***Lec. 5***

**Study of terrestrial and aquatic ecosystems of insects.**

**Aquatic insects**  or **water insects** live some portion of their [life cycle](https://en.wikipedia.org/wiki/Biological_life_cycle) in the water. They feed in the same ways as other [insects](https://en.wikipedia.org/wiki/Insect). Some *diving* insects ( submerged insects), such as [predatory](https://en.wikipedia.org/wiki/Predatory) [diving beetles](https://en.wikipedia.org/wiki/Diving_beetle),can hunt for food underwater.

Breathing

 All animals require a source of [oxygen](https://en.wikipedia.org/wiki/Oxygen) to live. One problem that aquatic insects must overcome is how to get oxygen while they are under water.

Insects draw [air](https://en.wikipedia.org/wiki/Air) into their bodies through [spiracles](https://en.wikipedia.org/wiki/Spiracles), holes found along the sides of the [abdomen](https://en.wikipedia.org/wiki/Abdomen). These spiracles are connected to [tracheal](https://en.wikipedia.org/wiki/Invertebrate_trachea) tubes where oxygen can be absorbed. All aquatic insects have become adapted to their environment with the specialization of these structures

**Aquatic adaptations for breathing**

Simple diffusion over a relatively thin integument.

Temporary use of an air bubble.

1. Extraction of oxygen from water using a **Plastron or physical gills**, The **plastron** is a series of hairs or bumps on the surface of an aquatic **insect**. The hairs and bumps are used to trap a thin layer of air against the body of the **insect**. As the **insect** breathes the oxygen the thin layer of air is prevented from shrinking due to the action of the hairs and bumps.
2. Storage of oxygen in [hemoglobin](https://en.wikipedia.org/wiki/Hemoglobin) molecules in [hemolymph](https://en.wikipedia.org/wiki/Hemolymph)
3. Taking oxygen from surface via [breathing tubes](https://en.wikipedia.org/wiki/Siphon_%28insect%29) (siphons)

The larvae and nymphs of mayflies, dragonflies and stoneflies possess tracheae but when in larval stage the tracheae are connected to gills, which are very thin extensions of the exoskeleton through which oxygen in the water can diffuse.

Some insects have densely packed hairs (setae) around the spiracles that allow air to remain near, while keeping water away from, the body. The trachea open through spiracles into this air film, allowing access to oxygen.

Other aquatic insects can remain under water for long periods due to high concentrations of hemoglobin in their hemolymph circulating freely within their body. Hemoglobin bonds strongly to oxygen molecules.

A few insects such as [water scorpions](https://en.wikipedia.org/wiki/Water_scorpion) and [mosquito larvae](https://en.wikipedia.org/wiki/Mosquito) have breathing tubes ("siphons") with the opening surrounded by [hydrofuge](https://en.wikipedia.org/wiki/Hydrofuge) hairs, allowing them to breathe without having to leave the water as in Fig.(1).

 FIGURE (1) Hydrofuge hairs on the tip of the siphon tube of an aquatic insect. When underwater, the hairs remain over the spiracular opening and prevent water from entering. At the surface, the hairs open up and allow air to enter.

Orders with aquatic or semiaquatic species

Collembola - [springtails](https://en.wikipedia.org/wiki/Springtail) is (semiaquatic species)

