46 MEMORABILIA ZOOLOGICA

Bolesław Burakowski

Laboratory methods for rearing soil beetles (*Coleoptera*)

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INTRODUCTION

Beetles are the most numerous group of insects; nearly 300,000 species have been described up till now, and about 6,000 of these occur in Poland. The morphological variability and different modes of life result from beetle ability to adapt to all kinds of habitats. Terrestrial and soil living forms dominate. Beetles undergo a complete metamorphosis and most species live in soil during at least one of the stages. They include predators, herbivores, parasites and saprophagans, playing a fairly significant role in nature and in man's economy.

Our knowledge of beetles, even of the common species, is insufficient. In spite of the fact that the beetle fauna of Central Europe has been studied relatively well, the knowledge accumulated is generally limited to the adults, while the immature stages have not been adequately studied. Moreover, little is known about their ecology, habitats, behaviour and life cycles. Beetle rearing is a very effective method for learning more about these insects. So far, there has been no comprehensive paper on beetle culture. More or less detailed instructions concerning rearing may sometimes be found in papers dealing with some other problems. Rearing methods used for representatives of several beetle families are given in collective publications edited by P. S. GALTSOFF et al. (1959) and G. B. WALSH and J. R. DIBB (1954). Field insectaria, cages and rearing containers are presented in a well illustrated paper by A. PETERSON (1934).

While identifying adults from Central Europe, it is very helpful to use the still popular 5-volume publication by E. REITTER (1908, 1909, 1911, 1912, 1916) and the more recent 11-volume collection of papers with revised terminology (ed. by H. FREUDE, K. W. HARDE, G. A. LOHSE, 1964–1983). In addition to this, some families with species occurring in Poland have been described by various authors in "Klucze do Oznaczania Owadów Polski". The general distribution of beetles and some faunistic data may be found in a study by A. HORION "Faunistic der deutschen Käfer" published in 12 volumes from 1941 to 1974. Occurrence of beetles in Poland, and their distribution in particular regions, short notices about the ecology and bionomics are presented in 17 volumes devoted to

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Coleoptera of the "Catalogus faunae Poloniae" (BURAKOWSKI, MROCZKOWSKI and STEFAŃSKA 1971–1991).

The existing identification keys to larvae of European species of beetles are usually limited to discussions of families or genera; only a few of them include all the species known from a particular territory. In this respect, collections of papers edited by M. S. GILJAROV (1964) and B. KLAUSNITZER (1978) are worth mentioning. If some genus includes species whose larvae are not known, then rearing larvae to adults in the laboratory is the only sure method for obtaining accurate identifications of species.

In the literature on beetle culture (HILDT 1910, TENENBAUM 1923) there are opinions that great difficulties must be overcome in rearing beetle larvae from egg to imago. Beetle culture is generally less popular than rearing butterflies from eggs and caterpillars. However, a wider use of this study method is confirmed by more and more frequently published reports about successful cultures of all the life stages of beetles.

Family: Tiger Beetles (*Cicindelidae*)

About 1,600 species have been described so far; they occur almost all over the world, except for most extreme northern areas. About 40 species occur in Europe and seven of these, belonging to one genus – *Cicindela* L. – live in Poland. These seven species are not distributed evenly all over the country, and each of them inhabits a definite habitat. Knowledge of the ecology and bionomics of particular species of tiger beetles, and of other beetles as well, makes it easier to find and run a successful culture not only of adults but of the immature stages as well.

In Poland, tiger beetles live in open, insolated places with sparse low vegetatiom; they do not occur in forests. *C. maritima* DEJ., considered to be a halophilous species, lives mainly along the sandy coast of the Baltic. The montane species *C. sylvicola* DEJ., occurs in the southern part of Poland in loam and limestone soils. The most common species, *C. campestris* L., settles in soils rich in humus, and lives both in lowland and in mountain areas where it reaches even beyond the upper limit of forests; it is often recorded in peatbogs and heaths. The equally common *C. hybrida* L. occurs only in sandy areas; it is recorded mainly on dunes, but also on the edges of forests and water bodies and on soft farm tract. Damp loam is inhabited by *C. germanica* L. The edges of pine forests are inhabited by the rare *C. sylvatica* L. *C. arenaria viennensis* SCHRANK, known only from a few sites, confines its territory to small barren sandy areas where water seeps from deeper layers to surface ones.

Adult tiger beetles are very predaceous and voracious. On bright warm days they attack, on the run, various live insects and spiders. When it is cloudy or rainy they hide in shallow burrows made in soil or occasionally under stones.

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Larvae are predaceous, too, and they wait for their prey hiding in vertical tube-like tunnels burrowed in soil. The body of larvae is adapted to living in tunnels and to obtaining food. The head and pronotum are highly sclerotized and fit the entrance hole in the burrow. Two hooks and setae stick from the fifth tergite of the abdomen. These hooks, clingy legs and the last segment of the abdomen bent forward allow the larva to move in the tunnel and to keep immobile in its vertical position while waiting at the entrance for passing prey, that is for small invertebrates.

The life cycle of tiger beetles generally lasts for two years but – depending on the habitat, food supply and climate – this period may be prolonged to three years or shortened to only one. Females oviposit in summer, laying eggs singly into wet soil; if it is loose sandy soil then down to 10–15 mm, but in the case of loam or cohesive soil – to a depth of 5 mm. A female laying eggs in cohesive soil uses its ovipositor to make a longish, oval cell and the bottom of this the egg is placed vertically so that it touches the soil with its polar part only. This position allows fresh air into the cell, protects the egg from microorganisms and enables a newly emerged larva to build a vertical tunnel.

Larvae moult three times in their lifetime. Since their bodies expand in the process they enlarge and deepen their tunnel. A first instar larva burrows a tunnel, 0.8–1.5 mm in diameter, to a depth of 4–6 cm. A second instar larva enlarges its tunnel until it is about 12–20 cm long and about 2.5–3.0 mm in diameter. The tunnel of a third instar larva may reach, in loose sand, down to 40 cm, and the entrance hole is 4–6 mm in diameter. Larvae leave their tunnels very rarely. Shortly before each moulting, wintering or pupation larvae close the external part of the tunnel with soil. A larva pupates on the bottom of its tunnel, in the pupal cell. The pupal stage lasts for about two weeks. The emerged adult either comes out of the soil, fulfils its functions and dies before winter (e.g. *C. germanica* L., *C. arenaria viennensis* SCHRANK) or overwinters in its pupal cell and appears in spring (e.g. *C. campestris* L. and *C. hybrida* L.).

In the literature there is little information about tiger beetle culture. As a rule, there are short, often sketchy remarks given in papers devoted to some other subject. For instance, FRIEDERICHS (1931) in a paper on the morphology and physology of sight in *C. hybrida* L., *C. campestris* L. and C. *sylvicola* DEJ. informed that he had reared adults in large cages encased in wire gauze, where the bottom was covered with sand and small stones. The cages were put in insolated places either on a window sill in the laboratory or outside. The sand was moistened with water every day. The beetles were fed with flies and insect larvae. They survived for 2–3 months. Their larvae were placed singly in test-tubes filled with sandy soil. The test-tubes were put into dark boxes with glass lids, and placed on a window sill or outside in an insolated place. Larvae were given the same food as that for imagines. Every day, the sand in the test-tubes was sprinkled with a few drops of water. Larvae were reared for a few months. The author pointed out that for the tiger beetles in his culture humidity had been more important then food.

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During his investigations on the importance of sight and memory in adults of *Cicindela hybrida* L., Świecimski (1957) reared these beetles in the laboratory at 21°C in different terraria measuring 25 x 16 x 18, 40 x 25 x 25 and 55 x 32 x 31 cm. The bottom of each terrarium was covered with sand, and xerophilous plants were planted there. The sand was sprinkled with water throughout the culture period. The beetles were fed with live invertebrates such as snails, beetles, flies and homopterans, also with insect larvae. The author found out that adults attacked their prey only when it was moving, but they paid no attention to dead animals. In Świecimski's (1957) experiments, the maximum distance at which prey was noticed by a tiger beetle was 23 cm.

A similar behaviour of adults was recorded by Faasch (1968) in her studies on the biology of *C. hybrida* L. and *C. campestris* L. This author reared imagines in glass terraria with a 20-centimetre layer of coarse-grained sand on the bottom. In the field imagines were reared in large containers measuring 180 x 30 x 40 cm, with one side made of a glass pane, another of some wire screen, and the bottom covered with sand. Larvae were reared singly in glasses 5 cm in diameter and 8.5 cm high, with sand filling two-thirds of their capacity. The sand was moistened regularly. Larvae and adults were fed with various insects, both their imagines and larvae, with spiders and finely cut beef. Many larvae pupated and, later, adults emerged.

During the author's own investigations into the morphology and bionomics of Polish species of *Cicindelidae* it appeared necessary to establish and carry out culture of all the life stages of particular species in this family.

Some general information about the occurrence of these beetles has been given in the Introduction. Imagines difficult to collect are caught into an entomological sweep net or by hand, but first dry sand is thrown onto a beetle ready to fly away. Catching larvae is easier. They can be found in greater numbers than adults, from spring to autumn, regardless of the weather. Holes leading to their tunnels indicate places where they live. Very frequently, within a small space there are several or over a dozen tunnels of larvae at three developmental stages. Even if a larva is being taken out of soil very carefully, with a shovel, its body may be damaged. And many other larvae are lost because they cannot be found if their tunnels are accidentally filled up with sand. It is time-consuming to examine soil in order to find larvae in soil samples. Better results can be achieved if the author's method is used. First, some tunnels must be found, then thin grass blades are carefully pushed into them to the right depth, so as not to damage the larvae staying at the bottom of the tunnels; as mentioned before, such a tunnel may be from 4 to 40 cm deep. Only now is soil removed along the blade until the larva is found. At the same time, other larvae, disturbed in other tunnels, crawl along blades to the surface of the soil, and these can be collected at smaller depths. Some may even come outside, others snatch the end of the blade with their mandibles and these must be pulled out very carefully. Due to their rapacity, both larvae and adults are carried singly to separate vials with wet soil collected from near their tunnel. The vials are stoppered with cotton-wool plugs.

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Every copulating pair of tiger beetles may be placed in a glass jar. The amount of soil required for culture is 1 – 2 dec^3.

At first, adult tiger beetles were kept in the laboratory in big glass terraria (Fig. 1) measuring 20 x 32 x 25 cm, and larvae in jars of 1.0 or 0.5 dec^3. The bottom of these containers was covered with a ten-centimetre layer of soil. Such cultures turned out to be uneconomical because they occupied a lot of room and much effort was required for establishing them and maintaining. The author's own

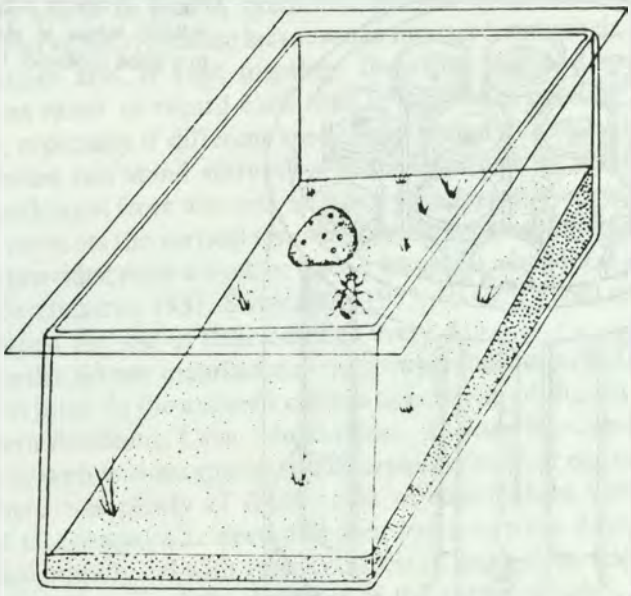

Fig. 1. A terrarium for rearing tiger beetles (*Cicindelidae*).

experience proves that beetle cultures can be run more successfully in much smaller glass containers where it is even easier to study closely the particular stages in life of a beetle. When the objective is to obtain eggs from adults, tiger beetles can be reared in pairs either in square aquaria measuring 10 x 20 x 14 cm, or of similar dimensions, and covered by a glass lid, or even in 0.5 dec^3 glass jars with a lid. They must have a slanting layer of wet soil, 1 – 4 cm thick, on the bottom. During rearing, as the soil dries out, moistening is applied only to one-third of it, at the thinner part of the layer. It is here that females oviposit into the wet soil and then first instar larvae appear. Here they are easier to observe and carry over to individual cultures. It is a little different when adults living in loam are reared. In this case, inseminated females may be placed in containers with sand only, save for a small lump of wet clay on the surface. A female may lay over 10 eggs into a lump measuring about 7 x 5 x 3 cm, and larvae will hatch in due course.

The adaptability of larvae is very great. If this ability to adapt is taken advantage of, rearing may be very successful even if the surface and volume of

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soil are further reduced. Eggs and first instar larvae can be placed in glass tubes 9–12 mm in diameter and 60 mm long, and third instar larvae in tubes that are 15–22 mm in diameter and about 100 mm long. Three-fourths of the tubes must be filled with soil. Eggs and first instar larvae are placed in a hollow made with a thin stick near the wall of the tube. Second and third instar larvae are put on the surface of the soil in the tube. The tubes are closed with cotton-wool plugs. It takes older larvae 10–30 minutes to burrow a tunnel in which they hide. The

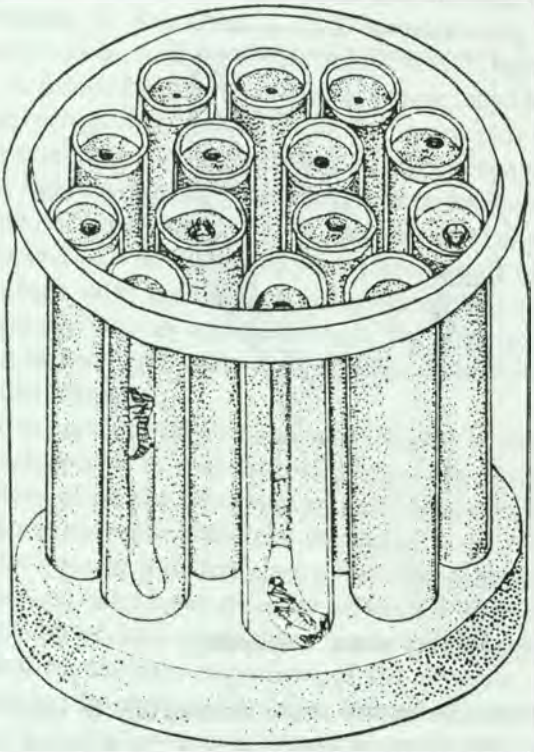

Fig. 2. A culture of tiger beetle (*Cicindelidae*) larvae in glass tubes placed in a glass container 1 dec^3 in volume.

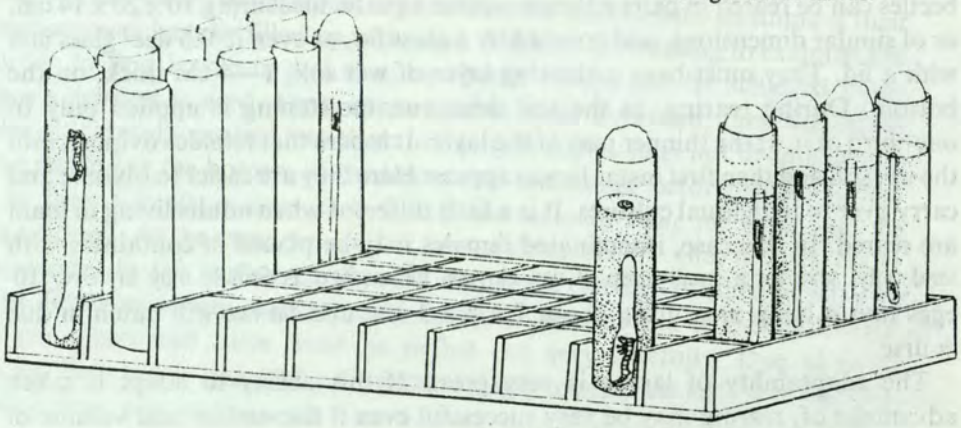

Fig. 3. A tray for tubes with a culture of tiger beetle larvae.

