Figure 3. Bracken (*Pteridium aquilinum*). Spores develop under rolled edges of the leaves. Unusual for ferns, bracken often thrives in dry sites, probably because deep underground rhizomes produce new plants by vegetative growth.

Photographs by Gregory Wiggins and Stephen Herrero.

Figure 4. The field horsetail is a common species of the genus *Equisetum*; spore-bearing shoots lacking chlorophyll appear in spring followed by the green photosynthetic plants. The history of this group of ancient plants extends through some 400 million years to the present. All that now remain are 15 species of *Equisetum* largely confined to northern latitudes. *Equisetum* may be the oldest surviving genus of plants on Earth.

Photographs by Gregory Wiggins and Stephen Herrero.

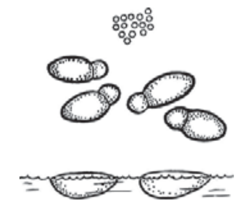
Figure 12. European frogbit (*Hydrocharis morsus-ranae*) is an aquatic plant introduced from Europe and spreading through parts of northeastern North America.

Photograph by Michael Butler.

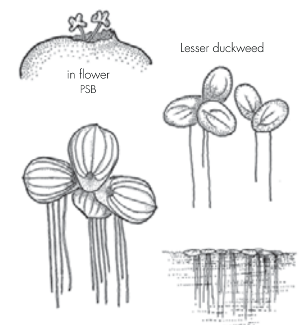
lobate plants of lesser duckweed (genus *Lemna*). These are green on the underside and bear a single rootlet on each lobe. Also mixed into the surface mat there may be somewhat larger lobes of greater duckweed (diameter up to 10 mm, genus *Spirodela*); these plants are brownish red on the underside, and bear a tuft of tiny roots. Another species of *Lemna*, star duckweed, grows in clumps just below the water surface; lobes of these plants grow in a branching pattern and are somewhat larger than other duckweeds.

Small as they are, duckweeds are not to be confused with algae, which also grow in these still waters but usually in masses of green filaments. As flowering plants, duckweeds can produce flowers and seeds, which algae, of course, cannot do (see Section 5). Even so, duckweeds rarely flower, and when they do the plants are so small that their simple flowers are usually not recognizable with the unaided eye. Pollination, when it does happen, would occur above the water surface. For the most part, duckweeds proliferate by budding off new plants—a more rapid and efficient way of reproducing in the few months of a short growing season at northern latitudes.

When you think about it, floating on the water surface is an effective way of living. All plants compete for the sunlight they must have to convert carbon dioxide of the atmosphere into their own carbon compounds for growth. Conventional plants extend their leaves into the sun's rays from upright stems, supporting the whole with roots held firmly in the ground. Trees competing for sunlight in a forest are the ultimate extension of that approach to life. But duckweeds in their extremely simplified form can float on the water surface beyond the shade of competing plants to gain greater exposure to the sun. In this way, duckweeds fix carbon efficiently, injecting organic compounds into the food webs of marshes and lakes. All species of duckweeds are eaten



Watermeal (*Wolffia*) is the smallest flowering plant.
PSB



Greater duckweed
PSB

Figure 49. The fiery hunter is one of the ground beetles (family Carabidae), named for the red to coppery pits on its elytra, and also because both adults and larvae are voracious predators on cutworms and other caterpillars. The scientific name *Calosoma calidum* is derived from the Greek *kalos*, beautiful, and *soma*, body; and from the Latin *calidus*, hot, in reference to the red pits. These beetles are widely distributed through North America where they occur in dry open areas with low vegetation. Adults live for several years and begin hibernation in late summer.

Illustration by Anker Odum.

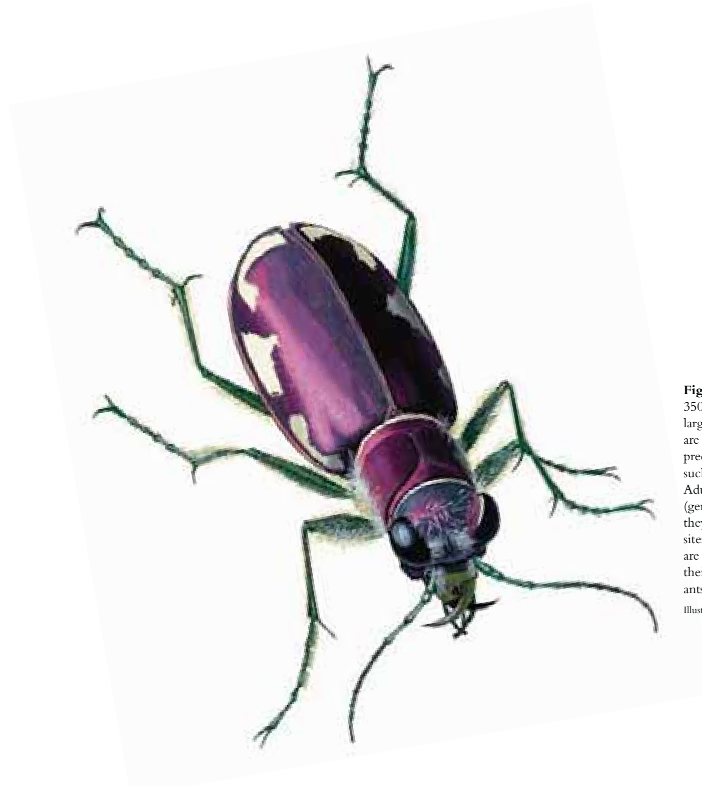


Figure 50. Beetles numbering some 350,000 known species comprise the largest order of insects. Tiger beetles are a small although common group of predacious beetles living in dry habitats such as sandy beaches and roadsides. Adult tiger beetles such as this one (genus *Cicindela*) have stout mandibles; they run and fly rapidly over open dry sites to capture insect prey. The larvae are concealed in short vertical burrows, their large mandibles ready to capture ants and other small insects that pass by.

