	G	lotic	Taeniopteryx	10,12	12	G	lotic
Nemoura	3,9	11	G	lotic					

Plate 1. Stonefly Nymphs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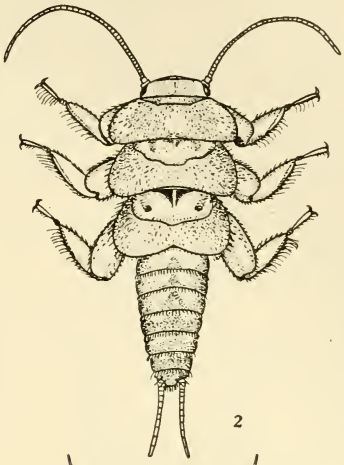
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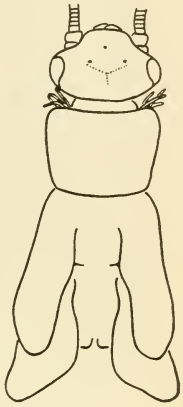
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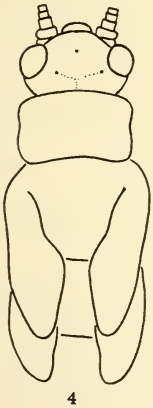
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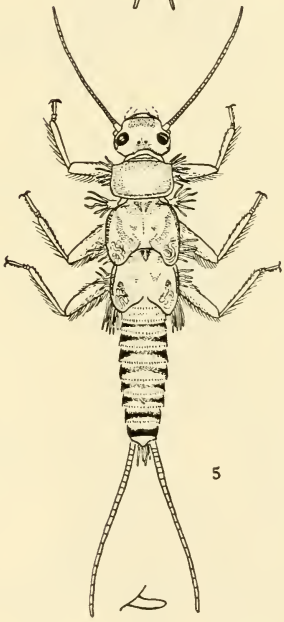
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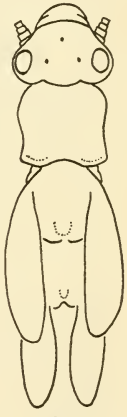
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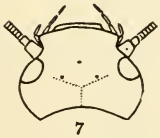
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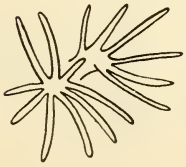
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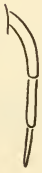
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11


12


13


14

(*Continued from page 8*)

16—Head emarginate in front: basal gill filaments almost wanting.....**Cynigmula**
—Head hardly emarginate: gill filaments well developed.....17

17—Gills of segment 1 enlarged, inturned, and meeting beneath the thorax..**Rhithrogena**
—Gills of segment 1 not enlarged, directed laterally.....18

18—Inner canine of mandible about half as long as the outer.....**Cynigma**
—Inner canine at least three fourths as long as the outer one (see fig. 13) .**Heptagenia**

19—Gills completely concealed under an enormously enlarged thoracic shield...**Baetisca**
—Gills exposed: thoracic dorsum normal.....20

20—Outer tails fringed alike on both sides.....21
—Outer tails heavily fringed on the inner side only.....34

21—Gills present on abdominal segments 1 to 7.....27
—Gills wanting from one or more of these segments.....22

22—One pair of gills thickened (operculate), covering those behind it.....23
—Gills all thin and freely exposed.....27

23—Operculate gill on segment 4.....**Ephemerella**
—Operculate gill on segment 2.....24

24—Hind wing sheath present.....**Oreianthus**
—Hind wing sheath absent: small hairy species.....25

25—Gills on segments 2 to 6 double: operculate gill triangular.....**Tricorythodes**
—Gills on segments 2 to 6 single: operculate gill squarish.....26

26—With three prominent tubercles on top of the head.....**Brachycercus**
—With no tubercles on top of the head.....**Caenis**

27—Gills of the first pair unlike those that follow.....28
—Gills of the first pair similar to the others.....32

28—Gills on segments 2 to 7 single clusters of slender filaments.....**Habrophlebia**
—Gills on segments 2 to 7 flattened and more or less plate like.....29

29—Margins of each gill on middle segments fringed.....**Thraulus**
—Margins of these gills broadly lobed or entire.....30

30—Gill on segment 1 simple; the others lobed at the apex.....**Choroterpes**
—Gill on segment 1 double; the others slender tipped.....31

31—Middle gills broad and lobed before the tip .....**Blasturus**
—Middle gills narrow and uniformly tapering.....**Leptophlebia**

32—With lateral spines on segments 2 to 9.....**Thraulodes**
—With lateral spines on segments 8 to 9 or on 9 only.....33

33—Hind dorsal margin of segments 1 to 10 finely spinulose.....**Paraleptophlebia**
—Hind dorsal margin of segments 7 to 10 only are so.....**Habrophleboides**

34—Claws of the fore legs unlike the other claws.....35
—Claws of the fore legs like those on the other legs.....37

35—Claws of the fore legs deeply cleft, appearing double.....36
—Claws of the fore legs simple, long, slender, bearing a few bristles beneath: front coxæ bearing a thumb-like appendage on the inner side.....**Ametropus**

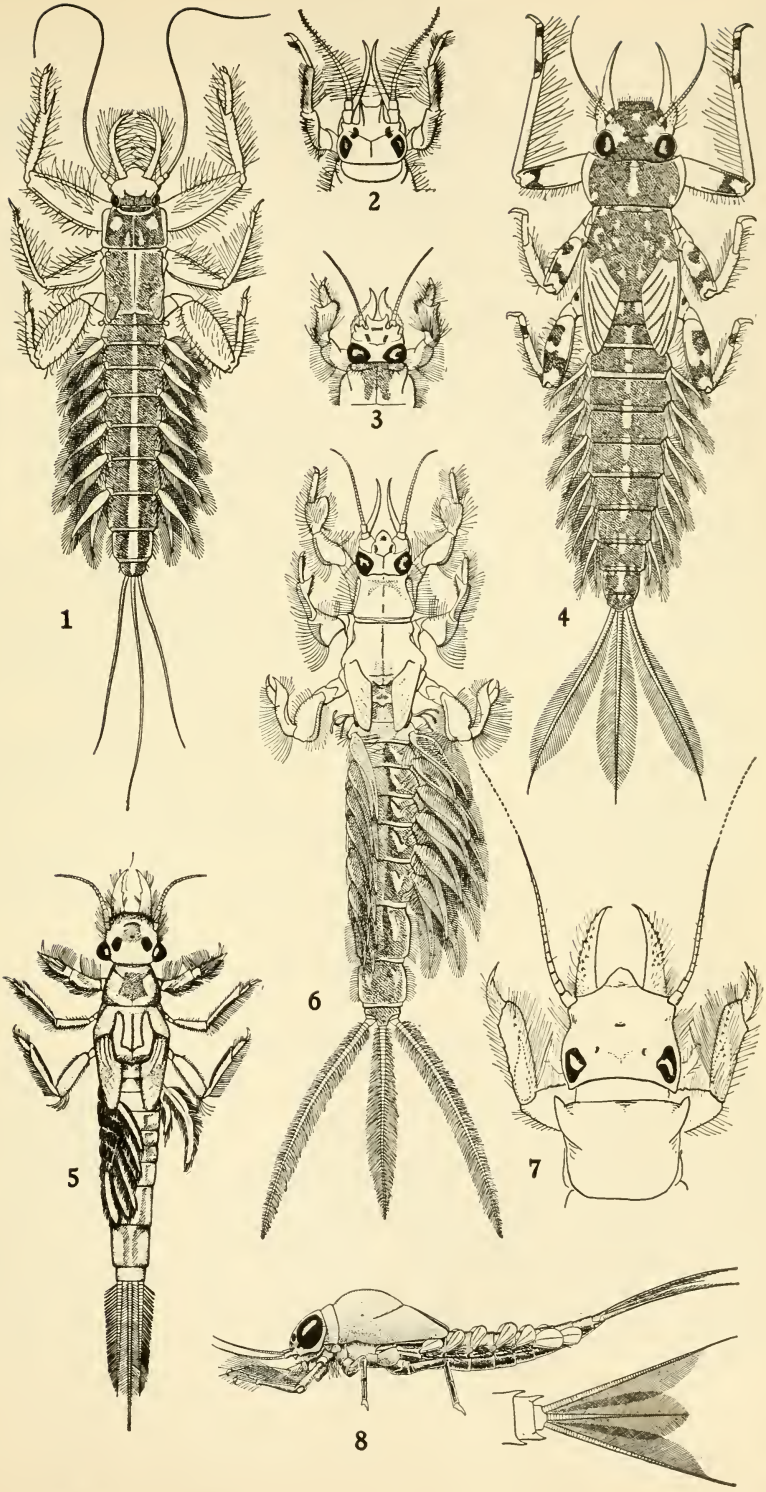
(*Continued on page 12*)

PLATE 2. MAYFLY NYMPHS

Genera	*Figs.*	*Length*	*Distr.*	*Waters*	*Genera*	*Figs.*	*Length*	*Distr.*	*Waters*
Campsurus.....	5	17	S	static	Hexagenia.....	6	27	E, C	static*
Ephemera.....	2(6)	18	E	both	Isonychia.....	8	15	G	lotic
Ephoron*.....	7	15	E, C	static	Pentagenia.....	3(6)	24	E, C	static
Euthyplocia....	1	29	S		Potamanthus...	4	13	E, C	lotic

* In settling basins in streams conditions are static. Drawings mainly from Kennedy.

Plate 2. Mayfly Nymphs



(*Continued from page* 10)

36—Maxillary palpus 2-jointed: tarsi longer than tibiæ.....**Metretopus**
—Maxillary palpus 3-jointed: tarsi at least as long as the tibiæ.....**Siphloplecton**

37—Posterolateral angles of the terminal abdominal segments prolonged into thin flat lateral spines.....38
—These angles not greatly prolonged, hardly more than acute.....41

38—Fore legs conspicuously fringed within by a double row of long hairs: Gills on base of maxillæ.....**Isonychia**
—No such hair fringes, and no gills on maxillæ.....39

39—Gill plates single on abdominal segments 1 to 7.....40
—Gill plates double on some of these segments.....**Siphlonurus**

40—Abdominal segments 5 to 9 very wide, onisciform.....**Siphlonisca**
—Abdominal segments 5 to 9 normal.....42

41—Maxillary palpus somewhat pincer-shaped at tip, and end of lacinia beset with simple spines.....**Parameletus**
—Maxillary palpus normal at tip, and end of lacinia beset with pectinate spines.....**Ameletus**

42—Gill plates folded double on some of the anterior abdominal segments.....43
—Gill plates all single.....45

43—Tracheae of the gill plates pinnately branched: two pairs of wing buds.....**Cloeon**
—These tracheæ palmately branched: hind wing buds lacking.....44

44—Gill flap folded over ventral surface: maxillary palpus 2-jointed.....**Callibaetis**
—Gill flap folded over dorsal surface of the gill plate: maxillary palpus 3-jointed.....**Centroptilum**

45—Tails 2.....46
—Tails 3 (except in the Western *Baetis bicaudatus*).....47

46—Hind wing buds present (very minute).....**Heterocloeon**
—Hind wing buds lacking.....**Pseudocloeon**

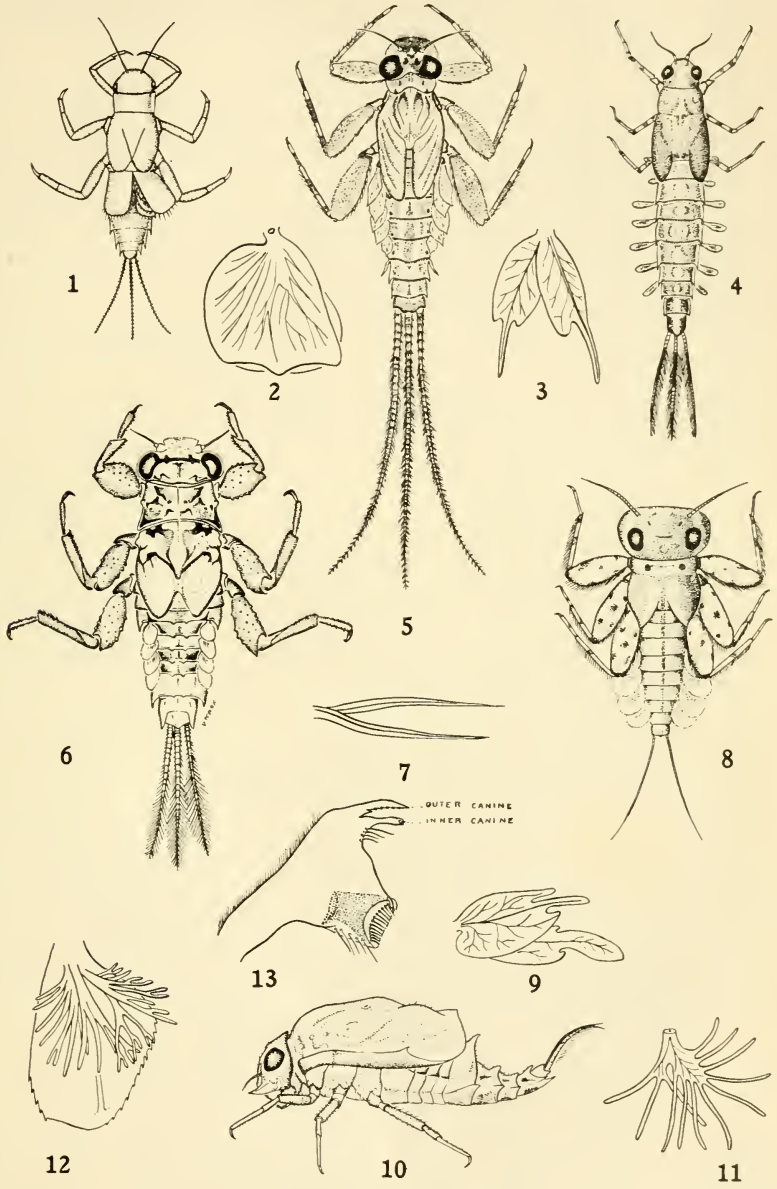
47—Middle tail shorter than the others (except in B. tricaudatus).....**Baetis**
—Middle tail as long as the others: last joint of labial palpus widely dilated.....48

48—Hind wing buds present.....**Centroptilum**
—Hind wing buds absent: gill tracheae branched to one side.....**Neocloeon**

PLATE 3. MAYFLY NYMPHS

Genera	*Figs.*	*Length*	*Distr.*	*Waters*	*Genera*	*Figs.*	*Length*	*Distr.*	*Waters*
Ameletus	4	9	G	both	Heterocloeon	(4)	4	N, E	static
Ametropus	(4)	15–17	SW	lotic	Iron	(8)	9	G	lotic
Baetis	(4)	6	G	lotic	Ironodes	(8)	15	W	lotic
Baetisca	10	10	E, C	lotic	Ironopsis	(8)	15	NW	lotic
Brachycercus	(1)	5–7	G	static	Leptophlebia	7(4)	7	G	both
Blasturus	3, (4)	9	E	both	Metretopus	(4)	10	N	static?
Caenis	1	3	G	static	Oreianthus	(1)	14–17	SE	lotic
Callibaetis	(4)	9	G	static	Paraleptophlebia	7(4)	5–9	G	both
Centroptilum	(4)	4	G	static	Parameletus	(4)	11–12	N	static
Chloeon	(4)	8	G	static	Pseudocloeon	(4)	2–4	G	static
Choroterpes	9(4)	7	G	lotic	Rhithrogena	(5)	10	W	lotic
Cynigma	(5, 12)	8–9	NW	lotic	Siphlonisca	(4)	19–20	NE	static
Cynigmula	(5, 12)	7	N, W	lotic	Siphloplecton	(4)	11–16	N, E	static
Epeorus	8	8	G	lotic	Siphlonurus	2(4)	11	G	static
Ephemerella	6	8–15	G	both	Stenonema	5	6–14	G	lotic
Habrophlebia	11(4)	5	E	lotic	Thraulus	(4)	6	N, W, S	static
Habrophlebiodes	(4)	6	E	static	Tricorythodes	(1)	4	G	lotic
Heptagenia	5	10	G	lotic					

Plate 3. Mayfly Nymphs



KEY TO THE GENERA OF NYMPHS OF DRAGONFLIES AND DAMSELFLIES: ODONATA*

1—Gills within the stout spine-tipped abdomen (suborder ANISOPTERA: dragonflies)..2
—Gills, three flat vertical plates at the end of the slender abdomen (suborder ZYGOPTERA: damselflies).....43

2—Labium flat.....3
—Labium spoon-shaped, covering the face up to the eyes..... 20

3—Antennæ short and thick.....4
—Antennæ slender and bristle-like, AESCHNINAE.....13

4—Antennæ seven-jointed, PETALURINAE.....**Tachopteryx**
—Antennæ four-jointed: third joint longest.....5

5—Tenth abdominal segment as long as all other segments combined.....**Aphylla**
—Tenth abdominal segment not longer than other single segments.....6

6—Middle legs closer together at base than are the fore legs.....**Progomphus**
—Middle legs not closer together at base than are the fore legs.....7

7—Wing cases strongly divergent.....**Ophiogomphus and Herpetogomphus**
—Wing cases parallel.....8

8—Abdomen and third antennal segment flat and nearly circular.....**Hagenius**
—Abdomen and third antennal segment more elongate.....9

9—Third antennal segment thin, flat, oval.....10
—Third antennal segment more nearly cylindric.....11

10—Third antennal segment broadly oval.....**Lanthus**
—Third antennal segment elongate.....**Octogomphus**

11—Dorsal hooks on abdominal segments 6–9 long and sharp.....12
—Dorsal hooks on abdominal segments 6–9 short and blunt.....**Gomphus**

12—Lateral abdominal appendages as long as inferiors.....**Gomphoides**
—Lateral abdominal appendages shorter than inferiors.....**Dromogomphus**

13—Lateral lobes of labium armed with strong raptorial setæ.....**Gynacantha**
—Lateral lobes of labium lacking raptorial setæ.....14

14—Hind angle of head strongly angulate.....15
—Hind angle of head broadly rounded.....17

15—Superior abdominal appendages as long as inferiors.....**Coryphaeschna**
—Superior abdominal appendages much shorter than inferiors.....16

16—Lateral lobe of labium squarely truncata on tip.....**Boyeria**
—Lateral lobe of labium with taper pointed tip.....**Basiaeschna**

* Since this key was prepared the nymphs have been described for a number of genera that are not included in it, genera that occur only along the southern border of the United States. Two papers that will be especially valuable for those who work in this region are:

Insects of Puerto Rico and the Virgin Islands by Elsie Broughton Klots (N. Y. Acad. of Sciences, Scientific Survey of Puerto Rico and the Virgin Islands, Part I, 107 pages, 7 plates).

The Nymphs of North American Libelluline Dragonflies by J. G. Needham and Elizabeth Fisher (Transactions of the American Entomological Society, 62: 107–116, 2 plates)

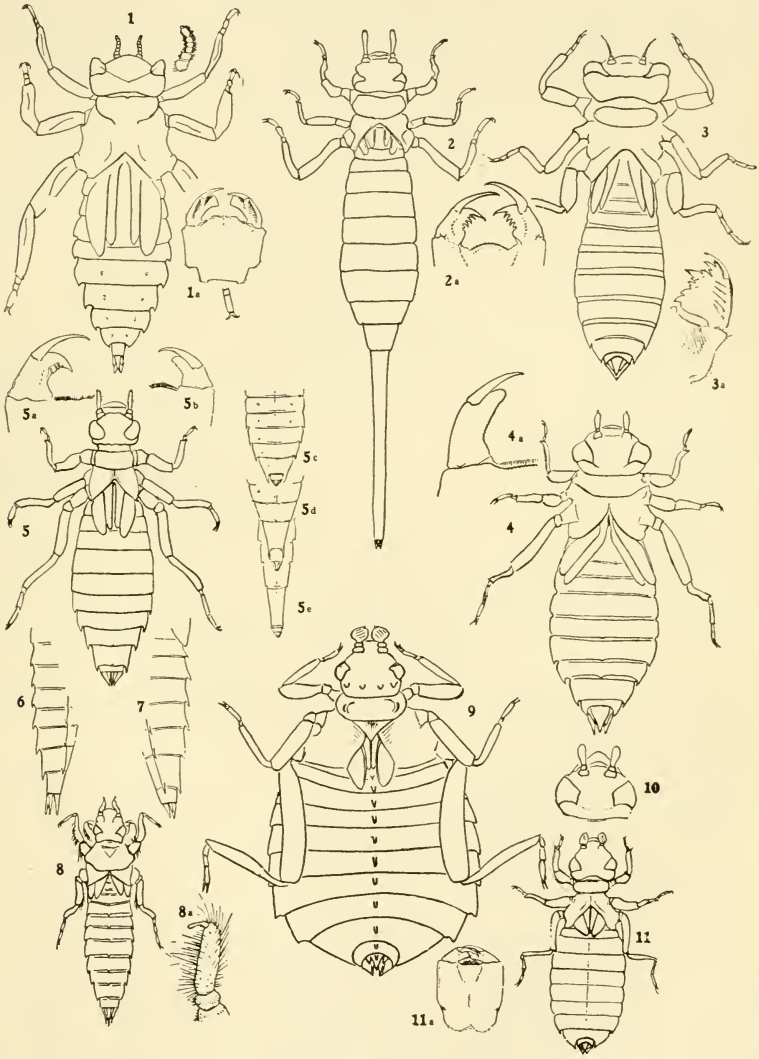
A new genus, *Tarnetrum*, has been erected for the two species of *Sympetrum* (one of them, *T. corruptum*, widely ranging) whose nymphs entirely lack dorsal hooks on the abdomen, and have the lateral spines of the eighth abdominal segment very minute or entirely wanting.

(*Continued on page* 16)

PLATE 4. DRAGONFLY NYMPHS

Genera	*Figs.*	*Length*	*Distr.*	*Waters*	*Genera*	*Figs.*	*Length*	*Distr.*	*Waters*
Aphylla.....	2	45	S	static	Herpetogomphus	(4)	27	G	lotic
Cordulegaster...	3	42	G	lotic	Lanthus.....	11	22	E	lotic
Dromogomphus.	7(5)	33	E, C	lotic	Ophiogomphus..	4	27	G	lotic
Gomphus.....	5	24–45	G	both	Octogomphus...10(11)		23	W	lotic
Gomphoides....	6(5)	34	SW	?	Progomphus....	8	30	G	lotic
Hagenius.....	9	40	E	static	Tachopteryx....	1	38	E	static

Plate 4. Dragonfly Nymphs



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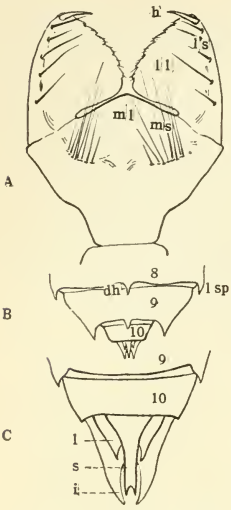


Fig. 1. Diagrams explanatory of terms used in the dragonfly key. *A* is a labium (of Perithemis); *m l* is its median lobe; *l l*, its lateral lobe; *m s*, mental setæ; *l s*, lateral setæ; *h*, hook.
B (Perithemis) and *C* (Anax) are from end of abdomen as viewed from above; 8, 9, 10 are the three last segments; *d*, *h*, dorsal hooks; *l sp*, lateral spines; *l*, lateral and *s*, superior, and *i*, inferior appendages.

17—Lateral spines on abdominal segments 7–9.....**Anax**
—Lateral spines on abdominal segments 6–9.....**Aeschna**
—Lateral spines on abdominal segments 4 or 5–9.....18

18—Low dorsal hooks on segments 7–9..... **Nasiaeschna**
—No dorsal hooks on abdomen.....**Epiaeschna**

20—Inner edge of lateral lobe of labium coarsely and irregularly toothed (Pl. 3a).....**Cordulegaster**
—Same, evenly and regularly toothed or entire.....21

21—Head with a high frontal horn..... 22
—Head smooth or with a low rounded prominence.....24

22—Dorsal abdominal hooks sharp, flat and cultriform....23
—Dorsal abdominal hooks thick and blunt.**Neurocordulia**

23—Head widest across the eyes.....**Macromia**
—Head widest across the bulging hind angles...**Didymops**

24—Dorsal hook on the ninth abdominal segment.....25
—No dorsal hook on the ninth abdominal segment.....29

25—Lateral setæ of labium 5.....26
—Lateral setæ of labium 7.....27

26—Lateral spines of 9 surpassing tips of terminal appendages .....**Epicordulia**
—Same shorter not surpassing tips of terminal appendages .....**Perithemis**

27—Lateral spines of 9 surpassing tips of terminal appendages .....**Tetragoneuria**
—Same, shorter not surpassing tips of terminal appendages.....28

28—Length under 15 mm.....**Helocordulia**
—Length over 20 mm.....**Somatochlora**

29—Eyes at sides of head.....30
—Eyes capping anterolateral angles of head; more frontal than lateral.....40

30—Abdominal appendages strongly decurved: lateral spines wanting.....**Mesothemis**
—Abdominal appendages straight or but a very little declined; lateral spines on 8 and 9.31

31—Dorsal hooks present.....32
—Dorsal hooks absent.....34

32—Spines of segment 9 very long.....**Celithemis**
—Spines of segment 9 short or moderate.....33

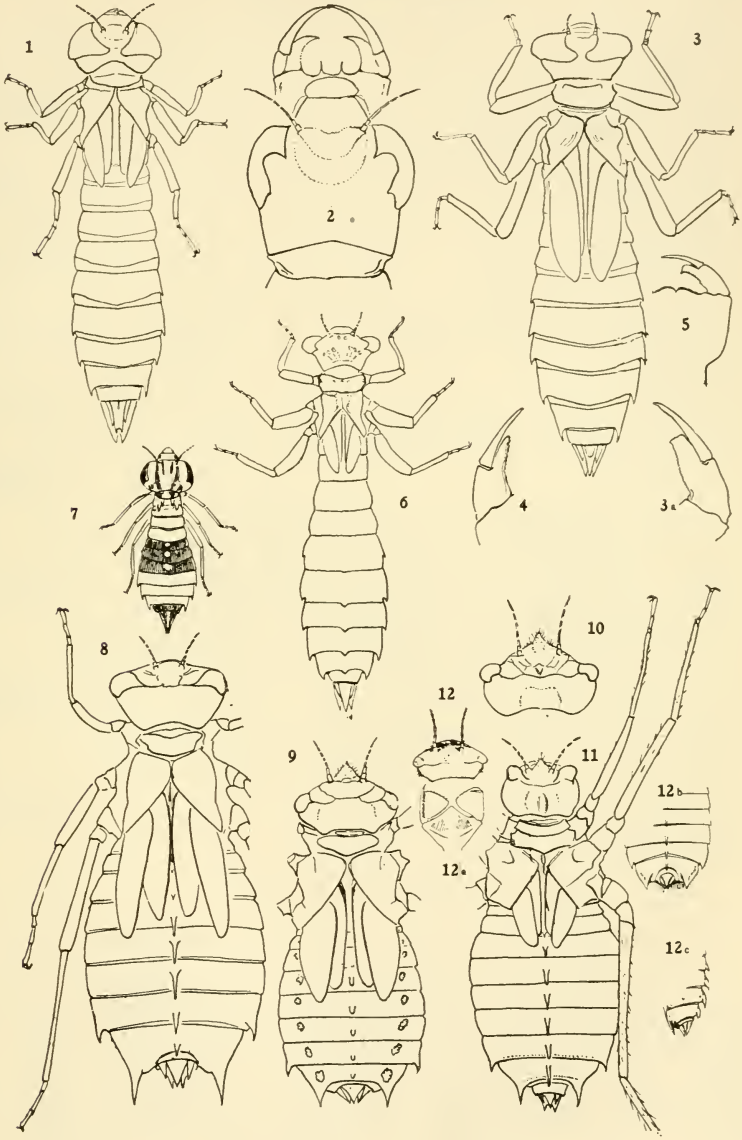
(*Continued on page* 18)

PLATE 5. DRAGONFLY NYMPHS

Genera	*Figs.*	*Length*	*Distr.*	*Waters*	*Genera*	*Figs.*	*Length*	*Distr.*	*Waters*
Aeschna.....	1	45	G	static	Nasiaeschna....	6	38	E, C	both
Anax.....	7*(1)	45	G	static	Didymops.....	11	28	E	static
Basiaeschna.....	4(3)	42	E	lotic	Epicordulia.....	8	27	E, S	static
Boyeria.....	3	38	E	lotic	Helocorulia.....	12	20	E	static
Coryphaeschna..	2	52	SE	static	Macromia.....	10(11)	32	G	static
Epiaeschna.....	5	48	E, C	static	Neurocordulia...	9	21	E, C	both
Gynacantha....	(1)	45	S	static	Tetragoneuria...	(8)	22	G	static

* A young nymph; the bands of color later disappear.
The first 8 are Aeschninæ, with flat labium. The remainder are Cordulinæ with spoon-shaped labium.
The lateral spines of the abdomen are in No. 2 on segments 7–9; in 1, 5 and 7, on 6–9; in 4, 6 and 8, on 5–9; and in No. 3, on 4–9.