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cotton-wool plugs may then be removed and the tubes may be open until pupae appear. Larvae usually adapt to such small containers and they never leave their tubes if they have enough food and the humidity of the soil is adequate. Smaller tubes with larvae are placed vertically in glass jars whose volume is 0.5 dec^3, bigger tubes in jars whose volume is 1 dec^3, all with lids (Fig. 2), or in aquaria covered by a glass pane. Tubes can be placed on specially constructed stands (trays) (Fig. 3) and these are put into bigger, closed glass containers. There must be a two-centimetre layer of moist sand on the bottom of the containers into which tubes are to be put. A small and shallow container should be used for rearing one larva only, because larvae make intersecting tunnels on the bottom of their container and, if kept together, they may eat one another. To make observations easier to record each tube or container must be labelled. This is important, especially if different species are reared at the same time.

Tiger beetles can stand starvation better than lack of water. Adults obtain water by sucking it from wet soil. In tubes with larvae, wet soil is indispensable because it prevents the vertical tunnels from collapsing. In the author's cultures water was provided once a week or once a fortnight when food was ample. Other authors (FRIEDERICHS 1931, ŚWIECIMSKI 1957, FAASCH 1968) reported that they had moistened the soil in their cultures every day.

Tiger beetles do not manifest any narrow specialization in feeding so long as their food is juicy. In the author's culture tiger beetle adults were fed with beetles of the genera *Bembidion* LATR., *Amara* BON., *Agonum* BON. and *Acupalpus* DEJ., occasionally with various species of *Elateridae*, with their elytra torn away. Even though there was plenty of food, cases of cannibalism were recorded. Two females of *C. germanica* L. devoured their partners a few days after copulation. Larvae were initially fed with various insects of small sizes, selected to match the age of a given larva and the diameter of the entrance hole.

Worker ants of *Lasius niger* (L.) proved to be the most suitable food, fresh and accessible, for the larvae of tiger beetles reared. These ants were therefore reared from May to September in order to provide a sufficient food basis for the tiger beetle larvae. An ant colony found in soil or under a stone was put, together with the soil, into a glass jar of dec^3 in volume, and a colony found in a rotting stump into a container of 2–3 dec^3 in volume. A detailed description of the culture methods for this and other ant species can be found in a paper by CZECHOWSKI and PISARSKI (1992).

Once a day, an appropriate amount of food, suited to the age of a given larva, was inserted, with tweezers, into the entrance hole of the larva's tunnel. And so, a first instar received one or two ants, a second instar 5–10 ones and a third instar – 10–20 ones. The larvae were fed at certain intervals which proved enough to keep them alive and to ensure the desired development. The larvae were given ants with crushed heads; living ants drag tiger beetle larvae out of their tunnels and kill them.

Larvae can stand starvation. An undernourished larva completes its development not within one year, but during two or even three. Hungry larvae often appear at the entrance and wait for prey. When they are full the food given is

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thrown away as from a catapult to a distance of 3–8 cm, and the same is also done with scrap and with anything that cannot be eaten. All this should be removed from time to time.

At the time of hibernation, when the larvae had closed the entrances to their tunnels, rearing containers were taken to a cool room and left until the tunnels were opened again. Starting in March, the culture was inspected every week and active larvae were taken to the laboratory. Here, the larvae were fed from time to time, they pupated and adults appeared from May to July. Cultures run in this way yielded satisfactory results. They provided possibilities for the development, from egg to aduls of most tiger beetle species occurring in Poland, including two rare species: *Cicindela germanica* L. and *C. arenaria viennensis* SCHRANK.

Family: Ground Beetles (*Carabidae*)

Ground beetles constitute one of the larger families in the taxonomic system of beetles. They live all over the world and they are particulary numerous in the temperate zone. About 40,000 species have been recorded up till now; about 2,800 species occur in Europe and these belong to nearly 200 genera. Data on the distribution of the 494 species living in Poland, and the source-books for these data, are presented in the second and third volumes of a catalogue of beetles (BURAKOWSKI, MROCZKOWSKI, STEFAŃSKA 1973, 1974). Beetles belonging to this family have been discussed in many papers on morphology, taxonomy, ecology and the role they play in nature and in man's economy. However, there is no monographic paper on ground beetles. Ample data on their bionomics and ecology are presented in papers by BURMEISTER (1939), LARSSON (1939), LINDROTH (1945) and THIELE (1977). Many ground beetles destroy pests, and this was taken into account in ecological studies undertaken first by NUNBERG (1949) and by KARPIŃSKI and MAKÓLSKI (1954). Similar investigations, mainly in forest biocoenoses, were carried out by other Polish entomologists, e.g. M. GÓRNY, L. GRÜM, A. LEŚNIAK and J. SZYSZKO.

An investigator interested in rearing ground beetles must be able to identify his experimental material to a species. The basis for determination may be provided by papers in the form of keys (KULT 1947, FREUDE, HARDE, LOHSE 1976). These keys make it possible to identify only adult stages. Unfortunately, immature stages are still very poorly known. The existing keys to the identification of larvae are very incomplete (LARSSON 1968, ŠAROVA 1964). Within the 76 species of the genus *Bembidion* LATR. occurring in Poland only 10 larvae have been described, in other genera such as *Amara* BON. or *Harpalus* LATR., with about 50 species each, nearly 30% of larvae are well-known. Larvae of the genus *Carabus* L. are the only ones that have been described very well (HŮRKA 1971). All the species occurring in Poland are listed in a key for identifying larvae.

Ground beetles are characterized by a variety of forms and modes of life, and by their ability to adapt to different habitats. The body of the largest species reaches 40 mm in length while that of the smallest ones is only 2–3 mm long.

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Ground beetles inhabit both open areas and those with trees, and the greatest species variety is recorded in forest habitats. Most species belong to epigean beetles and some of these, e.g. of the genera *Broscus* PANZ., *Clivina* LATR., and *Dyschirius* BON. can burrow tunnels in soil. A small number of species belonging to the genera *Calosoma* WEB., *Dromius* BON. and *Lebia* LATR. live on the ground in wooded areas; they climb up trees and bushes and are able to fly. Certain epigean species either are wingless or have reduced wings, e.g. such is the case in individuals of the genus *Carabus* L. With a few exceptions (*Dromius* BON., *Tachyta* KIRBY), the development of the preimaginal stages takes place in soil and, unlike the related family *Cicindelidae*, these larvae burrow horizontal tunnels and the active life of the larvae is generally shorter than that of the adult stages.

Most ground beetles feed on animal food either throughout their individual life or only at some stage of their development. These carnivores include predators attacking larvae and pupae of insects, and snails and therefore they are considered insects useful in agriculture and forestry. *Calosoma sycophanta* L., as an adult and a larva, can destroy 550 larvae of *Lymantria dispar* L. throughout its life. SHAROVA (1958) has distinguished 9 morphological types among larvae, depending on the way they feed and move in their habitat. The first four types include predators:

1) larvae living either on the surface of soil or under the bark of trees, and moving in the substratum (*Calathus* BON., *Trechus* CLAIRV., *Masoreus* DEJ., *Tachyta* KIRBY and others);

2) larvae stalking their prey on the soil surface, without burrowing tunnels (*Nebria* LATR., *Chlaenius* BON., *Agonum* BON., *Abax* BON., certain *Pterostichus* BON., and others);

3) larvae fedding on the soil surface but capable of burrowing tunnels to hide and pupate in (*Carabus* L., *Calosoma* WEB., *Cychrus* F. and others);

4) larvae permanently living in soil, burrowing tunnels and moving in varied substratum (*Omophron* LATR., *Elaphrus* F., *Sphodrus* CLAIRV., and others).

Type 5. includes saprophagous larvae living in soil (*Dicheirotrichus* DUVAL, *Trichocellus* GANGLB., *Bradycellus* ER., and others);

Types 6. and 7. — herbivorous larvae feeding on the soil surface and burrowing no tunnels (*Amara* sp.) or burrowing tunnels for hiding and pupating in (*Zabrus* CLAIRV., *Amara* sp.);

Type 8. — polyphagous larvae permanently living in soil and burrowing tunnels (*Harpalus* LATR., *Anisodactylus* DEJ., *Amara* sp.);

Type 9. — larvae of genera undergoing hypermetamorphosis (*Lebia* LATR., and *Brachynus* WEBER). Their first instar larvae have well-formed legs and are able to burrow tunnels while searching the soil for chrysomelid pupae; second and third instar larvae parasitize these pupae externally, and have reduced legs, mouth appendages and urogomphi. Larvae inhabiting loam soil of fields, meadows, pastures and logged forests have bodies adapted to burrowing. The body is stocky, with a wide head and clypeus, short antennae, mandibles, palpi,

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legs and urogomphi. Larvae living in light soil of various biotopes, in litter and in rotting wood have a slenderer body, a narrower head and clypeus, long mouth appendages, legs, and urogomphi.

Two developmental types of ground beetles are distinguished an the basis of the period of their reproduction and the hibernating stage (LARSSON 1939). The spring type comprises species which winter in the adult form which matures sexually in spring after some supplementary feeding, and the period of oviposition, larval development and the emergence of adults takes place in spring and summer. The autumn developmental type includes ground beetles which winter as larvae, or occasionally adults, and the period of the emergence of pupae, young beetles, oviposition and hatching of larvae takes place in late summer and in autumn.

The larval development of all species of ground beetles takes place in three stages, is very short, lasting from 30 to 50 days, and the entire development from egg to adult is 2 to 4 weeks longer. The larval development is 5 to 8 months longer in the case of a larva wintering as a third instar. First instar larvae do not take any food during a few days after hatching because they still feed on the embrionic yolk. When this is gone they begin to lead a mainly predatory life, usually preying at dusk or at night. In predaceous larvae digestion is extraintestinal.

Literature data on rearing ground beetles usually refer to bigger species, mainly those belonging to the genera *Calosoma* WEBER and *Carabus* L. A method used by BURGESS (1911) for rearing *Calosoma sycophanta* L. for practical purposes is described in detail and may be used for rearing other species. From 1905 to 1907 BURGESS had brought about 6,000 adults of *C. sycophanta* L. from Europe to New England in the U.S.A. in order to fight a dangerous forest pest *Lymantria dispar* L. introduced from Europe. The adults were kept in big glass containers covered by a wire screen or in cages made of wooden frames covered with canvas. The insectaria were protected from rain and the sun. Pairs of imagines were kept in containers with a 4–8-centimetre layer of wet soil to lay eggs in. The beetles were given twigs to climb, litter to hide in and *Lymantria dispar* L. caterpillars to feed on. They disliked beef and after a week did not eat it at all. Excrement and scrap were removed every day. Copulation took place several times during the period of oviposition; this is necessary because otherwise there is a great percentage of unfertilized eggs. Under natural conditions one female lays about 100 eggs; under the laboratory conditions the number of eggs laid by one female reached about 500.

After oviposition, the beetles were removed to other cages for further rearing. The embryonic development lasted for 3–10 days and depended on the ambient temperature. Larvae hatched in June and July. Mass culture in one container was limited because the larvae, just like the adults, were cannibalistic. Only first instar larvae could be kept together in one container, but not more than 10–15 individuals. Second instar larvae had to be removed and placed singly in glass vessels or in cages with wet soil. The larvae were fed with larvae and pupae of moths: *Lymantria monacha* L. and *Dendrolimus pini* L. but larvae of *Lymantria*

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dispar L. were the most suitable food. Earthworms given as food were not eaten at all. The larvae fed at night and during the day, especially if it was hot. They were extremely voracious. One larva devoured 41 larvae of *Lymantria monacha* L. in a fortnight. However, the larvae could stand starvation for some time: first instars for 3–4 days, second instars – 7 days, third instars – 8–10 days.

The larvae were characterized by great mobility: one larva covered 2,700 m in 72 hours. In mid-summer they burrowed into soil down to 15–18 cm and pupated there after 7–14 days. For the period of pupation and wintering the larvae were transferred into soil in large cylinders of galvanized wire screen closed at the bottom and on top with wire gauze. The cylinders were placed in the soil, their top flush with its surface. Emerged imagines remained in their pupal cells troughout winter until spring, and they usually came out 8–10 days after the appearance of *Lymantria monacha* L. larvae. BURGESS reared about 20,000 by this method, from 1906 to 1910. The reared larvae and adults of *Calosoma* WEB. formed the basis for colonies – 200–300 individuals in each – established in forests invaded by *L. monacha* L.

In Europe there were small-scale cultures of *Calosoma inquisitor* L. These beetles were reared in glass containers of 2.5 dec^3 in volume, and in pots partly filled with soil (HOLSTE 1915). Beetles caught in the field in spring were put into these containers, one pair per container. Females laid eggs one by one into small cells. Larvae were fed with larvae of winter moth (*Cheimatobia brumata* L.) Pupation took place in soil during the first week of June. The first beetles emerged in the middle of June. The beetles stayed in their pupal cells and overwintered there.

Species of the genus *Carabus* L. were frequently reared in order to describe their developmental stages and to study their bionomics LENGERKEN (1921) reared *C. auratus* L. in Petri dishes 30 cm in diameter and about 10 cm deep, filled with soil up to about 8 cm. But at 5 cm the soil did not touch the walls of the dishes prevented the beetles from getting out. The soil was moistened twice a day; during hot weather even more often. Earthworms, larvae and pupae of different insects were given as food. First instar larvae were carried to glass vessels with an eight-centimetre layer of soil. These larvae lived for 4–5 days and during the first days they took no food because they were still using the embryonic yolk. Later they devoured earthworms cut into pieces. Second instar larvae were placed singly in glass cylindres of 8–10 cm in diameter, filled with soil up to about 10 cm. They were fed with pieces of meal worms. At first, minute fragments were served with tweezers directly to the mandibles; later, larvae took the food themselves. Scrap was removed every day. Second and third instar larvae had a longer life than first instars and this depended on the amount of food taken and on the weather. Pupation was not recorded by the author. Culture methods for other species of the genus *Carabus* L. were described by OERTEL (1924) for *C. granulatus* L., by KIRCHNER (1927) for *C. cancellatus* Ill., and by DELKESKAMP (1930) for *C. nemoralis* MÜLL. These investigators put pairs of beetles into glass dishes of 10–20 cm in diameter, the bottom of which was covered with

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a 2–3-centimetre layer of wet soil. The dishes were covered either by wire gauze or by at glass lid (but the latter did not fit very closely). Small vessels with water were put into the dishes, and DELKESKAMP also added pieces of wood or bark for imagines to hide in. The soil in the dishes was moistened every day. Eggs were laid in the soil at a depth of 2 cm. They were easy to see through the glass on the bottom of the dishes and were carried, very carefully, on the tip of a small paint brush, to separate vessels. It was importand to put the eggs in the same position they had been laid. An egg advanced in its embryonic development was placed hirizontally, the concave part turned upwards. Imagines were fed with earthworms meat, snails, meal worms and bits of fruit. Emerged larvae were confined singly in open Petri dishes with a 5-centimetre layer of soil. Pieces of earthworms, meat and fruit were given these larvae on watch glasses. Every day, the soil was moistened and scrap removed. OERTEL and KIRCHNER used pincers to give earlier instars food directly to their mandibles; that was only during the first days of their life. Later, larvae fed on their own.

Before pupation, larvae burrowed into the soil and built pupal cells there. All the above-mentioned authors recorded a high mortality rate at all life stages. One-third of eggs laid did not produce any larvae. The same was the percentage of larvae that did not moult during the first stage. Depending on the food and ambient temperature the entire development, from egg to the appearance of a young adult, lasted from 43 to 83 days. For the species *C. granulatus* L. the duration of the particular stages was as follows: 6–7 days – embryonic development, 8–10 – first instar larva, 8–10 – second instar, 10–12 – third instar active on the surface, 6–7 – third instar, prepupal, in soil, 7–9 – pupa; thus the entire development from egg to the emergence of an adult lasted for 45–55 days.

