A Guide to the Study of Fresh-water Biology

James G. Needham
and
Paul R. Needham
# LIST OF PLATES

<table>
<thead>
<tr>
<th>No.</th>
<th>Plate Description</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Stony fly Nymphs</td>
<td>Plecoptera</td>
</tr>
<tr>
<td>2.</td>
<td>Mayfly nymphs</td>
<td>Odonata</td>
</tr>
<tr>
<td>3.</td>
<td>Dragonfly nymphs</td>
<td>Odonata</td>
</tr>
<tr>
<td>4.</td>
<td>Dragonfly nymphs</td>
<td>Odonata</td>
</tr>
<tr>
<td>5.</td>
<td>Damselfly nymphs</td>
<td>Odonata</td>
</tr>
<tr>
<td>6.</td>
<td>Water Bugs</td>
<td>Hemiptera</td>
</tr>
<tr>
<td>7.</td>
<td>Caddisworm houses</td>
<td>Trichoptera</td>
</tr>
<tr>
<td>8.</td>
<td>Beetle larvae</td>
<td>Coleoptera</td>
</tr>
<tr>
<td>9.</td>
<td>Crane-fly larvae</td>
<td>Diptera</td>
</tr>
<tr>
<td>10.</td>
<td>Misc. two-winged flies</td>
<td>Diptera</td>
</tr>
<tr>
<td>11.</td>
<td>Misc. Insects of several orders</td>
<td>Mollusca</td>
</tr>
<tr>
<td>12.</td>
<td>Crustaceans of several orders</td>
<td>Crustacea</td>
</tr>
<tr>
<td>13.</td>
<td>Clams and snails</td>
<td>Mollusca</td>
</tr>
<tr>
<td>14.</td>
<td>Misc. Invertebrates</td>
<td>Mollusca</td>
</tr>
<tr>
<td>15.</td>
<td>Blue-fish</td>
<td>Mollusca</td>
</tr>
<tr>
<td>16.</td>
<td>Grease</td>
<td>Mollusca</td>
</tr>
<tr>
<td>17.</td>
<td>Desmids</td>
<td>Desmidiaceae</td>
</tr>
<tr>
<td>18.</td>
<td>Diatoms</td>
<td>Bacillariaceae</td>
</tr>
<tr>
<td>19.</td>
<td>Protozoans</td>
<td>Bacillariaceae</td>
</tr>
<tr>
<td>20.</td>
<td>Flagellates</td>
<td>Bacillariaceae</td>
</tr>
<tr>
<td>21.</td>
<td>Rotifers</td>
<td>Bacillariaceae</td>
</tr>
<tr>
<td>22.</td>
<td>Entomostraca</td>
<td>Bacillariaceae</td>
</tr>
</tbody>
</table>
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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AND

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FOURTH EDITION
Revised and Enlarged

ITHACA • NEW YORK
COMSTOCK PUBLISHING COMPANY, INC.
1941
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
Contents

Part I. Aids to recognition of Fresh-water Organisms. Page

Insects ................................................................. 5
Crustaceans ......................................................... 36
Molluscs ............................................................... 38
Plancton ............................................................... 40
Other lesser Invertebrates ........................................ 41
(See also Finding List on next page.)

Part II. A Program of class work in Fresh-water Biology.

Collecting methods and apparatus .................................................. 64
Equipment .................................................................. 66
Practical Exercises:

A. Land-and-water studies:
   1. Local hydrography .................................................. 67
   2. The local water supply .............................................. 68
   3. A pond ................................................................ 68
   4. A stream .............................................................. 69
   5. A lake .................................................................. 70
   6. A marsh ............................................................... 70

B. Association studies:
   7. The life of a pond .................................................... 71
   8. The life of a rapid stream ........................................... 73
   9. The life of a slow stream ........................................... 74
  10. The life of a lake bottom with muddy shores ............. 75
  11. The life of a flood-plain marsh ............................... 76
  12. The life of an upland swamp or bog ......................... 77
  13. The life of rock ledges in a stream bed .................... 78
  14. The life of a spring brook ....................................... 79
  15. The "blanket algae" association ............................... 80
  16. Plancton ............................................................... 81

C. Adjustment studies:
   17. Hibernating devices of fresh-water animals ............. 82
   18. Reproductive methods of fresh-water mussels .......... 82
   19. A laboratory study of the gills of insects ................. 83

D. Economic studies:
   20. The fish-forage of a water meadow (partly quantitative) 85
   21. A study of fish food (partly quantitative) ............... 85

E. Demonstrations:
   22. The efficiency of stream-line form .......................... 86
   23. The relation between fecundity and nurture in fishes .. 87
   25. Fish-cultural methods ........................................... 88
## Group Finding List

### PLANTS

(Algae only; higher groups not treated.)

<table>
<thead>
<tr>
<th>Group</th>
<th>Plate</th>
<th>Figs.</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diatoms</td>
<td>20</td>
<td>All</td>
<td>p. 48</td>
</tr>
<tr>
<td>Desmids</td>
<td>19</td>
<td>All</td>
<td>46</td>
</tr>
<tr>
<td>Blue-Greens</td>
<td>17</td>
<td>All</td>
<td>40</td>
</tr>
<tr>
<td>True Greens</td>
<td>18</td>
<td>All</td>
<td>44</td>
</tr>
</tbody>
</table>

### ANIMALS

Protozoans: one-celled animals

<table>
<thead>
<tr>
<th>Group</th>
<th>Plate</th>
<th>Figs.</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metazoans: many-celled animals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coelenterates, Hydra</td>
<td>16</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Plathelminthes, flatworms</td>
<td>16</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Nemathelminthes, roundworms</td>
<td>16</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Trochelminthes, rotifers</td>
<td>23 and 16</td>
<td>11</td>
<td>56</td>
</tr>
<tr>
<td>Gasterotricans</td>
<td>16</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Annelids:

<table>
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<tr>
<th>Group</th>
<th>Plate</th>
<th>Figs.</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligochetes, bristle-worms</td>
<td>16</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Hirudineans, leeches</td>
<td>16</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Bryozoans, moss animalcules</td>
<td>16</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Molluscs, clams and snails</td>
<td>15</td>
<td>All</td>
<td>38</td>
</tr>
</tbody>
</table>

Arthropods:

<table>
<thead>
<tr>
<th>Group</th>
<th>Plate</th>
<th>Figs.</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arachnids, spiders and mites</td>
<td>16</td>
<td>1 and 2</td>
<td></td>
</tr>
<tr>
<td>Crustaceans:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malacostracans</td>
<td>14</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Entomostracans</td>
<td>24 and 14</td>
<td>59</td>
<td></td>
</tr>
</tbody>
</table>

Hexapods, Insects:

<table>
<thead>
<tr>
<th>Group</th>
<th>Plate</th>
<th>Figs.</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collembola, springtails</td>
<td>13</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Plecoptera, stoneflies</td>
<td>1</td>
<td>All</td>
<td>7</td>
</tr>
<tr>
<td>Ephemerida, mayflies</td>
<td>2 and 3</td>
<td>All</td>
<td>8</td>
</tr>
<tr>
<td>Odonata, dragonflies</td>
<td>4–7</td>
<td>All</td>
<td>14</td>
</tr>
<tr>
<td>Hemiptera, water bugs</td>
<td>8</td>
<td>All</td>
<td>20</td>
</tr>
<tr>
<td>Trichoptera, caddis worms</td>
<td>9</td>
<td>All</td>
<td>24</td>
</tr>
<tr>
<td>Neuroptera, spongilla-flies, etc.</td>
<td>12</td>
<td>8–10</td>
<td>30</td>
</tr>
<tr>
<td>Coleoptera, beetles</td>
<td>10 and 13</td>
<td>1– 7</td>
<td>26</td>
</tr>
<tr>
<td>Diptera, two-winged flies</td>
<td>11 and 12</td>
<td>All</td>
<td>28</td>
</tr>
<tr>
<td>Lepidoptera, moths</td>
<td>13</td>
<td>11, 12</td>
<td></td>
</tr>
</tbody>
</table>

Vertebrates, fishes, frogs, etc. (not included).