* Ephemeroptera - [mayflies](https://en.wikipedia.org/wiki/Mayfly)
* [Odonata](https://en.wikipedia.org/wiki/Odonata) - [dragonflies](https://en.wikipedia.org/wiki/Dragonfly) and [damselflies](https://en.wikipedia.org/wiki/Damselfly)
* Plecoptera - [stoneflies](https://en.wikipedia.org/wiki/Stonefly)
* [Megaloptera](https://en.wikipedia.org/wiki/Megaloptera) - [alderflies](https://en.wikipedia.org/wiki/Alderfly), [fishflies](https://en.wikipedia.org/wiki/Fishfly), and [dobsonflies](https://en.wikipedia.org/wiki/Dobsonfly)
* [Neuroptera](https://en.wikipedia.org/wiki/Neuroptera) - [lacewings](https://en.wikipedia.org/wiki/Lacewing)
* Coleoptera - [beetles](https://en.wikipedia.org/wiki/Beetle)
* [Hemiptera](https://en.wikipedia.org/wiki/Hemiptera) - true bugs ([water striders](https://en.wikipedia.org/wiki/Water_striders), [giant water bugs](https://en.wikipedia.org/wiki/Giant_water_bugs))
* [Hymenoptera](https://en.wikipedia.org/wiki/Hymenoptera) - [ants](https://en.wikipedia.org/wiki/Ant) (e.g. *[Polyrhachis sokolova](https://en.wikipedia.org/wiki/Polyrhachis_sokolova%22%20%5Co%20%22Polyrhachis%20sokolova)*) and [wasps](https://en.wikipedia.org/wiki/Wasp)
* [Diptera](https://en.wikipedia.org/wiki/Diptera) - [flies](https://en.wikipedia.org/wiki/Fly) and [mosquitoes](https://en.wikipedia.org/wiki/Mosquito)
* Mecoptera - [scorpionflies](https://en.wikipedia.org/wiki/Scorpionfly%22%20%5Co%20%22Scorpionfly)
* [Lepidoptera](https://en.wikipedia.org/wiki/Lepidoptera) - [moths](https://en.wikipedia.org/wiki/Moth)
* Trichoptera - [caddisflies](https://en.wikipedia.org/wiki/Caddisfly)

[Aquatic Insect Ecology](https://www.sciencedirect.com/science/article/pii/B9780123748553000170)

Anne E. Hershey & Robert, M. Northington,  in [Ecology and Classification of North American Freshwater Invertebrates (Third Edition)](https://www.sciencedirect.com/science/book/9780123748553), 2010

Aquatic insects are abundant in most freshwater habitats and often exhibit high diversity. In aquatic food webs, they serve as food items for nearly the full range of vertebrate and invertebrate predators, and many function as predators themselves.

Aquatic insects are hypothesized to be secondarily aquatic having evolved from terrestrial insects. Several features of aquatic insects support this hypothesis and include

1. The retention of a tracheal system for respiration.
2. The reliance of some groups on atmospheric oxygen.
3. The presence of a relatively impermeable cuticle.
4. The presence of primarily aerial adults in taxa with aquatic immatures.

 All of these features are advantageous and requisite for successful colonization of land, but disadvantageous for life in an aquatic

nvironment. In addition, and perhaps most importantly, the fossil record of groups considered to be precursors to insects lacks any evidence of obvious aquatic adaptations, suggesting that insects evolved from terrestrial, not aquatic, ancestors.

Generation Time

Aquatic insects generally have one (univoltine), two (bivoltine), or multiple (multivoltine) generations per year, depending on the order, species, and climatic conditions. However, in environments with very low annual temperatures (e.g., Arctic) or low food availability, an individual generation may require 2 or more years(semivoltine).

AQUATIC RESPIRATION

Aquatic insects evolved from terrestrial ancestors, and various adaptations have been necessary for them to return to the water. The oxygen content of water is considerably lower than in air because of the physical characteristics of gases in water. Therefore, to obtain a comparable degree of oxygen in the water, an aquatic insect must ventilate its gas exchange surface at a much higher rate than that of an air-breathing animal. However, the spiracles of terrestrial insects are too small to function in water, and their cuticles are impermeable to gas exchange. Obviously, to enable some insects to re exploit aquatic niches, it was necessary for them to evolve certain adaptations that allowed them to breathe in water.

Cutaneous Respiration

Another way to prevent water from entering the tracheal system is to completely close off the spiracles and respire through the cuticle. Larvae of the aquatic dipteran, *Chironomus,* have a thin cuticle that allows oxygen to diffuse into the well-developed tracheal system beneath it.