SCHERNEY (1959) recorded lower losses in rearing. On the basis of two experiments he presented a better culture method thanks to which it had been possible to obtain better results, i.e. more adult individuals were produced from eggs in such a culture, than when the previously known methods had been used. In the first experiment SCHERNEY put, in spring, 10 pairs of adults of *C. auratus* L., *C. cancellatus* ILL., *C. ulrichi* GERM., and *C. granulatus* L. into each of the netted cages with a 5-centimetre layer of soil he wanted to use. Eggs were carried to big Petri dishes with soil. First instar larvae hatched were placed in concrete rings of 1 m in diameter, sunk into soil at a depth of 30 cm, filled with soil and humus in equal parts, covered by thick screen. At the end of October, it was found out that the young beetles of the above-mentioned species that had emerged constituted 55, 67, 49 and 63% of the eggs, respectively. Thus, the losses were 45, 33, 51 and 37%. In the second experiment, 5 pairs of adults of the same 4 species were put directly into each of the concrete rings used, and females oviposited there. At the end of October, it turned out that more imagines were obtained and this time they constituted 79, 84, 67 and 81% of the eggs, so the losses were only 21, 16, 33 and 19%. The higher mortality in the first experiment may have been due to the fact that in the search for eggs, larvae and pupae the soil had been loosened several

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times and so its properties had changed. Moreover, insects may have been damaged while being carried to another place.

STIPRAJS (1961) reared about 20 species of the genus *Carabus* L.; 14 of these occur in Poland. Beetles of all the species oviposited and then larvae hatched. Unfortunately, it was impossible to rear adults of *C. hortensis* L. and *C. glabratus* PAYK. because their larvae did not develop beyond the second instar, and of *C. coriaceus* L. because the development stopped at the third instar. Due to the fact that they overwinter, larvae of the above species, like those of *C. violacus* L. and *C. scheidleri* PANZ., were more difficult to rear. The life cycle of the other species began in spring or early summer and ended in autumn, and for this reason they were easier to rear.

Basically, STIPRAJS's culture method did not differ from methods used by other authors. Adults were reared either in glass vessels with soil or in netted wooden cages that measured 20 x 15 x 17 cm. Sheet trays with a 5–6-centimetre layer of soil were put into the cages to prevent the wood from rotting. Stones, pieces of bark or wood were provided as hiding places for beetles. Adults were fed with earthworms, insects and their larvae, bits of meat or fish, and supplementary plant food was given in the form of bread, groats, flaked oats and pieces of juicy fruit. Adults were kept in pairs, sometimes several of them together. Eggs were transferred to Petri dishes, into holes made in moist soil. Larvae were reared in various glass vessels with soil or moss; they were mostly fed with earthworms, occasionally with snails, bits of meat and fish. Adult larvae were carried to glass jars with lids, 0.5 l in volume, filled with soil. Their metamorphosis took place there. Larvae already less active before pupation were placed in special hollows made in soil and covered with pieces of transparent celluloid. Young beetles with hardened elytra were put in cages and in autumn, in order to prepare them for overwintering, they were transferred to glass jars filled with soil, sawdust or moss and these were taken to a basement or a shed. STIPRAJS's (1961, 1964) successful rearing of 21 species should encourage more investigators to rear other *Carabus* L. species.

Data on cultures with small species of ground beetles are very scanty even though species with body length below 15 mm constitute the majority.

NETOLITZKY (1921) mentioned a culture of eight species of the genus *Bembidion* LATR. This author undertook short-term rearing of adults in shallow glass vessels or Petri dishes. Parts of insects were given as food. Adults survived for a few months. Some species laid eggs, and larvae hatched. There is no information as to whether pupae or adults were obtained. The author simply mentioned that small larvae had appeared on the fourteenth day after adults of *B. femoratum* (STURM) had been placed in the dishes, and bigger larvae were recorded a little later.

LEITNER (1943), who reared adults of two alpine species of the genus *Trechus* CLAIRV., also failed to get a new generation. In spite of this, the details of his culture are worth mentioning. Adults were kept in glass Petri dishes with a 4–3-centimetre layer of the soil collected together with the beetles. Flat pebbles were sometimes put into the dishes. The rearing was carried out in

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semi-darkness, in a cool room or, in summer, in a basement. Beetles were put into smaller dishes, one pair per dish. Adults were fed with some oligochaetes like earthworms cut into pieces and worms of the family *Tubificidae* (*Tubifex* HENLE). The beetles could stand starvation and survived several weeks without food. Larvae, too, were fed with oligochaetes, but they did not develop beyond the third instar.

LEITNER thought that rearing small *Carabidae* was not difficult. Under natural conditions they have territories smaller than those required by bigger species, e.g. of the genus *Carabus* L. It is therefore easier to provide them, in the laboratory, with suitable microhabitats to which they can adapt. Larvae moult three times, have a poorly sclerotized body, are not resistant to any lack of humidity in their habitat, to lack of food, to mechanical injuries and various infections. That is why they need, in their short active life (about 4–6 weeks), more attention than adult forms. It must also be added that overwintering larvae (this refers to a relatively small number of species) are more difficult to rear. In this case it is necessary to find the right time of their hibernation and it must not be overlooked when exactly they wake in spring to their active life, because appropriate food must be given at that very moment.

The author, in his cultures, generally used glass jars of 0.5–1 dec^3 in volume, with lids, and half filled with the soil collected together with adults or larvae. Adult females of smaller species and younger stages were put into carefully selected glass test-tubes. Narrow tubes, e.g. those of 10–15 mm in diameter and 60–100 mm high, have a great advantage: they provide a possibility for easier observations of oviposition, the appearance of consecutive larval stages, the preparation of the pupal cell, pupation and the emergence of the adult stage. They also maintain soil humidity a little longer. Such a test-tube was filled with a 1–2-centimetre layer of clay, a similar layer of the soil collected together with a given insect and a slanting layer of soil on the wall of the tube. Test-tubes closed with wet cotton-wool plugs were placed horizontally in glass jars filled with soil. The same kind of test-tubes was used in another case. This time they had three quarters of their volume filled with soil, and were placed in glass jars vertically. The culture methods depended on the size of a given species and the way it lived, but also on the experience and ingenuity of the investigator. In the rearing experiments made by the author, females of some species living on barren substratum (pure dune sand and the like) oviposited not only into the soil in their test-tubes but also among the fibres of wet strips of filter paper. After oviposition, the females were removed. Emerging larvae were carefully placed on the tip of a small paint brush and placed singly in similar tubes. The larvae, fed cerefully and kept on constantly wet filter paper, completed their development and sometimes young adults emerged. Under the laboratory conditions, an *Agonum quadripunctatum* (DE GEER) larva managed, throughout its life lasting for 14–19 days, to devour 6–9 pupae of the ant *Myrmica laevinodis* NYL., namely: the first instar ate 1 or 2 pupae, the second instar – 2–3, the third instar – 3–4 ones (BURAKOWSKI 1986).

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Adult stages of predaceous species were fed with parts of various insects, whereas larvae of herbivorous and polyphagous species with wheat grains, flaked oats, bits of fruit and plants. Larvae were given insect food, mainly larvae and pupae of ants, and of species that do not spin cocoons.

Another very interesting idea was employed by GÓRNY (1975) for rearing *Carabidae* and other insects whose preimaginal stages live in soil. To suit his purpose the author used wooden boxes in which "...the glass sheet in the front wall leaned towards the inside of the box where a wire screen was placed in a special way. The box was half filled with soil. This arrangement made the insects stay near the glass, and thus observations was possible".

Families: Hydraenid Beetles (*Hydraenidae*) and Water Scavenger Beetles (*Hydrophilidae*)

Species belonging to hydraenid beetles live mostly in aquatic habitats, but some of them lead a terrestrial life. To date, 65 species have been recorded from Poland. The aquatic species generally occur in shallow, much overgrown standing water, in small bogs, sloughs or puddles, more seldom in slowly running brooks and streams. Some inhabit the littoral of bigger water bodies overgrown (among others) with algae. Others live in the riparian zone, in silt or slime covered places, in wet humus, under rotting plant matter and in moss. Certain species of the genus *Elophorus* F. occur in meadows, cultivated fields and land for green crops where *E. nubilus* F., *E. aquaticus* (L.) and *E. guttulus brevipalpis* (BEDEL) are most frequently recorded. Adults are poor swimmers, but some can fly very well and they often come to sources of artificial light. They hibernate both in water and on land.

Most species of water scavenger beetles are associated with the aquatic environment. They inhabit small ponds, pools, bogs, turbaries, backwaters, puddles, water with a slow current, the densely overgrown littoral of bigger water bodies. A small number of species (*Sphaeridium* F. and some species of *Cercyon* LEACH) live in fresh cattle dung in pastures. So far, 61 species of water scavenger beetles have been recorded from Poland, and within these the genus *Cercyon* LEACH includes 19 species occurring in terrestrial habitats (BURAKOWSKI, MROCZKOWSKI, STEFAŃSKA 1976). The legless larvae of species of this genus inhabit wet soil on the shore land of water bodies, some distance off water under decaying plant matter, in excrement and under carrion.

Larvae of hydraenid and water scavenger beetles were sometimes found when soil samples were being collected. Indentifying them to the species is difficult due to lack of keys. Identification keys include only genera. The only sure method of identifying a larva is, therefore, to rear it until the imaginal stage. Larvae are usually found from May to August. It is recommended to put soil larvae into Petri dishes or one pint glass jars filled with a 2–4-centimetre layer of the soil collected together with them. The soil is covered with decaying plant matter, some excrement of other materials under which or among which the larvae have

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been. Larvae feed on microflora, dead plant or animal tissues (earthworms, insect larvae, snails and other invertebrates) and on organic detritus. Aquatic larvae are placed in aquaria-terraria. Certain species feed not only on algae and detritus but also on small crustaceans (*Ostracoda, Copepoda, Cladocera*), oligochaetes of the genus *Tubifex* HENLE, small insect larvae, tadpoles and fry. The pupation of larvae of all the species, including aquatic ones, takes place in soil; in shallow containers fully grown larvae often make their pupal cells near a glass wall, and this makes observation possible.

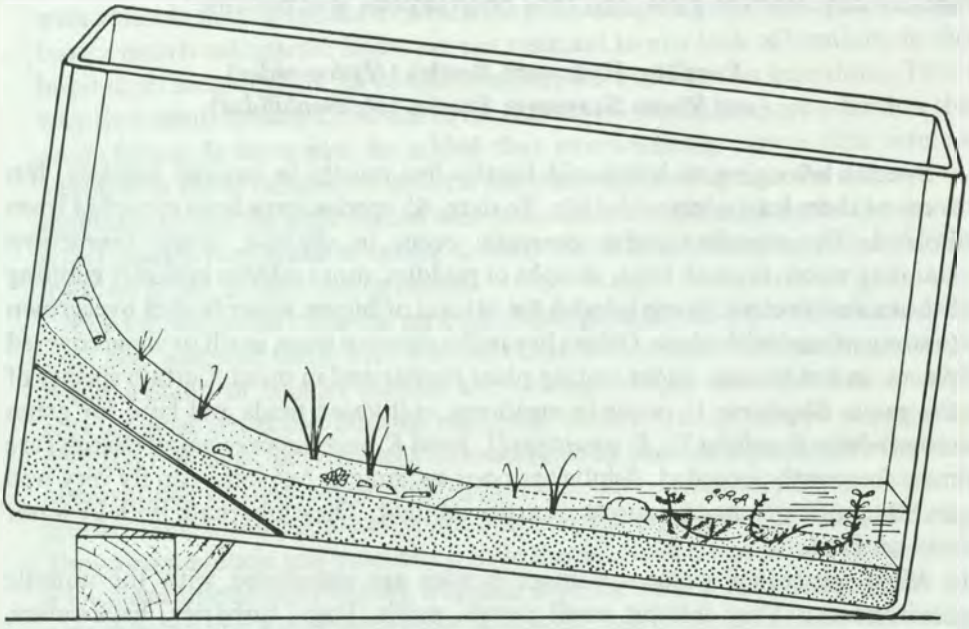

Fig. 4. An aquarium-terrarium for rearing hydraenid (*Hydraenidae*) and water scavenger (*Hydrophilidae*) beetles.

The equipment for rearing adults must include terraria for terrestrial species and aquaria-terraria for aquatic-terrestrial ones. Containers used for rearing adults may be in the form of glass aquaria e.g. those measuring 25 x 35 cm at the bottom and 20–30 cm high, covered with gauze or a 0.5–1 mm mesh screen. The bottom of a terrarium is filled with a 2–4-centimetre layer of soil and, on top of this, with the miscellaneous material from the natural habitat the beetles have come from. Then a shallow vessel with water is buried flush with the surface of the soil. Aquaria-terraria are filled with a 2–5-centimetre layer of soil. A slanting slope is made inside in the middle of a container and this must be covered by a close-fitting glass sheet with 2–3 cm of soil on top of it (Fig. 4). In this way the final instar larvae are forced to pupate in the thin layer; this makes observation possible. Moreover, it is easier now to take out final instar larvae and pupae because the glass can be removed together with the soil on it. The lower

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part of the container must be planted with uliginose and aquatic plants, but filamentous algae, duckweed, and rotten leaves must be put there as well. The initial amount of water should be up to 2–4 cm. After all these preparations the container must be tilted in such a way that a slope forms inside it. Then a suitable slat is put underneath to keep the container in the desired position. Small pebbles, decaying leaves, bits of rotten wood are now placed on the slope. A small, partly submerged stone may be added. The container is covered with fine mesh gauze and a glass sheet is put on top of this. The glass may be pushed aside and thus the moisture content of the slope can be regulated. Eggs are not laid into the water but deposited on the slope. Oviposition generally takes place in May, but in certain species even throughout the summer. Larvae of the genera *Hydraena* KUG., *Limnebius* BED. and *Ochtebius* LEACH easily drown in deep water so their aquaria-terraria must have shallow water. Both adults and larvae must be fed with filamentous algae.

Terraria for predaceous species of the genus *Sphaeridium* FABR. must be filled with a layer of soil and, on top of this, some fresh excrement taken before any coprophagous insects settle in it. Then adults of *Diptera* ovipositing in excrement are let in. Only after the emergence of dipteran larvae are adult beetles introduced.

Family: Silphid Beetles (*Silphidae*)

About 250 species of silphid beetles are recorded from the world over, and 26 of these occur in Poland. Adults of the family under discusscion can be identified thanks to the key prepared by MROCZKOWSKI (1955). The bionomics and morphology of larvae have been studied fairly well, but there still are no data on representatives of the genera *Pteroloma* GYLL., *Necrophilus* LATR. and *Agyrtes* FRÖL. Larvae, their development and the course of rearing of 10 species of the genus *Silpha* L. are now known thanks to studies carried out by HEYMONS, LENGERKEN and BAYER, who published the results of their investigations from 1926 to 1931 and in 1934. Larvae of all the Polish species (13) of the genus *Silpha* L. and some species of other silphid beetles may be identified with the help of an identification key by BYZOVA (1964).

Silphid beetles feed on varied food; most of them are necrophagous, others are predators, still others are herbivorous or feed on mixed food. Among necrophagous species, those belonging to the genus *Nicrophorus* F. are most distinguished. They feed on carrion, mainly that of vertebrates. Adults detect carrion by its odour and bury it in soil through tunnelling under it. A female oviposits into hollows in the wall of a narrow passageway leading to a chamber constructed in the soil under the carrion. The larvae living in the chamber depend on the female for food. The female feeds them with the carrion it has digested. The larval development is very rapid, a pupa emerges after about 10 days, and young adults appear after a further fortnight.

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All species of silphid beetles have an annual cycle. Adults hibernate in soil in open areas, under bark or in decaying wood. They appear in spring and, after some feeding on the right food, they mate. From May to August, females oviposit into the soil near their food source, single eggs are usually laid into cells at a depth of 0.5—3 cm; only *Silpha laevigata* F. lays eggs in clusters, 5—11 in each, at a depth of 2—4 cm. One female lays 1 to 3 eggs a day, and the total for one season is about 200. The embryonic development lasts for 5—10 days. The post-embryonic development takes 4—5 weeks. In the laboratory cultures carried out by HEYMONS and LENGERKEN the shortest development was recorded in *S. opaca* L., and the mean number of days the particular stages lasted was as follows: the first instar — 4.4; the second — 3; the third — 4.5; prepupa — 5; pupa — 8.2; the entire development — 25.1 days. The longest development, about 48 days, was recorded in the forest species *S. quadripunctata* L.: the first instar — 5.3 days; the second — 6.2; the third — 5.8; prepupa — 18.7; pupa — 11.5; the entire development — 47.8 days.

Larvae feed on appropriate food in litter, on the soil surface or in the undergrowth. Before pupation full grown larvae burrow into soil to a depth of 1—2 cm and build a pupal cell there. Young adults stay in this cell for a few days until their cuticle is fully coloured and sclerotized. After emerging onto the soil surface they usually feed until September or October and then they search for a place to hibernate in.