### AIDS

Recognition characters of the principal groups of crustaceans

Recognition characters of aquatic insect larvae

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—Larvae with wings developing externally (called nympha in this book) and no quiescent pupal stage. ................................................................. 2
   Larva 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 tracheae, 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) ................................................................. 5
   —Gills mainly on the sides of the abdomen; tarsal claws single; tails generally three. (Mayflies; see page 8) ................................................................. Ephemera

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 larvae, living on fresh-water sponges. Family Hemerobidae (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 gyrrinid beetle larva, which have paired lateral abdominal filaments), often entirely wanting .... 9

8—Abdominal segments each with a pair of long, lateral filaments. Family Sialidae (see page 30) of Neuroptera
   —Abdominal segments without long, muscular, lateral filaments, often with minute gill filaments; cylindric larvae, 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.

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)*

<table>
<thead>
<tr>
<th>1</th>
<th>With gills on a number of segments of the abdomen</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With no gills (except anal gills) on the abdomen</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>With large single lateral gills on abdominal segments 1 to 7</td>
<td>Oroperla</td>
</tr>
<tr>
<td></td>
<td>With small tufted ventral gills on the basal segments only</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>These gills on segments 1 and 2 only</td>
<td>Pteronarccys</td>
</tr>
<tr>
<td></td>
<td>These gills on segments 1, 2 and 3</td>
<td>Pteronarccella</td>
</tr>
<tr>
<td>4</td>
<td>Body depressed, roach-like in form; head bent under</td>
<td>Peltoperla</td>
</tr>
<tr>
<td></td>
<td>Body elongate, head directed forward</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>First and second tarsal segments very short, together less than half as long as the third segment</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>First and second segments more than half as long as the third</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td>With 2 ocelli: copious gill tufts under the thorax</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>With 3 ocelli: gill tufts various or wanting</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>Ocelli close together; anal gills present</td>
<td>Neoperla</td>
</tr>
<tr>
<td></td>
<td>Ocelli far apart (several diameters of one of them)</td>
<td>Atoperla</td>
</tr>
<tr>
<td>8</td>
<td>With branched gill tufts at the base of the legs</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>With gills if present minute unbranched and inconspicuous</td>
<td>12</td>
</tr>
<tr>
<td>9</td>
<td>Eyes set far forward, before the middle of the head</td>
<td>Perlinella</td>
</tr>
<tr>
<td></td>
<td>Eyes not before the middle of the head</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>Body freckled with small brown dots: length 10 mm</td>
<td>Perlesta</td>
</tr>
<tr>
<td></td>
<td>Body not so freckled; size much larger</td>
<td>11</td>
</tr>
<tr>
<td>11</td>
<td>With distinct occipital ridge, continuous across the head</td>
<td>Perla</td>
</tr>
<tr>
<td></td>
<td>Generally with this ridge not continued across the middle</td>
<td>Acroneuria</td>
</tr>
<tr>
<td>12</td>
<td>With minute fingerlike gills at the throat</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Without gills</td>
<td>14</td>
</tr>
<tr>
<td>13</td>
<td>These gills very minute (fig. 15)</td>
<td>Hydroperla</td>
</tr>
<tr>
<td></td>
<td>These gills larger, and generally more numerous</td>
<td>Perlodes</td>
</tr>
<tr>
<td>14</td>
<td>Head squarish with the small eyes set far forward</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Head more convex at sides with the eyes more prominent laterally</td>
<td>16</td>
</tr>
<tr>
<td>15</td>
<td>Pronotal disc heavily fringed with coarse hairs: tails 8 mm</td>
<td>Kathroperla</td>
</tr>
<tr>
<td></td>
<td>Pronotal disc not heavily fringed: tails 6 mm. long</td>
<td>Paraperla</td>
</tr>
<tr>
<td>16</td>
<td>Outer margin of wing buds when grown incurving only at the ends: tails longer than either abdomen or antennae</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Outer margin of wing buds broadly and regularly rounded: tails shorter than either abdomen or antennae</td>
<td>18</td>
</tr>
<tr>
<td>17</td>
<td>Maxillae very large, their projecting &quot;elbows&quot; visible from above the head</td>
<td>Isogenus</td>
</tr>
<tr>
<td></td>
<td>Maxillae not visible from above the head</td>
<td>Isoperla</td>
</tr>
<tr>
<td>18</td>
<td>Dorsum of thorax bare except for a few long hairs</td>
<td>Chloroperla</td>
</tr>
<tr>
<td></td>
<td>Dorsum clothed with short scurly pubescence</td>
<td>Alloperla</td>
</tr>
<tr>
<td>19</td>
<td>Second tarsal segment as long as the first</td>
<td>Taeniopteryx</td>
</tr>
<tr>
<td></td>
<td>Second tarsal segment shorter than the first</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>Hind wing cases much more widely divergent than the fore</td>
<td>Nemoura</td>
</tr>
<tr>
<td></td>
<td>Hind wing cases parallel with those of the fore wings</td>
<td>21</td>
</tr>
<tr>
<td>21</td>
<td>Pale and slender: middle abdominal segments longer than wide</td>
<td>Leuctra</td>
</tr>
<tr>
<td></td>
<td>Dark colored: middle abdominal segments wider than long</td>
<td>Capnia</td>
</tr>
</tbody>
</table>

* 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 tibiae longer than the hind ones .............................................................. 4
   —Fore tibiae shorter than the hind ones ............................................................. 5

4—Mandibular tusks hairy to their tips ................................................................. Ephrana
   —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 .............................................................. Ephorion
   —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 $750).

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:

Isomychla replaces Chironotones.
Paraleptophlebia replaces Leptophlebia in part.
Heptagenia replaces Eryonurus, and is itself replaced by Stenonema. There now appears to be general concurrence and agreement in the use of EPHEMOPTERA instead of EPHEMERIDA as the name of the Order.