Plate 5. Dragonfly Nymphs



(*Continued from page* 16)

33—Dorsal hooks as long as the segments which bear them..**Leucorhrinia** and **Dythemis**
—Dorsal hooks shorter than the segments which bear them.....**Sympetrum**

34—Abdomen smooth.....35
—Abdominal hairy.....38

35—Lateral spines very short.....**Paltothemis**
—Lateral spines long.....36

36—Spines of 8, short: of 9, long.....**Pachydiplax**
—Spines of 8 and 9 both long and similar.....37

37—Teeth on inner edge of lateral lobe of labium deeply cut.....**Pantala**
—Teeth obsolete.....**Tramea**

38—Lateral setæ 6.....**Nannothemis**
—Lateral setæ 7.....39
—Lateral setæ 8–10.....**Erythrodiplax**
—Lateral setæ more than 10.....**Sympetrum**

39—Lateral spines of 9 one fifth as long as 9.....**Cordulia**
—Lateral spines of 9 one third as long as 9.....**Dorocordulia**

40—Lateral setæ 0–3.....**Ladona**
—Lateral setæ 5–10.....41

41—Median lobe of labium evenly contoured.....**Libellula**
—Median lobe of labium crenulate on front border.....42

42—Lateral setæ 8.....**Orthemis**
—Lateral setæ 10.....**Plathemis**

43—Basal segment of antennæ as long as all others together.....44
—Basal segment of antennæ not longer than other single segments.....45

44—Median lobe of labium cleft below bases of lateral lobes.....**Agrion**
—Median lobe of labium cleft only to base of lateral lobes.....**Hetaerina**

45—Labium spoon-shaped, narrowed in the middle.....46
—Labium regularly tapered backward to middle hinge.....47

46—Mental setæ of labium 5 each side.....**Lestes**
—Mental setæ of labium 7 each side.....**Archilestes**

47—Gills half as broad as long: no mental setæ.....48
—Gills not more than one third as broad as long: mental setæ present.....49

48—Lateral setæ 1–4.....**Argia**
—Lateral setæ, none (occasionally 1).....**Hyponeura**

49—Hind angles of head angulate.....50
—Hind angle of head rounded.....51

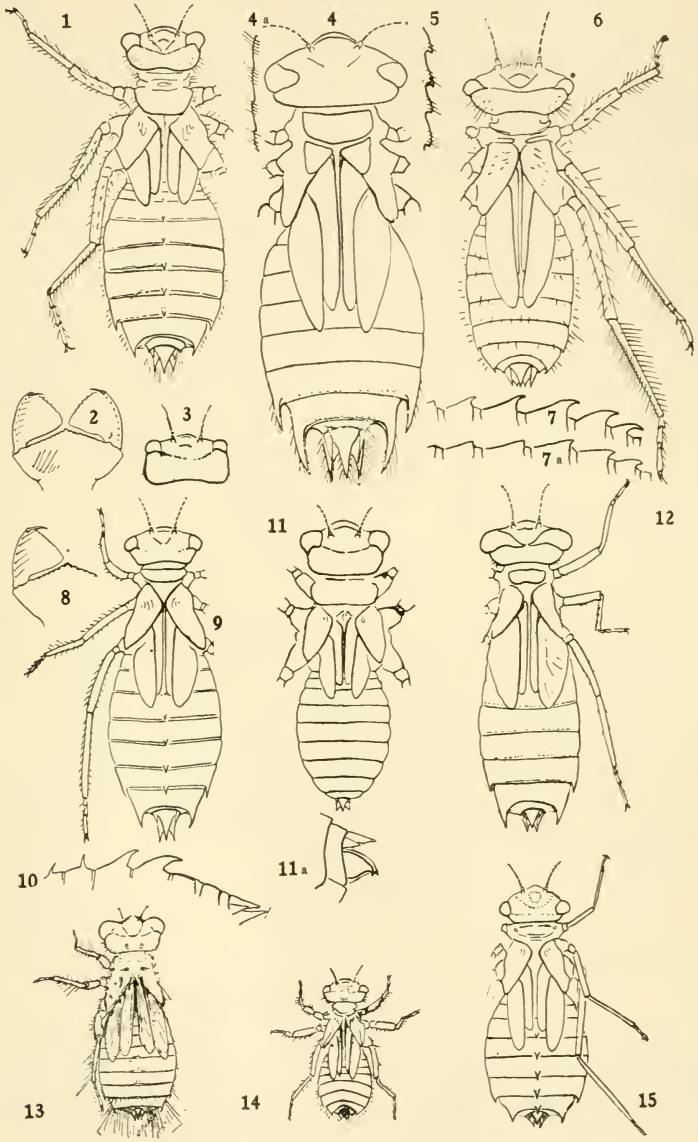
(*Continued on page* 20)

PLATE 6. DRAGONFLY NYMPHS

Genera	*Figs.*	*Length*	*Distr.*	*Waters*	*L.Set**	*Genera*	*Figs.*	*Length*	*Distr.*	*Waters*	*L. Set*
Celithemis...	10(9)	15–21	N, E, S	static	8–9	Nannothemis.	13	10	E, N	static	6
Cordulia.....	6	22	N	static	7	Orthemis....	2(1)	22	SW	static	8
Dorocordulia.	(6)	20	N	static	7	Pachydiplax.	12	18	G	static	10
Dythemis....	(9)	17	SW	lotic	10	Paltothemis..	(12)	23	SW		9
Erythrodiplax	(14)	12–14	E, S	static	8–10	Pantala.....	†5(4)	25	G	static	12–14
Ladona.....	8(1)	22	E	static	6	Perithemis...	15	15	SE	static	15
Leucorhinia..	9	18	E, N	static	10–11	Plathemis...	3(1)	24	G	static	10
Libellula....	1	22–27	G	static	5–10	Somatochlora	7(6)	26	E, N	static	6–7
Mesothemis..	11	17	G	static	8	Sympetrum..	14	13	G	static	9–14
						Tramea.....	4, 4a†	25	G	static	10–11

* *L. Set.*=the raptorial setæ on the lateral lobe of the labium, within.
† This is the toothed inner border of the lateral lobe of the labium: compare fig. 4a of plate.

Plate 6. Dragonfly Nymphs



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50—Gills widest in middle, one third as broad as long.....**Amphiarion**
—Gills widest toward the distal end, one sixth as broad as long.....**Chromagrion**

51—Mental setæ of labium 1 or 2.....**Nehalennia**
—Mental setæ 3 to 7.....52

52—Gills ending in slender tail-like tips.....53
—Gill tips blunt or merely acute.....58

53—Gills with about 6 crossbars of brown.....**Zoniagrion**
—Gills with fewer crossbars or with none.....54

54—Length of body 18 mm.....**Teleallagma**
—Length of body 11 or 12.....**Ischnura**

55—Notch in upper margin of middle gill beyond its middle.....56
—This notch before middle of gill or wanting.....57

57—Width of gill more than a third of its length.....**Telebasis**
—Width of gill less than a third of its length.....**Coenagrion**

58—Gill tips rounded.....**Hesperagrion**
—Gill tips angulate or slightly pointed.....59

59—Gills not pigmented: slender.....**Anomalagrion**
—Gills more or less strongly pigmented.....**Enallagma**

KEY TO THE GENERA OF AQUATIC HEMIPTERA

(After Hungerford; Kansas Univ. Sci. Bull., Vol. 11, 1919.)

1—Antennæ shorter than head.....2
—Antennæ as long as or longer than head, exposed.....6

2—Hind tarsi with indistinct setiform claws (save in Plea which is less than 3 mm. long).....3
—Hind tarsi with distinct claws.....4

3—Head overlapping thorax dorsally. Front tarsi 1-segmented, palæform CORIXIDAE (1 genus).....**Corixa**
—Head inserted in thorax. Front tarsi normal—NOTONECTIDAE.....10

4—Membrane of hemelytra (front wings) reticulately veined.....5
—Membrane of hemelytra without veins—NAUCORIDAE.....12

5—Apical appendages of the abdomen long and slender; tarsi 1-segmented—NEPIDAE.13
—Apical appendages of the abdomen short and flat, retractile—BELOSTOMATIDAE..14

6—Head as long as entire thorax; both elongated. Both about 10 mm. HYDROMETRIDAE (1 genus).....**Hydrometra**
—Head shorter than thorax including scutellum.....7

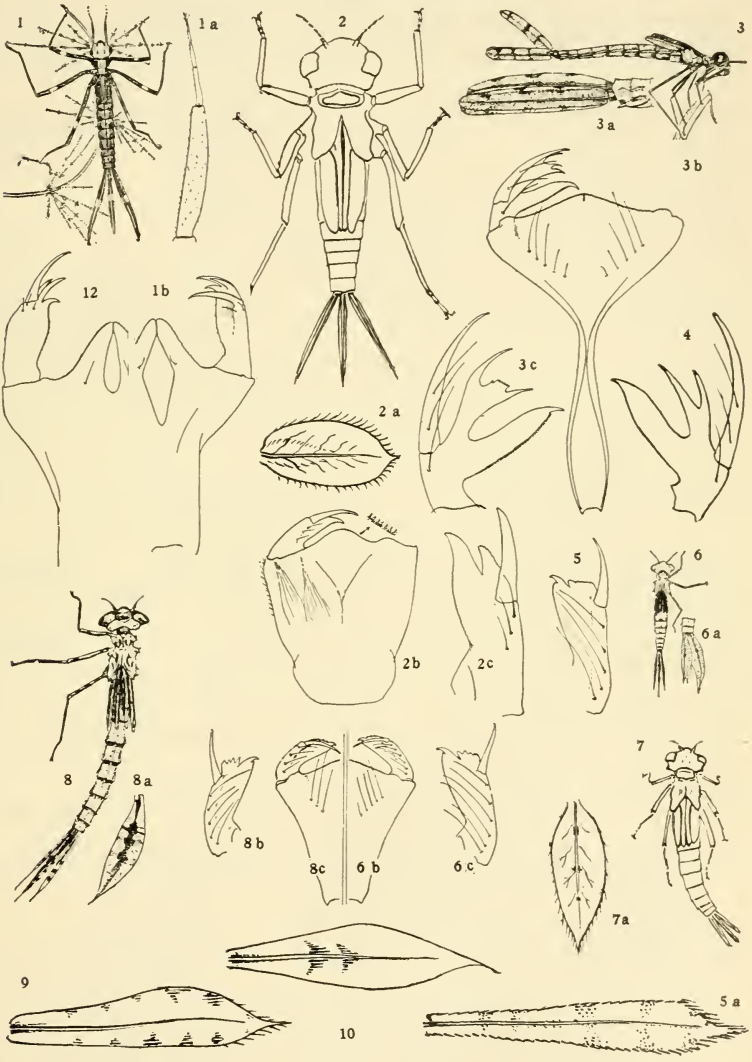
(*Continued on page* 22)

PLATE 7. DAMSELFLY NYMPHS

Genera	*Figs.*	*Length*	*Distr.*	*Water*	*L.Set**	*M*	*Genera*	*Figs.*	*Length*	*Distr.*	*Water*	*L.Set**	*M*
Agrion.....	1	20	G	lotic	0	0	Hetaerina...	12(1)	18	E, S, W	lotic	0	0
Amphiagrion.	7	11	G	static	5–6	4	Hyponeura..	(2)	22	SW	lotic	0–1	0
Anomalagrion	10(6)	8	E, S	static	5	4	Ischnura....	6	11–13	G	static	5–6	4
Archilestes...	4(3)	30	C, W	static	3	7	Lestes.....	3	20	G	static	3	5
Argia.....	2	12–17	G	both	1–4	0	Nehallennia..	9(6)	11	G	static	6	1
Coenagrion..	(8)	13	N	static	6–7	4–6	Telagrion....	(6)	18	SE	static	6	3
Chromagrion.	5(7)	12	E	static	5	3–4	Telebasis....	(6)	14	SW	static	6–7	2
Enallagma...	8	12–15	G	both	4–5	2–4	Zonagrion...	(8)	14	SW	static	5	3
Hesperagrion.	(8)	15	SW	static	6	3–4							

* Raptorial setæ inside the labium; L, lateral; M, mental setæ.

Plate 7. Damselfly Nymphs



(*Continued from page* 20)

7—Claws of at least front tarsi distinctly anteapical, with terminal tarsal segment more or less cleft....8
—Claws all apical, last tarsal segment entire....9

8—Hind femur extending beyond apex of abdomen; intermediate and hind pairs of legs approximated, very distant from front pair. Beak 4-segmented. GERRIDAE..17
—Hind femur not extending much beyond apex of abdomen; intermediate pair of legs about equidistant from front and hind pairs (except in Rhagovelia). Beak 3-segmented—VELIIDAE....23

9—Antennæ 4-segmented. Membrane of wing without cells. MESOVELLIIDAE.... Tarsi 3-jointed (1 genus **Mesovelia**)
—Antennæ 5-segmented: Tarsi 2-jointed (HEBRIDAE: length 2 mm.)....**Hebrus**

10—Legs quite similar....**Plea**
—Legs dissimilar, hind legs flattened and fringed for swimming....11

11—Last segment of antennæ much shorter than penultimate....**Notonecta**
—Last segment of antennæ longer than the penultimate....**Buenoa**

12—Front margin of prothorax deeply excavated for the reception of the head..**Ambysus**
—Front margin of prothorax not deeply excavated for the reception of the head ....**Pelocoris**

13—Body broadly oval and flat; legs not extremely long and slender; prothorax much broader than the head; anterior femora but little longer than tibiæ....**Nepa**
—Body elongate oval; legs not extremely long and slender; prothorax little broader than head; anterior femora considerably longer than tibiæ....**Curicta**
—Body very elongate; legs long and slender; prothorax narrower than head; anterior femora considerably longer than tibiæ....**Ranatra**

14—Mesothorax with strong midventral keel, membrane of hemelytra reduced...**Abedus**
—Mesothorax without midventral keel, membrane of hemelytra not reduced....15

15—First or basal segment of the beak longer than the second; furrow of the wing membrane nearly or quite straight. (Length about 1 inch or less)....**Belostoma**
—First segment of beak shorter than the second. Furrow of the wing membrane shallowly S-shaped. (Length more than $1\frac{1}{2}$ inches)....16

16—Anterior femora grooved for the reception of the tibiæ....**Lethocerus**
—Anterior femora not grooved for the reception of the tibiæ....**Benacus**

17—Inner margin of the eyes arcuately sinuate behind the middle. Body comparatively long and narrow, abdomen long....18
—Inner margin of the eyes convexly rounded; body comparatively short and broad, abdomen very short in some forms....21

18—Pronotum sericeous, dull; antennæ comparatively short and stout....19
—Pronotum glabrous; shining; antennæ long and slender....**Tenagogonus**

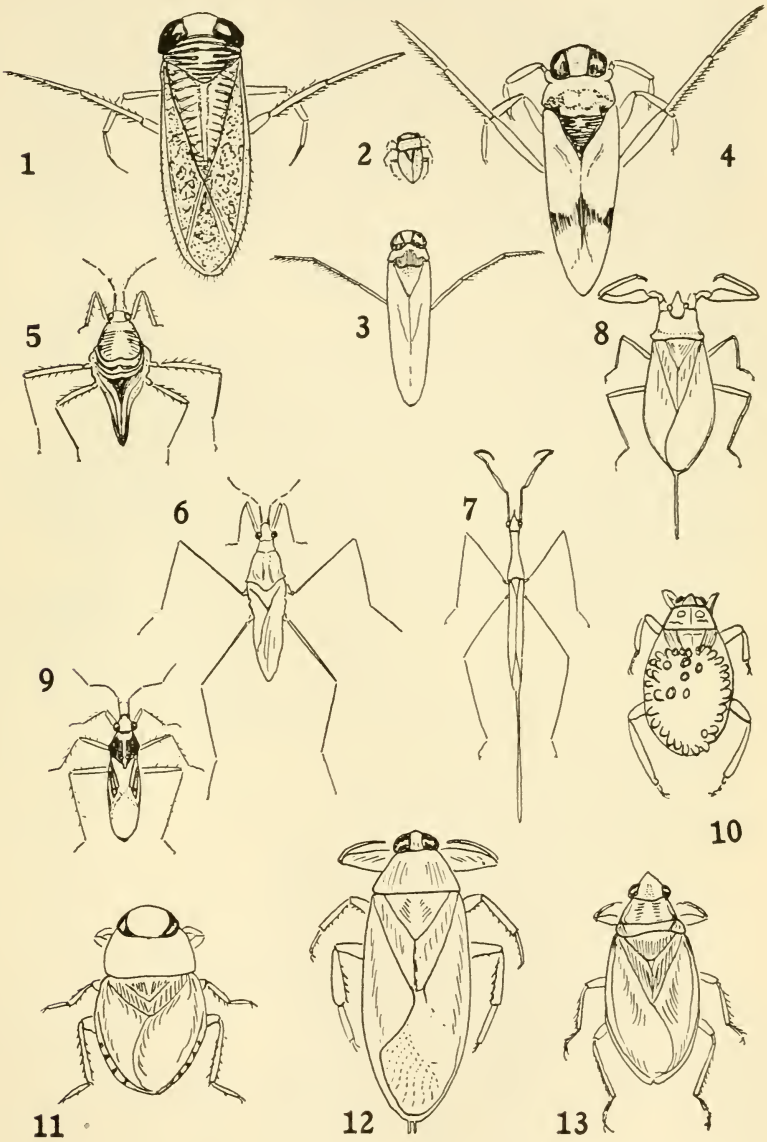
19—First segment of antennæ shorter than the second and third taken together....20
—First segment of the antennæ longer than the second and third taken together..**Gerris**

(*Continued on page* 24)

PLATE 8. WATER BUGS

Genus	*Figs.*	*Length*	*Distr.*	*Waters*	*Genus*	*Figs.*	*Length*	*Distr.*	*Waters*
Abedus	10	25	G	static	Mesovelia	9	5	G	both
Belostoma	13	25	G	static	Nepa	8	16	E	static
Benacus	12	37	G	static	Notonecta	4	12	G	static
Buenoa	3	6	G	static	Pelocoris	11	9	E	static
Corixa	1	6	G	static	Plea	2	3	G	static
Gerris	6	15	G	lotic	Ranatra	7	30	G	static
Hydrometra	(6)	10	G	lotic	Rhagovelia	5	4	G	lotic
Lethocerus	(12)	37	G	static					

Plate 8. Water Bugs



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20—Antennæ as long as half the body; sixth abdominal segment of the male roundly emarginate.....**Limnoporus**
—Antennæ not as long as half the entire length of the insect, not extending beyond the thorax; sixth abdominal segment of male doubly emarginate.....**Gerris**

21—First antennal segment much shorter than the other three taken together; not much longer than the second and third taken together, and sometimes shorter.....22
—First antennal segment nearly equal to the remaining three taken together, much longer than second and third; antennæ almost as long as entire body; hind femora twice as long as hind tibia.....**Metrobates**

22—Fourth (apical) segment of antennæ longer than the third.....**Trepobates**
—Fourth segment of antennæ never more than equal to third; basal segment of anterior tarsi much shorter than second; hind femur equal to or much shorter than hind tibia and tarsus taken together.....**Rheumatobates**

23—Last antennal segment longest.....24
—First antennal segment longest.....25

24—Ocelli in contact with inner margin of the eyes.....**Macrovelia**
—Ocelli absent.....**Microvelia**

25—Third segment of middle tarsus split and with feathery hairs set in the split.**Rhagovelia**
—Intermediate tarsi not split.....**Velia**

KEY TO GENERA OF CADDIS WORMS: TRICHOPTERA

1—Microcaddis fly larvæ: length less than 6 mm.: abdomen wider than thorax: case shaped like a spectacle case and generally carried edge upward: usually no gills. HYDROPTILIDAE (Not included in plate or table. Several genera.)
—Large caddis flies: abdomen of larva hardly wider than thorax.....2

2—Caudal prolegs separate: no portable cases (except **Glossosoma**).....3
—Caudal prolegs fused on middle line to form an apparent tenth segment.....9

3—Case turtle shaped, its opening below.....**Glossosoma**
—Case not so.....4

4—Gills present: net-spinners.....**Hydropsyche**
—Gills absent.....5

5—Free, living under stones: color green: seg. 9, chitinized above.....**Rhyacophila**
—Living in tubes: abdominal segment 9 not chitinized above.....6

6—In firm tubes in bottom mud.....**Phylocentropus**
—In filmy tubes below stones or among weeds.....7

7—In J-shaped tubes.....**Neureclipsis**
—In straight tubes.....8

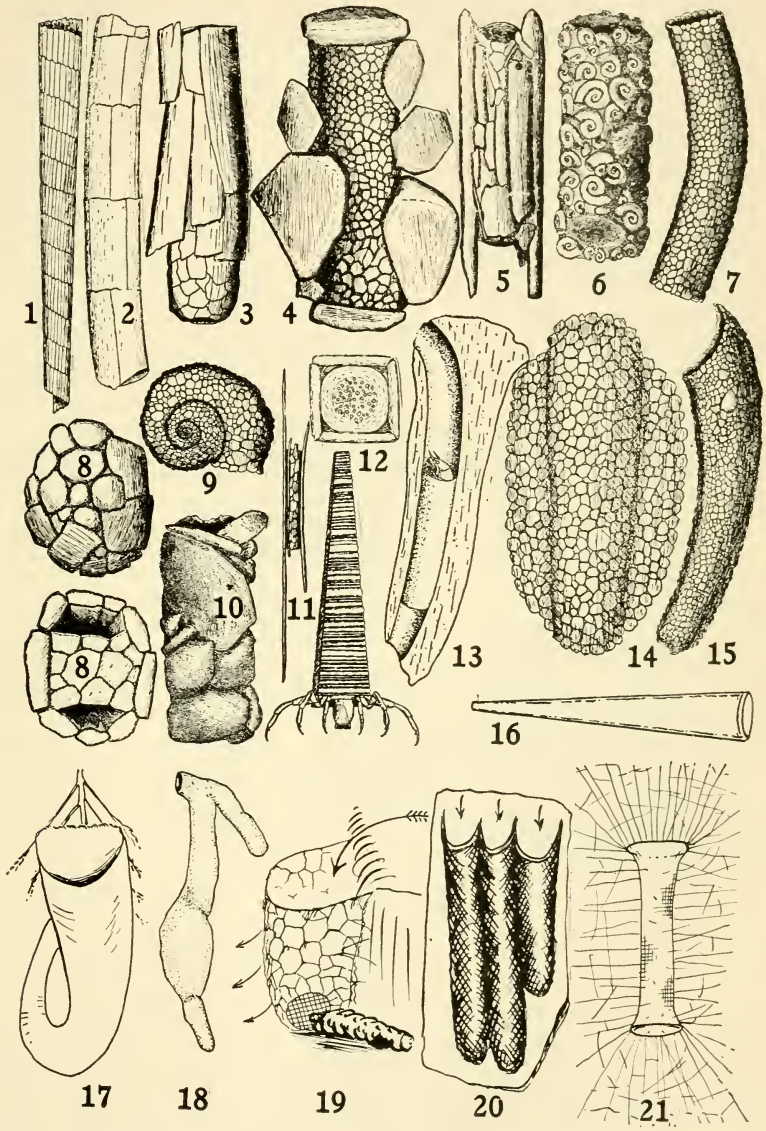
(*Continued on page* 26)

PLATE 9. CADDIS-WORM STRUCTURES*

Genera	*Figs.*	*Length*	*Distr.*	*Waters*	*Genera*	*Figs.*	*Length*	*Distr.*	*Waters*
Astenophylax...	5	50	NE	lotic	Neophylax.....	4	12	NE	lotic
Brachycentrus..	12	12	G	lotic	Neureclipsis....	17	..	N, E	lotic
Chimarrha.....	20	8	G	lotic	Neuronia.....	2	32	NE	static
Ganonema.....	13	18	NE	lotic	Phryganea.....	1	30	E, W	static
Glossosoma.....	8	9	G	lotic	Phylocentropus..	18	14	E, S	lotic
Glyphotaelius...	3	32	E	static	Platyphylax....	15	18	NE	lotic
Heliocopsyche...	9	6	G	lotic	Polycentropus...	21	17	G	lotic
Hydropsyche....	19	16	G	lotic	Psilotreta.....	7	15	NE	lotic
Limnophilus....	6, 10	18	N	static	Setodes.....	16	9	E, S	static
Mystacides.....	11	9	NE	static	Triaenodes.....	(1)	8	G	static
Molanna.....	14	12	E	lotic					

* See plate 13 for the worms themselves. Figures 2 to 15 are from Dr. J. T. Lloyd.