Both the adults and larvae of certain species of the genus *Silpha* L. manifest a great food specialization. The predaceous forest species *S. atrata* L. and *S. leavigata* F. feed on live snails, usually those that make medium or small shells. *S. quadripunctata* L. also leads a predaceous life, in the undergrowth and herb layer, attacking larvae and pupae of beetles, and larvae of butterflies; however the larva of this species feeds on dead insects in litter and on the surface of the soil. *S. undata* MÜLL and *S. opaca* L. are herbivorous species feeding mostly on grass leaves; but at the end of May *S. opaca* L. invades beets and usually devours fleshy leaves, thus causing great losses in crops. The other species feed on mixed food, generally of animal origin, such as dead snails, earthworms, insects, carrion of smaller animals, occasionally they supplement their food by eating living or dead parts of plants. In carnivorous silphid beetles digestion is extraintestinal.

If the food requirements of particular species are known, silphid beetles are not difficult to rear, and their individual development from egg to adult is relatively short. HEYMONS and LENGERKEN reared species of the genus *Silpha* L. under the laboratory conditions at 19—23°C. Adult forms were kept in glass dishes 22 cm in diameter, with their bottoms covered with wet soil and bits of turf; in the case of epigean forest species, pieces of bark, moss or dry leaves were put into the dishes, too. The species *S. quadripunctatus* L. feeding on the soil surface was reared in cylinders 15 cm in diameter and 25 cm high, and in wooden containers measuring 50 x 25 x 50 cm, and with gauze on the sides. The bottom of such containers was filled with soil, dry leaves, and fresh twigs with leaves were

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inserted in the soil. All the containers were covered with closely-fitting gauze. Mating pairs were placed individually in dishes 10 cm in diameter and 6 cm high, with 2–3 cm of wet garden soil on the bottom. In these dishes females oviposited, the post-embryonic development took place and a new generation grew. Silphid beetles feeding on snails were supplied with live *Helix hortensis* MÜLL., *H. nemoralis* L. and *Helicigona arbustorum* (L.), other predators with live pupae and larvae of insects, necrophages with sliced earthworms, dead imagines and larvae of insects, bits of beef, lean pork and poultry. Herbivorous species were given leaves of grasses, lettuce, spinach, and bits of fruit, usually apples. During the studies it was found out that species taking mixed food preferred products of animal origin, for instance, a *Silpha* female feeding on meat laid 3 times as many eggs as a female feeding on vegetable food. However when the larvae of the snail-feeding species were provided with meat only, the pupal stage was never attained because they died as the third instar larvae.

The author, in his own studies, managed to rear *S. sinuata* F. with success. This is a species never mentioned in the papers by HEYMONS, LENGERKEN and BAYER. A pair of beetles was put into a terrarium, 20 x 30 x 20 cm, covered with a fine mesh gauze screen. The bottom was filled with 3 cm of wet sand and dry tree leaves for adults and future larvae to hide in. Smoked fish, cheese and pieces of veal were supplied for food. Females oviposited from 1 to 12 August, the first instar larvae appeared on 5 August, the last on 18 August. In order to study their individual development, some first instar larvae were placed individually in one-pint glass jars prepared in the same way as the terrarium. The culture was carried out at 19–24°C. It was found out that the beetles underwent their postembryonic development within 23 days on average, and this meant 4 days each for the first and second instars, 6 days for the third, 9 days for prepupae and pupae. Young adults remained in their pupal cells for 3–4 days, after coming out of the soil they fed almost until October and then they disappeared to hibernate in the soil. Some first instar larvae were left in the terrarium and the first young beetles emerged from these appeared on the surface on 29 August, the last ones on 10 September.

Family: Rove Beetles (*Staphylinidae*)

The family of rove beetles includes more species than any other beetle family. To date, 1,172 species have been recorded from our country and they make about 20% of the coleopterofauna of Poland. Identification of adult stages of Polish rove beetles is made possible by keys to several subfamilies (SZUJECKI 1961, 1965, 1966, 1980). Even though their larvae are described more and more often, the taxonomy of the lower developmental stages of this family is still at a preliminary phase and the existing keys for identifying larvae (PAULIAN 1941, POTOCKAJA 1967) are very incomplete. These keys do not guarantee a perfect identification to a species in cases when not all larvae of species belonging to particular genera are known.

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Rove beetles occur in various habitats, from the seashore to mountain pastures and high mountain peaks. In respect of their ecological requirements they are a greatly varied group of beetles. They inhabit both open and forest areas. They occur in fields, pastures, meadows, waste land, peatbogs, sandy dunes, shady ravines, caves, wet areas, banks of running and stagnant waters, tree stands of all kinds, built-up areas especially if there are low buildings and a lot of greenery there, in gardens and parks. The majority of rove beetles live in various soil habitats. The mechanical composition of the soil and the humidity of the environment are the basic factors required by rove beetles for settling in soil habitats (SZUJECKI 1966).

Rove beetles, and specially their larvae lead a hidden type of life in soil, litter, compost earth, under stones, in decaying remains of plants and animals, in animal excrement, among moss and roots of grasses and herbaceous plants, in tufts of sedge and peatmoss, in flood debris along edges of waters, in ant hills and nests of hymenopterans, in underground burrows and nests of rodents and moles, in tree hollows, under bark, and in tunnels of different insects. Such habitats as these must be searched in order to collect rearing material of different species of rove beetles. Various methods must be used while collecting beetles, and sifting the substratum usually gives very good results.

Depending on the way they feed, rove beetles can be divided into predaceous, parasitic, herbivorous and saprophagous species; most species belong to predators.

The bionomics of most rove beetle species is either known poorly or not at all. In our latitudes they probably have an annual cycle. The majority of rove beetles undergo their larval development from May to August and they start to reproduce after overwintering. Females oviposit into the surface layer of wet substratum. The embryonic development generally takes 8–10 days, but at lower temperatures (e.g. 10°C) it may last for a month. They have three larval instar. The entire development from egg to adult is from 25 to 70 days for species which reproduce in spring. This period is from 4 to 6 months longer for species of rove beetles that oviposit in autumn. Their larvae undergo the winter diapause and the new generation emerges in spring. The optimum developmental conditions for larvae are found at 25°C and 100% relative humidity of the air. Pupation takes place in a cell made by the larva in soil or in some other substratum. The imago leaves its pupal cell shortly after emergence.

Due to the fact that the life-cycle of rove beetles is short, it is not very difficult to rear them from egg to imago. They are usually reared in glass containers of various sizes. The bottom of such containers is covered with the soil, litter or some other material in which adults or larvae have been found. SZUJECKI (1965) reared the litter species *Philonthus fuscipennis* (MANN.) in the laboratory. Adults were put in Petri dishes or in beakers of different diameters half filled with sand and litter. They were supplied with dead larvae and pupae of insects for food and they fed on these more readily than on live small insects. Scrap was not removed

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from the containers. Mixed with soil it formed clods in which the decomposition of organic matter took place. About 8 days after copulation females oviposited under these clods more often than under dead larvae or torn pupae. Eggs or emerged larvae were transferred to separate dishes. Better results, however, were recorded when eggs and larvae were left there, but adults were transferred instead. First instar larvae, not very active at first, fed exclusively on the decomposing animal remains left by adults. After a few days, the larvae were more active in their search for food, which consisted of dead insects. They manifested no cannibalistic tendencies. However, second and third instar larvae, very mobile and predaceous, attacked small insect larvae, or even younger ones of their own species. Larvae of the *Stegobium paniceum* (L.) were the most readily devoured food. One second instar ate 6 larvae of this species within 24 hours. Mortality in third instars was high. Out of 15 larvae only 7 built their pupal cells, and only 4 of these pupated. Under the laboratory conditions, the entire development from egg to adult lasted for 47 – 69 days. The duration of particular stages was as follows: egg – 3 – 10 days, the first instar larva – 5 – 10 days, the second and third instars – 16 – 23 days, prepupa – 6 – 8 days and pupa – 17 – 18 days.

A great number of predaceous rove beetles inhabit decomposing fragments of plants and feed on dipteran larvae feeding in the decaying plant matter. When suitable habitats and food bases for flies and beetles were being prepared, sliced plants of different species, mostly clover, were placed in shallow and open sheet dishes (MANK 1923). Bits of various fruits were used as bait for flies. After a dozen days or so, this plant pulp changed its colour and consistence as a result of decomposition, in some parts it became black wet and gluey, in others it remained relatively dry and green. The pasty layer was then full of dipteran larvae. Small vessels half filled with wet sand were used in this culture method. A little of the wet paste with dipteran larvae in it was put on the sand and then adults or larvae of rove beetles were placed there. Within about two months a few species [*Philonthus cyanipennis* (F). and *P. longicornis* STEPH. among others] were reared from the larvae.

A culture method for zoophagous rove beetles of the genera *Tachyporus* GRAV. and *Tachinus* GRAV. was worked out by LIPKOW (1966). The beetles were reared in Petri dishes, 5 – 10 cm in diameter, arranged in such a way that the bigger half was a water container and the part smaller in diameter was the rearing chamber (Fig. 5). Both parts of the dishes were separated by a strip of gauze kept in place on the lower part by a rubber band. This primitive hydrostat made air circulation possible and ensured the required humidity in the rearing chamber. A small gypsum block absorbing and giving off water was put on the gauze, and pieces of filter paper and lignin were provided for the insects to hide, moult and pupate in. Both parts of the dishes were bound with rubber tape to make the upper one fit closely to the gauze. Both the adult stages and larvae were fed with sliced invertebrates and live small insects. In spite of the prevailing conviction that

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these species are zoophagous, in the laboratory culture some first instar larvae of *Tachinus rufipes* DEG. attained the adult stage feeding exclusively on plant food (higher plants and fungi). However, young larvae of the species of the genus *Tychyporus* GRAV. survived on plant food only until the third larval instar. Out of the 15 species of the genus *Tachyporus* GRAV. 5 species were reared on plant food from the first instars to adults, and these were: *T. chrysomelinus* (L.), *T. hypnorum* (F.), *T. obtusus* ER., *T. pusillus* GRAV. and *T. solutus* ER.

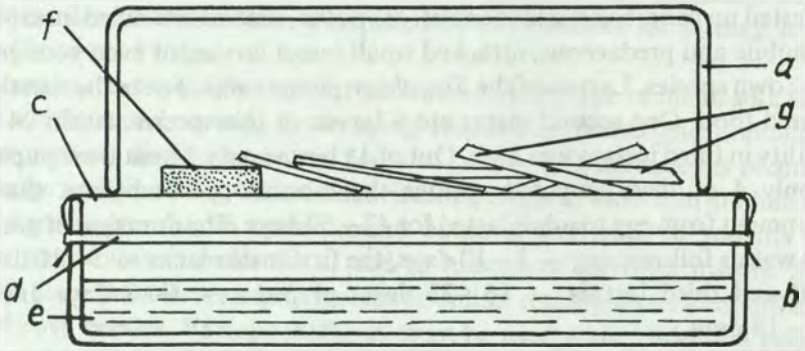

Fig. 5. A diagram of a container for rearing rove beetles (*Staphylinidae*): a, b – Petri dish, c – gauze or muslin, d – rubber tape, e – water, f – gypsum block, g – pieces of filter paper.

Rove beetles could be used in the biological control of plant pests. With this in mind, attempts were made at laboratory rearing of species of the genus *Aleochara* GRAV. *A. bilineata* GYLL., whose larvae parasitize in puparia of *Diptera*, is frequently mentioned in the literature as a species useful in fields with cabbage, cauliflower and other root crops. This species was reared in glass containers of 0.5 dec^3 in volume, with 5–7 cm of soil that was moistened every day (ADAŠKEVIČ 1970). The containers were covered with a wire screen. One, two or three pairs of adults of *Aleochara* were placed in each, and larvae and pupae of *Musca domestica* L. were supplied for food. One or two days after mating the females oviposited only if the puparia of *Hylemyia brassicae* BOUCHÉ were there. In their presence the females oviposited earlier and laid more eggs. In containers without puparia the females oviposited 6–19 days after they had been placed in the containers. Adults that were well fed lived for 185 days. Each female laid about 500 eggs on average. Larvae, within 10–20 hours after hatching, burrowed into young, 1–3-day old puparia of dipterans. At 23–30°C the entire development from egg to adult took from 24 to 61 days. The embryonic development lasted for 6–7 days, larval – 11–18 days, pupal – 16–27 days. Eight generations were obtained in the laboratory within one year. In order to store a greater number of parasitized puparia of *Diptera*, they were placed in a thermostat at 4–5°C and kept for up to 3 months.

WHITE and LEGNER (1966) reared *Aleochara taeniata* ER. in the laboratory. Adults of this species fed on eggs and larvae of the *Musca domestica* L. Females

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oviposited as early as the fourth day after copulation. First instar larvae burrowed into fly puparia and sealed the entrance holes with their excrement. Third instar larvae left the puparia and fed on fly pupae externally. The larval development lasted only for 6 – 7 days, and the pupal stage for 14 – 16 days. The entire development from egg to adult took about 25 days.

LOMAKIN (1981) reared the herbivorous species *Trogophloeus bilineatus* STEPH. This species inhabits slimy banks of water bodies, compost heaps and decaying plant matter in cultivated fields. Both adults and larvae feed on soil algae. For rearing adults were put into Petri dishes filled with 5 – 6 mm of a water solution of agar (10 g per 1 dec^3) with diluted mineral substances that were food for the algae. Membrane cellulose filters were placed on the surface of agar and algae were sown there by placing a lump of soil with algae within a circular area about 2 cm in diameter. Strips of blotting paper were inserted when there was too much water. At 22 – 24°C and humidity almost 100%, a green coat of alga colonies of several species was formed after 10 days. Adults of *T. bilineatus* STEPH. introduced there used their heads and legs to make tunnels in the agar mass. First instar larvae appeared 6 days after the imagines had been placed in the dishes, and they mostly stayed in the tunnels made by the adults. Older instars made burrows themselves, but they still spent more time among the algae they fed on. The larval development lasted for 17 days. Pupation took place in a cell a given larva had built in the agar layer. The pupal stage lasted for 9 days. The complete life-cycle from egg to adult took 30 to 32 days. The emerged beetles were transferred to different dishes where they gave rise to a new generation; first instar larvae appeared there after 13 days.

Many zoophagous rove beetles prey on larvae of coprophagous *Diptera* in animal excrement. Due to the unpleasant odour of the substratum they live in, these insects are rarely reared in the laboratory, but a method used by LIPKOW (1982) is worth mentioning. Fresh cow pats collected in a meadow were put on sheets of plastic film and left in the open air. These cow pats attracted dipterans which laid eggs singly. Adults of several rove beetle species of the genus *Philonthus* CURTIS appeared, too. Coprophagous beetles of the genus *Aphodius* Ill., however, never oviposited into the cow pats placed on plastic film. The fauna of the cow pats was examined 2, 3 or 4 weeks later and the presence of *Philonthus marginatus* (STROM), *P. splendens* (F.) and *P. varians* (PAYK.) was recorded. Larvae of these species reduced the abundance of the dipteran larvae, but there was great competition and cannibalism among them. Bigger larvae devoured smaller ones, especially during moulting. This left a small number of larvae, and generally only 2 – 3 larvae pupated in one pat.

The above examples of culture methods may be adapted or modified to rearing other rove beetles that inhabit various habitats and feed on different substances.

Family: Pill Beetles (*Byrrhidae*)

The literature provides no monographic publications of the whole family, only some genera have been studied better in respect of morphology and taxonomy.

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Knowledge about the bionomics and the young stages is very poor. The number of species recorded from Poland is small – only 23. A key for the identification of adults of species occurring in Poland was worked out by MROCZKOWSKI (1955). A key for identifying larvae that includes only 5 taxa at the generic level (EMDEN 1958) is the first attempt at classifying the larvae of *Byrrhidae*.

Pill beetle species are biologically connected with patches and associations of moss both in tree stand and in open areas. Adults feed on parts of moss that grow above the ground. Although their bodies are stocky and their movements slow, pill beetles have a great ability to spread along streams, roads and the path dividing forest sections. Larvae of most species occur in soil under patches of moss where they borrow mostly vertical tunnels and feed on the underground part of moss. Larvae of two species of the genus *Cytilus* ER. are the only ones that live above the ground and feed on moss leaves, but even these burrow into soil before pupation. Of course, the tunnels burrowed by pill beetle larvae under patches of moss growing on stones, rocks and tree trunks are shallow.