(Continued on page 10)

PLATE I. STONEFLY NYMPHS

<table>
<thead>
<tr>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distrib.</th>
<th>Waters</th>
<th>Genera</th>
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<td>Neoperla</td>
<td>(5)</td>
<td>19</td>
<td>F, S</td>
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<td>12</td>
<td>G</td>
<td>lotic</td>
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<td>W, C</td>
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<td>G</td>
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<td>Capnia</td>
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<td>5</td>
<td>N</td>
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<td>Perla</td>
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<td>10-26</td>
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<td>Kaphroperla</td>
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<td>18</td>
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<td>Taeniopteryx</td>
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<td>Nemoura</td>
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<td>11</td>
<td>G</td>
<td>lotic</td>
<td></td>
<td></td>
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<td></td>
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</table>
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—Operculat e gill on segment 4.................................................. Ephemerella
    —Operculat e gill on segment 2................................................ 24
24—Hind wing sheath present....................................................... Oreanthus
    —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..................... Habrophleboidea
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 coxe bearing a thumb-like appendage on the inner side........ Ametropus

(Continued on page 12)

<table>
<thead>
<tr>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr.</th>
<th>Waters</th>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr.</th>
<th>Waters</th>
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<td>17</td>
<td>S</td>
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<td>Hexagania</td>
<td>6</td>
<td>27</td>
<td>E, C</td>
<td>static*</td>
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<tr>
<td>Ephemerella</td>
<td>2(6)</td>
<td>18</td>
<td>E</td>
<td>both</td>
<td>Isonychia</td>
<td>8</td>
<td>15</td>
<td>G</td>
<td>lotic</td>
</tr>
<tr>
<td>Ephydipsis</td>
<td>7</td>
<td>15</td>
<td>E, C</td>
<td>static</td>
<td>Pentagenia</td>
<td>3(6)</td>
<td>24</td>
<td>E, C</td>
<td>static</td>
</tr>
<tr>
<td>Euthyrhoa</td>
<td>1</td>
<td>29</td>
<td>S</td>
<td>static</td>
<td>Potamanthus</td>
<td>4</td>
<td>13</td>
<td>E, C</td>
<td>lotic</td>
</tr>
</tbody>
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* In settling basins in streams conditions are static. Drawings mainly from Kennedy.
Plate 2. Mayfly Nymphs
36—Maxillary palpus 2-jointed: tarsi longer than tibiae ..........Metretopus
   —Maxillary palpus 3-jointed: tarsi at least as long as the tibiae ..........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
   maxillae ..................................................................................Isonychia
   —No such hair fringes, and no gills on maxillae ..........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 tracheae 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**

<table>
<thead>
<tr>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr.</th>
<th>Waters</th>
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<tr>
<td>Metretopus</td>
<td>(4)</td>
<td>15-17</td>
<td>SW</td>
<td>lotic</td>
</tr>
<tr>
<td>Baetis</td>
<td>(4)</td>
<td>6</td>
<td>G</td>
<td>lotic</td>
</tr>
<tr>
<td>Isonychia</td>
<td>(8)</td>
<td>15</td>
<td>W</td>
<td>lotic</td>
</tr>
<tr>
<td>Leptophlebia</td>
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<td>15</td>
<td>NW</td>
<td>lotic</td>
</tr>
<tr>
<td>Centroptilum</td>
<td>(4)</td>
<td>7</td>
<td>G</td>
<td>both</td>
</tr>
<tr>
<td>Metretopus</td>
<td>(4)</td>
<td>10</td>
<td>N</td>
<td>static</td>
</tr>
<tr>
<td>Callibaetis</td>
<td>(1)</td>
<td>14-17</td>
<td>SE</td>
<td>lotic</td>
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<tr>
<td>Pseudocloeon</td>
<td>(4)</td>
<td>11-12</td>
<td>N</td>
<td>static</td>
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<tr>
<td>Siphlonisca</td>
<td>(4)</td>
<td>5-9</td>
<td>G</td>
<td>both</td>
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<tr>
<td>Rheithrodena</td>
<td>(5)</td>
<td>10</td>
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<td>Siphlonisca</td>
<td>(4)</td>
<td>19-20</td>
<td>NE</td>
<td>static</td>
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<tr>
<td>Siphlonurus</td>
<td>(4)</td>
<td>11-16</td>
<td>N, E</td>
<td>static</td>
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<td>Siphlonurus</td>
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<td>11</td>
<td>G</td>
<td>static</td>
</tr>
<tr>
<td>Siphlonisca</td>
<td>(4)</td>
<td>6</td>
<td>N, W, S</td>
<td>static</td>
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<tr>
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<td>Siphlonurus</td>
<td>(4)</td>
<td>11</td>
<td>G</td>
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</table>
Plate 3. Mayfly Nymphs
KEY TO THE GENERA OF NYMPHS OF DRAGONFLIES AND DAMSELFIES: 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—Antennae short and thick........................................ 4
   —Antennae slender and bristle-like, Aeschninae........................................ 13
4—Antennae seven-jointed, Petalurinae.......................... Tachopteryx
   —Antennae 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 cylindrical....................................... 11
10—Third antennal segment broadly oval...................................................... Octogomphus
    —Third antennal segment elongate................................................................ 11
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 setae.............. Gynacantha
    —Lateral lobes of labium lacking raptorial setae........................................ 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............................................. Basi aeschna

* 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:


A new genus, Tarnetrum, has been erected for the two species of Sym petrum (one of them, T. corrypnum, 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

<table>
<thead>
<tr>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr.</th>
<th>Waters</th>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr.</th>
<th>Waters</th>
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<tbody>
<tr>
<td>Aphylla</td>
<td>2</td>
<td>45</td>
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<td>Herpetogomphus</td>
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<td>27</td>
<td>G</td>
<td>lotic</td>
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<tr>
<td>Cordulegaster</td>
<td>3</td>
<td>42</td>
<td>G</td>
<td>lotic</td>
<td>Lanthus</td>
<td>11</td>
<td>22</td>
<td>E</td>
<td>lotic</td>
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<tr>
<td>Dromogomphus</td>
<td>7(5)</td>
<td>33</td>
<td>E, C</td>
<td>lotic</td>
<td>Ophiogomphus</td>
<td>4</td>
<td>27</td>
<td>G</td>
<td>lotic</td>
</tr>
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<td>Gomphus</td>
<td>5</td>
<td>24–45</td>
<td>G</td>
<td>both</td>
<td>Octogomphus</td>
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<td>23</td>
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<td>30</td>
<td>G</td>
<td>lotic</td>
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<td>Hagenius</td>
<td>9</td>
<td>40</td>
<td>E</td>
<td>static</td>
<td>Tachopteryx</td>
<td>1</td>
<td>38</td>
<td>E</td>
<td>static</td>
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Plate 4. Dragonfly Nymphs
Continued from page 14)

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. Neurocordulia
   —Dorsal abdominal hooks thick and blunt........... Didymops

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

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

25—Lateral setae of labium 5............................ 26
   —Lateral setae 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........... Tetragonura
   —Same, shorter not surpassing tips of terminal appendages........... Perithemis

28—Length under 15 mm................................. 29
   —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...................... 33
   —Spines of segment 9 short or moderate............... 33

(Continued on page 18)

**PLATE 5. DRAGONFLY NYMPHS**

<table>
<thead>
<tr>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr. Waters</th>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr. Waters</th>
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<td>45</td>
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<td>Nasiaeschna</td>
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<td>38</td>
<td>E, C both</td>
</tr>
<tr>
<td>Anax</td>
<td>7*(1)</td>
<td>45</td>
<td>G static</td>
<td>Didymops</td>
<td>11</td>
<td>28</td>
<td>E static</td>
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<tr>
<td>Basiaeschna</td>
<td>4(3)</td>
<td>42</td>
<td>E lotic</td>
<td>Epicordulia</td>
<td>8</td>
<td>27</td>
<td>E, S static</td>
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<tr>
<td>Boyeria</td>
<td>3</td>
<td>38</td>
<td>E lotic</td>
<td>Helocordulia</td>
<td>12</td>
<td>20</td>
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<td>2</td>
<td>52</td>
<td>SE static</td>
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<td>48</td>
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<td>Neurocordulia</td>
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<td>21</td>
<td>E, C both</td>
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<tr>
<td>Gynancta</td>
<td>1</td>
<td>45</td>
<td>S static</td>
<td>Tetragonura</td>
<td>8</td>
<td>22</td>
<td>G static</td>
</tr>
</tbody>
</table>