Plate 9. Caddis-worm Houses



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8—Tubes open at both ends.....**Polycentropus**
—Tubes open at one end.....**Chimarrha**

9—Case coiled spirally like a snail shell.....**Helicopsyche**
—Case not so.....10

10—Case a bored-out piece of wood.....**Ganonema**
—Case not so.....11

11—Case a spiral of short sticks laid lengthwise.....12
—Case not spirally wound.....13

12—Large: length more than 20 mm.....**Phryganea**
—Small: length less than 15 mm.....**Triaenodes**

13—Case square in section: made of bits of wood placed crosswise.....**Brachycentrus**
—Case not so.....14

14—Case of sand grains with wings at side.....**Molanna**
—Case not so.....15

15—Case slender with very long side pieces.....**Mystacides**
—Case not so.....16

16—Case smooth, conical, parchment like.....**Setodes**
—Case not so.....17

17—Case cylindric, bulky, showing materials and construction in great variety: a considerable number of genera of Limnophilidæ. See J. T. Lloyd—*North American Caddis-fly Larvae* (Bul. 21 Lloyd Library, 1921) for particulars, also, C. Betten's *Caddis-flies or Trichoptera of N. Y. State.* N. Y. State. Mus. Bull. 292. 1934.

KEY TO THE GENERA OF BEETLE LARVAE: COLEOPTERA

1—Tarsal claws 2.....2
—Tarsal claws one.....10

2—Four hooks at end of abdomen.....GYRINIDAE—3
—No hooks at end of abdomen.....DYTISCSDAE—4

3—Lateral filaments of abdomen all plumose.....**Gyrinus**
—First and second not plumose.....**Dineutes**

4—Abdomen with long lateral filaments.....**Coptotomus**
—Abdomen with no lateral filaments.....5

5—Mandibles upturned at tip to meet snout.....**Hydroporus**
—Mandibles inturned at tip; no snout.....6

6—Prothorax longer than head.....7
—Prothorax not longer than head.....8

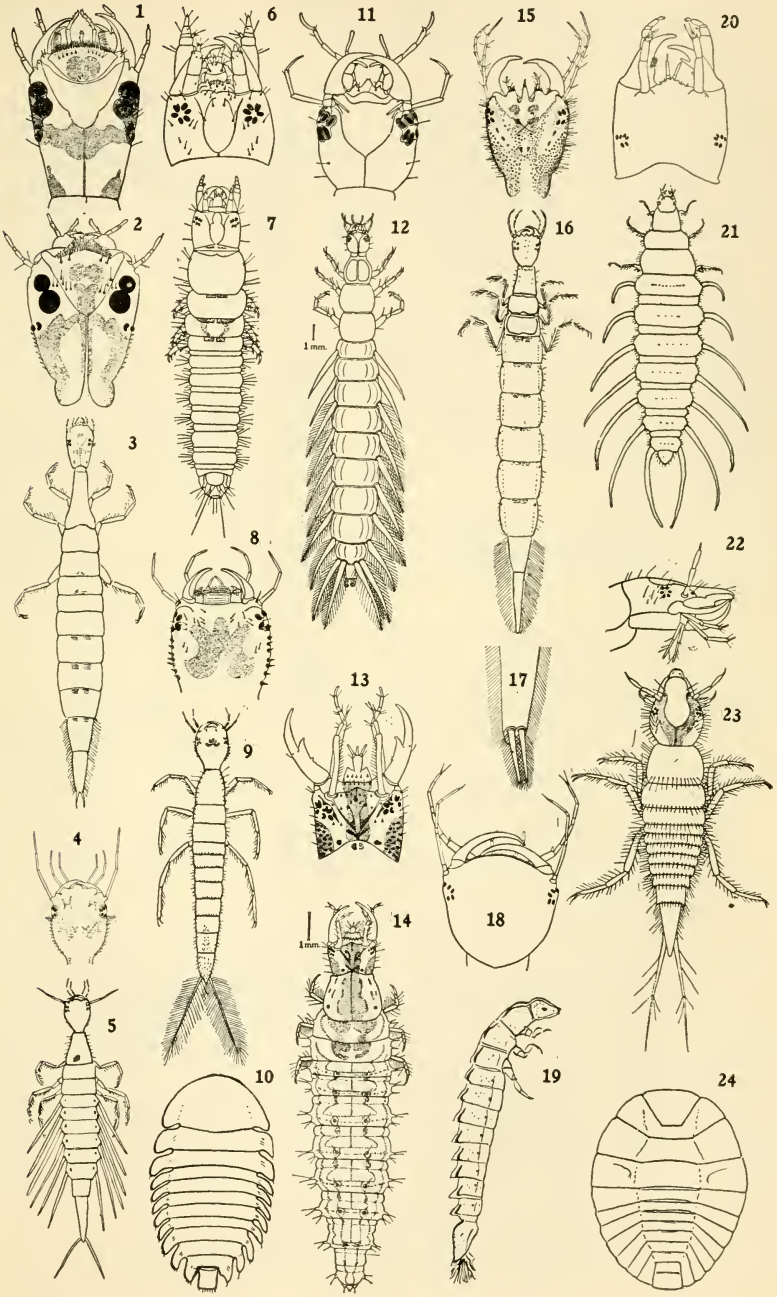
(*Continued on page 28*)

PLATE 10. BEETLE LARVAE

Genera	*Figs.*	*Length*	*Distr.*	*Waters*	*Genera*	*Figs.*	*Length*	*Distr.*	*Waters*
Acilius	2, 3	24	G	static	Enochrus	6, 7	7	G	static
Berosus	20, 21	10	G	static	Helichus	10	6	G	lotic
Coptotomus	4, 5	13	G	static	Hydroporus	22, 23	7	G	static
Cybister	15, 16	75	C	static	Hydrous‡	(14)†	22	G	static
Dineutes	11, 12	27	G	static	Laccophilus	8, 9	9	G	static
Gyrinus	(12)*	18	G	static	Psephenus	24	8	E	lotic
Dytiscus	17, 18	70	G	static	Thermonectes	1(3)	18	G	static
Elmis	19	5	G	lotic	Tropisternus	13, 14	12	G	static

Mostly, from Wilson. Larvæ of many genera, still unknown.
* Differs by having the first two lateral filaments plumose, not bare. † Differs by having a single tooth on the inner margin of the mandible. ‡Same as Hydrophilus in most of the books.

Plate 10. Beetle Larvae



(*Continued from page 26*)

7—Rear of head constricted to form a sort of neck.....**Acilius**
—Rear of head regularly sloping to rear.....**Thermonectes**

8—Cerci longer than abdomen is wide, plumose.....**Laccophilus**
—Cerci short.....6

9—Front margin of head smooth.....**Dytiscus**
—Front margin of head toothed.....**Cybister**

10—Carnivorous, with conspicuous rapacious mandibles.....HYDROPHILIDAE—11
—Herbivorous, with short blunt mandibles.....14

11—Abdomen with long lateral filaments.....**Berosus**
—Abdomen with no lateral filaments.....12

12—Abdomen depressed, parallel sided.....**Enochrus**
—Abdomen convex, tapered to rear.....13

13—Single tooth on inner edge of each mandible.....**Hydrous**
—Two teeth on inner edge of each mandible.....**Tropisternus**

14—Abdomen with numerous rows of dorsal spines.....HALIPLIDAE—15
—Abdomen with 2 rows of low tubercles or none.....PARNIDAE—16

15—Spines very long; body burr like.....**Peltodytes**
—Spines short, thorn like.....**Haliplus**

16—Body flat.....17
—Body cylindrical.....**Elmis**

17—Body subcircular; margin entire.....**Psephenus**
—Body oval; margin notched.....**Helicus**

Larvæ of many genera, still unknown. The best account of them is by Wilson in U. S. Bureau, Fisheries Bull. 39: 231, 1923.

KEY TO THE GENERA OF CRANE FLY LARVAE: DIPTERA

1—Head free; tail long, partly retractile.....2
—Head telescoped or slipped backward inside prothorax.....3

2—Color yellow or brown.....**Ptychoptera**
—Color rusty red or black.....**Bittacomorpha**

3—Body with numerous long spines longer than its own diameter.....**Phalacrocera**
—Body without such spines.....4

4—Spiracular disc at end of abdomen surrounded by 6 or 8 lobes.....5
—Spiracular disc at end of abdomen surrounded by 5 or fewer lobes.....7

5—Anal gills simple.....6
—Anal gills branched.....**Aeshnasoma**

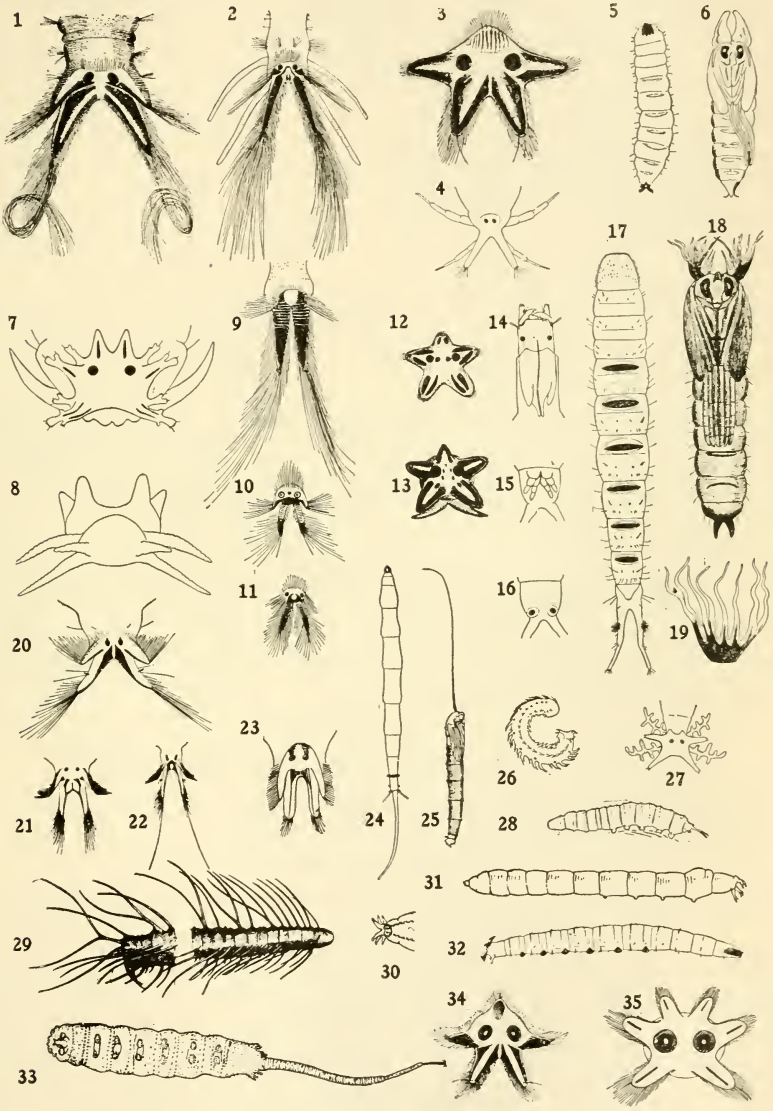
(*Continued on page 30*)

PLATE 11. CRANE FLY AND SYRPHUS FLY LARVAE

Genera	*Figs.*	*Length*	*Distr.*	*Waters*	*Genera*	*Figs.*	*Length*	*Distr.*	*Waters*
Aeshnasoma	27	45	NE	lotic	Pedicia	30, 31	42	E, W	both
Antocha	17–19	10	G	lotic	Phalacrocera	29	25	NE	static
Bittacomorpha	(24)*	32	E	static	Pilaria	9–11	16	E	static
Dicranota	14–16	18	NE	static	Ptychoptera	24, 25	31	G	static
Elliptera	5, 6	7	W	lotic	Rhaphidolabis	28	9	G	lotic
Eriocera	20–22	25–45	G	lotic	Rhamphidia	32, 34	10	G	both
Erioptera	12	10	G	both	Tipula	7, 8	16–55	G	both
Eristalis	33	9	G	both	Tricyphona	4	17	E	both
Hexatoma	23	14	G		Trimicra	13	15	G	lotic
Holorusia	35	55	W	?	Triogma	26	19	E	?
Limnophila	1, 2, 3	15	G	both					

Mostly from Dr. C. P. Alexander. * Differs by being rusty red in color.
Fig. 33 is a rat tailed maggot, (family Syrphidæ) larva of the Syrphus fly Eristalis.

Plate 11. Cranefly Larvae



(*Continued from page* 28)

6—Lobes of disc fringed with long hairs.....**Holorusia**
—Lobes of disc fringed with short hairs or none.....**Tipula**

7—Body covered with flat leaf-like projections.....**Triogma**
—Body bare.....8

8—Body depressed; no lobes on spiracular disc.....**Elliptera**
—Body cylindric; lobes present on spiracular disc.....9

9—Spiracular disc with 5 lobes.....10
—Spiracular disc with less than 5 lobes.....12

10—Creeping welts beneath abdominal segments.....**Ramphidia**
—No creeping welts present.....11

11—Color green.....**Erioptera**
—Color not green.....**Trimicra**

12—Spiracular disc with 4 lobes.....13
—Spiracular disc with 2 lobes.....16

13—Spiracular disc defined by ridge above; hair fringes short.....**Hexatoma**
—Spiracular disc not defined above by ridge; hair fringes long.....14

14—Disc bare across upper border.....**Eriocera**
—Disc hairy across upper border.....15

15—Lower border of spiracular disc cross lined with black.....**Pilaria**
—Lower border of disc little or not at all crossed with black.....**Limnophila**

16—Creeping welts black; spiracles invisible.....**Antocha**
—Creeping welts if present not black; spiracles easily visible.....17

17—Lobes long and densely clothed with long hairs.....**Pilaria**
—Lobes bare, or nearly so.....18

18—Lobes slender, tapering, body segments with transverse rows of bristles.**Rhaphidolabis**
—Lobes shorter, more blunt; body segments smooth.....19

19—Anal gills very unequally 2 segmented.....**Pedicia**
—Anal gills more equally divided into a larger number of segments.....20

20—Spiracles separated by their own width.....**Tricyphona**
—Spiracles separated by twice their own diameter.....**Dicranota**

KEY TO THE GENERA OF AQUATIC NEUROPTERA: LARVAE

1—Large forms with biting mouth parts. SIALIDIDAE.....2
—Small forms with piercing mouth parts. HEMEROBIIDAE.....4

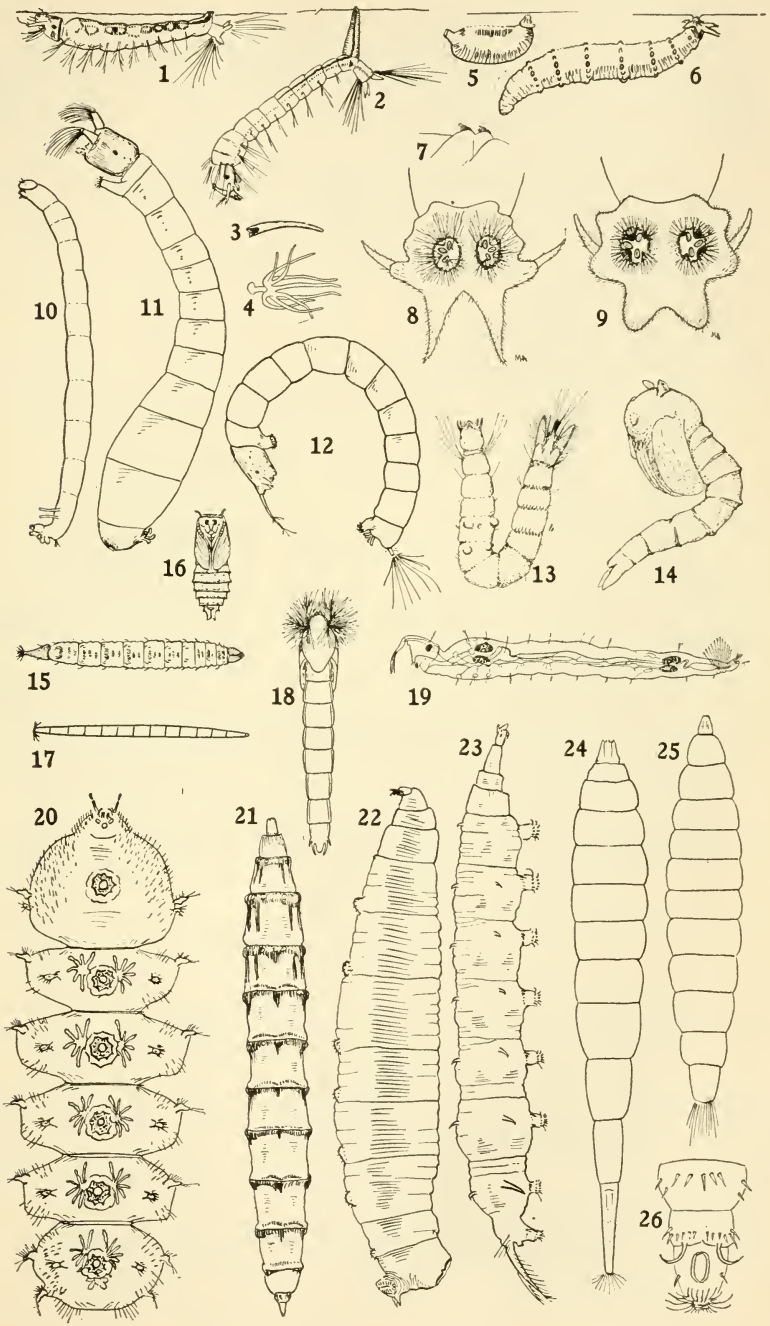
(*Continued on page* 32)

PLATE 12. MISCELLANEOUS DIPTEROUS LARVAE

Genera	*Figs.*	*Length*	*Distr.*	*Waters*	*Genera*	*Figs.*	*Length*	*Distr.*	*Waters*
Atherix	23	16	G	lotic	Odontomyia	25	12–50	G	static
Anopheles	1	10	G	static	Psychoda	15, 16	6	G	static
Bibiocephala	20	10	W	lotic	Sarcophaga	22	14	E	static
Blepharocera	(20)*a*	8	E, W	lotic	Sepedon	5–8	11	G	static
Ceratopogon	17	5	G	static	Simulium	11, 4	7	G	lotic
Chironomus	10, 18	2–22	G	both	Stratiomyia	24	27–40	G	static
Chrysops	(21)*b*	12	G	static	Tabanus	21	20–55	G	static
Corethra	19	8	G	static	Tanypus	(12)*c*	6	G	both
Culex	2, 3	7–12	G	static	Tanytarsus	12	3–7	N	both
Dixa	13, 14	6–10	G	static	Tetanocera	9(5.6)	11	G	static
Euparyphus	26(25)	12	G	lotic					

a Differs by lack of lateral pedunculate processes.
b Differs by having the last antennal joint longer than one preceding.
c Differs by lacking the peduncle under the antenna.

Plate 12. Miscellaneous Fly Larvae



(*Continued from page* 30)

2—Body ending in long median tail.....**Sialis**
—Body ending in a pair of stout hook bearing prolegs.....3

3—Lateral abdominal filaments with a tuft of tracheal gills beneath.....**Corydalus**
—Lateral abdominal filaments with no tracheal gills beneath.....**Chauliodes**

4—Bristles on back of thorax sessile.....**Sisyra**
—Bristles on back elevated on tubercles.....**Climacia**

KEY TO THE FAMILIES OF ADULT AQUATIC BEETLES

1—Hind leg shorter than the foreleg; eyes divided.....GYRINIDAE
—Hind leg longer than the foreleg; eyes simple.....2

2—Base of hind legs covered by coxal plates.....HALIPLIDAE
—Base of hind leg exposed.....3

3—Antennæ shorter than the palpi.....HYDROPHILIDAE
—Antennæ longer than the palpi.....4

4—Hind coxæ broadly fused with metasternum.....DYTISCIDAE
—Hind coxæ free.....PARNIDAE

For genera of adult beetles see Blatcheley's Coleoptera of Indiana.

KEY TO THE GENERA OF MOLLUSCS

1—Shell univalve—Snails.....2
—Shell bivalve—Clams.....11

2—No operculum.....3
—With operculum.....5

3—Shell patelliform, small, depressed.....**Ancylus**
—Shell flatly coiled, whorls all in about same plane.....**Planorbis**
—Shell spiral.....4

4—Shell spire sinistral (to left; see fig. 3).....**Physa**
—Shell spire dextral (to right).....**Limnaea**

5—Shell large, spire long, pointed; aperture one-third of length.....PLEUOCERIDAE—6
—Shell large, not long and pointed; blobose, spire short, obtuse, aperture and spire about equal in length.....VIVIPARIDAE—7
—Shell small, length and width under 11 and 6.5 mm., variable in form.....8

6—Shell conic; aperture subrhomboidal, prolonged into a short canal.....**Pleurocera**
—Shell slender, ovate-conic, with color bands, whorls rounded, aperture rounded in front, not prolonged into a short canal below.....**Goniobasis**

(*Continued on page* 38)

PLATE 13. MISCELLANEOUS INSECTS

Adult Insects

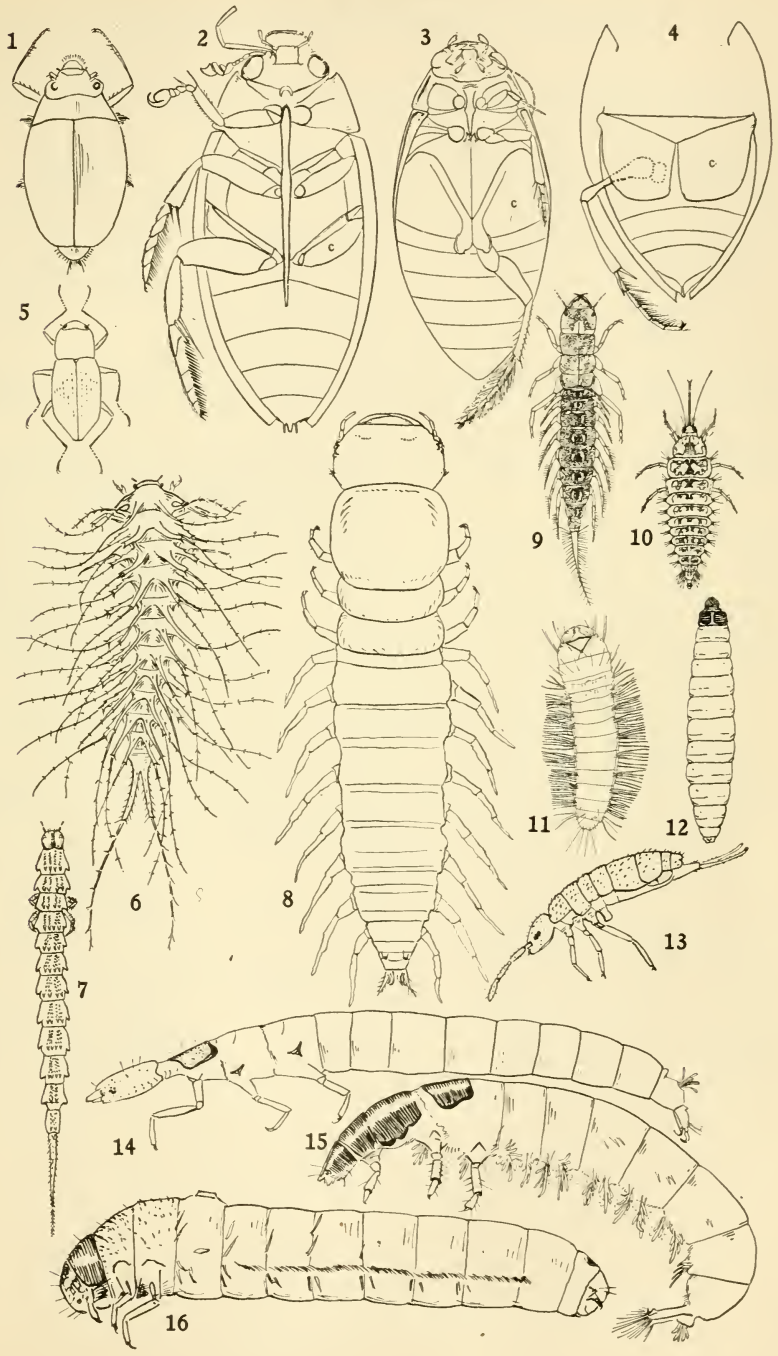
Figs. 1 to 5 represent families of adult beetles (larva at plate 10): 1, Gyrinidæ; 2, Hydrophilidæ; 3 Dytiscidæ; 4, Haliplidæ; 5 Parnidæ or Elmidæ Fig. 13 is a spring-tail (Collembola).

Larvae

Genera	*Figs.*	*Length*	*Distr.*	*Waters*	*Genera*	*Figs.*	*Length*	*Distr.*	*Waters*
Chauliodes.....	8	50	G	both	Hydropsyche....	15	18	G	lotic
Climacia.....	(10)*	5	E	lotic	Nymphula.....	12§	13	G	static
Corydalis.....	(8)†	75	G	lotic	Peltodytes.....	6	10	G	static
Elophila.....	11‡	8	E	lotic	Philopotamus...	14	10	G	lotic
Halesus.....	16	18	E	both	Sialis.....	9	22	G	static
Haliplus.....	7	9	G	static	Sisyra.....	10	5	E	lotic

* Differs by having dorsal setæ inserted on tubercles.
† Differs by having white gill tufts under lateral abdominal filaments.
‡ Another species of Elophila, lacking tracheal gills, lives in an ovate case on duck meat. (Lemna).
§ Other species of Nymphula have branched tracheal gills.