Another step toward respiration through the cuticle is the development of tracheal gills that are outgrowths of the body wall covered by relatively thin cuticles with rich supplies of tracheae. The abdominal gills of ephemeropterans are platelike outgrowths that undulate continuously to circulate oxygenated water over their surfaces as the insect swims (Figure 2). Zygopteran odonate larvae have three caudal gills that are similarly configured to take up oxygen, and their undulations also serve as rudders to aid in swimming.



FIGURE (2) Abdominal gills of the mayfly.

From McCafferty (1981). Reprinted with permission.Copyright © 1981

 Other Abiotic Factors

Many aquatic insects are sensitive to water level and flow rate (Ward 1992). Water level affects both the temperature and quality of the water; temperature because smaller volumes absorb or lose heat more quickly than do larger volumes, and quality because various solutes become more concentrated as water evaporates. Insects, and other aquatic arthropods, show life history adaptations to seasonal patterns of water availability or quality, often undergoing physiological diapause as water resources disappear (Batzer and Wissinger 1996, Ward 1992). Although most mosquitoes oviposit in surface water, floodwater mosquitoes, *Aedes* spp. and *Psorophora*spp., oviposit in soil at the high water line. Their eggs are resistant to desiccation and can remain dormant for several years. Egg hatch is stimulated by flooding, and the number of generations at a site depends on the frequency of flooding (Wiggins et al. 1980).

Light is an important factor affecting development, behavior and/or distribution of many insects. Some aquatic insects are negatively phototactic during most of their lives, but may move toward light under conditions of oxygen depletion (Ward 1992). Algal feeders are more likely to occur in illuminated portions of streams. Moonlight affects drift rates for species that disperse in stream currents and is a synchronizing agent for emergence of a number of aquatic species, especially nocturnal feeders, with different species emerging during different lunar phases (Ward 1992). A variety of insects are attracted to lights at night, an attribute that facilitates collection and measurement of diversity.

**What do they eat?**

The foods of aquatic insects are just as diverse as the habitats they live in. Although individual kinds of aquatic insects may only eat one type of food, all organic material in the water, living and dead, is eaten by some kind of aquatic insect. Scientists have found it informative to categorize aquatic insects according to how they obtain their food for studying the ecology of freshwater ecosystems. These categories are called functional feeding groups.

**Scrapers** have special mouthparts that remove algae growing on the surface of rocks or other solid objects. These mouthparts work like a sharp blade to remove the outermost layer of algae, which is attached very tightly but is very nutritious for those insects equipped to remove it.

**Collectors** acquire small pieces of decaying plant material (detritus). Some kinds use long hairs on their head or legs or silk nets to filter these small particles out of the water. Other kinds of collectors use their mouthparts to gather fine particles lying on the bottom and shove this material into their mouths.

**Shredders** have mouthparts that are designed to nibble off pieces of soft vegetation, such as leaves, flowers, or twigs, and grind up this material. Most aquatic insects shred pieces of vegetation that have dropped off of plants and are decaying. Most of this material comes from trees and shrubs that grow on land at the edge of the water. Only a few kinds of aquatic insects feed on parts of live plants that grow under the water.

**Predators** feed on other animals that are alive. Predators often have special structures for catching and subduing their prey, such as strong jaws with teeth, a sharp beak, or spiny legs. Predators eat other invertebrates most of the time, but some are large and strong enough to catch small vertebrates, such as fish and tadpoles.



**How do they reproduce?**

Only adult insects are capable of reproducing, and most aquatic insects spend their adult stage out of the water. After mating on land, females return to the water to deposity her eggs. Eggs are usually stuck on solid objects under water, but a few kinds deposit the eggs on trees or rocks above the water. Eggs usually hatch within a few days or weeks, but some may be programmed to not hatch for many months. A delay in hatching allows an aquatic insect to live in habitats that are too hot, too cold, or dry up during part of the year.