* A young nymph; the bands of color later disappear.
  The first 8 are Aeschninae, with flat labium. The remainder are Cordulinae 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. Leucorrhinia and Dythemis
34—Dorsal hooks shorter than the segments which bear them. Sympretum
35—Abdomen smooth
36—Abdominal hairy
37—Lateral spines very short
38—Lateral spines long
39—Spines of 8, short; of 9, long
40—Abdomens smooth, shorter than the segments which bear them
41—Abdominal hairy
42—Lateral setae 6
43—Lateral setae 7
44—Lateral setae 8–10
45—Spines of 8 and 9 both long and similar
46—Teeth on inner edge of lateral lobe of labium deeply cut
47—Teeth obsolete
48—Lateral spines of 9 one fifth as long as 9
49—Lateral spines of 9 one third as long as 9
50—Lateral spines of 9 one fifth as long as 9
51—Lateral spines of 9 one third as long as 9

(Continued on page 20)

PLATE 6. DRAGONFLY NYMPHS

Genera  Figs.  Length  Distr.  Waters  L.Set*  Genera  Figs.  Length  Distr.  Waters  L.Set
Cellithemis...  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
Leucorrhinia.  9  18  E, N static  10–11  Platthemis.  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  Sympretum.  14  13  G static  9–14

* L. Set. = the raptorial setae 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

1.  
2.  
3.  
4.  
5.  
6.  
7.  
8.  
9.  
10.  
11.  
12.  
13.  
14.  
15.  

Odonata
KEY TO THE GENERA OF AQUATIC HEMIPTERA

1—Antennae shorter than head. ........................................ 2
   —Antennae 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, paleform 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. Damsel-fly Nymphs
PLATE 8. WATER BUGS

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

(Continued on page 24)
Plate 8. Water Bugs
20—Antennae as long as half the body; sixth abdominal segment of the male roundly emarginate. ........................................ Limnoporus
—Antennae 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; antennae almost as long as entire body; hind femora twice as long as hind tibia .................................... Metrobates

22—Fourth (apical) segment of antennae longer than the third. ................................................................. Trepobates
—Fourth segment of antennae 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 larvae: 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)

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**PLATE 9. CADDIS-WORM STRUCTURES**

<table>
<thead>
<tr>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr.</th>
<th>Waters</th>
</tr>
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<td>Astenophylax</td>
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<td>50</td>
<td>NE</td>
<td>lotic</td>
</tr>
<tr>
<td>Brachycerus</td>
<td>12</td>
<td>12</td>
<td>G</td>
<td>lotic</td>
</tr>
<tr>
<td>Chimarrha</td>
<td>20</td>
<td>8</td>
<td>G</td>
<td>lotic</td>
</tr>
<tr>
<td>Ganonema</td>
<td>13</td>
<td>18</td>
<td>NE</td>
<td>lotic</td>
</tr>
<tr>
<td>Glossosoma</td>
<td>8</td>
<td>9</td>
<td>G</td>
<td>lotic</td>
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<tr>
<td>Glyptocerella</td>
<td>3</td>
<td>32</td>
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<td>Helicopsyche</td>
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<td>G</td>
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<td>Mystacides</td>
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<thead>
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<th>Waters</th>
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<td>Neureclipsis</td>
<td>17</td>
<td>32</td>
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<td>Neuronia</td>
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<td>40</td>
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<td>Phylotribus</td>
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<td>14</td>
<td>E, S</td>
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<td>Platysiphax</td>
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<td>Polycenopus</td>
<td>21</td>
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<td>Pseloteres</td>
<td>7</td>
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<td>Setodes</td>
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<td>Triaeonodes</td>
<td>(1)</td>
<td>8</td>
<td>G</td>
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* See plate 13 for the worms themselves. Figures 2 to 15 are from Dr. J. T. Lloyd.
Plate 9. Caddis-worm Houses
Fresh-water Biology

(Continued from page 24)

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. ............. Phryganea  
—Case not spirally wound ........................................ 12  
12—Large: length more than 20 mm.  
—Small: length less than 15 mm. .................................. Triaenodes  
13—Case square in section: made of bits of wood placed crosswise.  
—Case not so .................................................... 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 Limnophilide. 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. .................................. Dytiscidae—4  
3—Lateral filaments of abdomen all plumose. ................. Gyrinus  
—First and second not plumose ................................ Dineutes  
4—Abdomen with long lateral filaments.  
—Abdomen with no lateral filaments.  
5—Mandibles upturned at tip to meet snout  
—Mandibles inturned at tip; no snout  
6—Prothorax longer than head  
—Prothorax not longer than head  

(Continued on page 28)
Plate 10. Beetle Larvae
Fresh-water Biology

(Continued from page 26)

7—Rear of head constricted to form a sort of neck. ..................... Acilus
    —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. ............................................ Dyttiscus
    —Front margin of head toothed. ...................................... Cycbister

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

Larvae 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. Phalacroscera
    —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

<table>
<thead>
<tr>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr.</th>
<th>Waters</th>
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<td>27</td>
<td>45</td>
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<td>Antocha</td>
<td>17-19</td>
<td>10</td>
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<tr>
<td>Bittacomorpha</td>
<td>(24)*</td>
<td>32</td>
<td>E</td>
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<tr>
<td>Diceranota</td>
<td>14-16</td>
<td>13</td>
<td>NE</td>
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<td>Epictia</td>
<td>12</td>
<td>10</td>
<td>G</td>
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<tr>
<td>Eristalis</td>
<td>33</td>
<td>9</td>
<td>G</td>
<td>both</td>
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<tr>
<td>Hexatoma</td>
<td>23</td>
<td>14</td>
<td>G</td>
<td>both</td>
</tr>
<tr>
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<td>35</td>
<td>55</td>
<td>W</td>
<td>?</td>
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<td>Limnophila</td>
<td>1, 2</td>
<td>15</td>
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<td>both</td>
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Mostly from Dr. C. P. Alexander. * Differs by being rusty red in color.
Fig. 33 is a rat tailed maggot, (family Syrphidae) larva of the Syrphus fly Eristalis.
Plate 11. Cranefly Larvae
PLATE 12. MISCELLANEOUS DIPTEROUS 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.................................. Triograma
—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.................................................................................. 13
—Color not green................................................................. Erioptera
12—Spiracular disc with 4 lobes......................................................... 15
—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...................................................... 17
—Disc hairy across upper border...................................................... 17
15—Lower border of spiracular disc cross lined with black.................... Pilaria
—Lower border of disc little or not at all crossed with black.............. 15
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. Stalididae.............................. 2
—Small forms with piercing mouth parts. Hemerobiidae........................ 4

(Continued on page 32)
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—Antennae shorter than the palpi. ...................................... Hydrophilidae
—Antennae longer than the palpi. ..................................... 4

4—Hind coxae broadly fused with metasternum. ................... Dytiscidae
—Hind coxae free. ...................................................... Parnidae

For genera of adult beetles see Blatchley’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, Gyrinidae; 2, Hydrophilidae; 3 Dytiscidae; 4, Haliplidae; 5 Parnidae or Elmidae. Fig. 13 is a spring-tail (Collembola).