Plate 13. Miscellaneous Insects



RECOGNITION CHARACTERS OF SOME OF THE COMMONER

Single distinctive characters

1. Forms in which the immature stages (commonly known as *nymphs*) are not visible upon the back.

COMMON NAME	ORDER	FORM	TAILS
Stoneflies	Plecoptera	depressed	2, long
Mayflies	Ephemerida	elongate, variable	3, long: (rarely 2)
Damselflies	Odonata	slender, tapering rearward	see gills
Dragonflies	Odonata	stout, variable	very short, spine-like
Water bugs	Hemiptera	short, stout, very like adults	variable

2. Forms in which the immature stages differ very greatly from the adults of the same from the outside, and having the legs shorter, rudimentary, or even wanting (*larvae*

COMMON NAME	ORDER	LEGS	GILLS
Water moths	Lepidoptera	3 pairs of minute jointed legs followed by a number of pairs of fleshy prolegs	of numerous soft white filaments, or entirely wanting
Caddis worms	Trichoptera	3 pairs rather long	variable or wanting
Orl flies	Neuroptera	3 pairs shorter	7 pairs of long, lateral filaments
Dobsons	Neuroptera	3 pairs	tufted at base of lateral filaments, or wanting
Water beetles	Coleoptera	3 pairs	usually wanting
True flies	Diptera	*wanting*	usually only a bunch of retractile anal gills

3. Further characters of some common dipterous larvæ: these are distinguished from

COMMON NAME	FAMILY	HEAD	TAIL
Craneflies	Tipulidae	retracted and invisible	a respiratory disc bordered with fleshy appendages
Net veined midges	Blepharoceridae	tapering into body	wanting
Mosquitoes	Culcidae	free	with swimming fin of fringed hairs
Blackflies	Simuliidae	free	with caudal ventral *attachment disk*
True midges	Chironomidae	free	tufts of hairs
Soldier flies	Stratiomyiidae	small, free	floating hairs
Horse flies	Tabanidae	acutely tapering	tapering body
Snipe flies	Leptidae	tapering retractile	with two short tapering tails
Syrphus flies	Syrphidae	minute	extensile process as long as the body
Muscid flies	Muscoidea	rudimentary	truncated

FORMS OF AQUATIC INSECTS IN THEIR IMMATURE STAGES.

are printed in italics.

remarkably different from the adults. The wings develop externally and are plainly

GILLS	OTHER PECULIARITIES	HABITAT	FOOD HABITS
many, minute, around bases of the legs	.....	rapids	mainly carnivorous
7 pairs *on back*	.....	all waters	mainly herbivorous
3 leaf-like *caudal gill-plates*	immense grasping lower lip	slow and stagnant	carnivorous
internal gill chamber at end of body	immense grasping lower lip	slow and stagnant	carnivorous
wanting	*pointed beak* for puncturing and sucking	all waters	carnivorous

species, being more or less worm-like, having wings developed internally and not visible *proper*).

REAR END OF BODY	OTHER PECULIARITIES	HABITAT	FOOD HABITS
1 pair of fleshy prolegs with numerous claws on them	claws (crotchets) on all prolegs	all waters	herbivorous
do. with paired larger hooks at tip	mostly living in portable cases	all waters	mostly herbivorous
a long tapering tail	.....	gravelly beds	carnivorous
paired hooked claws	.....	all waters	carnivorous
variable	.....	slow or stagnant	carnivorous
see next table	head small often apparently wanting	all waters	see next table

aquatic larvæ of other groups by the absence of true legs.

FLESHY LEGS, OR PROLEGS	OTHER PECULIARITIES	HABITAT	FOOD HABITS
variable	.....	shoals	herbivorous mostly
wanting	flat *lobed body* with *row of ventral suckers*	rocks in falls	diatoms, etc.
wanting	*swollen thoracic segments*	pools at surface	herbivorous
one beneath the mouth	*"fans"* on head for food-gathering	rocks in rapids	herbivorous
1 *in front* 2 *at rear* end of body	live mostly in soft tubes	all waters	herbivorous
wanting	depressed form	still water at surface	herbivorous
wanting	tubercle covered *spindle shaped body*	beds in pools	carnivorous
stout paired beneath	.....	rapids under stones	carnivorous
wanting	.....	shallow pools	.....
usually wanting	.....	.....	.....

FRESH-WATER CRUSTACEA—RECOGNITION CHARACTERS

I. Malacostraca—size large—body of 20 segments.

NAMES	FIGURES	FORM	EYES	LEGS, PAIRS	CARAPACE	GILLS	LENGTH
Decapods	Pl. 14, C, L, N, P	Cylindric	Stalked	10	Covers thorax	Under carapace	40–300 mm.
Amphipods	Pl. 14, F, G, H, M	Compressed	Sessile	14	None	Under thorax	10–15
Isopods	Pl. 14, B	Depressed	Sessile	14	None	Under abdomen	10–20
Mysidacea	Pl. 14, K	Cylindric	Stalked	0	Covers all but 3 segments of thorax	Under carapace	30

II. Entomostraca—size small and body segmentation various.

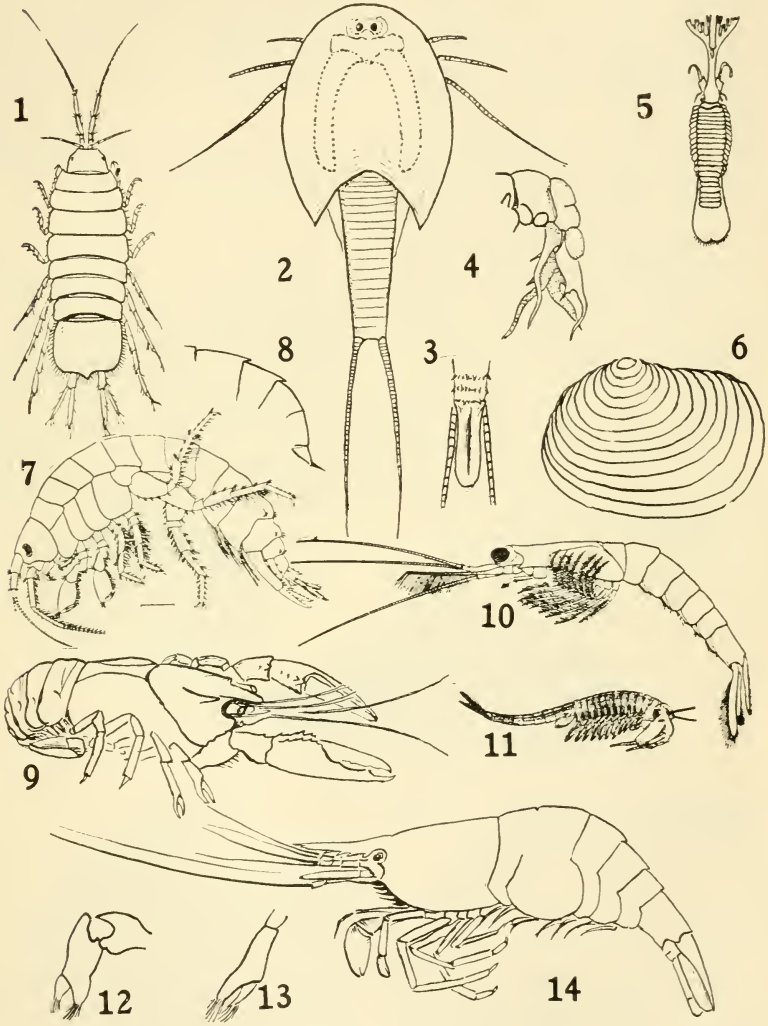
NAMES	FIGURES	FORM	EYES	LEGS, PAIRS	CARAPACE	HEAD	LENGTH
Branchipods	Pl. 14, E, O, Q	Cylindric	Stalked	19–23	Wanting	Free	25–50
Branchipods	Pl. 14, A, I	Depressed	Sessile	21–42	Broad	Consolidated	30–50
Branchipods	Pl. 14, D, J	Clam-like	Approximated	13–28	Bivalved	Free, between valves	6–11
Cladocerans (water fleas)	Pl. 24, figs. 1–15	Compressed	Sessile	5–6	Bivalved	Free	Microscopic
Copepods	Pl. 24, figs. 16, 17, 19, 20	Cylindric	Single	5	Short	Consolidated	Microscopic
Ostracods	Pl. 24, fig. 18	Clam-like	Approximated	3	Bivalved	Enclosed	Microscopic

PLATE 14. CRUSTACEANS

Genera	*Figs.*	*Length*	*Distr.*	*Waters*	*Genera*	*Figs.*	*Length*	*Distr.*	*Waters*
Apus	2	30	W	static	Lynceus	(6)‡	10	G	static
Asellus	1	15	G	static	Mysis	10	30	G	static
Cambarus	(9)*	80	G	both	Palaemonetes	(14)§	40	S	static
Estheria	6	12	W	static	Pontoporeia	(7)¶	11	G	static
Eubranchipus	11	25	G	static	Potamobius	9	100	W	both
Eucrangonyx	(7)†	20	G	static	Streptocephalus	4(11)	20	W	static
Gammarus	7	25	G	static	Syncaris	12–14	30	SW	lotic
Hyallella	8(7)	9	G	static	Thamnocephalus	5	40	W	static
Lepidurus	3(2)	50	W	static					

* Differs by having no gill on last thoracic segment.
† Differs by having tail-plate not cleft to base.
‡ Differs by having shell without lines of growth.
§ Differs by having no terminal hair tufts on fingers.
¶ Differs by having last leg shorter than the one before it.

Plate 14. Miscellaneous Crustaceans



(*Continued from page 32*)

7—Shell rather thin, globose, whorls convex; animal with foot not produced beyond snout.....**Viviparus**
—Shell thick and solid, more elongate whorls slightly convex, foot large, much produced beyond snout.....**Campeloma**

8—Shell flat, discoidal; operculum round, multispiral aperture round. VALVATIDAE 1 genus.....**Valvata**
—Shell globose or elongated, length under 10 mm., spire short.....AMNICOLIDAE—9

9—Aperture oval, length over 7.5 mm.....**Bythinia**
—Length under 7.5 mm.....10

10—Shell smooth, outer lip of aperture thin.....**Amnicola**
—Shell more slender and elongated; outer lip of the aperture thickened..**Paludestrina**

11—Large; length more than 20 mm.....14
—Smaller shells; under 20 mm. SPHAERIIDAE.....12

12—Umbone central, shell equilateral.....13
—Umbone subterminal, shell inequilateral.....**Pisidium**

13—Shell thin, rounded, polished, umbones quite prominent.....**Musculium**
—Shell thicker, striate, umbones not so prominent.....**Sphaerium**

14—Shell elongated, laterally compressed, rounded in front, almost lacking a posterior ridge. Beak sculpture consisting of a few parallel ridges following the growth lines.....**Margaritana***
—Shell oval to elongate; surface smooth or feebly corrugated.....**Unio***
—Shell thin, back sculpture consisting of several more or less doubly-looped parallel ridges, often slightly nodulous on the loops.....**Anodonta***

* These were formerly included in one family, the Unionidæ, but it has since been split up into many separate families and sub-families. Three common forms are here figured. For detailed information on the Bivalves see the Ward and Whipple "Freshwater Biology."

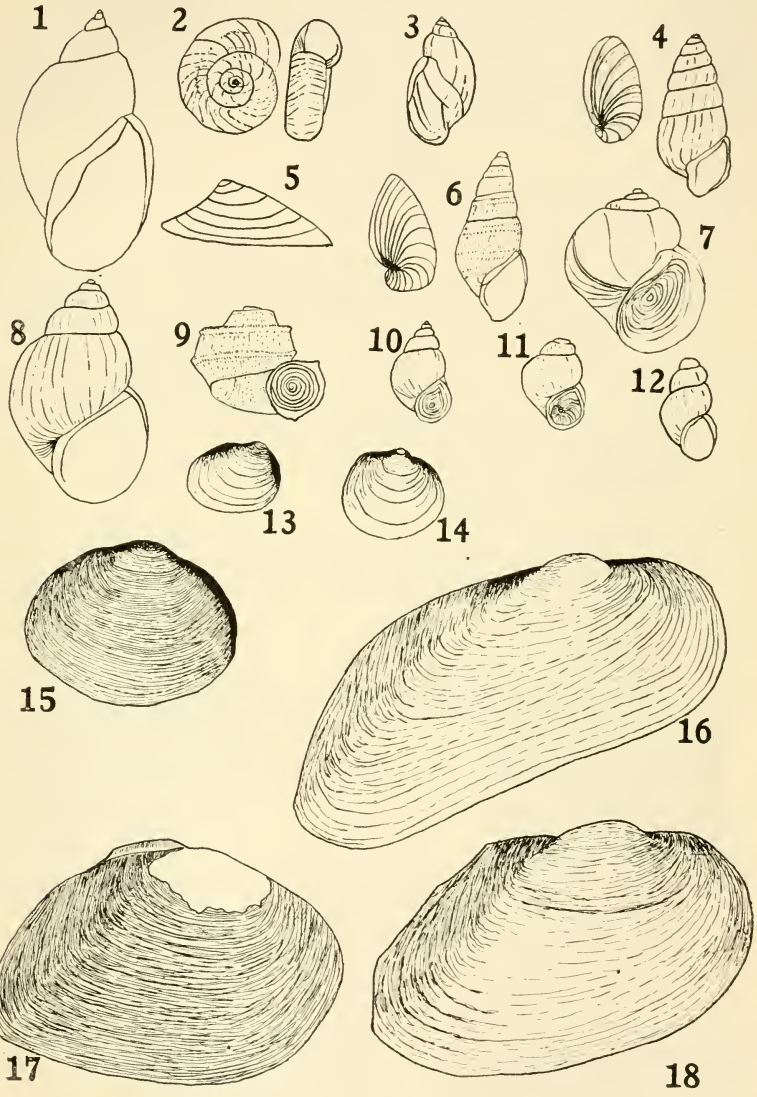
A spongilla fly, *sisyra*.

PLATE 15. MOLLUSCS

Genera	*Figs.*	*Length*	*Distr.*	*Waters*	*Genera*	*Figs.*	*Length*	*Distr.*	*Waters*
Amnicola.....	11	4	G	both	Paludestrina....	12	4	G	both
Ancylus.....	5	5	E	both	Physa.....	3	16	G	both
Anodonta.....	18	90	G	both	Pisidium.....	13	8	G	both
Bythinia.....	10	10	NE	both	Planorbis	2	3–21	G	both
Campeloma.....	8	25	N, S, E	both	Pleurocera.....	4	30	E, S, W	both
Goniobasis.....	6	22	S, W, C	both	Sphaerium.....	15	14	G	both
Limnea.....	1	10–50	G	both	Unio.....	17	100	E, S, C	both
Margaritana....	16	30	G	both	Valvata.....	9	5	G	both
Musculium.....	14	9	G	both	Vivipara.....	7	28	E S	both

Figures 4 and 6 show the operculum in detail beside the shell; 9, 10, 11, show it in the aperture.

Plate 15. Miscellaneous Molluscs



PLANCTON†

It will be noted that a number of forms, especially green algæ, are included which are not truly plancton organisms. The frequency with which they are brought in from the smaller ponds and streams by students, makes this seem advisable.

Except for the general arrangement, no originality is claimed for these keys. We are particularly indebted to the writings of Bessey, Birge, Butschli, Collin, Conn, Eyferth, Hausman, Herrick, Hudson and Gosse, Jennings, Kent, Stokes, Tilden, Van Douwe, West and Wolle. The figures are in part drawn from the objects themselves, a few from photographs and some from published papers.

ALGAE

1—Cells blue-green; reproduction by simple division. (See Pl. 17.) The blue-greens.—(Schizophyceæ) CYANOPHYCEAE....2
—Cells green, red or brown....20

2—Cells unicellular or in clusters and colonies, not truly filamentous; commonly embedded in a gelatinous matrix, more rarely freely floating....COCCOGONEAE—3
—Cells (except *Spirulina*, fig. 12) filamentous; branched or unbranched, multiplication by filamentous active hormogones....HORMOGONEAE—11

3—Multiplication by vegetative cell division....CHROOCOCCACEAE—4
—Multiplication by conidia. Epiphytes on algæ....CHAMAESIPHONACEAE

4—Cells solitary without gelatinous matrix. Cells spherical **Croococcus**; cylindrical (**Synechoccus, Chroothece**); fusiform, (**Dactylococcopsis**).
—Numerous cells in gelatinous matrix....5

5—Colonies and gelatine without definite form....6
—Cells in definite arrangement....7

6—Cells in several gelatinous capsules. Cells spherical enclosed in shapeless masses of gelatine, **Gloeocapsa**; cells elongate or elliptical, **Gloeotheca, Zachariasia.**
—Cells scattered within the gelatinous matrix. Cell spherical (fig. 13), **Aphanocapsa**; cell elongate....**Aphanothece**

7—Colonies free swimming....8
—Colonies attached....**Oncobrysa**

8—Cell division in 3 planes, colonies therefore in clumps. Cells spherical, colonies more or less spherical, or formed like a bunch of grapes (figs. 8, 9). **Microcystis**; colonies spherical when young, torn and net like when older, **Clathrocystis**; cells wedge shaped, colonies spherical....**Gomphosphaera**
—Cell division 2 plane, resulting colonies therefore only one cell deep....9

9—Colonies a hollow sphere (fig. 10)....**Coelosphaerium**
—Colonies sheetlike or disclike....10

10—Cell flattened, disclike (fig. 2)....**Tetrapedia**
—Cells not flat. Cells spherical (fig. 6), **Merismopedia**; cells cylindrical arranged palisade like....**Holopedium**

(*Continued on page* 42)

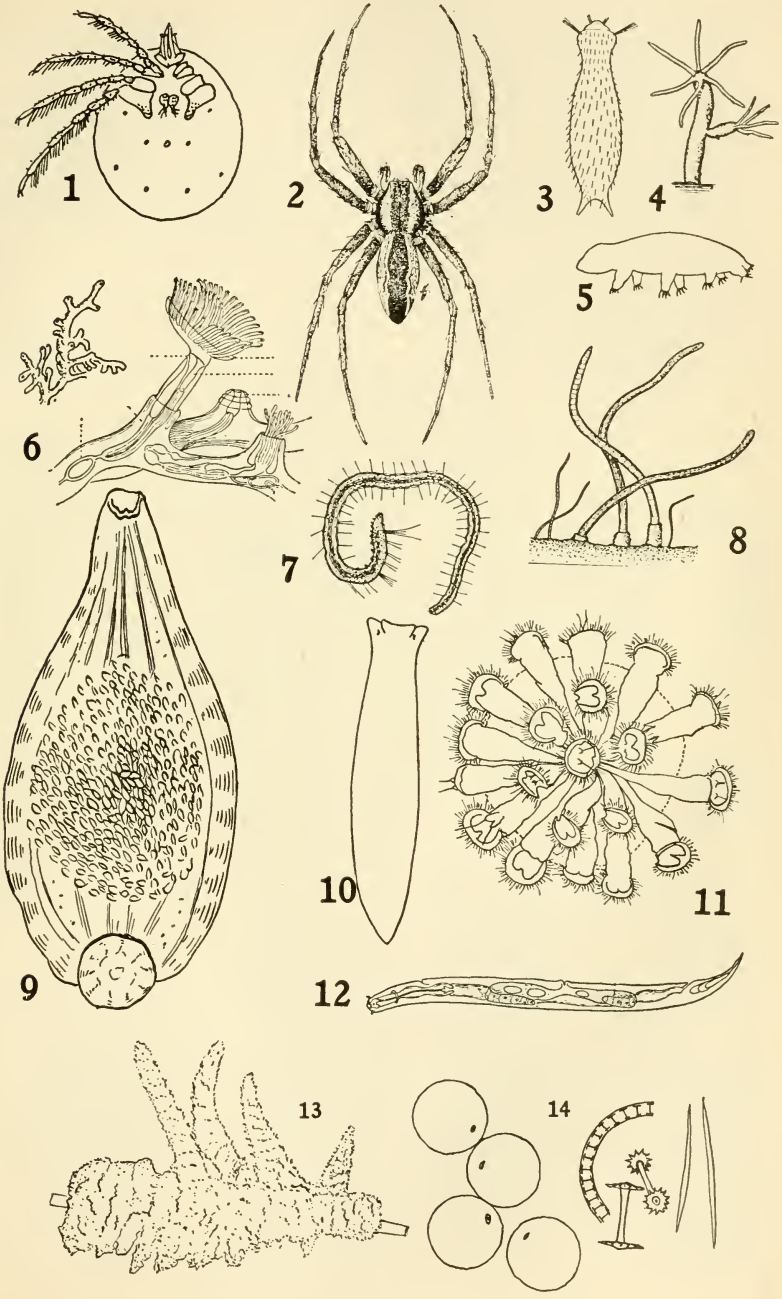
PLATE 16. SINGLE REPRESENTATIVES OF GROUPS OF LESSER INVERTEBRATES

1. A hydrachnid, or water mite ×10.
2. A water spider ×1.
3. A gasterotrich, Chaetonotus ×10.
4. A coelenterate, Hydra, ×10.
5. A tardigrade, Macrobiotus ×20.
6. A bryozoan, Plumatella ×3 and ×30.
7. A bristle-worm, Nais ×20.
8. A sewage worm, Tubifex ×20.
9. A leech, Clepsine ×3.
10. A flat-worm, Planaria ×5.
11. A colonial rotifer, Conochilus ×10.
12. A nematode worm ×10.
13. A fresh-water sponge ×½.
14. Gommules and spicules from the same.

For an introduction to the leeches see Nachtrieb's Leeches of Minnesota. Concerning the other groups see the larger text books of zoology.

† Reprinted from the *Genera of Plancton Organisms of the Cayuga Lake Basin*, by O. A. Johannsen and J. T. Lloyd, with additions in the Protozoa and some alterations of the keys by Dr. Johannsen. The plate on Protozoa (21) was arranged by Miss Elsie Broughton.

Plate 16. Miscellaneous Invertebrates



(*Continued from page* 40)

11—Filaments not attenuated and hair like at the ends....12
—Filaments conspicuously attenuated towards one or both ends. RIVULARIACEAE. Filaments each with a basal heterocyst; filaments radiating in a gelatinous mass (Fig. 7), **Rivularia, Gleotrichia.** Several other genera.

12—Filaments usually not branching; where they show branching there are not heterocysts....13
—Filaments branching. True branching, STIGONEMACEAE; false branching, heterocysts present....SCYTONE MACEAE

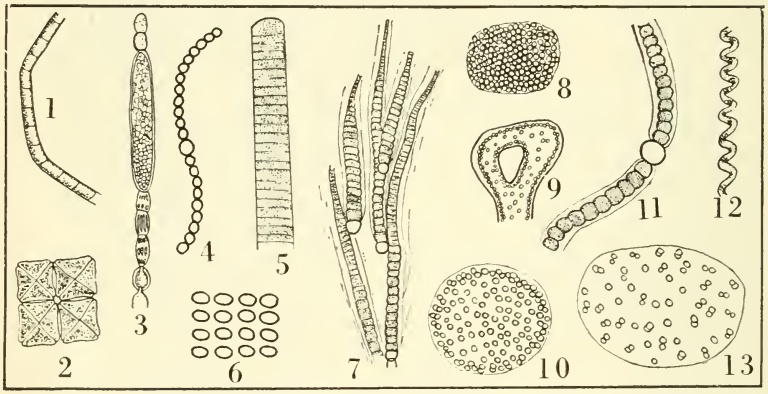
13—Cells of the filaments all of uniform size; without heterocysts.—OSCILLATORIACEAE....14
—Filaments with occasional cells of different color or larger size (heterocysts) NOSTOCACEAE....18

14—Filament without a sheath....15
—Filament enclosed in a gelatinous sheath....16

15—A single spiral cell (fig. 12)....**Spirulina**
—Multicellular. Filament a spiral, *Arthrospira;* not a spiral (fig. 5). (=**Oscillatoria**)....**Oscillaria**

(*Continued on page* 44)

Plate 17. Blue-Greens



1, Phormidium
2, Tetrapedia
3, Aphanizomenon
4, Anabæna
5, Oscillatoria
6, Merismopedia
7, Rivularia
8, 9, Microcystis
10, Cœlosphærium
11, Nostoc
12, Spirulina
13, Aphanocapsa

Anabæna, 4
Aphanocapsa, 13
Aphanizomenon, 3
Cœlosphærium, 10
Merismopedia, 6
Microcystis, 8, 9

Nostoc, 11
Oscillatoria, 5
Phormidium, 1
Ricularia, 7
Spirulina, 12
Tetrapedia, 2

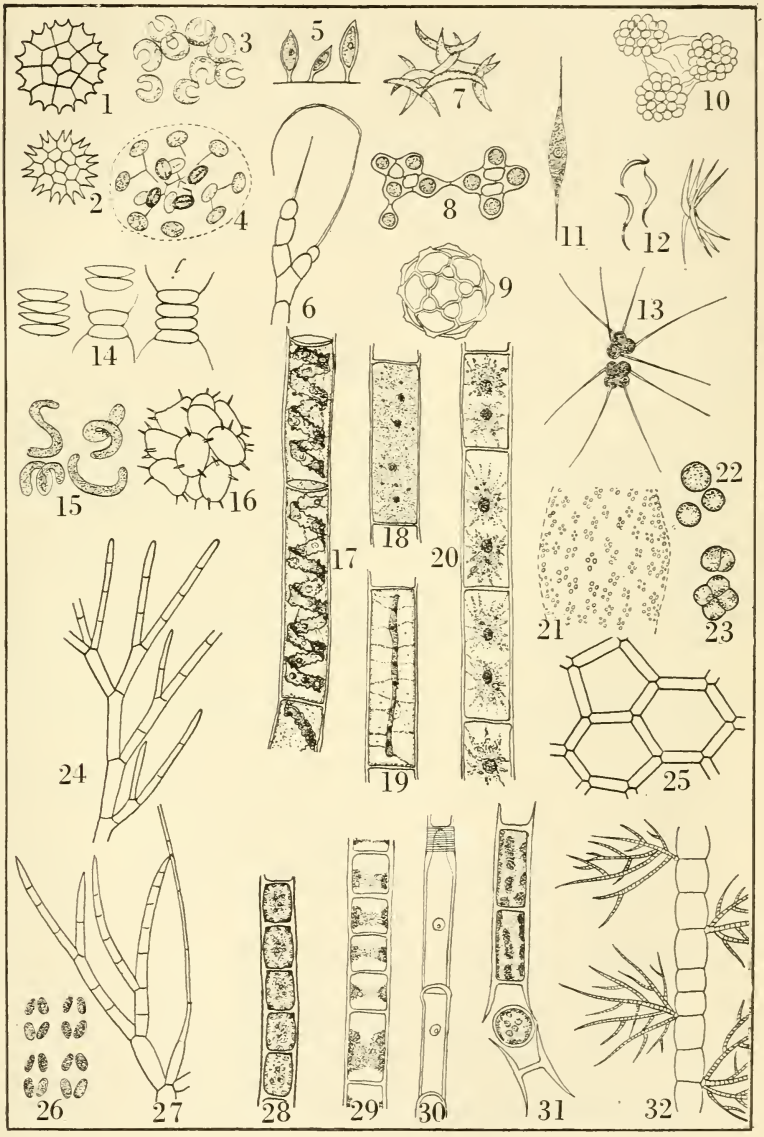
Plate 18. Green Algae

1, 2, Pediastrum
3, Kirchnerjella
4, Dictyosphærium
5, Characium
6, Bulbochæte
7, Selenastrum
8, 9, Cœlastrum
10, Botryoccoccus
11, 12, Ankistrodesmus
13, Richteriella
14, Scenedesmus
15, Ophiocytium
16, Sorastrum
17, Spirogyra
18, 19, Mougeotia
20, Zygnema
21, Tetraspora
22, 23, Pleurococcus
24, Cladophora
25, Hydrodictyon
26, Crucigenia
27, Chætophora
28, Microspora
29, Ulothrix
30, Oedogonium
31, Tribonema
32, Draparnaldia

Ankistrodesmus, 11, 12
Botryoccoccus, 10
Bulbochæte, 6
Characium, 5
Chætophora, 27
Cladophora, 24
Cœlastrum, 8, 9
Crucigenia, 26
Dictyosphærium, 4
Draparnaldia, 32
Hydrodictyon, 25
Kirchneriella, 3
Microspora, 28

Mougeotia, 18, 19
Oedogonium, 30
Phiocytium, 15
Pleurococcus, 22, 23
Pediastrum, 1, 2
Richteriella, 13
Scenedesmus, 14
Selenastrum, 7
Sorastrum, 16
Spirogyra, 17
Tiibonema, 31
Ulothrix, 29
Zygnema, 20

Plate 18. Green Algae



(*Continued from page* 42)

16—Only a single filament with one sheath.....17
—Usually several filaments in a more or less thick sheath. Several genera.