Collecting Aquatic Insects

Aquatic insects are always easy to collect because they are so numerous and they live in so many different places. The simplest way is just to pick up objects in the water, such as rocks, plants, sticks, or leaves, and examine the material. Sometimes it works best to place the object in a shallow pan with clean water. You can see aquatic insects with your naked eye, but a magnifying glass might help to find some of the smaller ones.

You will probably collect more organisms by using a net with fairly fine mesh. There is no reason to kill aquatic insects unnecessarily, so it is always best to release them back into the water alive after studying them for a while. However, since most aquatic insects are very abundant, it is acceptable to make a preserved collection of common ones for educational purposes. The best way to preserve aquatic insects is to place them in alcohol in a small clear container with a tight fitting lid. Rubbing alcohol (isopropanol) works fine. You should put a paper label in the container stating what kind of aquatic insect it is, as well as where and when you collected the organism. The labels should be written in pencil or indelible ink.

What Good Are They?

Aquatic insects are probably best known for their ability to tell us about the water quality in a particular environment. Some of them are very sensitive to pollution, while others are tolerant. If you take a sample of the aquatic insects in a particular place, and analyze the sample in terms of the sensitive kinds versus tolerant kinds, you can get a good measure of the environmental health. Healthy aquatic environments have a lot of different sensitive kinds, while polluted environments have only a few kinds of tolerant aquatic insects. This process is called biological monitoring (or biomonitoring) and is commonly done by government agencies as well as citizen volunteer organizations.

Some of the aquatic insects are responsible for breaking down the dead leaves and other plant parts that fall into bodies of water from land. This material provides the base of the food chain in some aquatic environments, especially small streams in forests.

Some scrape the algae that grow on all firm surfaces in water, such as rocks, logs, and the leaves and stems of live rooted plants. This layer of algae, which produces much oxygen and food for other organisms, is more productive if it is kept thin by the grazing of aquatic insects and other invertebrates.

Other kinds of aquatic insects are specialized for filtering fine particles that are suspended in the water. This is useful because it helps to keep the water clear enough for light to penetrate where algae and other plants are growing on the bottom. Other kinds mix the soft bottom sediments as they burrow in search of food. This makes the bottom healthier for organisms because it puts oxygen from the water into the bottom. Lastly, the aquatic insects that are predators reduce the numbers of other invertebrates and help keep a balance among the different kinds of organisms and the food that is available.

Major Groups of Aquatic Insects

There are so many different kinds of aquatic insects, it is difficult to appreciate their biological diversity without considering some of the individual kinds. The following section provides a brief summary of the eight major groups.

**Mayflies** (Ephemeroptera)
**Dragonflies and Damselflies** (Odonata)

**Stoneflies** (Plecoptera)
**True Bugs** (Hemiptera)

**Dobsonflies and Alderflies** (Megaloptera).

**Water Beetles** (Coleoptera)
**Caddisflies** (Trichoptera)

**True Flies** (Diptera)

WATER INSECTS THAT BURROW IN THE SAND

Several aquatic insect varieties burrow in mud and sand during their larval and nymph stages. Burrowing provides protection from predation and ensures moisture is available in low water conditions. Burrowing insects are common in warm and cold freshwater environments. The insects typically leave the burrow during emergence cycles that lead to the adult phase of the life cycle.

**Diptera**, **Trichoptera, Ephemeroptera, Megaloptera.**

Aquatic Insect Web Links

<http://www.people.virginia.edu/~sos-iwla/Stream-Study/StreamStudyHomePage/StreamStudy.HTML>
<http://www.usask.ca/biology/skabugs/>
<http://zebu.uoregon.edu/~dmason/rivsci/aquabugs.html>
http://www.fishing-in-wales.com/wildlife/insects/
http://www.bio.umass.edu/biology/conn.river/insects-general.html
http://www.dnr.state.md.us/bay/cblife/insects/
<http://www.fs.fed.us/r6/centraloregon/kids/kidswatersite/aquaticinsects/aquatic_insects.htm>
<http://www.dec.state.ny.us/website/dow/stream/>