Larvae

<table>
<thead>
<tr>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr.</th>
<th>Waters</th>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr.</th>
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<tbody>
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<td>G</td>
<td>both</td>
<td>Hydropsyche</td>
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<tr>
<td>Climacia</td>
<td>(10)*</td>
<td>5</td>
<td>E</td>
<td>lotic</td>
<td>Nymphula</td>
<td>12§</td>
<td>13</td>
<td>G</td>
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<td>Corydalis</td>
<td>(8)†</td>
<td>75</td>
<td>G</td>
<td>lotic</td>
<td>Peltodytes</td>
<td>6</td>
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<td>E</td>
<td>lotic</td>
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<td>G</td>
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<td>Halesus</td>
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<td>18</td>
<td>E</td>
<td>both</td>
<td>Sisyra</td>
<td>9</td>
<td>22</td>
<td>G</td>
<td>static</td>
</tr>
<tr>
<td>Halipus</td>
<td>7</td>
<td>9</td>
<td>G</td>
<td>static</td>
<td>Sisyra</td>
<td>10</td>
<td>5</td>
<td>E</td>
<td>lotic</td>
</tr>
</tbody>
</table>

* Differences by having dorsal setae inserted on tubercles.
† Differences 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
Recognize 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.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Order</th>
<th>Form</th>
<th>Tails</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stoneflies</td>
<td>Plecoptera</td>
<td>depressed</td>
<td>2, long</td>
</tr>
<tr>
<td>Mayflies</td>
<td>Ephemerida</td>
<td>elongate, variable slender, tapering rearward</td>
<td>3, long: (rarely 2) see gills</td>
</tr>
<tr>
<td>Damsels</td>
<td>Odonata</td>
<td>stout, variable</td>
<td>very short, spine-like</td>
</tr>
<tr>
<td>Dragonflies</td>
<td>Odonata</td>
<td>short, stout, very like adults</td>
<td>variable</td>
</tr>
<tr>
<td>Water bugs</td>
<td>Hemiptera</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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*

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Order</th>
<th>Legs</th>
<th>Gills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water moths</td>
<td>Lepidoptera</td>
<td>3 pairs of minute jointed legs followed by a number of pairs of fleshy prolegs</td>
<td>of numerous soft white filaments, or entirely wanting</td>
</tr>
<tr>
<td>Caddis worms</td>
<td>Trichoptera</td>
<td>3 pairs rather long</td>
<td>variable or wanting</td>
</tr>
<tr>
<td>Orl flies</td>
<td>Neuroptera</td>
<td>3 pairs shorter</td>
<td>7 pairs of long, lateral filaments tufted at base of lateral filaments, or wanting usually wanting usually only a bunch of retractile anal gills</td>
</tr>
<tr>
<td>Dobsons</td>
<td>Neuroptera</td>
<td>3 pairs</td>
<td></td>
</tr>
<tr>
<td>Water beetles</td>
<td>Coleoptera</td>
<td>3 pairs wanting</td>
<td></td>
</tr>
<tr>
<td>True flies</td>
<td>Diptera</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Family</th>
<th>Head</th>
<th>Tail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crane flies</td>
<td>Tipulidae</td>
<td>retracted and invisible</td>
<td>a respiratory disc bordered with fleshy appendages wanting</td>
</tr>
<tr>
<td>Net veined midges</td>
<td>Blepharoceridae</td>
<td>tapering into body</td>
<td>with swimming fin of fringed hairs with caudal ventral attachment disk tufts of hairs</td>
</tr>
<tr>
<td>Mosquitoes</td>
<td>Culcidae</td>
<td>free</td>
<td>floating hairs tapering body</td>
</tr>
<tr>
<td>Blackflies</td>
<td>Simuliidae</td>
<td>free</td>
<td>floating hairs tapering body</td>
</tr>
<tr>
<td>True midges</td>
<td>Chironomidae</td>
<td>free</td>
<td>with two short tapering tails extentile process as long as the body truncated</td>
</tr>
<tr>
<td>Soldier flies</td>
<td>Stratiumyidae</td>
<td>small, free</td>
<td></td>
</tr>
<tr>
<td>Horse flies</td>
<td>Tabanidae</td>
<td>acutely tapering</td>
<td></td>
</tr>
<tr>
<td>Snipe flies</td>
<td>Leptidae</td>
<td>tapering retractile</td>
<td></td>
</tr>
<tr>
<td>Syrphus flies</td>
<td>Syrphidae</td>
<td>minute</td>
<td></td>
</tr>
<tr>
<td>Muscid flies</td>
<td>Muscoidea</td>
<td>rudimentary</td>
<td></td>
</tr>
</tbody>
</table>
**Forms of Aquatic Insects in Their Immature Stages.**

are printed in italics.

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

<table>
<thead>
<tr>
<th>GILLS</th>
<th>Other Peculiarities</th>
<th>Habitat</th>
<th>Food Habits</th>
</tr>
</thead>
<tbody>
<tr>
<td>many, minute, around bases of the legs</td>
<td></td>
<td>rapids</td>
<td>mainly carnivorous</td>
</tr>
<tr>
<td>7 pairs on back</td>
<td>immense grasping lower lip</td>
<td>all waters</td>
<td>mainly herbivorous</td>
</tr>
<tr>
<td>3 leaf-like caudal gill-plates</td>
<td></td>
<td>slow and stagnant</td>
<td>carnivorous</td>
</tr>
<tr>
<td>internal gill chamber at end of body wanting</td>
<td>pointed beak for puncturing and sucking</td>
<td>all waters</td>
<td>carnivorous</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Rear End of Body</th>
<th>Other Peculiarities</th>
<th>Habitat</th>
<th>Food Habits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 pair of fleshy prolegs with numerous claws on them</td>
<td>claws (crotchets) on all prolegs</td>
<td>all waters</td>
<td>herbivorous</td>
</tr>
<tr>
<td>do, with paired larger hooks at tip</td>
<td>mostly living in portable cases</td>
<td>all waters</td>
<td>mostly herbivorous</td>
</tr>
<tr>
<td>a long tapering tail</td>
<td></td>
<td>gravelly beds</td>
<td>carnivorous</td>
</tr>
<tr>
<td>paired hooked claws</td>
<td></td>
<td>all waters</td>
<td>carnivorous</td>
</tr>
<tr>
<td>variable see next table</td>
<td>head small often apparently wanting</td>
<td>slow or stagnant</td>
<td>carnivorous</td>
</tr>
<tr>
<td></td>
<td></td>
<td>all waters</td>
<td>see next table</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Fleshy Legs, or Prolegs</th>
<th>Other Peculiarities</th>
<th>Habitat</th>
<th>Food Habits</th>
</tr>
</thead>
<tbody>
<tr>
<td>variable</td>
<td></td>
<td>shoals</td>
<td>herbivorous mostly</td>
</tr>
<tr>
<td>wanting</td>
<td>flat lobed body with row of central suckers</td>
<td>rocks in falls</td>
<td>diatoms, etc.</td>
</tr>
<tr>
<td>wanting</td>
<td>swollen thoracic segments</td>
<td>pools at surface</td>
<td>herbivorous</td>
</tr>
<tr>
<td>one beneath the mouth</td>
<td>&quot;fans&quot; on head for food-gathering</td>
<td>rocks in rapids</td>
<td>herbivorous</td>
</tr>
<tr>
<td>1 in front 2 at rear end of body wanting</td>
<td>live mostly in soft tubes</td>
<td>all waters</td>
<td>herbivorous</td>
</tr>
<tr>
<td>wanting</td>
<td></td>
<td>still water at surface beds in pools</td>
<td>herbivorous</td>
</tr>
<tr>
<td>stout paired beneath wanting</td>
<td>depressed form tubercle covered spindle shaped body</td>
<td>rapids under stones</td>
<td>carnivorous</td>
</tr>
<tr>
<td>wanting</td>
<td></td>
<td>shallow pools</td>
<td></td>
</tr>
<tr>
<td>usually wanting</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### PLATE 14. CRUSTACEANS