17—Sheath thick, slimy filaments often bent, agglutinated (fig. 1).....**Phormidium**
—Sheath firm, not slimy. Filaments not in bundles, **Lyngbya, Hypheothrix;** filaments in crest or prostrate bundles.....**Symploca**

18—Filaments contorted, within a definite gelatinous tegument (fig. 11).....**Nostoc**
—Filament more or less straight, free or in a formless slimy mass, without tegument..19

19—Heterocysts terminal; spores long and cylindrical.....**Cylindrospermum**
—Heterocysts not terminal. Filaments aggregated without order (fig. 4), **Anabaena;** filaments in bundles of plate like masses (fig. 3).....**Amphanizomenon**

20—Organism green, not yellowish green; if reddish then unicellular.....21
—Organism yellowish green, red or brown.....53

21—Organism with whorls of leaves. CHARACEAE.....**Chara, Nitella**
—Organism smaller, without whorls (see figs.).....CHLOROPHYCEAE—22

22—Thallus tubular, multinuclear, cell division not apparent; usually branched. **Siphonales**.....**Vaucheria**
—Thallus filamentous and septate, or unicellular, or expanded.....23

23—Thallus expanded, membranous.....**Ulvales**
—Thallus neither expanded nor membranous.....24

24—Thallus not filamentous; no conjugation.....PROTOCOCCALES—25
—Thallus filamentous, though filaments may unite in a plane; if unicellular then conjugation takes place.....42

25—Unicellular or of a definite number of ciliated motile cells.—VOLVOCACEAE. (see figs.).....26
—Cells not ciliated or motile. (see figs.).....30

26—Composed of colonies of many cells; cells with 2 cilia.....27
—Composed of single cells with 2 or rarely 4 cilia. Contents of cell close to cell wall (fig. 4), **Chlamydomonas;** contents of cell connected to cell wall by threads (fig. 2).....**Sphaerella**

27—Colonies spherical or circular.....28
—Colonies flat, cells 4–16, angles rounded in a colorless sheath (Compare also **Ulvella** fig. 14). (Fig. 10).....**Gonium**

28—No gelatinous cover. Many cells in a hollow globe (fig. 13), **Volox;** cells 16, arranged in 4 rows.....**Spondylomorum**
—With a gelatinous cover.....29

29—Colonies ovate or spherical. Cells 16–32, globose, not crowded (figs. 7, 8), **Eudorina;** cells, 8, 16, 32, or 64, globose, crowded (figs. 13, 16).....**Pandorina**
—Colony of 8 cells in an equatorial zone in a spherical or ellipsoidal investment.....**Stephanosphaera**

30—Cells formed in plates or network. HYDRODICTYACEAE, cells in a flat plate (fig. 1, 2), **Pediastrum;** cells form a net work (fig. 25).....**Hydrodictyon**
—Cells not in a plate or network.....31

31—Unicellular and solitary; cell with differentiation of base and apex (fig. 5). CHARACIACEAE.....**Characium**
—Cells without differentiation of base and apex.....32

32—Unicellular and globular or consisting of short, few celled filaments; firm cell wall. Often in damp situations (figs. 22, 23). PLEUROCOCCACEAE.....**Pleurococcus**
—Not as above.....33

33—Cells spherical and indefinite in number, embedded in a copious gelatinous envelope (fig. 21). PALMELLACEAE.....**Tetraspora,** et. al.
—Colonies free or colonial without copious gelatinous envelope; forming autospores.....PROTOCOCCACEAE—34

34—Cells elongated, frequently curved; solitary or in definite loosely coherent colonies..35
—Cells not elongated....37

35—Colonies enveloped in mucus (fig. 3)....**Kirchneriella**
—Colonies with little or no mucus....36

36—Cells attenuated to acute spines. Cells forming definite colonies each of a single row (fig. 14) **Scenedesmus**; cells solitary or loosely grouped in irregular bundles (figs 11, 12), **Ankistrodesmus**; cells lunate, arranged back to back (fig. 7)....
....**Selanastrum**
—Cells sublunate or ellipsoidal, arranged in groups forming irregular colonies....
....**Dimorphococcus**

37—Cells variable, united in a regular flat plate (fig. 26)....**Crucigenia**
—Cells not united in a flat plate....38

38—Cells angular with a definite number of angles; cells solitary....**Tetraedron**
—Cells globose or subglobose....39

39—Cells strictly globose, united in a spherical colony. Sphere hollow (figs. 8, 9), **Coelastrum**; sphere solid (fig. 16)....**Sorastrum**
—Cells not united in a spherical coenobium....40

40—Cells with 2 or more attenuated bristles (fig. 13)—**Phythelieae**....**Richteriella**
—Cells without bristles....41

41—Cells generally retained within large wall of mother cell....OOCYSTIDEAE
—Cells in grape like clusters, freely exposed in a thin gelatinous envelope (fig. 10), **Botrycoccus**; cells with well marked subdichotomous connecting threads, chloroplast parietal (fig. 4), **Dictyosphaerium**; cells in radiating series, connecting threads scarcely visible; chloroplasts axial....**Dictyocystis**

42—Cell division by intercalation of new cells producing transverse striation. **Oedigoniales.** Cells long, without laterally placed bristles (fig. 30), **Oedogonium**; cells short with laterally placed bristle (fig. 6)....**Bulbochaete**
—Cell division of the ordinary type....43

43—Filament attenuated and commonly ending in a bristle—**Chaetophorales**....44
—Filaments not ending in a bristle....51

44—Plant of branched filaments forming a flat cushion like expansion enveloped in mucilage. COLEOCHAETACEAE....**Coleochaeta**
—Plant entirely filamentous....45

45—Filaments branched....46
—Filaments not branched....50

46—Gametes arise from special cells only....TRENTEPOHLIACEAE
—Gametes arise from any cell of the filament....47

47—Small creeping filaments on water plants. Cells globose or cylindrical, HERPOSTEIRACEAE, **Herposteiron**; cells flask shaped, CHAETOSPHAERIDIACEAE....
....**Chaetosphaeridium**
—Plants not creeping....48

48—Plants less than one mm. high, without setæ....**Microthaminon**
—Plants larger, branches attenuated, and with setæ....49

49—Filaments fine. Filaments showing little difference in character of stem and branch, not in tufts in gelatinous masses, **Myxonema**; filaments in tufts in a dense gelatinous mass (fig. 27), **Chaetophora**; filaments and main branches large, bearing tufts of small branches (fig. 32)....**Draparnaldia**

50—Cells with thick lamellose coats, in a series inside a lamellose sheath. CYLINDROCAPSACEAE....**Cylindrocapsa**
—Cells without lamellose coat. ULOTHRICHACEAE. Chromatophore a homogeneous zonate band, with one to several pyrenoids (fig. 29), **Ulothrix**; chromatophore a parietal disk or plate, with one pyrenoid, **Stichococcus**; chromatophore granular, covering more or less completely the whole cell wall, containing starch but no pyrenoids (fig. 28)....**Microspora**

51—Chloroplasts numerous, parietal, each with a pyrenoid (fig. 24), **Cladophorales**..... **Cladophora**
—Chloroplasts single or several, large and of some definite shape, with pyrenoids. The entire contents of two cells unite to form a single zygote.....**Conjugatae*** 52

52—Thallus a thread of many similar cells, each a zygospore, produces only one germ plant. ZYGNEMACEAE. Chloroplasts of spiral bands (fig. 17), **Spirogyra**; chloroplast consists of two stellate bodies for each cell (fig. 20) **Zygnema**; chloroplast an axial plate (figs. 18, 19).....**Mougeotia**
—Unicellular, rarely bound together in a loose thread. DESMIDIACEAE (see page 46).

53—Organism yellowish green.....HETEROKONTAE..54
—Organism grayish or brownish or amber colored.....55

54—Plants unicellular.....**Chlorobotrys, Ophiocytium** (fig. 15)
—Plants filamentous, cell wall firm, splitting into H-shaped pieces (fig. 31) **Tribonema** .....(= **Conferva**)

55—Unicellular organisms consisting of 2 silicious valves. BACILLIARIACEAE (= Diatoms).....(See page 48)
—Cells neither silicious nor 2 valved. (See Pl. 22.) PHAEOPHYCEAE. A part of this group is included by the zoologists in the class MASTIGOPHORA among the Protozoa. (See page 54.)

DESMIDIACEAE

1—Cell wall apparently not divided into 2 parts, and without pores.....2
—Cell wall showing 2 segments, and with a differentiated outer porous layer.....4

2—Cells elongate, cylindrical and not constricted, forming loose filaments. Cell wall with a differentiated outer layer, of which the small roughnesses and spines form a part. Chloroplasts axile (fig. 1), **Gonatozygon**; chloroplasts parietal and spirally twisted (fig. 16).....**Genicularia**
—Cells solitary, relatively short and mostly unconstricted.....3

3—One chloroplast in each cell. Chloroplast spirally twisted, axile or parietal (fig. 2) **Spirotaenia**; chloroplast plane, axile, cells solitary (fig. 10).....**Mesotaenium**
—Two chloroplasts in each cell. Chloroplasts star shaped radiating from a central pyrenoid (fig. 25), **Cylindrocystis**; chloroplasts ridged with longitudinal serrated ridges (fig. 12).....**Netrium**

4—After division the cell remains free and solitary.....5
—After division the cells remain attached to form colonies.....9

5—Cells not constricted. Cells of moderate length, straight, cylindrical (figs. 17, 23), **Penium**; cells amost cylindrical, scarcely attenuated, chloroplasts single, **Roya**; cells strongly attenuated towards each extremity, two chloroplasts in each cell (figs. 5, 6, 7, 8).....**Closterium**
—Cells more or less constricted at the middle.....6

6—Cells elongated and cylindrical, constriction slight. Base of semi-cells plicate (figs. 3, 4), **Docidium**; base of semi-cells plane (fig. 20), **Pleurotaenium**; apices of cells cleft, apical incision narrow (fig. 19).....**Tetmemorus**
—Cells relatively short, deeply constricted.....7

7—Cells in vertical view radiating, triangular, quadrangular or radiate, rarely fusiform (figs. 13, 14).....**Staurastrum**
—Cells compressed (at right angles to the plane of the front view), in the vertical view fusiform or elliptical.....8

*The 2 orders Schizogoniales and Microsporales are not represented in our plancton.

(*Continued on page* 48)

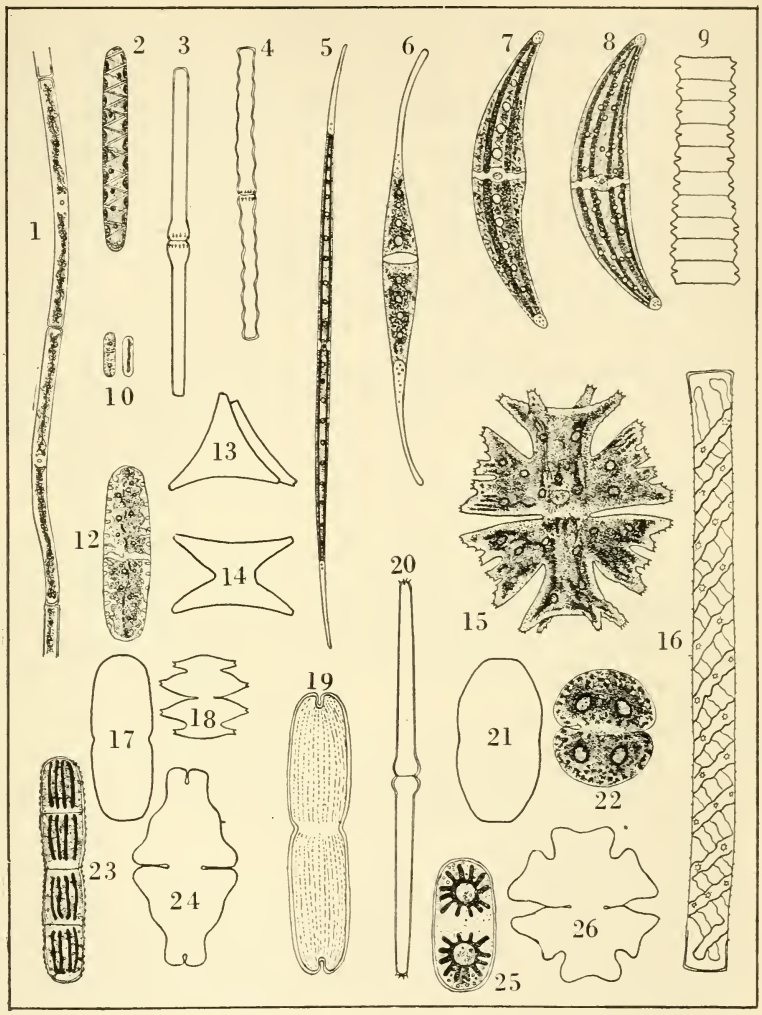


Plate 19. Desmids

1, Gonatozygon
2, Spirotænia
3, 4, Docidium
5, 6, 7, 8, Closterium
9, Desmidium
10, Mesotænium
12, Netrium
13, Staurastrum (end)
14, Staurastrum (side)
15, Micrasterias
16, Genicularia
17, Penium
18, Micrasterias
19, Tetmemorus
20, Pleurotænium
21, 22, Cosmarium
23, Penium
24, Euastrum
25, Cylindrocystis
26, Euastrum

Closterium, 5, 6, 7, 8
Cosmarium, 21, 22
Cylindrocystis, 25
Desmidium, 9
Docididium, 3, 4
Euastrum, 24, 26
Genicularia, 16
Gonatozygon, 1
Mesotænium, 10
Micrasterias, 15, 18
Netrium, 12
Penium, 17, 23
Pleurotænium, 20
Spirotænia, 2
Staurastrum, 13, 14
Tetmemorus, 19

(*Continued from page* 46)

8—Cells lobed or incised. Cells mostly oblong or elliptical moderately lobed (figs. 24, 26), **Euastrum**; cells very much compressed, deeply lobed or incised (fig. 15, 18) ..... **Micrasterias**

—Cells with a more or less entire margin, often furnished with warts or spines (figs. 21, 22), **Cosmarium**; with spines commonly in pairs, **Xanthidium**; spines 4 or 8 occasionally 16 ..... **Arthrodesmus**

9—Colonies spheroidal, joined by gelatinous bands. Bands narrow, few cells, **Cosmocladium**; bands very broad, many cells ..... **Oocardium**

—Colonies thread like; cells attached by their apices to form long filaments 10

10—The line of division of the cell where the new and old parts of the cell wall are fitted together, does not develop a girdle during division 11

—The line of division of the cell develops a girdle during division. Cells short, rarely circular with produced angles (fig. 9), **Desmidium**; cells elongate, cylindrical ..... **Gymnozygas**

11—Cells attached by special apical processes. Apical processes very short, **Sphaerozosoma**; apical processes long and overlapping the apices of the adjacent cells .... **Onychonema**

—Apices of cells plane and flat. Cells slightly constricted, **Hyalotheca**; cells deeply constricted ..... **Spondylosium**

BACILLARIACEAE (Diatoms.)*

1—Cells in transection circular, less commonly polygonal or elliptical, and rarely irregular; valves marked concentrically or radiately by dots, areolations, lines or ribs; cells often with spines, processes or horns ..... CETRICAEA—2

—Cells in transection narrowly elliptical to linear, less commonly broadly elliptical, lunate cuneate or irregular valves marked pinnately or transversely by dots, areolations lines or ribs; cells without spines ..... PENNATAE—5

2—Cells short box-shaped or discoid, mostly circular in transection, usually without horns or projections 3

—Cells of other forms 4

3—Cells forming filaments, girdle side marked. Valve uniformly marked (figs. 1, 2, 3, 4) (=**Lysigonium**), **Melosira**; margin and center of valve differently marked, central portion areolated ..... **Hyalodictya**

—Cells single, girdle side not marked. Without spines (figs. 9, 10). **Cyclotella**; with circle of spines (figs. 5, 8) ..... **Stephanodiscus**

4—Cells two to many times as long as broad, circular, rarely round elliptical in transection; girdle with numerous interzones ..... **Rhizosolenia**

—Cells box shaped, as long as broad or shorter, elliptical, sometimes lunate in transection; valves with horns, valves with transverse septa, without spines ... **Terpsinoe**

5—Rachis of the valves (i.e. the line between the divergent pinnate markings) evident as a narrow unmarked strip (pseudoraphe), rarely wanting; valve without slit (raphe, text fig. 2) 6

—Rachis otherwise; raphe (slit) present 13

6—Cells usually but little shorter than broad, or longer, with numerous interzones, mostly united into filaments 7

—Cells prevailingly much shorter than broad (rod-shaped, the longer axis of rod representing transverse axis of cell) often united into filaments 8

7—Transverse rib of valves, when present, not extending into the cell cavity. Valves with a few prominent transverse ribs, **Tetracyclus**; valves finely transversely striate only, pseudoraphe absent (figs. 28, 36) ..... (=**Striatella**) **Tabellaria**

—Transverse ribs of the valves extending deep into cell ..... **Denticula**

* Adapted from Bessey.

8—Cells cuneate in girdle view (i.e. valves not parallel) rachis median, interzones present....9
—Cells rectangular in girdle view, or if cuneate the rachis not median, interzones present or absent....10

9—Valves without transverse ribs, cells not stalked....**Sceptroneis**
—Valves finely transverse-striate and with transverse ribs (fig. 11)....**Meridion**

10—Rachis median, without central eye....11
—Rachis near one margin....12

11—Valves with transverse ribs (figs. 12, 13, 14)....(=**Odontidium**) **Diatoma**
—Valves without transverse ribs. Cells arranged radially (fig. 37) **Asterionella** cells in filaments or zig-zag chains, valves flat (fig. 15) **Fragilaria**; cells single or forming fan like stalked clusters (figs. 21, 22)....**Synedra**

12—Ends of valves alike. Pseudoraphe and central nodule evident, **Ceratoneis** pseudoraphe and central nodule not evident (figs. 6, 7)....**Eunotia**
—Ends of valves unlike....(=**Actinella**) **Tibiella**

13—Rachis containing an elongate slit (raphe) through the cell wall....14
—Rachis evident as a narrow, unmarked strip or keeled; valve with 2 lateral wing keels, each enclosing a raphe....23

14—Rachis commonly median, often more or less lateral, not keeled or when keeled not punctate, interzones present or absent....15
—Rachis lateral, less often median, punctate keeled raphe not plainly visible Keel median, **Bacillaria**; keel at one edge (figs. 19, 20)....(**Homoeocladia**) **Nitzschia**

15—Valves parallel....16
—Valves not parallel....21

16—Rachis of valve not keeled....17
—Rachis of valve with a keel; keel (including raphe) sigmoid, median....**Amphiprora**

17—Raphe almost straight....18
—Raphe strongly sigmoid. Cell not twisted (fig. 23), **Gyrosigma**; cell twisted....**Scoliopleura**

18—Raphe with a simple border....19
—Raphe bordered by 2 ridges. Central nodule small or only slightly elongated **Brebissonia**; central nodule much elongated, riblike....**Amphipleura**

19—Septa of interzones (when present) not fenestrated....20
—Septa of interzones fenestrated. Both valves with a raphe, **Mastogloia**; only one valve with a raphe....**Cocconeis**

20—Cells straight in girdle view. Including the subgenera **Stauroneis** (fig. 16), **Frustulia** (fig. 18), and **Pinnularia** (fig. 34). (Figs. 24, 25, 26, 27)....**Navicula**
—Cells curved. Both valves with a raphe, **Rhoiconeis**; only one valve with a raphe, **Achnanthes** including **Achnanthidium** (figs. 39, 40).

21—*Ends* of valves approximating. Cells straight in girdle view (figs. 20, 30) **Gomphonema**; cells curved in girdle view....**Rhoicosphenia**
—*Edges* of valves approximating....22

22—Valves without transverse ribs. Girdle narrow, not striate (fig. 33), **Cymbella**; girdle broad, striate (fig. 41)....**Amphora**
—Valves with transverse ribs, raphe not evident. (Fig. 35)..(**Cystopleura**) **Epithemia**

23—Valve surface undulate....(=**Cymatopleura**) **Sphinctocystis**
—Valve surface not undulate. Valve cuneate, reniform, elliptical or linear (fig. 38), **Surirella**; valves subcircular, saddle shaped (figs. 31, 32)....**Campylodiscus**

PROTOZOA

1—Animals with tentacles, and when adult usually attached by a stalk....SUCTORIA
—Animals with speudopods, flagella or cilia....2

2—Animals with pseudopods....3
—Animals with cilia or flagella....4

3—Pseudopods flowing.....RHIZOPODA
—Pseudopods ray like.....HELIOZOA

4—Animals with cilia.....CILIATA. (See page 54)
—Animals with one or two, rarely more, long flagella. MASTIGOPHORA. (See page 55.)

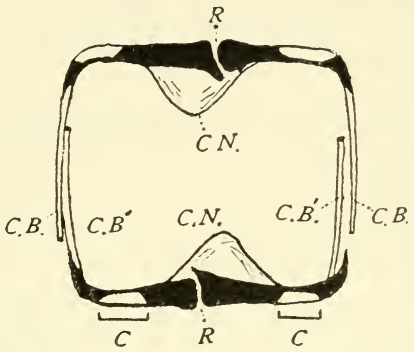


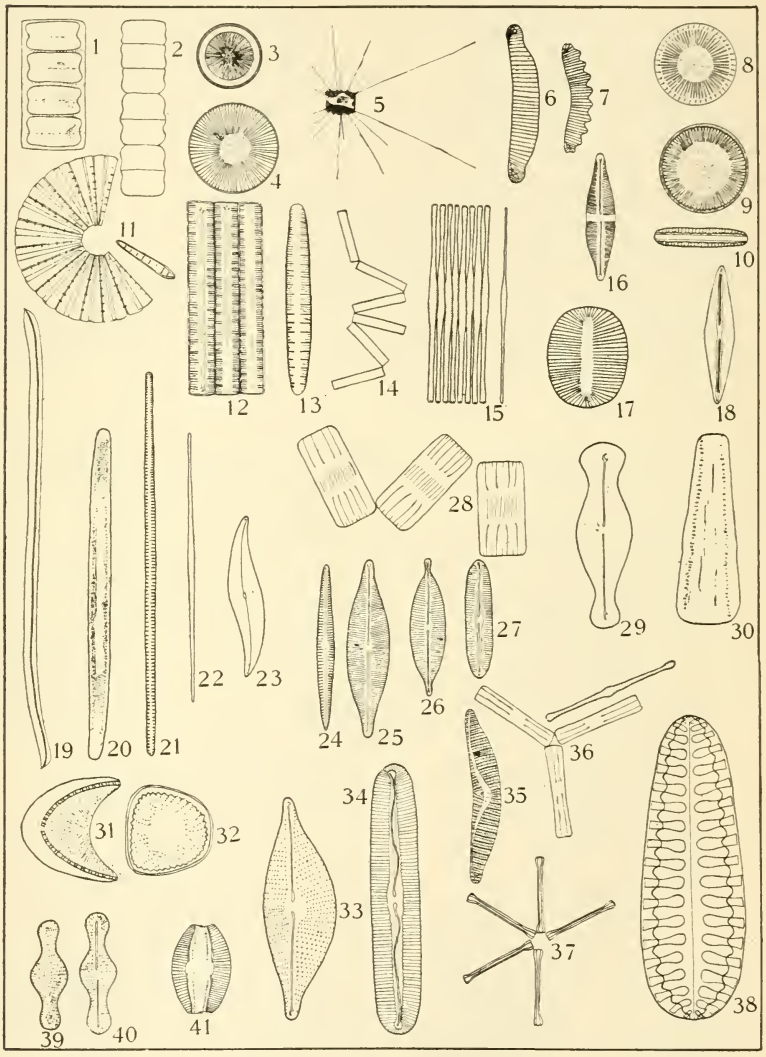
Fig. 2. Transverse section of the frustule of a *Navicula*. (From Van Heurck, after West.) *CB* and *CB'*, the two connecting-bands forming the girdle; *R*, raphe; *CN*, central nodule; *C*, costa of valve.