Illustration by Anker Odum.

Figure 62. Monarch butterfly caterpillars with their prominent bands of yellow, black, and white are clearly meant to be seen by predators. These caterpillars feed almost exclusively on milkweed (2.3.5.2); they avoid the milky latex of the plant by severing the lactiferous ducts in the leaves, causing the leaf to droop and the latex to flow from the opening while the caterpillar eats the leaf beyond the puncture.

Photograph by Kit Chubb.

Figure 19). Aposematic colour patterns often focus on patterns of black contrasting with orange, red, yellow, and white.

The most impressive biological feature of monarch butterflies is their extraordinary migration, behaviour more like a bird than an insect. This species ranges through South America and to Australia and New Zealand. Monarch butterflies reproduce year round at warmer latitudes, but in Canada and much of the United States they cannot survive winter conditions. Consequently, natural selection has opened a migratory lifestyle as a solution to exploiting the rich food resources provided by milkweeds in much of North America. Every year in late summer to early autumn throughout eastern and central North America, monarchs fly southward to particular locations in montane forests of central Mexico where they pass the relatively mild winter festooned inactively on the branches of fir trees. On return of spring to their mountain retreat, the butterflies become active again, mate, and begin their return migration. As the migrants follow the northward advance of spring, females deposit eggs on milkweed plants, and adults developing from those larvae continue the return migration northward. Through subsequent generations, monarch butterflies reach the northern limit of their range at latitudes of Ontario, arriving in May and June as milkweeds there are beginning a new season. Monarchs arriving in Ontario complete a first generation in about 6 weeks, followed by a second generation that appears as adults in late summer. These butterflies accumulate an energy reserve of body fat and then, on some cue, fly southward again.

Monarch caterpillars are dependent on milkweeds for their food. Although milkweeds of some species are aggressive native plants, there are fewer of them than there were a century ago. Modern agricultural efficiency, employing larger unbroken tracts of land cultivated for corn and soybeans in eastern and central areas of North America, has reduced milkweed density substantially. In Ontario, milkweed (2.3.5.2) is classed as a noxious weed and its destruction is encouraged; the butterfly relationship seems simple enough—less milkweed, fewer monarchs. Monarch butterflies are now placed as vulnerable on the list of endangered species in Canada (see Sources: 3.6.4.18). In addition to massive reduction in their larval food plants through much of North America, these butterflies are also suffering loss of their overwintering forests in Mexico because trees are cut for firewood. There are, however, movements under way to plant other trees in more accessible areas, saving the fir trees higher up in the mountains for the butterflies and secondarily for the ecotourists.

Figure 65. Lichens are a symbiotic partnership between a fungus and an alga or a cyanobacterium. Foliose lichens (A) are leaf-like in form and often reveal cup-like fruiting bodies that produce spores. Fruticose lichens (B) are closely branched forms resembling miniature shrubs.

Photographs by Kit Chubb.

Lichens reproduce and disseminate through propagules comprising fungal hyphae surrounding cells of the photosynthetic partner, or by fungal spores alone that subsequently become infected by the appropriate alga or cyanobacterium.

Lichens are one of the first organisms to colonize newly exposed volcanic rocks. Growing on rock faces, their simple fungal hyphal filaments penetrate granular rock surfaces, augmenting the fragmentation of mineral materials important in forming soils and opening the way for plant seeds to germinate. Lichens in which the photosynthetic partner is a cyanobacterium bring an additional asset to soil-building because they incorporate or fix atmospheric nitrogen into compounds that plants require for growth (Section 6). Nitrogen fixation by lichens with cyanobacterial symbionts contributes significantly to the nutrients of coniferous forests; soluble nitrogenous compounds produced by lichens growing on the trees are washed by rain to the forest floor and absorbed by mycorrhizal fungi on the roots of trees.

Fruticose lichens (Figure 65B) grow especially abundantly on Arctic tundra where they are an important food resource for caribou, leading to the misleading name "reindeer moss." Humans lack the intestinal bacteria required to efficiently break down the cells of lichens, and consequently lichens are starvation food for humans. Even so, for Arctic aboriginal people dependent on caribou, lichens make a fundamental contribution to their food chain. Lichens are also useful sources of dyes for artifacts made by aboriginal peoples.

Lichens grow very slowly and are resistant to extremely low temperatures; they are abundant on Arctic tundra, in the Antarctic, and on mountain peaks. Exposed to the sun on bare rock surfaces, they are also tolerant to heat and desiccation. In areas of thin mineral soil in the open field at the farm, fruticose lichens grow in dense patches. During periods of extended drought they dry out to become brittle and fragile, but quickly become soft and pliant when rain returns.

Despite their resistance to physical extremes of natural environments, lichens are highly susceptible to airborne pollutants such as the sulphur dioxide that causes acid precipitation. Lichens are eliminated on continued exposure to these substances and their disappearance is used as an indicator of plumes of atmospheric pollution.

The perception that lichens represent a functional symbiosis between a fungus and a