<table>
<thead>
<tr>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr.</th>
<th>Waters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apus</td>
<td>2</td>
<td>30</td>
<td>W</td>
<td>static</td>
</tr>
<tr>
<td>Asellus</td>
<td>1</td>
<td>15</td>
<td>G</td>
<td>static</td>
</tr>
<tr>
<td>Cambarus</td>
<td>(9)*</td>
<td>80</td>
<td>G</td>
<td>both</td>
</tr>
<tr>
<td>Estheria</td>
<td>6</td>
<td>12</td>
<td>W</td>
<td>static</td>
</tr>
<tr>
<td>Eubranchipus</td>
<td>11</td>
<td>22</td>
<td>G</td>
<td>static</td>
</tr>
<tr>
<td>Eucrangonyx</td>
<td>(7)+</td>
<td>20</td>
<td>G</td>
<td>static</td>
</tr>
<tr>
<td>Gammarus</td>
<td>7</td>
<td>25</td>
<td>G</td>
<td>static</td>
</tr>
<tr>
<td>Hyallella</td>
<td>8(7)</td>
<td>9</td>
<td>G</td>
<td>static</td>
</tr>
<tr>
<td>Lepidurus</td>
<td>3(2)</td>
<td>50</td>
<td>W</td>
<td>static</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr.</th>
<th>Waters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lynceus</td>
<td>6(9)</td>
<td>10</td>
<td>G</td>
<td>static</td>
</tr>
<tr>
<td>Mysis</td>
<td>10</td>
<td>30</td>
<td>G</td>
<td>static</td>
</tr>
<tr>
<td>Palaemonetes</td>
<td>(4)</td>
<td>40</td>
<td>S</td>
<td>static</td>
</tr>
<tr>
<td>Pontoporeia</td>
<td>7(7)</td>
<td>11</td>
<td>G</td>
<td>static</td>
</tr>
<tr>
<td>Potamocephus</td>
<td>10</td>
<td>20</td>
<td>W</td>
<td>both</td>
</tr>
<tr>
<td>Streptoccephalus</td>
<td>11</td>
<td>20</td>
<td>W</td>
<td>static</td>
</tr>
<tr>
<td>Syncaris</td>
<td>12-14</td>
<td>30</td>
<td>SW</td>
<td>lotic</td>
</tr>
<tr>
<td>Thamnocephalus</td>
<td>5</td>
<td>40</td>
<td>W</td>
<td>static</td>
</tr>
</tbody>
</table>

* 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
Fresh-water Biology

(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
—Shell globose or elongated, length under 10 mm., spire short. *Valvata*

9—Aperture oval, length over 7.5 mm. *Bythina*
—Length under 7.5 mm. *Campeloma*

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. *Sphaeriidae*
—Smaller shells; under 20 mm. *Amnicolidae*

12—Umbone central, shell equilateral. *Musculum*
—Umbone subterminal, shell inequilateral. *Sphaerium*

13—Shell thin, rounded, polished, umbones quite prominent. *Musculum*
—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 Unionidae, 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**

<table>
<thead>
<tr>
<th>Genera</th>
<th>Figs.</th>
<th>Length</th>
<th>Distr.</th>
<th>Waters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amnicola</td>
<td>11</td>
<td>4</td>
<td>G</td>
<td>both</td>
</tr>
<tr>
<td>Ancylus</td>
<td>5</td>
<td>5</td>
<td>E</td>
<td>both</td>
</tr>
<tr>
<td>Anodonta</td>
<td>18</td>
<td>90</td>
<td>G</td>
<td>both</td>
</tr>
<tr>
<td>Bythina</td>
<td>10</td>
<td>10</td>
<td>NE</td>
<td>both</td>
</tr>
<tr>
<td>Campeloma</td>
<td>8</td>
<td>25</td>
<td>N. S. E</td>
<td>both</td>
</tr>
<tr>
<td>Goniobasis</td>
<td>6</td>
<td>22</td>
<td>S, W, C</td>
<td>both</td>
</tr>
<tr>
<td>Limnæ</td>
<td>1</td>
<td>10–50</td>
<td>G</td>
<td>both</td>
</tr>
<tr>
<td>Margaritana</td>
<td>2</td>
<td>30</td>
<td>G</td>
<td>both</td>
</tr>
<tr>
<td>Musculum</td>
<td>14</td>
<td>9</td>
<td>G</td>
<td>both</td>
</tr>
<tr>
<td>Sphaerium</td>
<td>2</td>
<td>3–21</td>
<td>G</td>
<td>both</td>
</tr>
<tr>
<td>Pleurocera</td>
<td>4</td>
<td>30</td>
<td>E, S, W</td>
<td>both</td>
</tr>
<tr>
<td>Unio</td>
<td>17</td>
<td>100</td>
<td>E, S, C</td>
<td>both</td>
</tr>
<tr>
<td>Valvata</td>
<td>9</td>
<td>5</td>
<td>G</td>
<td>both</td>
</tr>
<tr>
<td>Vivipara</td>
<td>7</td>
<td>28</td>
<td>E S</td>
<td>both</td>
</tr>
</tbody>
</table>

Figures 4 and 6 show the operculum in detail beside the shell; 9, 10, 11, show it in the aperture.
Plate 15. Miscellaneous Molluses

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
PLANCTON†

It will be noted that a number of forms, especially green alge, 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.—
   (Schizophyceae) Cyanophyceae ................................................................. 2
   —Cells green, red or brown ........................................................................... 20

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

3—Multiplication by vegetative cell division .............................................. Chroococcaceae—4
   —Multiplication by conidia. Epiphytes on alge. .................................. Chamaesiphonaceae

4—Cells solitary without gelatinous matrix. Cells spherical Croococcus; cylindrical
   (Synechoccus, Chrootheca); fusiform, (Dactylococcosis).
   —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, Gloecocapsa; cells elongate or elliptical, Gloecotheca, 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 ........................................................................ 9
   —Cell division 2 plane, resulting colonies therefore only one cell deep .......... Gomphosphaera

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

10—Cell flattened, disclike (fig. 2) ................................................................. Holopedium
   —Cells not flat. Cells spherical (fig. 6), Merismopedia; cells cylindrical arranged
   palisade like ................................................................................................. (Continued on page 42)

PLATE 16. SINGLE REPRESENTATIVES OF GROUPS OF LESSER INVERTEBRATES

3. A gastrotrich, Chaetonotus X10. 10. A flat worm, Planaria X5.

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

Filaments usually not branching; where they show branching there are no heterocysts
—Filaments branching. True branching, Stigonemaceae; false branching, heterocysts present

Cells of the filaments all of uniform size; without heterocysts—Oscillatoriaae.
—Filaments with occasional cells of different color or larger size (heterocysts) Nostocaceae.