Plate 20. Diatoms

1, 2, 3, 4, Melosira
5, Stephanodiscus
6, 7, Eunotia
8, Stephanodiscus
9, 10, Cyclotella
11, Meridion
12, 13, 14, Diatoma
15, Fragilaria
16, Stauroneis
17, Cocconeis
18, Frustulia
19, 20, Nitzschia
21, 22, Synedra
23, Gyrosigma
24, 25, 26, 27, Navicula
28, Tabellaria
29, 30, Gomphonema
31, 32, Compylodiscus
33, Cymbella
34, Pinnularia
35, Epithemia
36, Tabellaria
37, Asterionella
38, Suriella
39, 40, Achnanthidium
41, Amphora

Achnanthidium, 39, 40
Amphora, 41
Asterionella, 37
Campylodiscus, 31, 32
Cocconeis, 17
Cyclotella, 9, 10
Cymbella, 33
Diatoma, 12, 13, 14
Epithemia, 35
Eunotia, 6, 7
Fragilaria, 15
Frustulia, 18
Gomphonema, 29, 30
Gyrosigma, 23
Melosira, 1, 2, 3, 4
Meridion, 11
Navicula, 24, 25, 26, 27
Nitzchia, 19, 20
Pinnularia, 34
Stauroneis, 16
Stephanodiscus, 5, 8
Suriella, 21, 22
Synedra, 38
Tabellaria, 28, 36

Plate 20. Diatoms



RHIZOPODA

1—Animal without shell; nucleus present....2
—With shell....3

2—Web like membrane between pseudopods....**Hyalodiscus**
—Without membrane between pseudopods. Plasma with fine hyaline rods, **Pelomyxa**; plasma without hyaline rods (fig. 1)....**Amoeba**

3—Pseudopods finger like....4
—Pseudopods thread like; shell of evident structure with one pseudopod opening, chitinous; without sand grains....7

4—Shell chitinous, yellowish, watch glass shape; pseudopod opening on under side....5
—Shell structure not homogeneous....6

5—With variable number of spines (figs. 2)....**Centropyxis**
—Without spines though sometimes with scalloped edge (fig. 3)....**Arcella**

6—Shell made of sand grains, diatoms, etc. (fig. 4)....**Difflugia**
—Shell pear shaped, made of 4-sided plates....**Quadrula**

7—Shell pear shaped; or spherical; compressed, of spirally arranged plates; mouth with toothed plates....**Euglypha**
—As above but with eccentric mouth....**Trinema**
—Shell with fine markings, neck bent to one side....**Cyphoderia**

HELIOZA

1—Without outer envelope....2
—With outer envelope of silicious pieces or shell....4

2—Body commonly amoeboid with pseudopods either from all sides or from one place; reddish (fig. 5)....**Vampyrella**
—Body spherical; pseudopods from all sides, flexible with axial fiber....3

3—Ectoplasm sharply distinct from entoplasm; many nuclei....**Actinosphaerium**
—Ectoplasm not sharply distinct; central nucleus (fig. 6)....**Actinophrys**

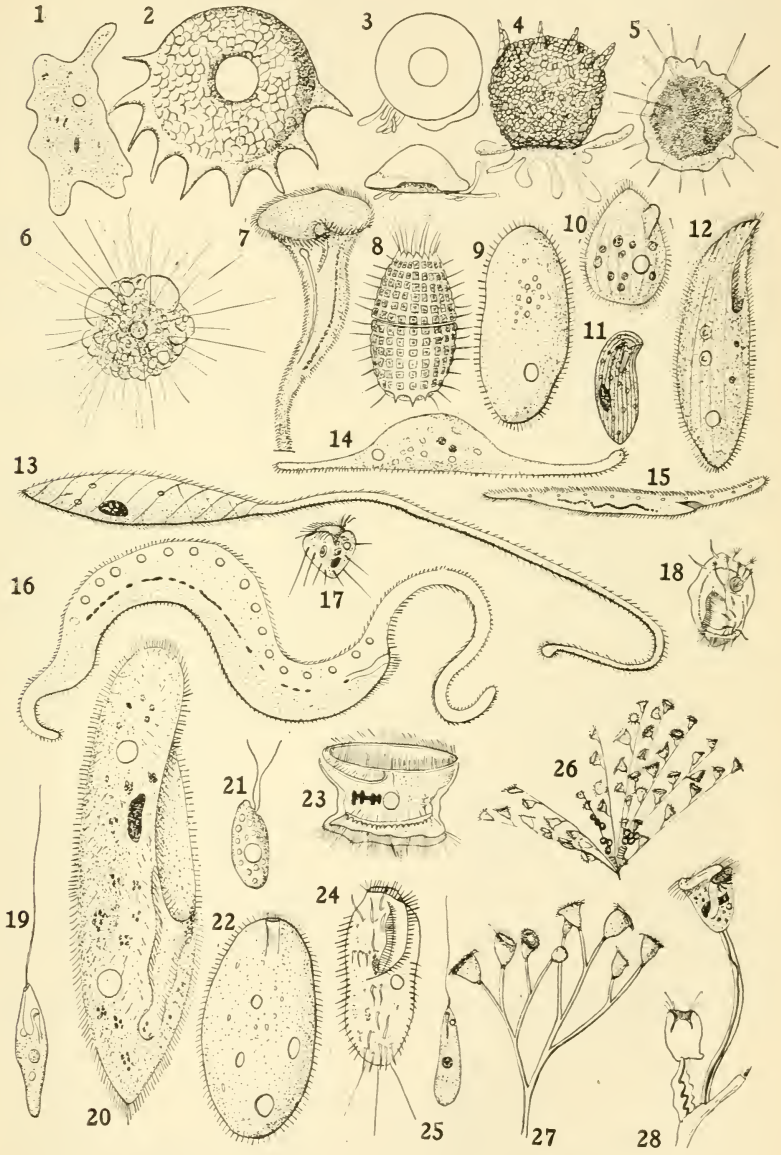
4—Envelope of radiate spines with basal plate....**Acanthocystis**
—Envelope of silicious shell, with rounded openings....**Clathrulina**

Plate 21. Protozoans

1, Amœba
2, Centropyxis
3, Arcella
4, Difflugia
5, Vampyrella
6, Actinophrys
7, Stentor
8, Coleps
9, Holophrya
10, Colpodium
11, Chilodon
12, Loxodes
13, Lacrymaria
14, Lionotus
15, Amphileptus
16, Dileptus
17, Halteria
18, Euplotes
19, Peranema
20, Paramœcium
21, Chilomonas
22, Frontonia
23, Trichodina
24, Stylonychia
25, Astasia
26, Carchesium
27, Epistylis
28, Vorticella

Actinophrys, 6
Amœba, 1
Amphileptus, 15
Arcella, 3
Astasia, 25
Carchesium, 26
Centropyxis, 2
Chilodon, 11
Chilomonas, 21
Coleps, 8
Colpodium, 10
Difflugia, 4
Dileptus, 16
Epistylis, 27
Euplotes, 18
Frontonia, 22
Halteria, 17
Holophrya, 9
Lacrymaria, 13
Lionotus, 14
Loxodes, 12
Paramœcium, 20
Peranema, 19
Stentor, 7
Stylonychia, 24
Trichodina, 23
Vampyrella, 5
Vorticella, 28

Plate 21. Protozoans



CILIATA

1—Body more or less uniformly ciliate, in few cases lacking on one side....2
—Cilia restricted to a part of the body....11

2—Mouth without a definite spiral zone of cilia....3
—Mouth surrounded by a zone of large cilia. Body more or less funnel shaped (fig. 7), **Stentor**; body purse shaped....**Bursaria**

3—With shell composed of several pieces (fig. 8)....**Coleps**
—Without shell....4

4—With a broad ring like band of cilia....**Urocentrum**
—With cilia on ventral surface only....5
—With cilia uniform over whole body....6

5—Pharynx basket like; body flat; mouth on anterior half (fig. 11)....**Chilodon**
—With long neck, body oval, ending in a short tail....**Lionotus**
—With anterior end hooklike; body brownish (fig. 12)....**Loxodes**

6—Mouth lateral, in front of middle, with projecting undulating membrane, no peristome (fig. 10)....**Colpodium**
—Without undulating membrane....7

7—Mouth nearly terminal. Pharynx not apparent, body ovate (fig. 9), **Holophyra**; pharynx evident, long contractile neck (fig. 13)....**Lacrymaria**
—Mouth ventral, not terminal....8

8—With elongate proboscis....9
—Without proboscis....10

9—Mouth open, pharynx rodlike (fig. 16)....**Dileptus**
—Mouth commonly closed; no pharynx. Body with broad clear border. **Loxophyllum**; body without clear border (fig. 15)....**Amphileptus**

10—Mouth near middle (fig. 20)....**Paramoecium**
—Mouth surrounded by a furrow extending far backwards (fig. 22), **Frontonia**; mouth bearing a few long cilia on its posterior left side....**Colpoda**

11—Ventral surface with large cilia; a dorsal zone wound to left....12
—A dorsal zone wound to right....15

12—Body not flattened; with projecting bristles (fig. 17)....**Halteria**
—Body more or less flat; cilia in groups....13

13—With many cilia on margin....14
—No marginal cilia (fig. 18)....**Euplotes**

14—Five or more longitudinal rows of ventral cilia....**Urostyla**
—Five ventral cilia. No caudal bristles, body flexible, **Oxytricha**; usually three caudal bristles (fig. 24), **Stylonychia**; two rows of ventral cilia, 3 sternal and no anal cilia ....**Uroleptus**

15—With chitinous lorica (case); unstalked or with short stalk....**Cothurnia**
—No lorica....16

16—Disclike, parasitic on Hydra (fig. 23)....**Trichodina**
—Stalked forms....17

17—Simple retractile stalk (fig. 28)....**Vorticella**
—Branched stalk. Each individual contracting separately (fig. 26), **Carchesium**; stalk not retractile (fig. 27)....**Epistylis**

MASTIGOPHORA

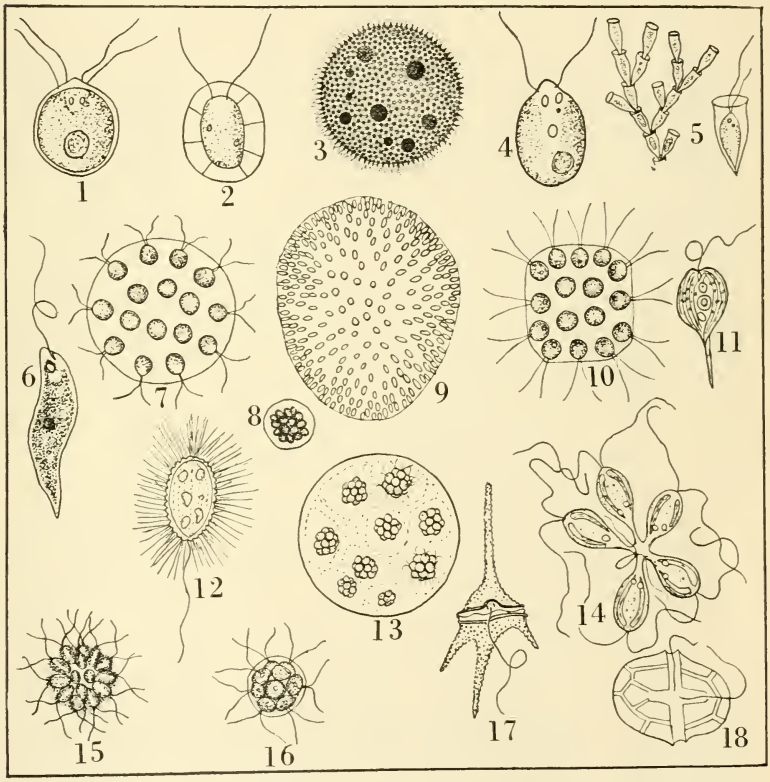
1—With 2 flagella, one in a longitudinal groove projecting backwards, the other in a transverse groove; colored or hyaline. **Ceratium** (fig. 17), **Peridinium** (fig. 18).
—With one flagellum set in a collar....**Choanoflagellata**
—With one more flagella, without collar or furrow....2

2—One or several flagella, mostly directed forward 3
—Usually 2 flagella, one directed forward, the other backwards . . . . . **Heteromastigoda**

3—Mostly small species, with one large flagellum and one or more smaller secondary flagella. Colonial species, **Dinobryon** (fig. 5); **Uroglena** (fig. 9); solitary, with a shell of plates bearing spines (fig. 12) . . . . . **Mallomonas**
—Larger species, with one large flagellum (sometimes 2), mouth at base of flagellum . . 4
—With 2 or more equal flagella 6

(*Continued on page* 56)

Plate 22. Flagellates



1, Carteria
2, Sphærella
3, Volvox
4, Chlamydomonas
5, Dinobryon
6, Euglena
7, Eudorina
8, Eudorina (young colony)
9, Uroglena
10, Gonium
11, Phacus
12, Mallomonas
13, Pandorina
14, Ulvella
15, Synura
16, Pandorina
17, Ceratium
18, Peridinium

Carteria, 1
Ceratium, 17
Chlamydomonas, 4
Dinobryon, 5
Eudorina, 7, 8
Euglena, 6
Gonium, 10
Mallomonas, 12
Pandorina, 13, 16
Peridinium, 18
Phacus, 11
Sphærella, 2
Synura, 15
Uroglena, 9
Ulvella, 14
Volvox, 3

(*Continued from page* 55)

4—One larger and one secondary flagellum; body flexible (fig. 25, Pl. 21).....**Astacia**
—One evident flagellum.....5

5—Colorless flexible species (fig. 19, Pl. 21).....**Peranema**
—Species typically green, with cuticula. Flexible with red eye spot (fig. 6), **Euglena**; not flexible, flattened striate (fig. 11).....**Phacus**

6—Solitary. Colorless, 2 flagella, with pharynx, body slightly flattened, **Chilomonas**; colored, 4 flagella (fig. 1), **Carteria**; green, 2 flagella, spherical (fig. 4).....**Chlamydomonas**
—Colonial. With 2 brown band like chromatophores, spherical colonies (fig. 15) **Synura**; With green chromatophores (see VOLVOCACEAE, page 44).

ROTIFERA*

1—Head and foot telescopic retractile, body ringed, movements leech like, lateral palpi wanting.....2
—Head and foot not telescopic retractile, not leech like, lateral palpi usually distinct..3

2—Corona two circular retractile lobes. Eye in neck (fig. 1) **Philodina**; eye in proboscis (fig. 2, 3) **Rotifer**; eyes absent.....**Callidina**
—Corona a flat ventral ciliated disc (fig. 4).....**Adineta**

3—Adult animals attached, or in colonies; if separate, usually in tubes.....4
—Not fixed when adult; rarely in tubular case.....8

4—Corona with long setæ or cilia, or both.....5
—Corona without setæ. Body elongate, **Acylus**: body short (fig. 7), (**Cupelopagis**) **Apsilus.**

5—Corona with long slender setæ. Setæ scattered on lobe of corona (fig. 5) (**Collotheca Floscularia**: setæ in whorls or rows (fig. 6).....**Stephanoceros**
—Corona with strong conspicuous moving cilia.....6

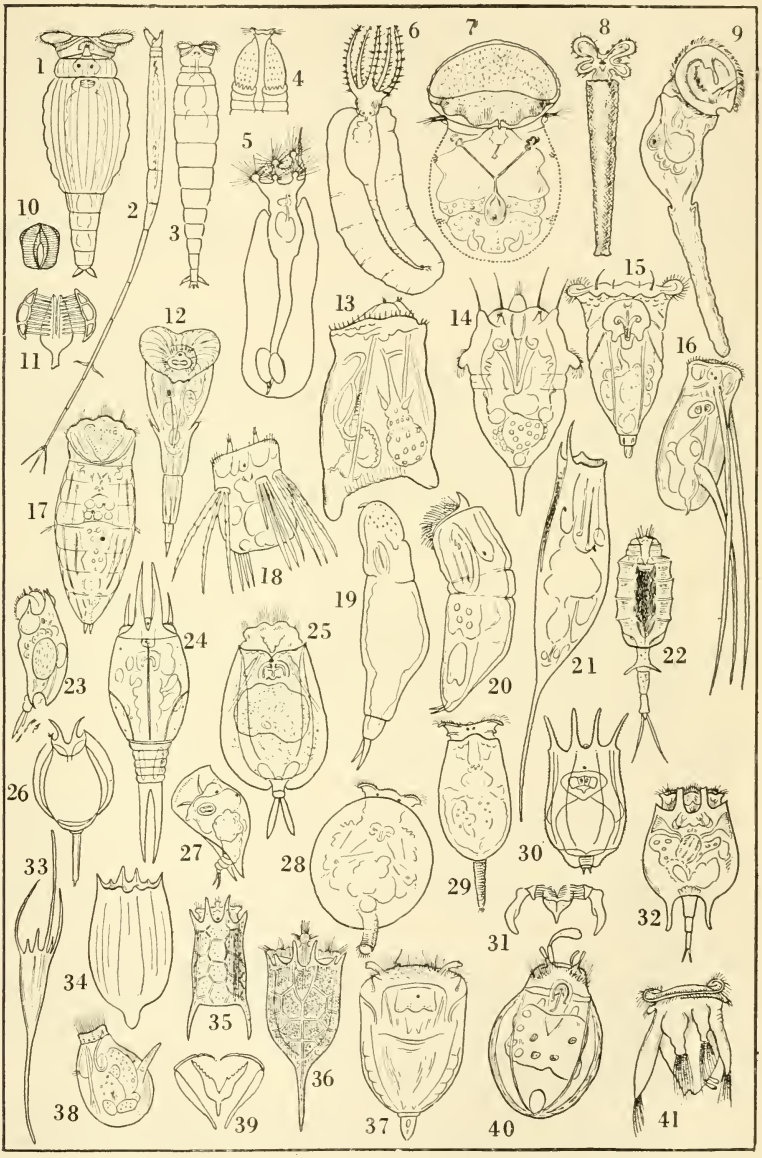
(*Continued on page* 58)

* Adapted from Keys given by Jennings, Collin, et al.

Plate 23. Rotifers

1, Philodina
2, 3, Rotifer
4, Adineta
5, Floscularia
6, Stephanoceros
7, Apsilus
8, Melicerta
9, Conochilus
10, Ramate jaws
11, Malleo-ramate jaws
12, Microcodon
13, Asplanchna
14, 15, Synchæta
16, Triarthra
17, Hydatina
18, Polyarthra
19, Diglena
20, Diurella
21, Rattulus
22, Dinocharis
23, 24, Salpina
25, Euchlanis
26, Monostyla
27, Colurus
28, 29, Pterodina
30, Brachionus
31, Malleate jaws
32, Noteus
33, 34, Notholca
35, 36, Anuræa
37, Plœsoma
38, Gastropus
39, Forcipate jaws
40, Anapus
41, Pedalion

Plate 23. Rotifers



(*Continued from page* 56)

6—Colonial, frequently in spherical clusters. Clusters attached, (**Lacinularia**), **Megalotrocha, Sinantherina.** Free swimming colonies or cluster (fig. 9) **Conochilus.**
—Not attached, inhabiting a tube (fig. 9).....**Conochilus**
—Attached, separated, or in branching colonies of one to 30 individuals.....7

7—Corona of 3 or 4 lobes (fig. 8) (**Floscularia** Cuv.).....**Melicerta**
—Corona with not more than two lobes. Dorsal antenna present, **Limnias:** dorsal antenna not evident (**Ptygura**).....**Oecistes**

8—Body with skipping appendages; no foot. (Fig. 41).....**Pedalia**
—Foot usually present.....9

9—Animal with flexible cuticle (**Illoricata**).....10
—Animal with stiff armor (**Loricata**).....19

10—Foot narrow stilette form, corona heart shaped (fig. 12) **Microcodon:** foot shorter, corona circular.....**Microcodides**
—Foot absent, or foot with two toes.....11

11—Intestine ends blindly, no anus; body sac like.....12
—Anus present.....13

12—Body large, cuticle delicate; stomach without blind evaginations. Foot present, **Asplanchnopus;** foot absent (fig. 13).....**Asplanchna**
—Body very small, cuticle firm; stomach with blind sacs.....**Ascomorpha**

13—Foot lacking; body with skipping appendages. With 12 blade-like appendages (fig. 18), **Polyarthra;** with two or three appendages (fig. 16) **Triarthra, Pedetes, Filinia.**
—Foot present, body without skipping appendages.....14

14—Corona large, nearly transverse, with prominences bearing styles.....15
—Corona without prominences bearing styles.....16

15—Form broad, corona transverse, flat or convex with four long styles and two ciliated auricles (fig. 14, 15).....**Synchaeta**
—Two eyes. Slender foot, stomach 6-lobed (**Enteroplea**) **Triphylus;** corona extended into a large fringed proboscis (**Rhinoglena**).....**Rhinops**
—One eye or none. Eye apparently wanting, body long conical (fig. 17), (**Epiphanes**) **Hydatina;** one eye, body quadrate or sac-like (**Epiphanes**) **Notops;** one eye, body long conical, humped.....**Cyrtonia**

16—With auricles, sometimes retracted.....17
—Without auricles.....18

17—With three eyes.....**Eosphora**
—With one eye. Body with many transverse folds, **Taphrocampa;** body without such folds (inclusive **Copeus**).....**Notommata**

18—One eye. Eye cervical, **Proales;** eye near front.....**Furcularia**
—Two eyes. Eyes cervical (**Dicranophorus**) **Distemma;** eyes frontal (fig. 19) (**Cephalodella**).....**Diglena**

19—Foot present.....20
—Foot lacking. Armor oval compressed (fig. 40) (**Chromogaster**) **Anapus;** dorsum of armor with longitudinal striations (fig. 33, 34), **Notholca;** dorsum of armor marked with polygonal areas, anterior margin spined (fig. 35, 36) (**Keratella**) **Anuraea;** similar but anterior margin not spined.....**Anuraeopsis**

20—Foot transversely ringed or wrinkled; very retractile.....21
—Foot not wrinkled though often jointed.....22

21—Foot ending in a ciliated cup, armor dorso-ventrally flattened (fig. 28, 29)...**Pterodina**
—Foot ending in one or two toes. Armor arched dorsally, flat or slightly convex ventrally (fig. 30) **Brachionus;** armor irregularly oblong, marked with grooves (fig. 37) **Ploesoma;** armor compressed laterally, without distinct grooves (fig. 38). **Gastropus**

22—Viewed dorsally armor unsymmetrical, of one piece. With two toes, equal, or the shorter one over 1–3 as long as the longer (fig. 20) **Diurella**; with single toe, or with an additional inconspicuous shorter one (fig. 21) (**Trichocerca**).....**Rattulus**
—Viewed dorsally, armor symmetrical.....23

23—Armor cleft dorsally. Armor covering only dorsal half of body, **Diaschiza**; armor well developed, enclosing body (fig. 23, 24) (**Salpina**).....**Mytilina**
—Armor not cleft dorsally.....24

24—Armor of one more or less cylindrical piece, foot 3-segmented.....25
—Armor either of several pieces, or ventrally cleft.....27

25—Two lateral eyes, armor flattened, not spined (**Squatinella**).....**Stephanops**
—Only a median eye.....26

26—With long dorsal spines, foot short (**Polychaeta**).....**Macrochaeta**
—Without long dorsal spines. Head armored, body armor strong (fig. 22) **Dinocharis**; head with only weak cuticle, body armor thin.....**Scaridium**

27—Foot not annulate, one to three segmented.....28
—Foot annulate, sometimes attached mid-ventrally.....29

28—Armor smooth, much longer than broad.....**Schizocerca**
—Armor, exclusive of spines, not much longer than broad. Foot one-segmented (fig. 30) **Brachionus**; foot 3-segmented (fig. 32) (**Platyias**).....**Noteus**

2—Head with chitin cap. Armor of two lateral plates, body compressed (fig. 27) **Colurella**; armor of dorsal and ventral plates, body depressed (**Lepadella**).....**Metopidia**
—Head not armored. Foot 3-segmented, two large toes (fig. 25) **Euchlanis**; foot 2-segmented, one toe (fig. 26) **Monostyla**; foot one-segmented, two toes (**Cathypna, Distyla**).....**Lecane**

CRUSTACEA

The following table includes only the genera of the free swimming, fresh water Entomostraca found in Eastern United States. An immature stage, known as **Nauplius** is shown in fig. 3.