The life cycle of pill beetles probably lasts for two years because larvae of different stages may be found at the same time. In early spring or late autumn, both adults and last instar larvae or the prepupal stage are recorded in pupal cells. Larvae moult several times during their development, but the exact number of moults is not known. The final instar larvae of most species pupate in summer or autumn in the surface layer of soil, and sometimes, yet more seldom, just under patches of moss. The pupal stage lasts for about two weeks.

Pill beetles are not difficult to find if the requirements of particular species are known very well. The majority are widely spread species. There are exclusively montane species, e.g. *Carpathobyrrhulus tatricus* MROCZK. and *Byrrhus luniger* GERM. *Porcinolus murinus* (F.) and *Morychus aeneus* F. are connected with sandy soils, *Syncalypta paleata* ER. with wet loams, and *Lamprobyrrhulus nitidus* (SCHALL.) with insolated open areas. The role larvae of pill beetles play in the process of soil formation is important, especially in barren sandy soil of glacial origin, in the layer of organic litter on rocks, in peatbogs, sites of a fire, everywhere where large patches of sod and moss can be found. In pine plantations the density of larvae reaches up to 12.5 per 1 m^2 on average (SZUJECKI 1980). Larvae contribute to the improvement in soil properties through burrowing in the soil and leaving their excrement there. In barren soil pill beetle larvae are a kind of a substitute for the activity of earthworms which avoid such habitats.

There are no data on any culture of these beetles to be found in the literature devoted to the family under discussion. The author undertook short-term cultures of older larvae and pupae found under the natural conditions usually towards the end of summer or in autumn. Larvae were reared in fruit jars (capacity 0.5–1 dec^3) covered with a loosely fitting lid or in aquarium-type containers covered with a glass pane; but there was a crack between the pane and one wall of the aquarium. The size of an aqarium depended on the size of moss patches available. A square of soil with a patch of moss was removed, with

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a shovel or a knife, from the field. Such a piece of soil was 5–10 cm thick. Then, in the laboratory, the square was divided into fragments fitiing particular containers. Larvae found in the field were placed in small containers, but older larvae and pupae were put singly into tubes 12–20 mm in diameter and 60–80 mm high, filled with the soil collected together with them. The larvae from small containers were transferred to tunnels artificially made in the soil along the walls of fruit jars and aquaria. Some larvae refused to accept the ready-made tunnels and built their own. The soil and moss were occasionally moistened, but very carefully so as not to provoke any growth of mould. It was necessery to aerate the containers. The individual cultures in tubes were generally put vertically into fruit jars, of the capacity of 1 dec^3, and with 2–3 cm of wet sand on the bottom. In late autumn the containers with larvae were carried into a cool room and left there until spring. Over a dozen cultures of larvae and pupae of pill beetles carried out by the author yielded adults of several species, with *Curimopsis paleata* (Er.) among others. Numerous larvae and pupae were found in damp clay soil under moss, near Czorsztyn (southern Poland), in July.

Family: Click Beetles (*Elateridae*)

The click beetle family includes about 10,000 species distributed all over the world, but they occur more abundantly in the subtropical and tropical regions. So far, 123 species have been recorded from Poland; 83 of these undergo their larval development in soil while the remaining 40 are biologically connected with wood at different stages of decay.

Their larvae, called wireworms, have a body that is slender, chiefly cylindrical, strongly sclerotized, generally yellow or brown, only larvae of species of the genus *Cardiophorus* Esch. are white or pale-yellow, and their body is covered with a soft cuticle. The larval development takes a few year and wireworms may therefore be found in soil all the year round. The opinion that wireworms are crop pests in agriculture, horticulture and forestry increased the interest of many investigators in this group of insects. In the literature there are many publications dealing with the larvae and the world references include over 1,500 titles (Gaedike 1969). In comparison with other families, the morphology and taxonomy of these larvae have been studied fairly well; only 11 larvae of the click beetle species occurring in Poland have not been identified yet. Wireworms may be identified with the help of publications by Dolin (1964) and Rudolph (1974). Physiographic studies of soil wireworms of arable land in Poland were conducted by Piekarczyk (1966).

The most favourable conditions for the development of click beetles are found in soils rich in humus and sufficiently moist. Habitats that are either too dry or very wet are characterized by an insignificant number of species. Two groups – dendrophilous and soil ones – have been distinquished among the larvae of click beetles. Certain species are characterized by a narrow scope of ecological tolerance and they may inhabit only (for instance) patches of moss [*Sericus*

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brunneus (L.), *Limonius aeneoniger* (DEG.], the tunnels of dendrophagous larvae (*Procraerus tibialis* LAC.) or gravel pits near rivers (species of the genus *Zorochrus* THOMS.). Some bionomical and ecological data on click beetles can be found in publications about the elaterofauna of the Bieszczady Mts. (BURAKOWSKI 1971), the Pieniny Mts. (BURAKOWSKI 1979b), Warsaw and the Mazovian Lowland (BURAKOWSKI and NOWAKOWSKI 1981).

The life cycles have been studied fairly well in dendrophilous species (*Ampedus* DEJ., *Procraerus* REITT., *Elater* L. and others) and in those soil species that are considered crop pests [*Agriotes* ESCHSCH., *Cidnopus* THOMS., *Pseudathous niger* (L.), *Athous haemorrhoidalis* (F.), and others].

Species belonging to the same genus usually have a similar life cycle. Under the climatic conditions of central Europe the development of the majority of species takes 3–5 years. Species of the genus *Adrastus* ESCHSCH. are the only ones that complete their development in two years. With lack of food or under unfavourable conditions in their habitat, larvae of the last stage moult twice or more times and their development is one year or a few years longer.

Females, after leaving their pupal cells, and after some feeding and insemination, oviposit from May to August, depending on the species. Eggs are usually laid singly or in small clusters. The total number of eggs laid varies from several dozen to over 120. Soil species oviposit in the surface layer of soil, at a depth of 0,5–2,0 cm, and the soil humidity is the vital factor here. The eggs, very sensitive to dessication, are covered by the female with a sticky secretion. The embryonic development generally lasts for 7–20 days. Young larvae feed on wet plant and animal detritus, together with the microorganisms it contains. Larvae do not manifest any food specialization, most of them are omnivorous so long as the food is juicy because they are able to take only small bits of solid food. In certain species carnivorous or herbivorous tendencies dominate over saprophagous ones. Larvae of *Adelocera murina* (L.), *Harminius undulatus* (DEG.), many species of the genus *Ampedus* DEJ. attack small animals, especially larvae and pupae of insects. Species of the genus *Agriotes* ESCHSCH. and *Sericus brunneus* (L.), however, are mainly herbivorous ones. A larva of the same species may change its diet at different periods in its life. There is an opinion that if older larvae, even herbivorous ones, take animal food, their pupation is speeded up. Throughout their lives larvae moult 8–18 times, and at least twice a year, i.e. once after taking a sufficient amount of food in spring an then in autumn before they begin their winter diapause.

Last stage larvae of the majority of species (*Ampedus* DEJ., *Agriotes* ESCHSCH., *Ctenicera* LATR., *Selatosomus* STEPH., and others) build, from July to September, a cell where they pupate. These beetles do not leave their pupal cells upon emergence, but they stay there until spring. Only a small number of species winter as larvae [*Harminius undulatus* (DEG.), *Crepidophorus mutilatus* ROSENH., species of the genus *Adrastus* ECHSCH, and others] and these pupate from April to June. The pupal stage lasts for 7–20 days. These beetles live for a short time. Males perish shortly after mating and females after oviposition. It is therefore difficult to find adults in autumn.

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There is very little information about the way these beetles feed. Adults of *Agriotes* ESCHSCH. were seen feeding on grass, corn and clover. However, they do no harm because they take very little food and live so short. *A. ustulatus* (SCHALL.) beetles occur mostly on flowers of umbelliferous plants because they feed on their nectar and pollen. *Adelocera murina* (L.) was seen devouring a colony of aphids. Beetles of some dendrophilous species feed on rotting wood or on excrement of other dendrophagous larvae and thus staying in the habitat where larvae live.

Culture methods for click beetles are similar to those used in rearing other soil or dendrophilous species of insects. Clay flower pots (DAVIS 1915), galvanized cylinders (LANE 1924) or drain pipes without glazing (BRYSON 1929) were used in order to study the life cycle under the natural conditions. Observations on the behaviour of particular developmental stages, on oviposition and development of wireworms under the laboratory conditions were made in various glass containers such as e.g. Petri dishes, fruit jars, cylinders an test-tubes of different sizes depending on the size of a given species.

A metod used by BRYSON (1929) under field conditions is worth presenting here. BRYSON used drain pipes about 30 cm long and 15 cm in diameter because he wanted to find out the depth at which larvae of *Ctenicera destructor* (BROWN), a dangerous crop pest in the U.S.A., underwent their pupation. Two such pipes were connected very precisely an filled with sifted soil. A cylinder formed in this way was buried vertically in soil, flush with its surface. The bottom of the lower drain pipe was stoppered with a close-fitting stone so that no larva could escape. Wheat and oat were sown in such cylinders, and sprouting seeds of the two were added as well. 25 larvae of the final stage were placed in each container in spring. The upper drain was covered with a closely fitting screen and a wire hoop was fixed to make pulling the cylinder out of the soil possible. As the young plants were devoured by wireworms new seeds were sown from time to time. The plants were watered only when the crops were germinating. In autumn, the drain pipes were pulled out and transported to the laboratory. There thin layers of soil were carefully taken out of the cylinders and it was found out that 92% of hatched adults were in their pupal cells below 15 cm, at a depth of 23 cm on average. This method of rearing yielded good results because the 525 larvae placed in the cylinders had producted 231 adults.

DAVIS's (1958) aim was to obtain eggs of *Ctenicera aeripennis* (BROWN) under the laboratory conditions. In his culture he placed adults in closed, small glass jars filled with wet soil. Carrots were supplied for food. Two–tree days after oviposition eggs were removed from the soil by means of gentle rinsing with water on a piece of cloth. Then, on the tip of a small paint brush, they were carried onto wet circular blotting paper placed in a Petri dish. The embryonic development lasted for 16–20 day at 28°C and 75% relative humidity. 24 hours after their emergence the larvae were transferred singly into small dishes with roasted loam; then distilled water was added until 27% relative humidity was reached. One grain of wheat, barley or rye, or 5 grains of flax were put into each dish as food for the larvae. During his 12-week study of young larvae, DAVIS recorded the highest mortality during the first two weeks.

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The complete life cycle of the species under discussion was studied under the laboratory conditions in Canada (ZACHARUK 1962). Pairs or inseminated females were placed in small containers half filled with sifted soil, and the humidity there was about 15%. The females laid about 200 eggs each. The eggs were removed from the soil in the way described by DAVIS (1958). Larvae were reared singly in soil the acidity of which was about 7 pH, at a temperature of 38–39°C. The first five instar larvae were reared in closed test-tubes with sifted soil of 10–15% humidity. The food consisted of grains of wheat put in the bottom, and sprouting seeds were also added. Inspections were made either every day or twice a week. The later instar larvae meant to provide adult forms were reared in small glass dishes of 0.06 dec^3 in volume with unsifted soil of 15–20% humidity. Wheat grains supplied for food were not sprouting. Both the food and the soil were changed once a week or once a fortnight. It was found that larvae producing males moulted 9–10-times throughout their lives, and female larvae 10–11 times. The larval development took from one year to over two years, the pupal stage from 2 to 3 weeks. ZACHARUK's method proved successful because 85 adults were obtained out of the initial 120 larvae used in the culture.

A. CHRZANOWSKI was the precursor of field and laboratory studies on wireworms in Poland. In 1927 he published results of his experiments on *Agriotes obscurus* (L.), a pest in agriculture, especially in corn and root crops. CHRZANOWSKI reared the species under discussion in the soil of a bed about 200 x 60 cm in a covered insectarium. The bed was surrounded with boards sumberged 30 cm in the soil. The inside of the box was divided into 30 x 25 cm sections by higher boards also submerged 30 cm in the soil so that the wireworms had no possibility to enter any adjacent sections. The 16 sections thus made inside the box were sown with rye, spring wheat, barley, oat, pea, vetch, sugar beet, and red clover. There were 50 plants in each patch. Fifteen larvae were introduced into each section on 29 April; an inspection made on 14 May revealed that corn plants had been the most favourite food, aspecially oat and wheat, whereas pea had been less attractive and vetch was almost untouched. The larvae were most dangerous directly after sowing and at the beginnng of the vegetation of the plants. CHRZANOWSKI also placed females, before their oviposition, on a similar bed the sections of which were sown with oat, barley, spring wheat, vetch, but there were extra portions of red clover, sod, loosened and hardened soil. 350 adults were placed in the box covered with a frame screened with close mesh, and this prevented the adults from leaving the box, but they could move freely to a suitable section in order to mate an oviposit. The greatest numbers of copulating pairs were recorded on clover and on the grass of the sod. The largest number of eggs laid was found in the sections with clover and also in the soil with sod, but fewer in the sections with oat, barley, wheat and vetch, and those devoid of plants. In the hardened soil eggs had been laid only at the partitions.

CHRZANOWSKI carried out his observations on the life cycle of *A. obscurus* (L.) in the spring of 1922. He put adults into cages made of fine wire gauze and the females oviposited there at the end of May and at the beginning of June. Some of

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the emerged larvae perished before winter, but the remaining 63 were reared in three wire screen vases kept in an open insectarium. The larvae were fed with carrots, beets and potatoes. Unfortunately, the containers had rusted and in 1926 only one of them still contained 3 adults (out of the initial 11 larvae). Thus the result of this culture method was very poor indeed. However, the small number of beetles may also have resulted from larval cannibalism. On the basis of his observations CHRZANOWSKI established that the life cycle of *A. obscurus* (L.) lasted for four years, oviposition took place in May and June, larvae hibernated four times, the pupal stage lasted for 2 – 4 weeks, adults hatched in June and July, some of them came up to the surface, others remained in their pupal cell at 7 – 10 cm in the soil throughout the winter.

Click beetles were also reared under natural conditions in boxes with concrete walls (SUBKLEW 1934). The bottom of the boxes was either concrete or covered with a layer of slag. The lower part of the boxes was filled with peat because it absorbs water very well. The peat was covered with a layer of soil that had been sifted in order to eliminate any natural enemies (*Carabidae, Staphylinidae*). The top of the boxes was covered with windows. In the boxes oat and barley were sown and potatoes and beets planted as food for the larvae.

The entire life cycle of soil species of click beetles was also under observation in cages made of iron galvanized screen (LAFRANCE 1963). Each 120 x 240 x 60 cm cage consisted of two parts. Thanks to a movable partition such a cage could be used for two experiments.

A very interesting way of obtaining larvae for test studies was given by CUTHBERT (1962). He used a glass jar of about 1 dec^3 in volume, with a metal screw-cap which had a round hole in it. Wire gauze, of a diameter larger than that of the jar, was thrust into a ring in such a way that it formed a convexity directed towards the inside of the jar (Fig. 6). Such jars were filled with tufts of dry grass and 75 – 200 adults were placed there. Bits of apples or pears were supplied for food. Then a Petri dish larger than the diameter of the jar was filled with soil consisting of equal parts of peat and sandy loam. The jar with the adults was turned upside down and the cap, together with the gauze, was pushed into the soil in the dish so that females would be able to oviposit through the mesh into the soil. This method made it possible to obtain 200 – 500 larvae from 75 – 100 adults. Emerged larvae could be reared singly in small glass cylinders with caps full of holes for ventilation and maintenance of humidity. Three quarters of each cylinder were filled with the same soil as that in the Petri dishes. The larvae were fed with 3 – 5 grains of boiled wheat. In order to maintain humidity in the cultures the cyliders with larvae were placed in containers with pieces of wet paper.

LAFRANCE (1963, 1964) used a device consisting of two vessels which served the purpose of maintaining permanent humidity of the soil in which eggs and young larvae were kept. One vessel contained distilled water, the other was filled with soil up to three quarters of its capacity (one third of it was garden soil and two thirds – peat). The latter was put on the former, and covered with a metal top with gauze. The upper vessel had a hole in its bottom with a wick dipped in the water in the lower one (Fig. 7).