Filament without a sheath
—Filament enclosed in a gelatinous sheath

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

Plate 17. Blue-Greens

Plate 18. Green Algae
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, Hyphethephrix; filaments in crest or prostrate bundles. Symplocca

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
—Thallus filamentous and septate, or unicellular, or expanded. Vaucheria

23—Thallus expanded, membranous ........................................... Ulvales
—Thallus neither expanded nor membranous .............................. 21

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. 15), Volvox; cells 16, arranged in 4 rows. ........... 29
—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), Pediasstrum; 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 32
—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). PLEUROCOCCEAE .......... 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 ........................................ 34
34—Cells elongated, frequently curved; solitary or in definite loosely coherent colonies
—Cells not elongated

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

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

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

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

39—Cells strictly globose, united in a spherical colony. Sphere hollow (figs. 8, 9), Coelos-
—Sorastrum
—Cells not united in a spherical coenobium

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

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),
—Botryococcus; cells with well marked subdichotomous connecting threads, chloro-
—Platiastrum; cells in radiating series, connecting threads scarcely visible; chloroplasts axial

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

43—Filament attenuated and commonly ending in a bristle—Chaetophorales
—Filaments not ending in a bristle

44—Plant of branched filaments forming a flat cushion like expansion enveloped in
—Coleochaetae
—Plant entirely filamentous

45—Filaments branched
—Filaments not branched

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

47—Small creeping filaments on water plants. Cells globose or cylindrical, Herpos-
—Chaetosphaeridium
—Plants not creeping

48—Plants less than one mm. high, without setae
—Plants larger, branches attenuated, and with setae

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

50—Cells with thick lamellose coats, in a series inside a lamellose sheath. Cylindo-
—Cylindrocapsa
—Cells without lamellose coat. Ulothrichaceae. Chromatophore a homogeneous
—Microspora
—zonate band, with one to several pyrenoids (fig. 29), Ulothrix; chromatophore a
—Cylindrocapsa
—parietal disk or plate, with one pyrenoid, Stichococcus; chromatophore granular,
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. Zygemaceae. Chloroplasts of spiral bands (fig. 17), Spirogyra; chloroplast consists of two stellate bodies for each cell (fig. 20) Zygema; 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

55—Unicellular organisms consisting of 2 silicious valves. Bacillariaceae (= Diatoms). (See page 48)
—Cells neither silicious nor 2 valued. (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. 10). Genticularella
—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). Cladophora
—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 plankton.

(Continued on page 48)
Plate 19. Desmids

1. Gonatozygon
2. Spirotenia
3, 4. Docidium
5, 6, 7, 8. Closterium
9. Desmidium
10. Mesoteniun
11. Nitrium
12. Staurastrum (end)
13. Staurastrum (side)
14. Micrasterias

16. Geniculatia
17. Penium
18. Micrasterias
19. Tetmemorus
20. Pleuroterium
21. Cosmarium
22. Cylindrocytis
23. Penium
24. Euastrum
25. Cylindrocytis
26. Euastrum

Closterium, 5, 6, 7, 8
Cosmarium, 21, 22
Cylindrocytis, 25
Desmidium, 9
Docidium, 3, 4
Euastrum, 24, 26
Geniculatia, 16
Gonatozygon, 1

Mesoteniun, 10
Micrasterias, 15, 18
Nitrium, 12
Penium, 17, 23
Pleurotenia, 20
Spirotenia, 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, *Cosmo-
cladium*; bands very broad, many cells ........................................... *Oocysta*

—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 ...... 15

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

—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 ir-
regular; valves marked concentrically or radiately by dots, areolations, lines or ribs; cells often with spines, processes or horns. ........................................... *Cetricalae*—2

—Cells in transection narrowly elliptical to linear, less commonly broadly elliptical, lunate cuneate or irregular valves marked pinnately or transversely by dots, areo-
lations lines or ribs; cells without spines. ........................................... *Pennisetae*—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)
 (=*Lysigiurnium*, *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 transec-
tion; girdle with numerous interzones ........................................... *Rhizosolenla*

—Cells box shaped, as long as broad or shorter, elliptical, sometimes lunate in transec-
tion; 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 prevailingy much shorter than broad (rod-shaped, the longer axis of rod repre-
senting 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) Diatomata
—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. Pseudopareph and central nodule evident, Ceratoneis pseudopareph 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 ........................................................................................................................................................................... 17
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), Frustulina (fig. 18), and Pinularia (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 ................................................................................................................................. 22
—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 ............................................................................................................................................................... 23
—Valve surface not undulate. Valve cuneate, reniform, elliptical or linear (fig. 38), Surirella; valves subcircular, saddle shaped (figs. 31, 32) ................................................................ Camptolodiscus

PROTOZOA

1—Animals with tentacles, and when adult usually attached by a stalk .................................................................................. SUCTORIA
—Animals with pseudopods, 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, Nitzchia
21, 22, Synedra
23, Gyrosigma
24, 25, 26, 27, Navicula
28, Tabellaria
29, 30, Gomphonema
31, 32, Cymatodiscus
33, Cymbella
34, Pinnularia
35, Epithemia
36, Tabellaria
37, Asterionella
38, Surirella
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
Surirella, 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....................................... 3
   —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).................................. 9
   —Without spines though sometimes with scalloped edge (fig. 3)...... Centropyxis

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

2. Centropyxis 16. Dileptus
3. Arcella 17. Halteria
4. Difflugia 18. Euplotes
5. Vampyrella 19. Peranema
6. Actinophrys 20. Paramoecium
7. Stentor 21. Chilomona
8. Coleps 22. Frontonia
9. Holophrya 23. Trichodina
11. Chilodon 25. Astasia
12. Loxodes 26. Carchesium
13. Lacrymaria 27. Epistylist
14. Lionotus
## 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). —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—with 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 ........................................... *Colpodium*

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 10, Gonium 11, Phacus 12, Mallomonas 4, Chlamydomonas 5, Dinobryon 14, Ulvella 15, Synura 6, Euglena 16, Pandorina 7, Eudorina 17, Ceratium 8, Eudorina (young colony) 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
Sphaerella, 2
Synura, 15
Uroglena, 9
Ulvella, 14
Volvox, 3
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 setae or cilia, or both......................................................... 5
   —Corona without setae. Body elongate, Aclylus: body short (fig. 7), (Cupelopagis) Apsilus.

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

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

Plate 23. Rotifers

1, Philodina 20, Diurella
2, 3, Rotifer 21, Rattulus
4, Adineta 22, Dinocaris
5, Floscularia 23, 24, Salpina
6, Stephanoceros 25, Euchlanis
7, Apsilus 26, Monostyla
8, Melicerta 27, Colurus
9, Conochilus 28, 29, Pterodina
10, Ramate jaws 30, Brachionus
11, Mallo-rameat jaws 31, Mallo-rameat Jaws
12, Microcodon 32, Noteus
13, Asphlanchna 33, 34, Notholca
14, 15, Syncheta 35, 36, Anuraea
16, Triarthra 37, Phloeora
17, Hydatina 38, Gastropus
18, Polyarthra 39, Forcipate Jaws
19, Diglena 40, Anapus

Adineta, 4
Anapus, 40
Anuraea, 35, 36
Apsilus, 7
Asphlanchna, 13
Brachionus, 30
Colurus, 27
Conochilus, 9
Diglena, 19
Dinocaris, 22
Diurella, 20
Euchlanis, 25
Floscularia, 5
Fornipate Jaws, 39
Gastropus, 38
Hydatina, 17
Mallo-rameat Jaws, 31
Apsilus, 4
Microcodon, 12
Monostyla, 26
Noteus, 32
Notholca, 33, 34
Pedalion, 41
Philodina, 1
Pkesoma, 37
Pterodina, 28, 29
Renate jaws, 10
Rattulus, 21
Rotifer, 2, 3
Salpina, 23, 24
Stephanoceros, 6
Syncheta, 14, 15
Triarthra, 16
Plate 23. Rotifers
(Continued from page 56)