1—Without a shell like covering of the body; with four or five 2-branched swimming feet on the thorax, abdomen without appendages.....**Copepoda**—2
—Usually with a shell like covering which may or may not entirely cover the body; if without shell the paired eyes are pedunculate.....5

2—Cephalothorax distinctly separated from abdomen, the latter small.....3
—Cephalothorax not sharply differentiated; antennæ short, at most 8-segmented—(Harpactidae); with 8-segmented antennæ (fig. 19).....**Canthocamptus**

3—First antennæ long, about as long as the body, 23–25 segmented; in the male, one is modified into a grasping organ; fifth feet not rudimentary..(Centropagidae)—4
—Antennæ shorter than cephalothorax; female with 2 egg sacks (fig. 20)—(Cyclopidae).....**Cyclops**

4—Endopodites of swimming feet of 3 segments. Antennæ of 23 or 24 segments—**Osphranticum**; antennæ of 25 segments (fig. 17).....**Limnocalanus**
—Endopodite of first swimming feet of one or two segments. Endopodite of first, second, third and fourth swimming feet of one segment, **Epischura**; endopodite of first swimming feet of two segments, of third and fourth feet of three segments (fig. 16).....**Diaptomus**

5—Trunk limbs leaf like in form; mandible without palp.....Phyllopoda—6
—Trunk limbs not leaf like; mandible with palpus; body not distinctly segmented with caudal furca; antenna large, used for locomotion; bivalve shell, enclosing entire body.....Ostracoda—34

6—With 10 or more pairs of trunk limbs.....7
—With 4 to 6 trunk limbs; shell bivalved, generally covering body but leaving head free.....CLADOCERA—13

7—Without shell; paired eyes pedunculate. The fairy shrimp, etc.....ANOSTRACA—8
—With shell; paired eyes sessile.....10

8—Clasping antennæ of male biarticulate. Frontal appendage present—(CHIROCEPHALIDAE).....9
—Clasping antennæ of male triarticulate—(STREPTOCEPHALIDAE).....**Streptocephalus**

9—Frontal appendage of male rather short.....**Eubranchipus**
—Frontal appendage of male long and vertical.....**Branchinela**

10—Shell resembling that of a small clam.....**Conchostraca**—11
—Shell not clam like.....**Notostraca**

11—Shell spheroidal without lines of growth—(LIMNETIDAE).....**Limnetis**
—Shell with concentric lines of growth.....(LIMNADIIDAE)—12

12—Shell with 4 to 5 lines of growth.....**Eulimnadia**
—Shell with 18 to 22 lines of growth. Pediculated dorsal organ on front of head—**Limnadia**; no dorsal organ present.....**Estheria**

13—Shell restricted to the brood chamber; feet flattened and jointed—GYMNOMERA—*Polyphemus pediculus* (fig. 13); *Leptodora kindti* (fig. 15).
—Shell covering the body; feet not distinctly jointed.....CALYPTOMERA—14

14—Six pairs of feet; foliacious.....CTENOPODA—15
—Five or six pairs of trunk limbs, first two pairs more or less prehensile—ANOMOPODA.19

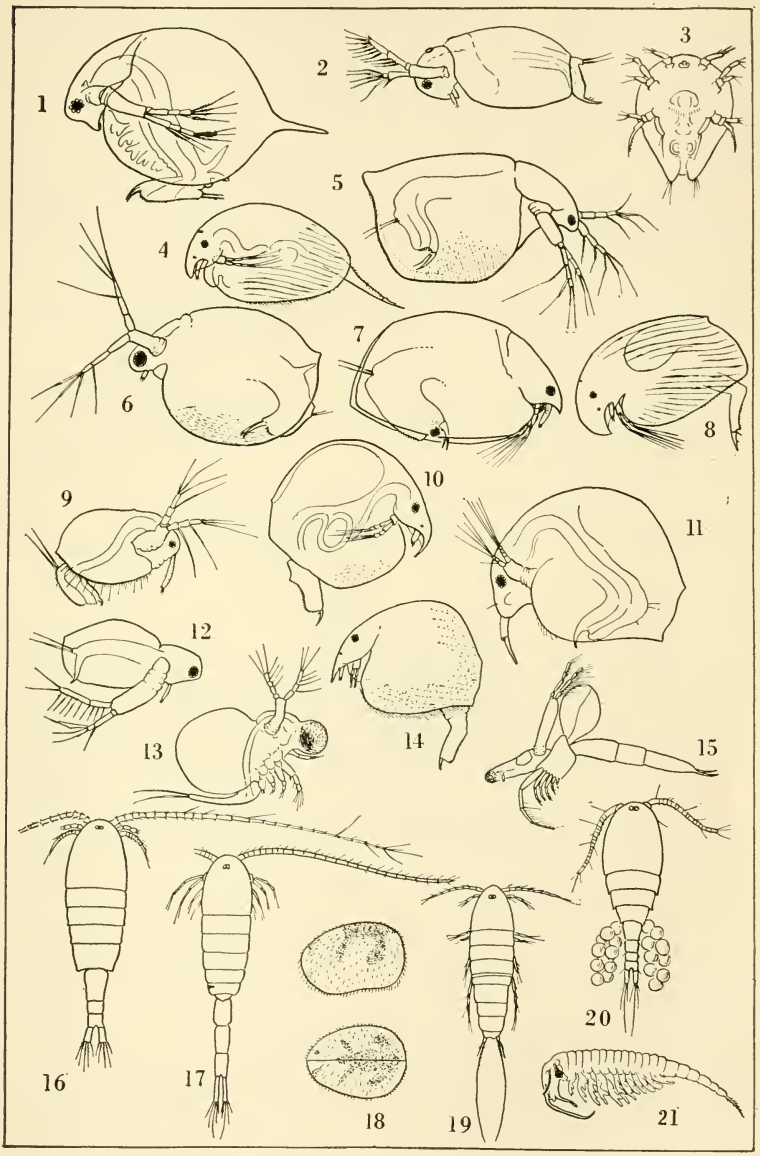
(*Continued on page* 62)

Plate 24. Crustaceans

1, Daphnia
2, Sida
3, Nauplius
4, Camptocercus
5, Simocephalus
6, Ceriodaphnia
7, Eurycerus
8, Acroperus
9, Macrothrix
10, Chydorus
11, Bosmina
12, Diaphanosoma
13, Polyphemus
14, Alonella
15, Leptodora
16, Diaptomus
17, Limnocalanus
18, Cypridopsis
19, Canthocamptus
20, Cyclops
21, Eubranchipus

Acroperus, 8
Alonella, 14
Bosmina, 11
Camptocercus, 4
Canthocamptus, 19
Ceriodaphnia, 6
Chydorus, 10
Cyclops, 20
Cypridopsis, 18
Daphnia, 1
Diaphanosoma, 12
Diaptomus, 16
Eubranchipus, 21
Eurycercus, 7
Leptodora, 15
Limnocalanus, 17
Macrothrix, 9
Nauplius, 3
Polyphemus, 13
Sida, 2
Simocephalus, 5

Plate 24. Crustaceans



(*Continued from page* 60)

15—Swimming antennæ of female two branched, the dorsal with many lateral and terminal setæ.....(SIDIDAE)—16
—Animal enclosed in a large globular, transparent, gelatinous case open ventrally and forming two valves. Antennæ of female with single ramus—(HOLOPEDIDAE).....
.....**Holopedium**

16—Dorsal ramus 3-jointed, ventral ramus 2-jointed; beak present (fig. 2).....**Sida**
—Dorsal ramus 2-jointed; ventral ramus 3-jointed.....17

17—Dorsal ramus with interior process or expansion on basal joint.....**Latona**
—Dorsal ramus without process.....18

18—Posterior margin of shell valves with several long setæ; Eyes dorsal far from insertion of antennule—**Latonopsis.** Eye ventral or in middle of head...**Pseudosida**
—Posterior margin of shell valves without setæ (fig. 12).....**Diaphanosoma**

19—Second antennæ with superior branch 4-segmented; inferior branch 3-segmented..20
—Second antennæ with both branches 3-segmented.....CHYDORIDAE—28

20—With 5 pairs of feet; first antennæ small, if rarely large (as in Moina) then not inserted at anterior end of head; intestine with 2 hepatic caeca....DAPHNIDAE—21
—First antenna long; often with 6 pairs of feet; usually no hepatic caeca.....22

21—Head of female with beak. Head keeled above, no transverse suture on neck, shell with polygonal marks and with posterior spine (fig. 1)—**Daphne;** spine on shell produced in a straight line with the ventral margin, shell with indistinct net like markings—**Scapholeberis;** spine absent or very short and blunt; markings of transverse lines (fig. 5).....**Simocephalus**
—Head without a beak. First antenna of female very short, head small and depressed (fig. 6).—**Ceriodaphnia;** first antenna large, head high.....**Moina**

22—First antenna large and fixed; 6 pairs of feet (fig. 11)—BOSMINIDAE.....**Bosmina**
—First antenna long and freely movable.....MACROTHRICIDAE—23

23—Intestine convolute.....24
—Intestine simple.....26

24—Valves with spines at upper posterior angle.....**Ophryoxus**
—Spines absent.....25

25—Convolutions of intestine in middle of body. Dorsal margin of shell with conspicuous short backward pointing tooth about the middle—**Drepanothrix;** no dorsal tooth
.....**Parophryoxus**
—Convolutions of intestine in hind part of body. Posterior margin of shell truncated —**Acantholeberis;** posterior margin rounded with slighly pointed protuberance in middle.....**Streblocerus**

26—Upper posterior margin of shell truncated diagonally; general form oval-triangular the head constituting the apex. Ventral and posterior edges of valves enormously dilated.....**Ilyocryptus**
—General form ovate, upper posterior margin of shell rounded, not truncated. Setæ on ventral margin of shell only.....27

27—Setæ long, movable, spine like, and projecting in several directions (fig. 9).....
.....**Macrothrix**
—Setæ short and close set; mid-posterior extremity forming apex of roughly heart shaped shell.....**Lathonura**

28—Anus at extremity of post abdomen; 2 hepatic setæ (fig. 7).....**Eurycercus**
—Anus on dorsal side of post abdomen; no hepatic setæ.....29

29—Head and back with high keel; post abdomen very long and slender; with marginal and lateral teeth (fig. 4).....**Camptocercus**
—Not with all the above characters.....30

30—Hind margin of shell not much less than greatest depth.....31
—Hind margin of shell much less than greatest depth.....32

31—Body compressed; claw on the concave side with one or two teeth in the middle. Shell with crest,—**Kurzia,** and **Acroperus** (fig. 8); no crest, post abdomen with marginal and lateral teeth.....**Alonopsis, Euryalona**
—Body not much compressed; claw without tooth or with basal tooth only. Beak not produced much beyond first antennæ—**Oxyruella, Leydigia, Alona, Graptoleberis;** beak much longer than the first antennæ—**Alonella** in part and **Rhynchotalona.**

32—Body noticeably longer than wide–**Pleuropus, Alonella** in part.....**Dunhevedia**
—Body spherical or nearly so.....33

33—Post abdomen short with prominent pre-anal angle (fig. 10).....**Chydorus**
—Post abdomen large, pre-anal angle not conspicuous (fig. 14).....**Alonella**

34—Last pair of trunk limbs bent backwards within the shell and not used for locomotion. CYPRIDIDAE. About 12 eastern genera. *Cypridopsis vidua* is most common. It has a broad shell marked dorsally and laterally with three prominent dark bands (fig. 18).
—Last pair of trunk limbs directed downwards and used for locomotion—CYTHERIDAE. The genus **Limnicythere** is a free swimming freshwater form.

PART II

PRACTICAL EXERCISES IN FRESH-WATER BIOLOGY

Suit the order to season and weather.

Select according to locality and available materials.

Repeat when desirable in a new place or season.

Permanent records will be of scientific value.

The text to accompany these exercises is Needham and Lloyd's *Life of Inland Waters.**

COLLECTING METHODS AND APPARATUS

For fishes, frogs and salamanders the best collecting methods are those of the fisherman, who uses nets, seines and traps. His minnow pails and live boxes are also the best means of keeping living material. These have been evolved through age-long experience.

Fig. 3. A lifter, made by folding the edges of a rectangular strip of wire cloth, say 3 x 6 inches. The lower edge should be a woven edge. A tinner's shears and 4-inch folding tongs are the tools needed for making this and the two next following pieces of apparatus.

For the commoner invertebrate animals, nets and retainers of a finer mesh must be used, and special aids for the discovery and manipulation of these smaller forms are desirable. The following are recommended:

1. An ordinary white enamelled steel vegetable dish about 7 x 10 x 2 inches is excellent for examining a fresh catch. When a dip net is dumped into the dish, the animals at once swim or crawl out from the trash and are easily seen against the white background. They can be picked up easily and uninjured on the bug lifter shown in figure 3.

2. A hand screen such as is shown in figure 4 is the most useful single tool for collecting small animals from rapid streams. It is held in the current by one person while another turns stones on the upstream side. The dislodged insects, etc., are washed by the current upon the screen, which is then lifted from the water. The larger and more conspicuous of them may be picked off by hand; but it is better to dump the catch into a white lined dish, as described above, and then to use a bug lifter. All of them, big and little, may be found in this way.

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If the handles are made of light wood, such as willow or cypress, the dumping is easy. Bring the two handles together and grasp them with one hand, and dash them downward against the other hand held stiffly over the dish of water. If aimed aright the catch will all be discharged by the jolt into the dish.

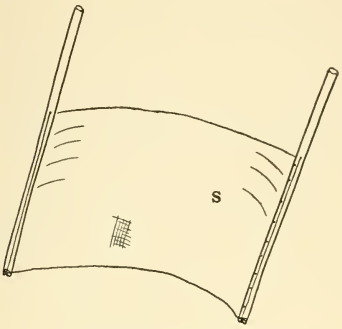


Fig. 4. Hand screen for stream collecting. S is a sheet of wire screen 1 x 2 feet, woven edge below. The opposite edge, if not also woven, should be folded neatly, leaving no projecting wire-ends to prick fingers. The folded ends of the cloth are inserted in slots sawed in the handles and nailed fast there.

3. If material is to be kept alive, there is no better retainer for it than the pillow cage shown in figure 5. It may be made of any desired mesh or dimensions. It may be immersed in stream or pond or tank. Half immersed it makes a good rearing cage for aquatic insects. A square yard of wire cloth makes four cages of suitable size for this.

4. Dip nets such as are sold by dealer's in collector's supplies, are useful for light work about weed beds in ponds.

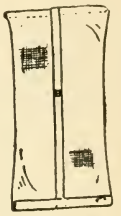


Fig. 5. Wire Cage made from a square of wire cloth by first folding edges together (as at *a*) to form a cylinder, and then cross folding the ends. It opens easily and closes securely with the fingers. Top edges should be woven or else there will be pricked fingers.

5. A sieve net of metal, well braced and strong, is most desirable for collecting bottom forms. It gathers the mud and sifts it at one operation. It is supplied with a long handle and is used as a rake from the shore. Where there is much loose trash on the bottom a common garden rake will answer some of the same purposes.

6. A very satisfactory dredge for use in any depth of water may be made out of the sieve net if a short wooden handle be substituted for the long one, a cord attached to its tip and the net be lowered and dragged from a slow moving boat. The bottom stuff when brought to the surface is sifted before removal.

7. Plancton nets of fine silk bolting cloth are needed for obtaining the microscopic life of the open water. These are obtainable from dealers in biological supplies. No. 12 silk is of the mesh best suited to gathering a good catch quickly and in considerable variety.

For drawing waterweeds ashore many kinds of weed hooks have been devised; but we have found nothing better than the weighted ring of barbed wire. A few other standard tools, such as hay knife and marl sampler for the bog study, are mentioned under the particular studies for which they are useful aids.

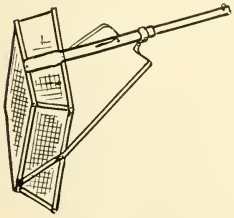


Fig. 6. Sieve net with detachable handle. As shown, it is supplied with a short handle and tow-line, ready to be used as a dredge. Sifting is done before lifting from water. Weight the bottom of the net for dredging.

EQUIPMENT

For the work outlined in the following pages certain equipment is desirable:

1. *Personal equipment.*
   (*a*) Clothing suitable for field work.
   (*b*) Note book, soft pencil for labelling, hard pencil for drawing and red and green pencils for diagrams.
   (*c*) A pocket lens.
   (*d*) Containers, suitable for brining materials collected back to the laboratory in fit condition for study. Quart glass jars for living materials, and vials of alcohol for "pickles" are recommended.
   These things the student should take and care for in the field.

2. *Equipment for common use.*
   That part of it needed for each study should be provided by the instructor, delivered at the place where needed for use, and returned to storage afterward. The numbers in parentheses after the items in this list indicate the pieces required for a field class of twenty students: Pans (10), lifters (20) and pails (2), dip nets (10) and sieve nets (3), seines (1), hand screens (5), and weed rings (2), plancton nets (1) and thermometers (1).

A recently devised net for general collecting, one that will serve for more uses than any other known to us, is the apron net shown in figure 7. It is so shaped at the front that it may be pushed through water weeds or under bottom trash. Its wide-meshed cover allows the animals to enter while keeping out the weeds and coarser trash. A final push through the water lands the catch at the rear, where it is easily accessible for picking-over by hand.

The smaller animals that are mixed with the trash in the net may best be found by dumping the contents of the net into a white dish, where they will at once reveal their presence by their activity. They may be taken from the water most easily and without injury on a lifter such as is shown in figure 3.

This net may also be used for scraping up and sifting the bottom mud and sand to obtain burrowers. It may be used for collecting the insects and other animals that abound among the loose stones in rapid streams by setting it edgewise against the bottom facing upstream and stirring the stones above it. The animals, dislodged by the stirring, will be swept by the current into the net.

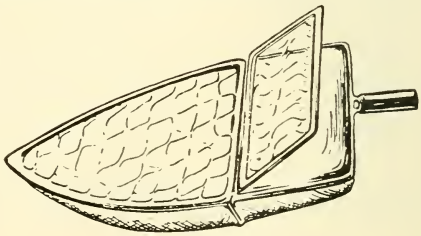


Fig. 7. The Apron Net.

Old leaf drifts, caught on obstructions in the current, may be stirred in the same way to get the animals hiding in them; but more stirring and overturning of the leaves will be necessary to dislodge them.

A. LAND-AND-WATER STUDIES

STUDY 1

LOCAL HYDROGRAPHY

Materials needed: Maps in blank for individual use:

1. Drainage map of the region (state or province) with streams and lakes indicated.
2. Local map covering the area to be traversed by the class.
3. Detail maps of particular bodies of water.
4. Topographic quadrangles (U. S. Geol. Surv.)

Work Program:

1. Study of these maps.
2. Reading.
   (a) Chapter I in the text, *Life of Inland Waters.*
   (b) Local geography and hydrography (whatever is available).

*For Record:**

1. On map 1 mark:
   (a) Your own location.
   (b) The location of any biological field stations, state or national fish hatcheries, or other large enterprises of limnological interest.
   (c) Large parks and reservations.
   (d) The principal drainage areas (do this by drawing a red line along the divide between principal watersheds).
2. On map 2 mark the location of:—
   (a) The choice aquatic collecting grounds of your locality.
   (b) The location of principal springs and marshes, swamps and bogs.
   (c) The falls, dams and swimming holes in the streams.
   (d) The lakes and ponds.
   (e) The more popular fishing grounds.
3. On detail maps of local hydrography (may be deferred to studies 4 and 5).
   (a) If of a lake or pond or bay, soundings being given, draw contours (with appropriate contour interval) and indicate by wash of colors the areas of bottom that differ in character and in vegetation (if known).
   (b) If of a stream, draw a profile (adjusting longitudinal and vertical scale to the dimensions of your note book: data for this may be taken from U. S. Geol. Surv. topographic quadrangles).

* Data for this exercise are to be supplied largely by the instructor.

STUDY 2

THE LOCAL WATER SUPPLY

Work Program:

1. A study of local weather records of rainfall and temperature (Summaries supplied by the U. S. Weather Bureau).
2. An inspection of a local water purification plant. (The courteous cooperation of the manager of the plant will be necessary.)
3. Reading in text *Life of Inland Waters*, pp. 25 to 42 and in Ward and Whipple's *Fresh Water Biology*, Chapter XXXI.

For record include:

1. Plotted curve of mean annual precipitation by months.
2. The same, for temperature.
3. A brief statement of the source of the local supply of public drinking water (with sketch map, if not already shown on the maps of Study I); nature of supply; catchment area; principal sources of pollution therein; location of filter plant; place of storage after filtration, etc.
4. A simple diagram to explain treatment of the water as it passes through the filter plant. Show where (1) coagulation, (2) sedimentation, (3) filtration and (4) sterilization successively occur and tell means whereby accomplished.

STUDY 3

A POND

Work Program:

1. An examination of the physical features of a small pond.
2. Reading in *Life of Inland Waters*, pp. 59 to 76.

For Record include:

1. A sketch map of the pond (showing bottom contours, if soundings have been made).
2. Vertical section of same, with longitudinal and vertical scale selected to fit size of note book used.
3. A description of the pond with notes arranged under the following principal headings:
   - A. Name: kind of pond (mill-dam, natural pond, etc.)
   - B. Water: its color, transparency, temperature, etc.
   - C. Banks: elevation, percentage of area, overhung, vertical, sloping, flat, etc.
   - D. Bed:
     - (a) Percentage of its area covered with mud, sand, gravel, boulder, flat rock, hard clay, etc.
     - (b) Percentage of its area covered with emergent and floating plants, with submerged weed beds.
   - E. Miscellaneous: Pollution, sources, nature, and other artificial alterations; constructions, plantings, etc.

Study 4

A STREAM

Work Program:

1. An examination of the physical features of a local stream.
2. A gathering from maps, charts, surveys, etc., of such data as may be available concerning it.
3. Reading in the *Life of Inland Waters*, pp. 77 to 88 about streams in general, and in such works as may be available about the particular stream selected for this study.

For Record include:

1. A sketch map of the entire stream.
2. Detail maps of any part of it that are to be selected for special study later.
3. A profile (unless done under Study I).
4. A description of it with notes arranged under the following principal headings:

A. The stream: its sources, affluents, outlet, length and volume and permanence

B. The water: its color, turbidity, temperature and chemical character.

C. The stream bed.

(a) Its configuration—falls, riffles and runs—their height, length and continuity. Plunge, scour and settling basins.

(b) Its materials—fixed ledges, stones, logs, etc.—shifting gravel, sand, mud, etc.

D. The banks:

(a) Their elevation (at mean water level) and uniformity.

(b) Relation of channel, flats and shoals.

(c) Shore vegetation and shade.

(d) Changes due to eroding, aggrading and obstructions.

E. Habitats: percentage in falls and riffles.
percentage in runs.
percentage in slack water (no visible current).
percentage in mill dams and ponds.

F. Miscellaneous: pollution: its places, sources, nature, extent.
Other artificial alterations; constructions; plantings, etc.

STUDY 5

A LAKE

Work program:

1. An examination of the more available physical features of a lake.
2. Assembling from maps, charts, etc., such data as may be available concerning it.
3. Reading *Life of Inland Waters*, pp. 59 to 76.

For Record include:

1. A map of the lake with bottom contours.*
2. Detail map of any small part of it selected for special study.
3. A profile diagram of it, cross-lined at regular temperature intervals (mid-summer records being available) to show thermocline.
4. A description of the portion examined in detail, with notes arranged under the following headings:
   A. Areas examined: form, depth, embayments, affluents, etc.
   B. Water: transparency, temperature, chemical character, etc.
   C. Shore line: elevation, percentage eroding, aggrading, etc.
   D. Bed: percentage of area covered with emergent and floating plants, submerged weed beds, with algæ, or bare.
5. Miscellaneous:
   (a) Pollution, sources, nature.
   (b) Other artificial alterations, constructions, plantings, etc.

STUDY 6

A MARSH

Work Program:

1. An examination of the physical features of a marsh.
   (a) By inspecting the vegetation.
   (b) By sampling the water.
   (c) By probing the bottom with a marl sampler.
2. A study of such topographic and other maps are are available.
3. Reading in the *Life of Inland Waters*, pp. 89 to 97.

* Unless already done under Study I.

For Record include:

1. A sketch map of it, showing the location of the main features mentioned below.
2. Sections of it showing (to a scale) height of vegetation and depth of bottom muck or marl, as well as depth of water.
3. A description of it with notes arranged under the following headings:
   - A. Name: kind of marsh (as marked by dominant vegetation), area, shape elevation; affluents, outlet, included islands and ponds, etc.
   - B. Water: color, transparency, temperature, chemical character, etc.
   - C. Bottom: (describe by layers the places selected for study).
   - D. Vegetation: give the percentage areas covered by principal dominant types by submerged vegetation and by open water.
   - E. Miscellaneous:
     (a) Pollution: sources, nature.
     (b) Other artificial alterations—drainage ditches and other constructions.

B. ASSOCIATION STUDIES

STUDY 7

POND LIFE

Work Program:

1. A trip to a pond for:
   - A. Individual hand picking and dip net collecting.
   - B. Seine, sieve net and weed ring collecting.
2. A laboratory examination of the catch.
3. Reading in the *Life of Inland Waters*, pp. 314 to 341.

For Record include:

1. The name of the pond and a brief statement of its location and chief physical characteristics—area, depth, transparency, etc.
2. An annotated list of the organisms collected, arranged under the following column headings:
   - I. Plants—with notes on size, color, relative abundance, habitat, growth habits, etc.
     - A. Seed plants—emergent—floating—submerged.
     - B. Algæ—microscopic ones, only when these appear in masses or tinge the water with color.
       Fringing (sessile) algæ.
       Slime-coat algæ.
       Free floating algæ.

II. Animals—with notes on size, relative abundance, feeding habits, stages or ages found, habitats and special adaptations, and activities.

A. Vertebrates—fishes—others.

B. Invertebrates.

(a) Free swimming.

(b) On the surface.

Walking on the surface.

Lying in the surface film.

Suspended from the surface film.

(c) On the vegetation (and on other supports).

Sessile forms.

Free ranging forms.

Tube dwellers.

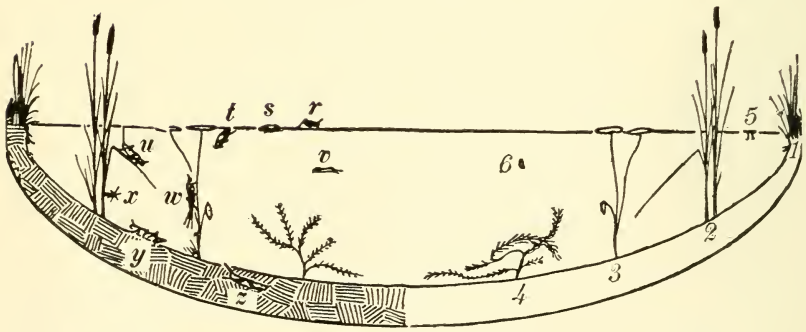
(d) On the bottom.

Sprawlers.

Burrowers that dig.

Burrowers that squeeze through.

Tube dwellers.



3. Make this diagram over to suit the pond studied. Write in the names of the most typical forms of each stratum.

STUDY 8

THE LIFE OF A RAPID STREAM

Work Program:

1. A trip to a swift flowing, preferably stony, brook for:
   - A. Individual collecting by hand picking from stones, logs and leaf drifts.
   - B. Hand screen, sieve net, and seine collecting.
2. A laboratory examination of the materials collected.
3. Reading in the *Life of Island Waters*, pp. 258 to 261; 363 to 376.

For Record include:

1. A sketch map of the bit of stream examined showing the types of habitats from which collections were made: falls, rapids, runs, scour-basins, bars, mud beds, etc.
2. An annotated list of the organisms collected arranged under the following headings:
   - I. Plants—with notes on size, relative abundance, habitat, growth habits, etc.
     - A. Seed plants—in current and in edges.
     - B. Algæ—microscopic ones only when these appear in masses or color the bottom.
       - Fringing (sessile) algæ.
       - slime coat algæ.
       - Encrusting algæ.
   - II. Animals with notes on size, color, relative abundance, feeding habits, stages or ages found, habitat and special adaptations or activities.
     - A. Vertebrates, fishes and others.
     - B. Invertebrates.
       - Free-ranging.
       - Sessile, on the stones or on bottom.
       - Burrowers that dig.
       - Burrowers that squeeze through.
       - Tube dwellers.

STUDY 9

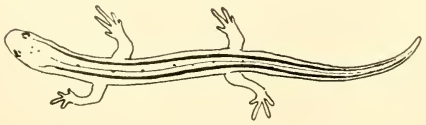
THE LIFE OF A SLOW STREAM

Work Program:

1. A trip to a meandering bottom-land stream for:
   A. Individual hand picking and dip net collecting from leaf drifts, brush and trash trailing in the edges.
   B. Seine, sieve net and weed-hook collecting.
2. A laboratory examination of the catch.
3. Reading in the *Life of Inland Waters*, pp. 363 to 376.

For Record include:

1. A sketch map of the bit of stream examined, showing types of habitats from which collections were made; open channel, obstructions, settling basins, bars, etc.
2. An annotated list of the organisms collected arranged under the following headings.
   I. Plants—with notes on size, color, relative abundance, habitat, growth habits, etc.
      A. Seed plants—in the edges and in the settling basins.
      B. Algæ—microscopic ones only when these appear in masses.
         Fringing (sessile) algæ.
         Slime-coat algæ.
   II. Animals—with notes on size, color, relative abundance, feeding habits stages or ages found, habitat and special adaptations or activities.
      A. Vertebrates fishes and others.
      B. Invertebrates:
         Free ranging.
         Sessile.
         Burrowers that dig.
         Burrowers that squeeze through.
         Tube dwellers.



STUDY 10

THE LIFE OF A LAKE SHORE

(Macroscopic)

Work Program:

1. A trip to a lake for:
   - A. Individual collecting by hand picking at the shore line and dip net collecting in the shoals.
   - B. Seine net and trap collecting (the aid and equipment of professional fishermen should be utilized for this).
   - C. Sieve net, dredge, and weed-hook collecting from a boat.
2. A laboratory examination of the catch.
3. Reading in the *Life of Inland Waters*, pp. 251 to 258; 315 to 325.