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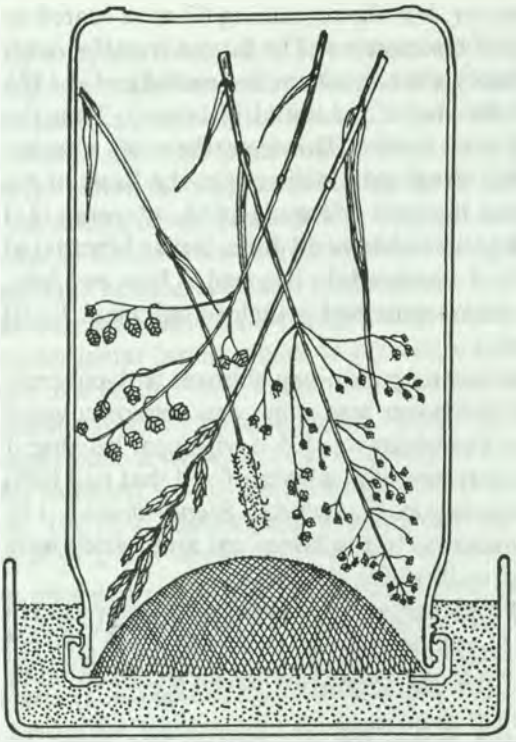

Fig. 6. A device for rearing adults of click beetles (*Elateridae*) aimed at obtaining eggs and young larvae.

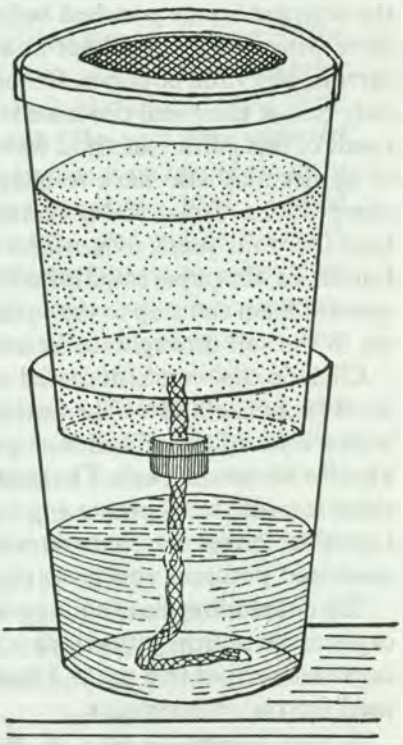

Fig. 7. A diagram of a device for rearing larvae of soil click beetles (*Elateridae*) at constant humidity: water from the lower container seeps into the soil in the upper one.

A similar arrangement was used for direct observation of the embryonic development under the binoculars. Eggs were placed on blotting paper in a Petri dish covered with a lid. There was a hole in the bottom of the dish and it was stoppered with a rubber stopper with a tube 5 cm long and 5 mm in diameter. The tube was filled with absorbing cotton carrying water from a lower container to the dish (Fig. 8).

Apart from rearing larvae of click beetles on natural food, attempts were made to feed them on an artificial diet. DAVIS (1959a) placed older larvae in test-tubes filled with wet cotton wool. They were fed on food in the form of powder or pills. Out of 543 larvae feeding on powdered food placed on the bottom of their test tubes 88% survived for two months, and 76% – four months. Out of 272 larvae feeding on pills placed above the wet cotton wool 86% survived for 2 months. In older larvae the highest increase in their body mass within two months was recorded after they had been given food in which the proportion of casein and dextrin was either 2:8 or 7:3 (DAVIS 1961). However, the literature provides no information about any possibility of rearing *Elateridae* on artificial diets from the first instar larva to the adult stage. Attempts at rearing wireworms

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on artificial diets should nevertheless be made, particularly in order to obtain a large number of larvae of beetles for test studies. Such attempts were successful in the case of rearing larvae of the old house borer *Hylotrupes bajulus* (L.) of the family *Cerambycidae*. The entire life cycle was shortened from 9 to 11 months, which contrasts favourably with a 2–3 years culture on natural food (CANNON, ROBINSON 1982).

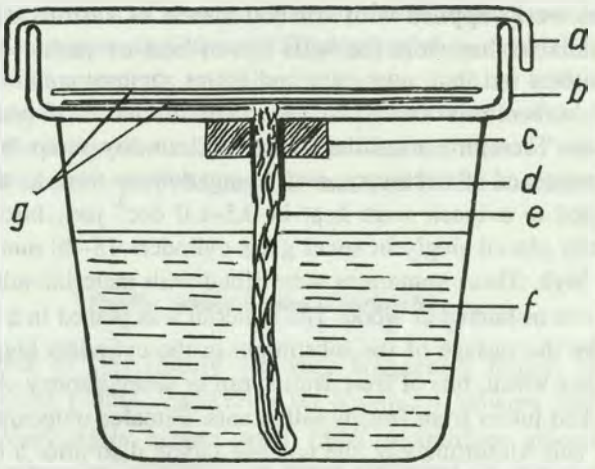

Fig. 8. A diagram of a device for observations of the embryonic development of click beetles (*Elateridae*): a, b – Petri dish, c – rubber plug, d – tube, e – swab of absorbing cotton, f – water, g – two pieces of filter paper.

Click beetle larvae perish when their rearing medium is not moist enough, but they can go a long time without food. Older instar larvae of *Ctenicera aeripennis* (KIRBY) were reared without any food both in sterilized and in unsterilized soil, and they lived for over 40 days; 70% of larvae reared in unsterilized soil survived for 60 weeks, but only 30% of those in sterilized soil lived that long. The larvae moulted during that period of starvation. Eighteen larvae were measured after moulting and 5 had grown, 12 were of the same size and one was smaller (DAVIS 1959b).

In his own cultures of several dozen species of *Elateridae* the author fairly easily obtained adults from older larvae and from pupae. They were usually placed singly in jars of 0.5 dec^3 in volume covered with a loosely fitting lid, or in small glass cylinders stoppered with a cotton wool plug. A half or three quarters of these containers were filled with the material collected together with larvae or pupae. Care was taken to keep the material in the containers sufficiently moist throughout the rearing. This was done in the following way: the cotton wool plugs in the tubes were moistened, water was pipetted directly into the material in the containers and the rearing vessels were placed on wet sand in terraria covered with a glass pane. All cultures were carried out from April to October at room temperature, but from November to March the rearing containers were kept in

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an unheated room (an attic) where, at that time, the temperature was not lower than $-10°C$ and not higher than $+13°C$.

Herbivorous larvae of *Agriotes* ESCHSCH. were fed with sprouting wheat. Polyphagous larvae of the genera *Selatosomus* STEPH., *Athous* ESCHSCH., *Cidnopus* THOMS., *Ctenicera* LATR. were given no only plant food but crushed larvae and pupae of insects as well. Predaceous and necrophagous larvae of *Adelocera murina* (L.), *Crepidophorus mutilatus* (ROSENH.), of the genus *Melanotus* ESCHSCH., and *Ampedus* GERM. were supplied with crushed insects of various stages and if this food was unavailable they were fed with bits of beef or veal.

It must be pointed out that more care and better sanitary conditions are required for cultures of herbivorous soil wireworms than for those of predaceous and saprophagous ones. Therefore, moulding plant food an any scrap must be removed, soil must be moistened if necessary, and changed from time to time.

Adults expected to oviposit were kept in 0.5–1.0 dec^3 jars. Inseminated females were occasionally placed singly in small glass cylinders 18–20 mm in diameter and about 100 mm high. These containers were filled with material suitable for a given species, either soil or humus or wood. The material was placed in a slanting position in order to make the surface of the substratum in the cylinders bigger. Adults were fed with sprouting wheat, bits of fruit, fruit syrup or diluted honey. *Adrastus axillaris* ER. beetles sucked juices from freshly killed ants. Females oviposited in the surface layer of loamy soil. Unfortunately, the hatched larvae died after a few months (BURAKOWSKI 1971). In another case the author managed to study the development of larvae of the soil species *Ctenicera virens* (SCHRANK) for several years. These larvae, however, did not pupate (BURAKOWSKI 1979b). This species was reared in a jar. One third of the jar was filled with limestone soil, called the rendzina, with some tufts of grass planted and a few stones placed there. Females oviposited into the soil and the eggs produced larvae. These were supplied with sprouting wheat and dead insects for food. Due to extreme cannibalism of the larvae, only one larva was still alive in each container after four years.

The author's cultures of *Ampedus elegantulus* (SCHÖNH.) were successful. It was possible to study the ecological requirements and to describe the larvae of this species (BURAKOWSKI 1962) which settled in wood previously attacked by fungi and dendrophagous insects. The larval development lasted for 4–6 years. The larvae were predaceous and necrophagous, feeding mostly on insect larvae and pupae. The cultures were made in 1–2-litre jars filled with wood material inhabited by xylophagous larvae.

In the laboratory, the most favourable conditions, similar to natural ones, may be created for those species that undergo their development in a relatively small area, in tree hollows, in rotting stumps or in the humus around the base of old trees. The author had no difficulty in rearing *Elater ferrugineus* L., a species occurring in tree hollows and in the humus around deciduous trees. Adults of this species are found very rarely because they appear for a short time from June to July. Larvae at different stages are easier to find in old trees with hollows. They live from 4 to 7 years, depending on the external conditions. The author found

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a larva 18 mm long so it must have been at least two years old. After 5 years of rearing the larva grew to 40 mm, then it pupated and finally the adult emerged. Young saprophagous larvae were reared together in 0.1 dec^3 glass jars, but older ones, from 10 to 14 mm long, were reared singly in small glass cylinders 40 mm in diameter and 100 mm high. The glass jars were filled up to three quarters of their capacity, whereas the cylinders were filled with 100 cm^3 of crumbled touchwood, sawdust and excrement left mainly after the feeding of larvae of such touchwood-feeding species of the family *Scarabaeidae* as *Osmoderma eremita* (SCOP.) and *Potosia aeruginosa* (DRURY). The larvae fed on shreds of the spawn of fungi developing on excrement, and also on humus together with the microorganisms developing in it. Older larvae were supplied with larvae and pupae of *Scarabaeidae* and *Cerambycidae* and with beef or veal for food. In the course of the culture no scrup was ever removed and the material in the containers was never changed.

Family: Soldier Beetles (*Cantharidae*)

Adults of species of this family are very frequently found, in spring and summer, on different plants, especially on hawthorn flowers and on umbelliferous plants. Very agile larvae with thick tomantose pilosity are very frequently found when soil samples are being collected or sorted out or when litter is being sifted. Even though *Cantharidae* are widely distributed and occur very often, knowledge about the bionomics, ecology and morphology of the young stages is incomplete. Larvae have been studied very poorly. Most identification keys make it possible to identify larvae only to a genus.

Cantharidae occur both in open areas and in wooded ones where they occupy wet habitats suitable for their development. *Rhagonycha fulva* (SCOP.) is the most abundant and ubiquitous species. Agricultural and horticultural areas are settled by a characteristic group consisting of *Cantharis fusca* L., *C. livida* L., *C. rufa* L. and *Rhagonycha limbata* THOMS. Moist meadows are inhabited by *C. bicolor* HERBST, *C. fulvicollis* SCOP., *C. lateralis* L. Banks of lakes and ponds are a habitat where *C. lateralis* is the most abundant. *C. figurata* MANNH. is the dominant in the entomofauna of peatbogs. Edges of forests, orchards, hedges are settled mostly by *C. nigricans* MÜLL. and *C. pellucida* F. *C. discoidea* AHR. and *C. haemorrhoidalis* F. occur in coniferous forests, *C. cyanipennis* (FALD.) dominates in deciduous forests, and *Podabrus alpinus* PAYK. — in mountaineous areas. *C. obscura* L. and *C. rustica* FALLEN prefer dry biotopes to any other. Bigger species, with body length of from 6 to 18 mm, have been studied more thoroughly. The bionomics of smaller species (about 40%), with body length of 2—5 mm, is hardly known at all. Small species generally live in forest and wooded areas. Their larvae belong to the composition of the entomofauna of litter, decaying wood and moss growing over lower parts of tree trunks. They also live in tree fungi, under loosened bark and in tunnels of dendrophagous insects.

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The life cycle of all cantharid species lasts for one year, with five-sixths of the year taken by the life of the larva. Adult forms leave their pupal cells and appear on the surface from mid-May to the end of June, but in some species even until August. *Rhagonycha fulva* SCOP. is the first to appear, *C. bicolor* HERBST. is the last, coming out in July and August. The imago lives for about 4 weeks on average. These beetles feed on the pollen, nectar and petals of flowers. Umbelliferous plants and hawthorn are their favourite feeding places. Under natural conditions these beetles have been recorded feeding on berries, fruit and fresh epidermis of young oak twigs. Both adults and larvae devour various small invertebrates.

Mating may take place even on the second day after the beetles come out of soil, and it sometimes lasts for 12 hours. A female oviposits after 10—14 days, and the whole process takes about 10 days. With the last segments of its abdomen a female makes hollows in soil. Eggs are laid into these, usually in the evening, every two or three minutes. They are laid in clusters. Occasionally one cluster may contain several hundred eggs. According to JANSSEN (1963), under the laboratory conditions one *Cantharis livida* L. female laid 571 eggs within 10 hours, and a *C. obscura* L. — 2761 eggs in 5 clusters, and one of them contained 701 eggs. The embryonic development lasts for 8—14 days. *Cantharidae* have 6—7 typical larval stages but these are preceded by two or three pre-larval ones and the latter are characterized by some embryonic features. Their body is poorly sclerotized, their legs, antennae and mouth appendages are not fully developed and, moreover, the first of these has a head with a process for cutting the egg. They stay in the cluster, take no food but live on the embryonic yolk. First instar larvae appear after 3—6 days and these leave their clusters and disperse in search of food.

Larvae feed mostly on food of animal origin. Small insects with soft bodies fall their prey most frequently. These larvae lead a predatory life but they must chance directly on their food since their sense of smell is hardly developed. Their digestion is extraintestinal. They also take plant food by sucking juices out of sprouting seeds, soft fruit and rotting grass leaves. The development of the first four larval stages is relatively short: a new stage appears every 10—20 days after moulting. Fifth and sixth instar larvae overwinter and therefore these stages take 160—200 days while the entire larval development lasts for about 310 days. Before their moults, hibernation or pupation larvae burrow into the surface layers of soil where they construct pupal cells. After each moulting a larva stays in its cell for a few days until its cuticle sclerotizes. Pupation takes place in spring. The pupal stage lasts for 10—20 days. After the process of their colouration is completed beetles come out of soil and they begin to fly in search of food and in order to mate.

Cantharidae are very difficult to rear from egg to imago. JANSSEN (1963), while he was rearing some species, recorded high larval mortality. About half the larvae perished during the first stage, one third of them reached the third stage. Mortality was relatively low during the fifth and sixth stages. Only half the sixth

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and seventh instar larvae pupated. The 200 first instar larvae of *Cantharis fusca* L. used in the culture produced only 15 adults (8%) and, respectively, 150 larvae of *C. livida* L. – 24 (16%), 300 larvae of *C. rufa* L. – 34 (11%), 200 larvae of *Rhagonycha fulva* (SCOP.) – 25 (13%) adults. The above author carried out his laboratory cultures at 15–19°C. He placed pairs of beetles in glass containers 8 cm high and 9.5 cm in diameter, with the bottom made of plaster of Paris 1 cm thick. The bottom was covered with 1–2 cm of sifted garden soil and small twigs were pushed into this. The containers were covered with wire gauze and water, readily drunk by the beetles, was sprayed through this every day. Narrow soil tunnels were made at the walls of the containers and females oviposited there. The beetles were fed with sliced larvae of the meal worm *Tenebrio molitor* L. and bits of apples. Egg clusters, with the soil removed, were placed on blotting paper in small Petri dishes where there was a layer of wet, previously roasted sand. These dishes served during the embryonic development in the egg and during the development of two or three prelarval forms, until the first instar larvae emerged.

Larvae were reared in bigger dishes with sifted, moistened garden soil. To make observations easier, younger larvae were provided with a thin layer of soil, older ones with a thicker layer – about 1 cm. A small gypsum-block about 0.5 cm thick was put on the soil and in this way regular humidity was maintained. Under these blocks larvae could find shelter and build pupal cells before their moulting and pupation. The larvae were fed with pieces of beetle larvae of the genera *Pyrochroa* MÜLL., *Ampedus* DEJ. and *Tenebrio* L., with sprouting seeds, rotting grass leaves, raspberries, bits of apples and carrots. They devoured the germinal part of crushed wheat grains. Occasionally, there were several dozen first and second instar larvae under one grain. Food was served on bits of blotting paper. Every 4–6 days, inspection was made, the soil and gypsum-blocks moistened, scrap removed and fresh food provided. In his experimental cultures JANSSEN supplied three groups of larvae with food that was either purely animal or purely plant or mixed. The highest mortality was recorded for the group fed with plant food, the lowest – for that fed with animal food.