6—Colonial, frequently in spherical clusters. Clusters attached, \( \text{(Lacinularia)} \), \( \text{Mega-} \)lotrocha, Sinantherina. Free swimming colonies or cluster (fig. 9) Conochilus.
   —Not attached, inhabiting a tube (fig. 9) \( \text{Conochilus} \)
   —Attached, separated, or in branching colonies of one to 30 individuals. \( \text{Conochilus} \)

7—Corona of 3 or 4 lobes (fig. 8) \( \text{Floscularia} \) Cuv. Meliceret \( \text{Anuraeopsis} \)
   —Corona with not more than two lobes. Dorsal antenna present, Limnias; dorsal antenna not evident (Ptygura). \( \text{Oecistes} \)

8—Body with skipping appendages; no foot. (Fig. 41) \( \text{Pedalia} \)
   —Foot usually present. \( \text{Pedalia} \)

9—Animal with flexible cuticle (Illoricata) \( \text{Microcodides} \)
   —Animal with stiff armor (Loricata) \( \text{Microcodides} \)

10—Foot narrow stilette form, corona heart shaped (fig. 12) \( \text{Microcodon} \); foot shorter, corona circular. \( \text{Microcodides} \)
   —Foot absent, or foot with two toes. \( \text{Microcodides} \)

11—Intestine ends blindly, no anus; body sac like. \( \text{Ascomorpha} \)
   —Anus present. \( \text{Ascomorpha} \)

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

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

14—Corona large, nearly transverse, with prominences bearing styles. \( \text{Synchaeta} \)
   —Corona without prominences bearing styles. \( \text{Synchaeta} \)

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

16—With auricles, sometimes retracted. \( \text{Eosphora} \)
   —Without auricles. \( \text{Eosphora} \)

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

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

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

20—Foot transversely ringed or wrinkled; very retractile. \( \text{Anuraeaopsis} \)
   —Foot not wrinkled though often jointed. \( \text{Anuraeaopsis} \)

21—Foot ending in a ciliated cup, armor dorso-ventrally flattened (fig. 28, 29) \( \text{Pterodina} \)
   —Foot ending in one or two toes. Armor arched dorsally, flat or slightly convex ventrally (fig. 30) \( \text{Brachionus} \); armor irregularly oblong, marked with grooves (fig. 37) \( \text{Ploesoma} \); armor compressed laterally, without distinct grooves (fig. 38). \( \text{Gastropus} \)
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) .......... Rattulius
—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 (Squatina) ....................... Stephanops
—Only a median eye .................................................................. 26
26—With long dorsal spines, foot short (Polychaeta) ........................................ 28
—Without long dorsal spines. Head armored, body armor strong (fig. 22) Dinocharis; head with only weak cuticle, body armor thin .................................. Scardium
27—Foot not annulate, one to three segmented. ............................................. 28
—Foot annulate, sometimes attached mid-ventrally ...................................... 29
28—Armor smooth, much longer than broad .............................................. 30
—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 palp; 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 antennae of male biarticulate. Frontal appendage present—(Chirocepha
dalidae) ............................................................... 9
—Clasping antennae 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 ..................... Calypтомera—14
14—Six pairs of feet; foliacious ................................................ Ctenoпoda—15
—Five or six pairs of trunk limbs, first two pairs more or less prehensile—Аномопoda. 19

(Continued on page 62)

Plate 24. Crustacea

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
Ceriodaphnia, 6
Chydorus, 10
Cyclops, 20
Cypridopsis, 18
Daphnia, 1
Diaphanosoma, 12
Dioptomus, 16
Eubranchipus, 21
Eurycerus, 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. (SIDDIDÆ)—16
—Animal enclosed in a large globular, transparent, gelatinous case open ventrally and forming two valves. Antennæ of female with single ramus—(HOLOPEDIDÆ)...

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 Chydroridæ—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...Daphniidæ—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) Simeocephalus
—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) Bosminidæ...Bosmina
—First antenna long and freely movable Macroturricidæ—23

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

24—Valves with spines at upper posterior angle...
—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 Paraphryxus
—Convolutions of intestine in hind part of body. Posterior margin of shell truncated Acantholeberis; posterior margin rounded with slightly 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. Hyocryptus
—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...Lathonopsis

28—Anus at extremity of post abdomen; 2 hepatic setæ (fig. 7) Eury cercus
—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

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
   —Body spherical or nearly so

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

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.

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.

* Published by The Comstock Publishing Co., Inc., Ithaca, N. Y. Price $3.00.
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.

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.

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.
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 (3), 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.

   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.

Fig. 7. The Apron Net.
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 1); 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 1).
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, afluents, 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 algae, 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. Algae—microscopic ones, only when these appear in masses or tinge the water with color.
         Fringing (sessile) algae.
         Slime-coat algae.
         Free floating algae.
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. Algae—microscopic ones only when these appear in masses or color the bottom.
         Fringing (sessile) algae.
         slime coat algae.
         Encrusting algae.

   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. Algae—microscopic ones only when these appear in masses.
         Fringing (sessile) algae.
         Slime-coat algae.
   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 sub-
   merged 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. Algae—Microscopic ones, only when these appear in masses or tinge the
         water with color.
         Free floating alge. Fringing (sessile) alge. Slime-coat alge.
   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. Algae—microscopic ones, only when these appear in masses, or tinge the water with color.
      Free floating algae.
      Fringing (sessile) algae.
      Slime-coat algae.

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

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. Algae—microscopic ones, only when these appear in masses, or color the ledges.
         Fringing (sessile) algae.
         Slime-coat algae.
         Encrusting algae.

   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.


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. Algae—microscopic ones only when these appear in masses or color the bottom.
         Fringing (sessile) algae. Slime-coat algae. Encrusting algae.

   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 algae 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 algae 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 algae" 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.
      Filamentous green algae. Other green algae.

   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, hydans, 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 algae.
   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 Spheriidiæ 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.
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 Unionidae and Sphaeriidae.

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 Batis).
   (b) Internal (as in Libellula, Anax, Gomphus).
   (B) Preserved specimens:
      1. Of gill-bearing larvae (in variety).
      2. Of pupae 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 tracheae 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 \( \frac{1}{4} \) 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 \( \frac{1}{4} \) 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 algae 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 larvae.
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 aerated 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 plancton 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

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<th>Diameter</th>
<th>Number</th>
<th>Diameter</th>
<th>Number</th>
<th>Diameter</th>
<th>Number</th>
<th>Diameter</th>
<th>Number</th>
</tr>
</thead>
<tbody>
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<td>Inch</td>
<td>Inch</td>
<td>Number</td>
<td>Inch</td>
<td>Number</td>
<td>Inch</td>
<td>Number</td>
<td>Inch</td>
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<td>0.230</td>
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<td>0.140</td>
<td>24,661</td>
<td>0.070</td>
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## Conversion Table

- 1 inch = 25.4 millimeters
- 1 millimeter = 0.03937 inch
- 1 quart = 0.9464 liter
- 1 liter = 1.0567 quarts
- 1 pound = 0.4536 kilogram
- 1 kilogram = 2.2046 pounds
- Fahrenheit = 9/5 Centigrade + 32°F
- Centigrade = 5/9 Fahrenheit + 32°C

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