For Record include:

1. A sketch map of the shore visited, showing areas of emergent vegetation, of submerged weed beds, of bare bottom, etc., with depths.
2. An annotated list of the organisms collected arranged under the following headings:

   I. Plants—with notes on size, color, relative abundance, growth habits, etc.

   A. Vascular plants:
   Emergent at shore. Floating. Rooted, with floating leaves.
   Wholly submerged (in what succession with increasing depth).

   B. Algæ—Microscopic ones, only when these appear in masses or tinge the water with color.
   Free floating algæ. Fringing (sessile) algæ. Slime-coat algæ.

   II. Animals—with notes on size, color, relative abundance, feeding habits, stages or ages found, habitat and special adaptations or activities.

   Vertebrates—fishes and others.

   Invertebrates:
   Free swimming.
   On surface.
   On vegetation:
   Sessile.
   Free ranging.
   In tubes.
   On bottom:
   Sprawlers.
   Burrowers that dig.
   Burrowers that squeeze through.
   Tube dwellers.

STUDY 11

THE LIFE OF A FLOOD-PLAIN MARSH

Work Program:

1. A field trip to a marsh for the purpose of:
   A. Individual collecting by hand picking from the stems and leaves of aquatic plants and from fallen brush and logs; also dip net collecting from pools.
   B. Sieve and seine collecting from the more open water areas.
2. A laboratory examination of the catch.
3. Reading in the *Life of Inland Waters*, pp. 261 to 281; 341 to 348.

For Record include:

1. A sketch map showing the collecting places.
2. An annotated list of the organisms collected and observed, arranged under the following headings:

   I. Plants—with notes on size, color, relative abundance, growth habits, etc.

      A. Vascular plants—mosses.
         Emergent.
         Floating.
         Wholly submerged.

      B. Algæ—microscopic ones, only when these appear in masses, or tinge the water with color.
         Free floating algæ.
         Fringing (sessile) algæ.
         Slime-coat algæ.

   II. Animals—with notes on size, color, relative abundance, feeding habits stages or ages found, habitat and special activities.

      A. Vertebrates:
         Fishes.
         Other vertebrates.

      B. Invertebrates:
         Free swimming.

         On surface.

         On vegetation.
            Sessile.
            Free ranging.
            In tubes.

         On bottom:
            Sprawlers.
            Burrowers.
            Tube dwellers.

STUDY 12

THE LIFE OF AN UPLAND SWAMP OR BOG

Work Program:

1. A collecting trip for the purpose of:
   - A. Individual collecting by hand picking from the vegetation withdrawn from the water and by dip nets from the pools.
   - B. Sieve net and seine collecting from the more open waters.
   - C. Examination of the bog cover or swamp tussocks or both by means of slicing them with a hay knife.
   - D. Examination of the bottom by means of a marl sampler (if not done in Study 6).
2. A laboratory examination of the materials collected.
3. Reading in the *Life of Inland Waters*, pp. 348 to 355.

For Record include:

1. A sketch map showing the location of the collecting places.
2. Diagrams showing the composition and stratification of the bog cover and tussocks with some of the more important component plants named in the diagrams.
3. Diagram showing zonal arrangement of vegetation about the borders.
4. An annotated list of the plants and animals collected and observed arranged under the following headings:

   I. Plants—with notes on size, color, localization, relative abundance, growth habits, etc.

   A. Vascular plants and mosses.
   1. Bog cover plants by zones.
   2. Tussock-forming plants and "fillers."
   3. Scatterlings.

   B. Algæ—microscopic ones, only when these appear in masses.
   Free floating algæ.
   Fringing (sessile) algæ.
   Slime-coat algæ.

   II. Animals—with notes on size, color, relative abundance, feeding habits, stages or ages found, habitat and special activities.

   A. Vertebrates:
   Fishes.
   Other vertebrates.

   B. Invertebrates:
   Free swimming.
   On surface.
   On vegetation:
   Sessile.
   Free ranging.
   In tubes.

   On bottom:
   Sprawlers.
   Burrowers.
   Tube dwellers.

STUDY 13

THE LIFE OF ROCK LEDGES* IN A STREAM BED

Work Program:

1. A trip to a stream where the water flows over rock ledges, for:
   A. Individual collecting by hand picking.
   B. Hand screen collecting of scrapings and other dislodgments.
2. A laboratory examination of the catch.
3. Reading in the *Life of Inland Waters*, pp. 258 to 261; 363 to 375.

For Record include:

1. A sketch map of the ledges.
2. A diagrammatic profile showing the localization of the principal organisms found.
3. An annotated list of the organisms collected, arranged under the following headings:

   I. Plants—with notes on size, color, relative abundance, habitat, growth habits, etc.
      A. Vascular plants (mosses in crevices, etc.)
      B. Algæ—microscopic ones, only when these appear in masses, or color the ledges.
         Fringing (sessile) algæ.
         Slime-coat algæ.
         Encrusting algæ.

   II. Animals—with notes on size, color, relative abundance, feeding habits, stages or ages found, habitat and special adaptations or activities.
      A. Vertebrates—salamanders.
      B. Invertebrates.
         Free ranging:
            Exposed on top of stones.
            Under shelter of stones and in crevices.
         On vertical face of stones.
         Sessile.
         Tube dwellers.

* A sluice-way of a mill or of a power plant (if flow is permanent) will offer similar conditions.

Study 14

THE LIFE OF A SPRING BROOK

Work Program:

1. A field trip for the purpose of:
   A. Individual collecting by hand picking from sticks and stones lifted from the water, and from roots and stems trailing in the edges and from watercresses, and by means of dip nets from the pools.
   B. Hand screen collecting from the riffles and sieve net collecting from the sand bars and mud of the basins.
2. A laboratory examination of the materials collected.
3. Reading in text, *Life of Inland Waters*, pp. 57, 58; 77–88 and 363–376.

For Record include:

1. A sketch map showing collecting places.
2. A tabular statement naming a few of the forms most characteristic of the following situations:
   (a) On exposed surfaces of stones.
   (b) In sheltering crevices beneath stones and gravel.
   (c) In sand and gravel bars.
   (d) In mud beds of settling basins.
   (e) On roots and trailing in the edges of the current.
3. An annotated list of the organisms studied arranged as follows:

   I. Plants—with notes on size, relative abundance, habitat, growth habits, etc.
      A. Seed plants—in current and in edges.
      B. Algæ—microscopic ones only when these appear in masses or color the bottom.
      Fringing (sessile) algæ. Slime-coat algæ. Encrusting algæ.

   II. Animals—with notes on size, color, relative abundance, feeding habits stages or ages found, habitat and special adaptations or activities.
      A. Vertebrates—fishes and others.
      B. Invertebrates:
      Free ranging.
      Sessile, on the stones or on bottom.
      Burrowers that dig.
      Burrowers that squeeze through.
      Tube dwellers.

STUDY 15

THE "BLANKET ALGAE" ASSOCIATION

This is a study of some of the minute animals and plants that live in floating masses of green algæ in still water. If pailsful of such material be gathered (as by lifting it gently from the water with a dip net), brought into the laboratory and distributed in white-bottomed dishes for individual student's use (a handful in each dish), and left standing undisturbed for a few minutes, there will be good collecting with a dropping tube about the edges of the dish. There will be algæ in variety, and many kinds of minute animals. A moment's inspection of the latter will show that they differ in size, color, form, speed and manner of swimming.

This is a study of the forms that are large enough to be discovered with the unaided eye, and small enough to be picked up with an ordinary dropping tube. They are to be placed on slides for examination with a microscope.

Work Program:

1. A laboratory examination of samples of the floating "blanket algæ" from some pond or pool or sheltered bay.

2. Reading in the text about the several groups of which representatives are found. Emilie L. Platt's *Population of the Blanket Algae of Pools* (Amer. Nat. 49: 752) may be consulted with profit.

For Record include:

1. A brief statement of the nature and source of the materials examined.

2. An annotated and illustrated list of the organisms found with notes on all of them and with simple outline sketches of representatives of the groups named below:

   I. Plants—with notes on size, color, growth habit, etc.

      Diatoms. Desmids. Blue greens.

      Filamentous green algæ. Other green algæ.

   II. Animals—with notes on size, color, stages or ages found, habits of locomotion, of feeding, etc.

      Insects (very young stages of such as mayflies, dragonflies, damselflies, bugs, caddisflies, midges,* mosquitoes and other two-winged flies, and beetles.

      Crustaceans (scuds, cladocerans, copepods and ostracods.

      Molluscs (snails).

      The larger rotifers.

      Other invertebrates especially water mites, hydras, young leeches, and bristle worms).

* Recognizable in swimming by their figure-of-8 loopings.

STUDY 16

PLANCTON

Work Program:

1. A laboratory examination of a fresh catch of surface plancton from a lake or pond (obtained by drawing a towing net of No. 12 silk bolting cloth through the water: should be used at once after taking, so that the activities and natural colors of the living organisms may be noted).*
2. Reading in *Life of Inland Waters*, p. 18, 242–249 and 295–312. Also, such reference works on plancton as may be available.

For Record include:

1. An annotated list of the plancton organisms found arranged under the following headings:

   I. Plants—with notes on size, color, relative abundance, growth habit and lice aggregation (illustrate these with simple diagrams), flotation devices, etc.
   Diatoms.
   Desmids.
   Blue greens.
   Green algæ.
   Miscellaneous plant fragments.

   II. Animals—with notes on size, relative abundance, feeding habits, swimming habits, egg-carrying habits, etc.
   Protozoans.
   Rotifers.
   Crustaceans.
   Miscellaneous animals and animal products (eggs, statoblasts, shells, etc.).

* To concentrate plancton, pour the water containing it through fine silk bolting cloth in a funnel whose converging sides dip below the surface of water in an overflowing jar. Take the concentrate from the funnel with a dropping tube, and mount on slides for the microscope.

C. ADJUSTMENT STUDIES

STUDY 17

HIBERNATING DEVICES OF SOME AQUATIC ANIMALS

Materials needed: Preserved specimens of:

Cladocerans bearing ephippia with winter eggs.
Bryozoans bearing hibernacula.
Freshwater sponges bearing hibernacula.
Slide mounts to show the lesser details.

Work Program:

1. A laboratory examination of the materials provided.
2. Reading in text *Life of Inland Waters*, pp. 164–169 and 261–268, and in advanced text books of zoology, about the life cycle in these three groups, and in rotifers.

For Record

1. Sketch carefully:
   (a) A Cladoceran (Daphnia) with developing ephippium.
   (b) A mature free-floating ephippium containing two winter eggs.
   (c) A spray of skeleton of a Bryozoan (Plumatella) showing receptacles for several zooids.
   (d) A hibernaculum of Plumatella showing layers.
   (e) A hibernaculum of Pectinella showing layers and marginal hooks.
   (f) One or more hibernacula of a fresh-water sponge (Spongilla) showing outlet tube.
   (g) A hibernaculum of Carterius showing outlet tube.
   (h) Spicules of flesh and hibernaculum of same, highly magnified.
2. Label these drawings so as to indicate sources and significance of the things seen.

STUDY 18

REPRODUCTIVE METHODS IN FRESH-WATER MUSSELS

Materials needed: (A) Living gravid mussels representing the families Spheriidæ and Unionidæ.

(B) Microscopic preparations: sections of normal and gravid gills: slide mounts (glochidia, etc.).

Work Program:

1. A laboratory examination of the above materials.
2. Reading in the text, *Life of Inland Waters*, pp. 180–182 and 287–292.

For Record include:

1. Sketches of Spaerium, an adult and the largest young found inside it, side by side, and to the same scale.
2. Diagram of a side view of Anodonta with one valve removed, foot, body, and gills uncovered, to show brood pouch.
3. Diagram side by side of two chambers each of normal and gravid gills of Anodonta from slides.
4. Sketches of glochidia in two positions.
5. Explanation of figures, and notes adequate to indicate the contrast in reproductive methods in the families of Unionidæ and Sphæriidæ.

Study 19

A LABORATORY STUDY OF THE GILLS OF INSECTS

Materials needed: (A) *Living larvae* having gills of the following types:

1. Blood gills (as in Chironomus, Culex, or Corethra).

2. Tracheal gills.
   (a) External: filiform (as in Hydropsyche or in Perla); lamelliform (as in Enallagma or Bætis).
   (b) Internal (as in Libellula, Anax, Gomphus).

(B) *Preserved specimens:*

1. Of gill-bearing larvæ (in variety).

2. Of pupæ showing tube gills.

Work Program:

1. Mount a living larva having blood gills in a copious supply of water; cover and study the gills directly, noting their number, position and relations. Focus carefully upon one gill to see the outline of its internal cavity, and to see the leucocytes that drift about in it.

2. To study the external tracheal gills, snip off a few gills with fine scissors and mount them in water; cover and examine at once, to see the tracheoles before the penetration of the water into them has rendered these invisible. While filled with air they appear as sharply defined black lines. They are not visible in preserved specimens. Study especially the division of the large tracheæ into fine tracheoles, and the disposition of the latter, and their inter-communications.

3. The internal gills of a dragonfly are arranged in rows upon the inner walls of a gill chamber that is made out of the posterior third of the alimentary canal. It is so fine a piece of respiratory apparatus, so unique in plan, and it exhibits such delicacy and refinement of structure, it is well worth a careful examination.

   It will be well, first, to see the external evidences of its operation. Regular respiratory movements of the abdomen can usually be seen in a nymph that lies quietly in a shallow dish of water. They may often be seen intensified if the nymph be turned over on its back. With the expansion of the abdomen, water is slowly taken in through the anal aperture, to be expelled with its contraction. The currents of the water may be demonstrated by placing some colored fluid in the water close beside the anal opening. This is best done by holding the point of a copying (indelible) pencil until its color is imparted to the water. The forcible ejection of water from this gill chamber as an aid to propulsion may be seen while the nymph is swimming about. Some idea of the force of the expulsion

may be gained by tilting the abdomen of a swimming nymph upward until it touches the surface of the water, when the water in the gill chamber will be shot into the air.

To study the structure of the gill chamber and of the gills themselves, the following method will be found to be expeditious and satisfactory. Kill the nymph by snipping off its head. Then snip off the abdomen at its base, trim off its sharply triangular lateral margins for its whole length; pin it down to the waxed bottom of a dissecting dish that is small enough for use on the stage of a dissecting microscope or under a pocket lens; carefully lift off the roof of the abdomen (already loosened at the sides by the trim-off of the margins), by seizing it in front with the forceps.

This will expose the gill chamber, which occupies the greater part of the abdominal cavity, and terminates the alimentary canal. The severed posterior end of the stomach will be seen in the middle in front, terminated in the rear by a dense cluster of nephridia (Malpighian tubules), and followed by a slender, white, ventrally curved and much concealed intestine, joining it to the gill chamber. On either side of the stomach will be seen a large, silvery white air trunk, which breaks up posteriorly into a great brush of lesser branches that penetrate the walls of the gill chamber. This chamber itself, will be somewhat collapsed; it may be distended by injecting air or water through the anal aperture with a fine-pointed pipette; its longitudinal extent may be seen by lifting the stomach with a forceps and drawing it forward. If turned to one side, a ventral longitudinal tracheal trunk may be seen on either side of the body, breaking up in the rear, like the dorsal trunk, into a multitude of branches, and entering the walls of the gill chamber from below.

Through the transparent walls of the gill chamber may be seen lines of the black pigment that occupies the bases of the internal gill plates. Discovering thus the location of the rows of gills, the chamber may be safely opened by inserting the point of a fine scissors and cutting the wall for its entire length between two rows. The circular muscles of the wall will, by their contraction turn the whole organ inside out, and fully expose the rows of beautiful, feathery, purplish tinted gill plates. Then if a row be isolated with scissors and mounted on a slide in water, a few individual gills may readily be isolated with needles under a dissecting lens, covered, and studied with a microscope.

4. Read in the text, *Life of Inland Waters*, pp. 273 to 281; Ward and Whipple's *Fresh Water Biology*, pp. 876 to 880.

For Record:

1. Prepare sketches and diagrams illustrating the principal type of gills studied.
2. Prepare a table of *Gills of Insect Larvae* writing the names of the insects in the left hand column, grouping them by orders, and having the following column headings:

   Name (of the insect).

   Gill type (blood gill, tracheal gill, tube gill, etc., simple or compound).

   Number (total).

   Form* (in general, filiform, lamelliform, telescopic, retractile).

   Location* (on the body, whose divisions may be conveniently designated as H—I, II, II—1, 2, 3, 4, 5, 6, 7, 8, 9, 10, for head, thorax, and abdomen respectively).

   Differentiation* (all alike or unlike on this insect; and if unlike, differing how).

* A diagram may express this best.

D. ECONOMIC STUDIES

STUDY 20

THE FISH-FORAGE OF A WATER MEADOW

Materials for this study and for Study 21 should be collected at the same time and place this, to show what is present; that, to show what is selected by the fishes.

Apparatus needed: Hedges shears, hand screens, pails, white lined dishes and lifters.

Work Program:

1. Gathering with a seine the small fishes (to be used in Study 21) and other larger active animals present.
2. Individual examination of ¼ square meter of the weed bed* and count of its animal population.
3. Sieve net examination of the bottom mud under some of the sample plats.
4. Reading in text, *Life of Inland Waters*, pp. 377 to 400.

For Record include:

1. A diagram of a vertical section of a bit of the weed bed showing stratification and naming the principal plant and animals in each stratum.
2. A count of the animals present† in the ¼ square meter individually counted. List them by groups. Underscore carnivores in red and herbivores in green.

STUDY 21

A STUDY OF FISH FOOD

Materials for this study should be obtained along with those for the preceding one.

Work Program:

1. A laboratory examination of the contents of the alimentary tract of a number of young fishes to determine what they have eaten.
2. Reading in *Life of Inland Waters*, Chapter VII.

For Record include:

1. The names and lengths and dates of capture of the specimens examined.
2. A table of the foods identified, showing separately for each species, and for each large difference in size and age, the following:
   I. Plants eaten—state and condition, percentages of algæ and fragments of higher plants.
   II. animals—numbers and percentages.
   Other fishes.
   Herbivorous invertebrates, naming kinds as far as possible.
   Carnivorous invertebrates, naming kinds as far as possible.

* Obtain, from an undisturbed part of the weed bed, Elodea, Potamogeton or other dense-growing submerged water weeds by shearing off the weeds at sides and at level of bottom mud with hedge shears, quickly lifting the loosened mass on a hand screen shoved beneath it, and dumping in a pail for subsequent division and examination in the white lined dishes.

† Only such of the animals as are large enough to be taken up with the lifter need be counted. Counts should be careful enough to give an accurate idea of relative abundance. If counts of entire class are averaged the result will be more accurate. Do not overlook the tube-dwelling midge larvæ.

E. DEMONSTRATIONS

STUDY 22

THE EFFICIENCY OF STREAM-LINE FORM

Take a double handful of grafting wax* and manipulate it until it becomes plastic under the warmth of the hands. Embed a slender wire in the middle of the wax, anchoring it there to a centrally located button. Make a loop in each free end, for attachment to the hook of a delicate spring balance.

Then mold the wax successively into each of the four forms suggested below, suspend it on the balance, lower it into a swift, smoothly flowing current of clear water in a chute or trough, and observe the pull:

1. A cone whose section is an equilateral triangle, with the wire in the axis of the cone.
2. An oval (that of a hen's egg) with the wire in its long axis.
3. A mass in the form of a sunfish with the wire in its long axis.
4. A mass in the form of a trout with the wire in its long axis.

Do not alter the amount of wax during the experiment; only change its form. The indicator of the spring balance will oscillate about a mean which is the normal pull, measuring resistance of the current.

For Record:

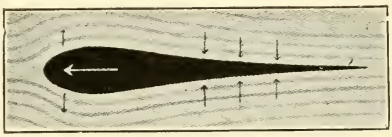
This may be set down in figures as follows:

1. Pull on cone, direct	grams; reversed	grams.
2. Pull on oval, direct	grams; reversed	grams.
3. Pull on sunfish, direct	grams; reversed	grams.
4. Pull on trout, direct	grams; reversed	grams.

* Grafting wax may be purchased from dealers in horticultural supplies. It may be made as follows:

Rendered tallow	1 part
Beeswax	2 parts
Rosin	4 parts

Melt together with moderate heat; pour into a pail of cold water; pull (like taffy) until light colored. Smear hands with tallow while pulling.



STUDY 23

THE RELATION BETWEEN FECUNDITY AND NURTURE IN FISHES

Materials needed:

1. Fishes bearing the full complement of mature eggs.*
2. Photographs and specimens illustrating nesting habits.

The following nurture-types are suggested for use:

A. Fishes that scatter their eggs widely in weedy shoals, giving them no further care: carp, pike, etc.

B. Fishes that seek out better ærated situations in which to oviposit, such as gravel beds in the riffles of streams: suckers, trout, etc.; or that hang their egg-strings up on green water weeds; as yellow perch.

C. Fishes that make simple open nests on the bottom, place their eggs in them and guard the eggs until hatching is over; such as sunfishes, black bass, etc.

D. Fishes that add to this some care for the young after hatching; such as the common catfish, or bullhead.

E. Fishes that build covered nests high up in the weeds and place their eggs inside, and guard the young there after hatching; such as the stickleback.

The Record of this study may be put into a table having the following column headings:

Kind of fish.

Locality whence obtained, and date.

Restriction of egg-laying area.

Preparation and construction of nest.

Extent of care of eggs by male and female.

Extent of care of young by male and female.

Number of eggs laid by a single female.

* Either fresh or preserved specimens will do for this: indeed, preserved ovaries, if whole and well preserved and positively determined, may be used. To save the labor of counting prodigious numbers, measure the ovary and the eggs, and (using the table on the last page herein) compute totals. Get volume by immersing whole ovaries in a graduated beaker of water. Deduct volume of water. Deduct 5% additional for sterile tissue in the egg mass (approximate only, but near enough for the purposes of this study). To get average diameter of eggs, place a line of them in the bottom of a V-shaped groove, side by side and touching, and count the number to the inch: reduce that number to the fractional form used in the table.

STUDY 24

APPARATUS AND METHODS FOR QUANTITATIVE STUDY OF PLANCTON

Quantitative studies of placton are so time consuming as to be unsuited to the work of an elementary class program, but the apparatus and methods used are very interesting, and the biological results, still more so. It is proposed that these be shown in demonstration when materials are locally available.

STUDY 25

FISH-CULTURAL METHODS

If a fish hatchery can be visited, the superintendent (or other qualified person) may be engaged to give a demonstration of the methods used there:

1. In stripping and in fertilizing (inseminating) eggs.
2. In incubating eggs, both heavy and light.
3. In caring for and feeding the fry.
4. In providing for the next-building fishes.
5. In transporting and planting fry and fingerlings, etc.

TABLE FOR FINDING NUMBER OF FISH EGGS OF GIVEN DIAMETER PER LIQUID QUART.

Diameter	Number	Diameter	Number	Diameter	Number	Diameter	Number
Inch		*Inch*		*Inch*		*Inch*	
0.300	2,506	0.230	5,562	0.160	16,521	0.090	92,826
	2,531		5,635		16,835		95,990
	2,557		5,709		17,157		99,297
	2,583		5,785		17,487		102,762
	2,609		5,862		17,825		106,390
0.295	2,636	0.225	5,941	0.155	18,172	0.985	110,190
	2,663		6,021		18,528		114,172
	2,690		6,102		18,894		118,346
	2,718		6,185		19,270		122,730
	2,746		6,269	0.151	19,655		127,333
0.290	2,775	0.220	6,355	0.150	20,050	0.080	132,170
	2,804		6,442		20,456		137,251
	2,833		6,531		20,874		142,600
	2,863		6,622		21,303		148,220
	2,893		6,715		21,744		154,155
0.285	2,923	0.215	6,809	0.145	22,197	0.075	160,400
	2,954		6,905		22,662		166,995
	2,985		7,002		23,140		173,950
	3,017		7,102		23,633		181,300
	3,050		7,204		24,140		189,070
0.280	3,083	0.210	7,307	0.140	24,661	0.070	197,290
	3,116		7,412		25,197		205,992
	3,150		7,520		25,748		215,204
	3,184		7,629		26,316		224,995
	3,219		7,741		26,901		235,377
0.275	3,254	0.205	7,855	0.135	27,504	0.065	246,410
	3,290		7,971		28,125		258,141
	3,326		8,089		28,764		270,631
	3,363		8,210		29,422		283,936
	3,400	0.201	8,333		30,101		298,132
0.270	3,438	0.200	8,459	0.130	30,801	0.060	313,289
	3,476		8,587		31,523		329,490
	3,515		8,717		32,268		346,828
	3,555		8,851		33,036		365,405
	3,595		8,987		33,829		385,331
0.265	3,636	0.195	9,126	0.125	34,647	0.055	406,733
	3,677		9,268		35,492		429,750
	3,719		9,413		36,364		454,539
	3,762		9,561		37,265		481,270
	3,806		9,712		38,198		510,139
0.260	3,850	0.190	9,866	0.120	39,161	0.050	541,362
	3,895		10,023		40,156		575,173
	3,940		10,184		41,186		611,893
	3,986		10,348		42,251		651,776
	4,033		10,516		43,354		695,223
0.255	4,081	0.185	10,688	0.115	44,494	0.045	742,613
	4,129		10,863		45,676		794,400
	4,178		11,042		46,899		851,128
	4,228		11,225		48,166		913,380
0.251	4,279		11,412		49,480		981,852
0.250	4,331	0.180	11,603	0.110	50,841	0.040	1,057,350
	4,383		11,799		52,254		1,140,780
	4,436		11,999		53,720		1,233,250
	4,490		12,203		56,239		1,335,960
	4,545		12,412		56,817		1,450,406
0.245	4,601	0.175	12,627	0.105	58,456	0.035	1,578,320
	4,658		12,846		60,159		1,721,630
	4,716		13,069		61,925		1,883,020
	4,776		13,298		63,766		2,065,130
	4,835		13,533	0.101	65,680		2,271,500
0.240	4,895	0.170	13,774	0.100	67,670	0.030	2,506,310
	4,956		14,020		69,741		
	5,019		14,272		71,899		
	5,083		14,529		74,146		
	5,148		14,793		76,486		
0.235	5,214	0.165	15,064	0.095	78,927		
	5,281		15,341		81,473		
	5,350		15,625		84,130		
	5,419		25,916		86,904		
	5,490		16,215		89,800		

CONVERSION TABLE

1 inch	=25.4 millimeters.	1 liter	= 1.0567 quarts.
1 millimeter	= 0.03937 inch.	1 pound	= 0.4536 kilogram.
1 quart	=57.75 cubic inches.	1 kilogram	= 2.2046 pounds.
1 quart	= 0.9464 liter.	Fahrenheit=9/5 centigrade+32°	
1 liter	=61.0234 cubic inche	Centigrade=5/9 Fahrenheit±32°)	

From von Bayer in Rept. 4th Internat. Fisheries Congress.