JANSSEN'S cultures in the open area were carried out in bigger containers with about 10 cm of soil and these were arranged in a sheltered place protected from rain.

The author's own observations made during field studies and in the laboratory have confirmed the difficulties in keeping alive larvae reared at younger stages. However, it was fairly easy to obtain imagines from older larvae collected in late autumn or early spring. Pupae, if carefully extracted from soil, could also easily become adults under the laboratory conditions. Larvae and pupae were placed singly in glass tubes about 20 mm in diameter and about 80 mm high. Three quarters of each tube were filled with the substratum the forms had been found in. The tubes were stoppered with cotton wool plugs and put horizontally in a vessel with wet sand. The optimum temperature for such rearing was 15–19°C. Pupae and prepupae were provided with a hollow in the soil that would imitate their pupal cell, while active larvae – with a long tunnel.

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Family: Lagriid Beetles (*Lagriidae*)

Lagriid beetles occur most abundantly in the subtropical zone; the total number of identified species is about 2,000, but in Poland there occur only two species and one of these – *Lagria hirta* (L.) – is common.

Adults appear in May or June and survive until July and August. They occur mainly in insolated forest clearings, on the edges of deciduous and mixed tree stands, in logging places and along the forest sections. They stay on the foliage and branches of trees, bushes, on perennial plants and grasses because they feed on their living tissues. A female oviposits either directly into humus or under various small bits of plants on the ground. The embryonic development lasts for about two weeks. The life cycle is completed in two years. The larva hibernates and it moults several times, the last time after the second overwintering. Larvae mostly feed on dead leaves lying on the ground and on the bark of fallen twigs. Since its food is poor in protein but rich in cellulose substances, the larva makes use of the protein substances provided by symbiotic bacteria that decompose cellulose in the alimentary canal. During the individual development, these symbionts are carried from one stage to another, from egg to imago. The female has special inter-segment pockets in the abdomen and they are connected with the genital chamber. These pockets contain a colony of bacteria that are transferred onto the eggs and then they reach the embryo.

Pupation takes place in May or June in pupal cells constructed in the surface layer of soil. In our climate, adults do no damage because they stay on plants for a short time and never in great masses. Larvae may play a positive role in biocoenoses through their share in the process of litter decomposition.

Lagriid beetles are not difficult to rear if the objective is to obtain particular developmental stages. The whole, two-year life cycle was never achieved in the laboratory. Adults caught in the field or those reared from older larvae and pupae oviposited in the laboratory. These eggs produced larvae which, unfortunately, never survived until hibernation.

The rearing was done in 0.5 – 1 dec^3 glass jars or in small aquarium receptacles covered with gauze. The bottom of these containers was covered first with a layer of soil, then with sifted leaf litter, finally with rotten and fresh leaves and twigs. The contents of the containers was moistened a little, but moulding was prevented. The food of adult forms was supplemented with bits of fresh fruit. A few pairs of imagines or a greater number of larvae were reared in one container (Burakowski 1976). Any pupa found was placed in a small hollow made in the soil and covered with dry pieces of leaves or blotting paper. During winter the containers were covered with a lid or glass pane and kept in a cool room.

Family: Comb-claw Beetles (*Alleculidae*)

In Poland the family of comb-claw beetles is represented by 22 species (Burakowski 1976). Their larvae are similar in appearance to those of certain

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species of darkling and click beetles. To date, the European literature has never presented a full scientific description of these larvae.

Comb-claw beetles occur in open and forest areas. Two bionomic groups have been distinguished on the basis of their larval development. One group includes species whose larvae live in litter and soil, the other – species feeding in decaying wood invaded by fungi. Larvae of nine species living in the surface layers of soil feed on humus, underground plant remains and dying parts of plants. The two-year life cycle may be prolonged to three years. Larvae are the only hibernating stage. Before pupation, which takes place in spring or early summer, a larva prepares its pupal cell in the soil or humus and spins a cocoon out of the surrounding material. The pupal stage takes from one to three weeks. Adults emerged from soil larvae feed on the pollen and nectar of flowers, especially of umbelliferous plants.

A short report by BURAKOWSKI (1976) is the only paper describing a culture of comb-claw beetles for morphological and taxonomic studies. It was not difficult to rear species whose larvae fed in the rotting wood of the basal parts of trunks, in broken branches, strumps, logs, and especially in tree hollows. Larvae collected together with decaying or rotten wood were placed in cloth bags and carried to the laboratory where they were put into glass jars of $1-2$ dec^3 in volume. Moist cotton wool or wood wool was placed on top of the wood material or part of the dry-rot was sprinkled with water at one side of the jar. Rearing species that fed on dry-rot did not require much trouble because the jars with their contents were miniatures of tree hollows. In order to record the moment pupae or imagines appeared it was enough to inspect the jars every two months, but during spring inspections had to be done every two or three weeks. The wood decomposing because of the activity of fungi served as food for the larvae whose excrement accumulated, as in a tree hollow, on the bottom of their container. Prior to pupation larvae of some species spin a cocoon in crumbled touchwood and excrement. Adults of tree species lead a nocturnal life and they are not found on leaves or flowers. They feed on rotten wood. The females kept in the glass jars were not suplied with any additional food but they oviposited nevertheless. The eggs produced larvae and the author, in this cultures of touch-wood feeders, obtained adults of species of the following genera: *Allecula* F., *Prionychus* SOL., *Pseudocistela* CROTCH., and *Mycetochara* BERTH. Some species of the last genus were reared in two succeeding generations although the rearing containers and food material had not been changed.

Soil larvae were also reared in big jars filled with the soil collected together with them. Care was taken to collect the soil and place it in the jars without disturbing its natural arrangement. The places inhabited by the larvae had also provided dead parts of plants, tufts of grass and moss which were placed in the jars. Adult forms were also provided with fresh leafy twings of bushes and trees, and with flowers, those of umbelliferous plants were the best. These were changed when they withered.

It is more difficult to provide favourable laboratory conditions for species of comb-claw beetles whose larvae live in soil. These larvae should have a possibility

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of moving over a horizontal plane and searching for appropriate food. Narrow rearing containers make it more difficult to maintain the mycoflora on plant remains in the soil (but there is not so much trouble in the case of cultures of species that develop in rotten wood). The author reared only older larvae and pupae of soil species and obtained adults of the following species: *Hymenalia rufipes* (F.), *Isomira murina* (L.), *Omophlus betulae* (HERBST), and *Cteniopus flavus* (SCOP.). A female of the last species laid eggs which produced larvae but these died in a short time.

There are occasional remarks in the literature about damage done by *Alleculidae*, but such damage is never great because comb-claw beetles never occur in great numbers. And to some extent they even play a positive role because their larvae feed mainly on dead plant remains and their excrement enriches the soil.

Family: Darkling Beetles (*Tenebrionidae*)

The majority of darkling beetle species live in tropical areas and in the southern part of Europe. About 20,000 species have been recorded so far. Only 58 species occur in Poland. This group of beetles evokes a rather poor interest, probably because of their offensive odour. Apart from the bionomics of synanthropic species and warehouse pests, the bionomics of most species has been studied very poorly.

The species occurring in Poland may be divided into four groups but the bioecological differences between them are not very great. They are as follows:

1. Species inhabiting soil. Larvae of this group develop among plant detritus. This group includes species of the genera: *Blaps* F., *Melanimon* STEV., *Opatrum* F., *Phylan* STEPH. Some species, such as *Pedinus femoralis* (L.) also feed on living tissues of roots of different plants, and *Phaleria cadaverina* (F.) – on animal detritus.

2. Species living in fungi that grow on tree trunks. Larvae of this group (species of the genera *Bolitophagus* ILL., *Diaperis* GEOFFR., *Eledona* LATR., *Haplocephala* CAST.) mostly feed in polypores of the genera *Fomes* FR., *Polyporus* (MICH.) FR. and *Polystictus* FR.

3. Species found in old, generally deciduous trees. This groups includes the majority of darkling beetles whose larvae develop either in the dry-rot in tree hollows, e.g. *Neatus picipes* (HERBST), *Pentaphyllus testaceus* (HELLW.), *Tenebrio opacus* DUFT. or in rotting wood invaded by fungi, such as *Laena reitteri* WEISE, *Scaphidema metallicum* (F.), *Uloma culinaris* (L.) or under loose, fungus-ridden bark e.g. species of the genera *Hypophloeus* F. and *Palorus* MULS.

4. Synathropic species. In the hot climate they originally developed in rotting wood, but under the conditions of the temperate zone they occur mainly as pests in warehouses, storerooms and other heated rooms where they undergo their development in products of plant origin, usually in corn grains.

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Adult forms lead a hidden, generally nocturnal life. Only species of the tribes *Opatrini* and *Helopini* may be found feeding during the day. Many species are wingless and these do not occur on flowering plants. Their glands produce an offensive odour, either creosotic (*Blaps* F., *Tenebrio* L.) or aldehydic (*Tribolium* MAC LEAY). They are recorded mainly in dry biotopes. There are two exceptions, though, *Phaleria cadaverina* (F.) – a species inhabiting the seashore, and *Alphitobius diaperinus* (PANZ.) – a species feeding in very wet corn products. Both larvae and adults feed on detritus and on plant and animal remains. They can stand starvation very well, for instance a *Blaps* sp. imago survived for over 90 days at a temperature of about 20°C and relative air humidity about 70%. Their water requirement is low, too. Water in their food usually proves enough for them. Some imagines are characterized by longevity in comparison with their life at the larval stage. The larval development of *Tribolium confusum* DUV. lasts for merely a few weeks whereas the adult may live up to two years. Steppe species of the genus *Blaps* F. live very long indeed. The larval development of species of this genus lasts for from 9 to 16 months. The author received for his culture a pair of *Blaps* sp. beetles caught in Syria (Palmyra) in August 1974. The male lived until December 1980, the female survived until February 1985, and this means that it had lived for over 10 years in the culture. This fact confirmed previous data from the literature (LABITTE 1916).

In the climate of Central Europe darkling beetles have a one-year life cycle, but under unfavourable conditions their development takes two years. Synanthropic species are the only ones that may have two generations within a year [*Gnathocerus* (F.), *Tenebrio molitor* L.] or even 4–6 generations (species of the genera *Alphitobius* STEPH. and *Tribolium* MAC LEAY).

Females usually lay single eggs near their food substratum. Only a few species, such as *Tenebrio* sp., lay batches of over a dozen eggs. Eggs are covered with a sticky substance and parts of the surrounding substratum stick to this, making the eggs difficult to find. The total number of eggs laid is from 150 in species of the genus *Alphitobius* STEPH. to about 500 in *Tenebrio* L. and *Tribolium* MAC LEAY. Oviposition and the embryonic development depend on temperature. *Tribolium* sp. oviposits at a temperature above 14°C. In the genus *Blaps* F. larvae emerge from eggs after about 35 days at 15°C, but after 7 days at 30°C. The number of larval moults varies in different species, e.g. it is 6–7 in *Tribolium* sp., 10–13 in *Blaps* F. and 10–16 in *Tenebrio* L. 60–80% is considered to be the optimum relative air moisture for the development of larvae. However, larvae can survive even if this moisture is lowered to 20% because their body is covered with the chitin that makes them resistant to drying. Larvae lead a hidden life, they avoid direct contact with light. Before pupation most species construct a pupal cell in the substratum. Larvae of species of the genus *Platydema* CAST. spin a cocoon, *Gnathocerus cornutus* F. pupates in a cell made from parts of sticky flour, and *Tenebrio molitor* L. on the surface of the food substance. The majority of species pupate in late summer or in autumn, only some of them (*Crypticus* LATR. and *Bolitophagus* ILL.) in spring.

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Darkling beetles are not difficult to rear because they can stand lack of food and water. However, a fairly high temperature must be maintained, especially for synanthropic species. Rearing may be done in all sorts of containers except wooden ones. For most species of the genus *Blaps* F. the best are glass aquarium-type containers, for instance those measuring 20 x 30 x 25 cm and filled with 8 – 12 cm of pure sand. On the surface of this, adults of *B. halophila* FISCHER are provided with pieces of clay flower pots to hide in, and *B. mortisaga* (L.) with pieces of thick, rotting twigs to hide in and to be used as food for their larvae. 2 – 3 pairs of adults may be put into such containers. Separate pairs may also be reared in glass jars of 1 – 2 dec^3 in volume, covered with a loosely fitting top. Aquarium-type containers are covered with a glass pane. The sand is moistened only in one part of a container. This gives the beetles a possibility of choosing a suitable place to settle in.

In his cultures of *Blaps* sp. the author supplied both imagines and larvae with slices of stale moulding bread for food. The beetles devoured this readily and during feeding they were covered all over with green spores. Larvae burrowing tunnels in the sand fed on the part of the bread in direct contact with the sand. About once a month, the sand in the cultures was moistened, any scrap removed and new food given. The food of the adults was supplemented by bits of fruit. The larval devolopment and the pupal stage depended on temperature. Under the laboratory conditions a larva usually built a big pupal cell at a depth of 6 – 10 cm in the sand after 9 – 16 months. At that moment all moistening of the culture had to be interrupted. The pupal stage lasted for about 35 days at 20°C and about 20 days at 25°C. Larvae which burrowed tunnels in rotting twigs also pupated in the sand. A beetle stayed in its pupal cell for about a week after emergence and then, after its body was fully coloured and sclerotized, it came up to the surface.

Culture methods for synanthropic species such as *Tenebrio molitor* L. or species of the genus *Tribolium* MAC LEAY are often used in model laboratory experiments, but also when larvae and pupae are to be used as food for predaceous beetles, and for birds and fish as well.

Tenebrio molitor L. material for rearing can be obtained without any difficulty. Adults and larvae can be found in any place where there are scraps of grain products. Mass culture may also be begun with larvae bought in a zoological shop. They do not require a lot of space. They may be kept in a glass container filled with a sufficient amount of food. Shallow aquaria half filled with flour are the best. The optimum stock is 80 larvae per 1 dec^3 of flour mixed with bread crumbs. On the surface are placed slices of bread and pieces of loose, crumpled material (a sock, a cloth bag, a piece of some clothes) and these are slightly sprinkled with water. The larval devolopment takes 12 – 18 months at 20°C, and 6 – 8 months at 25°C. The duration of the pupal stage also depends on temperatue; it lasts for about 30 days at 15°C, and for only 5 days at 32°C. The newly hatched beetles must be transferred to another container with flour, on top of which there are dry leaves, moss and twigs. All these are slightly sprinkled with water. Females usually oviposit after 10 – 14 days.

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A similar culture method is used for rearing species of the genus *Tribolium* MAC LEAY, but in this case a smaller container is used, e.g. a 1 – 2 dec^3 glass jar. The culture material may be obtained from laboratories of different biological institutes. In the last decade, *T. destructor* UYTT. has been the most common species found in untidy larders. The development of the larva and the pupa depends on the temperature, too. In *T. confusum* DUV. a larva lives for about 60 days at 20°C, 22 days at 25°C, and 17 days at 32°C. The pupal stage of this species lasts for 17 days at 22°C, and 5 days at 32°C. No instances of cannibalism have been recorded even with a high density of larvae in the culture. But in a culture neglected for a long time a high mortality is recorded and this is due to the strong odour produced by the imagines.

Alphitobius diaperinus (PANZER) is a species that requires a relatively high temperature and humidity of the substratum for its devolopment. In Poland, it does not occur under natural conditions but it is more and more frequently found on poultry farms, usually under the feeding trays and watering troughs. Both the adult and the larva feed on wet, mouldy remains of the food provided for the poultry. Rearing is done in glass jars with lids. The bottom of the jars is covered with a 3 – 4-centimetre layer of wet sand, a similar layer of flaked oats or the food mixture given on poultry farms, and then a slice of bread is put on top of all this. Beetlees are put into thus prepared jars which are placed in a warm place, e.g. above a heater. After a few days the bread and corn are already mouldy and this is the best food for beetles of this species. Females oviposit directly into the moulding food. At 30°C the embryonic development takes 5 – 7 days, and the larval development about 35 days. At 20°C the development may be prolonged up to 12 months. Before pupation larvae burrow into the sand where they build pupal cells. Larvae of this species are not readily eaten by other predaceous beetles but *A. diaperimus* (PANZER) pupae are an excellent food for carnivorous insects. During culture, mould developing on the surface is accompanied by colonies of mites. When these appear, adults and larvae of *Alphitobius* go down to the wet layer where mites cannot reach. Upon emergence the beetles must be transferred to another rearing container, not infested with mites.

Family: Scarab Beetles (*Scarabaeidae*)

To date, 147 species of scarab beetles have been recorded from Poland. Only 12 of them undergo their development in rotten wood, especially that of deciduous trees, and all the other species are associated during their larval development, with the soil habitat and most of them feed on animal excrement.

This group of species is known fairly well as far as the taxonomy of the adult forms is concerned (STEBNICKA 1976, 1978). The lower developmental stages, on the other hand, been studied very insufficiently. The existing keys for identifying larvae include only about 35% of species recorded in this country. It is possible to identify only certain genera and the most common species (MEDVEDEV 1952). The

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surest way to verify whether the identification has been correct is therefore through rearing.

Most species of scarab beetles inhabit various plant associations in light soils that are sufficiently moist, but some species occur in such habitats as excrement, burrows of rodents, tree hollows, ant hills.

The life cycle of scarab beetles may take form one to two, three or even five years and most of this time generally falls to the larval development. Two generations may occur within one year only in exceptional cases. The life cycle may be longer or shorter depending on the climate, length of the vegetative period and food supply. However, irrespective of the length of life of a given generation all the larvae of scarab beetles have three growth stages, moult three times and pupate after the last moulting.

European scarab beetles may be divided, on the basis of the behaviour of their larvae, into the following bioecological groups:

1. Species whose larvae live freely in soil and feed mostly on living, but sometimes on dead, roots. When very young, these larvae usually feed on humus. This group includes, among others, the subfamilies *Melolonthinae, Hopliinae, Rutelinae* and *Sericinae*. Larvae of some species are considered pests of agricultural and forest crops. Adults are herbivorous as well;

2. Species whose larvae live in different types of excrement feeding on it. Species of the subfamily *Aphodiinae* belong here;

3. Species whose larvae are unable to find food themselves but use that has been prepared by adults. Basing on the quality and the way their food is prepared the following may be distinguished: a) species whose larvae feed on excrement accumulated by imagines in the form of balls or wads in soil. These include species of the subfamilies *Coprinae, Geotrupinae* and *Scarabaeinae,* b) species whose larvae feed on rotten plant matter prepared by adults in soil in separate cells and tunnels, and these include *Lethrus apterus* (LAXMANN) and *Geotrupes stercorosus* (SCRIBA);

4. Species whose larvae live in places where plant detritus accumulates, e.g. in compost heaps, piles of sawdust or bark, in humus or litter. This group is represented by *Epicometis hirta* (PODA), *Oryctes nasicornis* (L.) and by some species of the subfamily *Aphodiinae*;

5. Species whose larvae feed on material of plant origin accumulated in ant hills. These include certain species of the genus *Potosia* MULS.;

6. Species whose larvae feed on decaying wood and live in tree stumps or hollows. This group is represented by species belonging to the subfamilies *Valgiinae, Trichiinae* and *Cetoniinae*.

It is rather difficult to rear species that feed on living plant tissues because they must be provided with fresh food all the time. Saprofagous species, both coprophagous and xylophagous ones, are far easier to rear. Examples of cultures of some species are given below.

(Ad 1). Publications devoted to the May bug, *Melolontha melolontha* (L.), and *M. hippocastani* F. are a source of many indications helpful in rearing these

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beetles. In order to obtain eggs and then larvae SCHUCH (1938) and WILLE and WILDBOLZ (1953) placed each pair of beetles in glass cylinders 20 cm high and 9.5 cm in diameter. These were covered with gauze, open at the bottom and inserted vertically in flower pots filled with garden soil (Fig. 9). The lower layer of the soil, about 5 cm thick, was pressed hard and covered with loose soil which was kept moderately moist all the time. The beetles were given young leafy twigs of oak and beech trees for food; hornbeam and hazel twigs were devoured less readily.

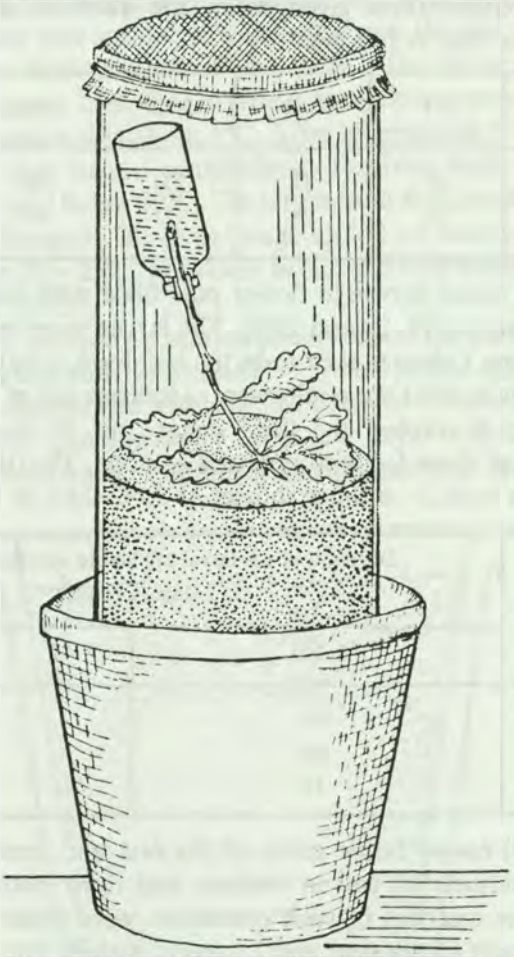

Fig. 9. A cylinder and a flower pot for rearing adults of beetles *Melolontha* sp. (*Scarabaeidae*).

In order to keep the plants fresh a little longer the twigs were put into glass tubes filled with water. The tubes were stoppered around the twigs with closely fitting water-proof material so that the water could not flow out when the twigs were inclined for their leaves to touch the soil. These plants were changed every other day. In such cylinders, females survived for 39 days on average, males lived a little shorter. The females laid eggs into the soil, some of them only once, others several times. One female laid from 13 to 29 eggs. The embryonic development lasted for

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from 8 to 13 days. Under natural conditions, the life cycle of *Melolontha melolontha* (L.) takes 3–4 years, that of *M. hippocastani* F. – 3–5 years. Under the laboratory conditions and at constant temperature this period may be much shorter. First instar larvae do not survive until their first moult if the temperature is either below 12°C or above 32°C. At a constant temperature of 18°C the total duration of the larval and pupal stages is 358 days, but this period may be shortened to 222 days at a constant temperature of 23.5°C (WILLE, WILDBOLZ 1953). At the temperatures given below the duration of particular stages, reckoned in days, was as follows:

Temperature	L I	L II	L III	Pupa	Larva + pupa
18°C	41	45	234	38	358
23.3°C	33	28	121	40	222

THIEM (1951) reared larvae in flower pots filled with soil and kept in three rooms at temperature 15, 20 and 25°C. The larvae were fed with celery, sugar beets and potatoes. Celery proved to be the best food, potatoes the worst. After 67 days of rearing at 20°C the results were as follows: out of 15 first instar larvae reared on celery 8 reached the third instar, out of those reared on beets – 4 larvae, out of those fed with potatoes – none. The duration of the life of particular stages were 5–6 times shorter at 25°C than at 15°C:

Temperature	Duration of the larval life before moulting to the next stage, in days	
	L I/II	L II/III
15°C	119	120
20°C	42	50
25°C	18	25

HURPIN (1964) reared beetle grubs of the first and second instars in closed polystyrene containers 80 cm^3 in volume, and third instar grubs in 240 cm^3 containers. Three quarters of such containers were filled with moist peat (in weight it was 1 part of dry peat and 2 parts of water). The culture was done at 20°C. Every 8–15 days the larvae were fed with bits of carrots and roots of dandelions. The peat was changed as it became contaminated with excrement and scrap. Such cultures provided 30 beetles out of 100 eggs, after 13 or 15 months. These hatched beetles were meant to produce a new generation and for this purpose they were kept in a room at a temperature of 13°C for about 3 months. The adults were then transferred into a room where the temperature was 20°C, and there they were fed with young oak shoots. Out of the beetles that had hatched only half the females were able to oviposit.

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Experiments were made to study to what extent the activity of larvae, and pupation, depended on temperature (ENE 1942, VOGEL and ILIĆ 1953, WILLE and WILDBOLZ 1953). In order to find this out larvae were reared in wire baskets 10–20 cm in diameter and 25–39 cm high, in sheet cans 4.5 cm in diameter and 7 cm high, and in glass cylinders 12 cm in diameter and 50 cm high covered at the bottom and on top with a wire screen. These containers were filled with humus and the larvae were fed with oak and beech roots, with wheat grains, carrots and potatoes. The rearing containers were inspected every week when fresh food was given, the substratum was sprinkled with water and the soil was changed, if necessary. The larvae began to feed only at 11.5°C. The larvae devoured about 100 g of food throughout their life. In winter the cultures were kept in a cellar where the air temperature was about 5°C. After hibernation if larvae could not find the right food they turned cannibalistic. Pupation took place at a temperature above 14°C and below 30°C. The larvae built their pupal cells below the level at which they foraged. The pupal stage took 4–5 weeks at the optimum temperature between 20–25°C, but it was prolonged to 8 weeks at 15°C and up to 3 or 4 months at 12°C.

An unconventional method for rearing one species of the genus *Anomala* SAM. was applied by FUJIYAMA and TAKAHASHI (1973). Adults and eggs laid by females were placed in Petri dishes filled with sawdust that had been boiled for one hour and then washed with running water for a few days. Within 24 hours after hatching the larvae were transferred singly to containers 150 cm^3 in volume, and

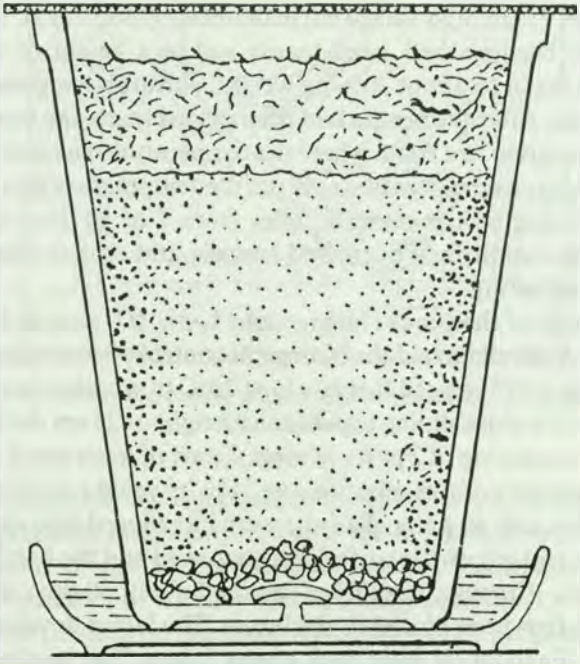

Fig. 10. A culture of species of the subfamily *Aphodinae* in a flower pot.

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three quarters of these were filled with sawdust. The larvae were fed with oak leaves that had been washed, then dried in the sun, and later portions of these were mixed with wet sawdust.

The above indications for rearing may be used and adapted in cultures of other species of scarab beetles whose larvae live in soil and feed on the underground parts of plants or on detritus.

(Ad 2). Species of the subfamily *Aphodinae* are best reared in flower pots with two thirds of these filled with soil which is covered with excrement of herbivorous mammals and then a glass pane is put on top of this (Fig. 10). Species feeding in detritus are kept in the soil they have been found in. The flower pots stand in dishes with water and thus humidity is maintained. For direct observations beetles and larvae are placed in Petri dishes or in glass jars 0.5 dec^3 in volume.

(Ad 3). There is distinct competition between coprophagous scarab beetles and dipterans. While taking food and making dung balls for their offspring scarab beetles bring about a change in the consistence of dung. It becomes porous, dessicates very quickly and is no longer a suitable food for dipterans. The mortality of dipteran eggs and larvae increases. Certain species of coprophagous scarab beetles from Africa and southern Europe were introduced in Australia and North America in order to decrease populations of coprophagous dipterans oppressive to cattle and man. These beetles were first reared on a large scale in laboratories and then acclimatized in the field.

For instance, in California, cultures of *Onthophagus taurus* SCHREBER, a species also occurring in Poland, were undertaken. The beetles were placed in cylindrical cardboard boxes 25 cm high and 24 cm in diameter (MOON et al. 1980). The boxes were filled with hard pressed, sand-loamy soil to a height of 18 cm and were moistened with water to about 20% by weight. Natural cow pats were put on the surface of the soil. After the beetles had been placed there, the boxes were covered with gauze and carried to a room where the temperature was similar to that under natural conditions. At the base of a cow pat the temperature was 16 – 36°C (28°C on average). Young beetles matured after from 7 to 10 days of feeding in the dung. After copulation they burrowed tunnels and stored dung balls there as food for their offspring.

Another species of the genus *Onthophagus* LATR. (*O. gazella* F.) was imported from Africa to Australia to aid the biological control of coprophagous dipterans. BLUME and AGA (1975) reared this beetle at 29°C in wooden boxes measuring 60 x 60 x 30 cm, with a glass sliding top. Up to a height of 25 cm the boxes were filled with a mixture consisting of 2 parts of sand, 1 part of loam and 1 part of peat soil. The average humidity of this mixture was 25% by weight. Cow dung was put on the surface of the soil. 40 pairs of adults were introduced into each box. After 10 days, the excrement left on the surface was removed and the beetles transferred to other containers. The new generation emerged about 30 days after the paternal generation had first been placed in the boxes. The larval development lasted for about 21 days. Each larval stage took about 7 days. The beetles attained sexual maturity about 5 days after they had emerged from the pupa. The continuous

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reproductive activity lasted for about 60 days in the life of the adults. On average one female bred 90 individuals of a new generation in its life time.

An interesting way of rearing larger coprophages of the genus *Geotrupes* LATR. was applied by KLEMPERER (1978, 1979). He put adults and larvae into specially built narrow cages with glass walls (Fig. 11). The narrower walls and the bottom consisted of wooden slats 15 × 30 mm thick and two glass sheets of 270 × 360 mm placed on the slats. The sheets were covered with cardboard covers to keep off light. The entire structure, i.e. the frames, glass sheets and covers were fastened with clasps. Such a cage was partly filled with garden soil (with water contents of 22% by weight) which was slightly pressed when the bottom of the cage was tapped against some soft base. Fresh horse dung 15 mm thick was put on the soil and this was covered with cellulose pulp made of bits of filter paper

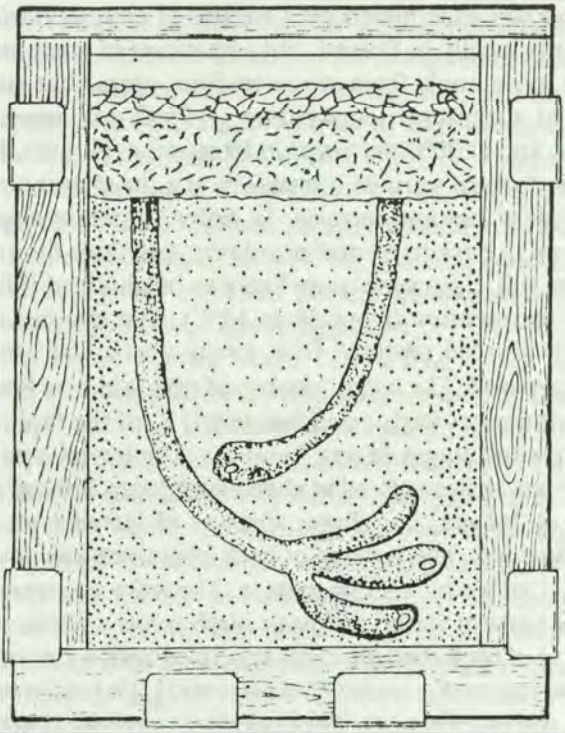

Fig. 11. A shallow terrarium for rearing coprophagous species of the genus *Geotrupes* LATR. (*Scarabaeidae*).

with 80% water content; the top of the cage was covered with a fine mesh wire screen. A cage prepared in this way and with the cardboard cover removed made direct observations of the beetles possible without disturbance to them. The proceeding construction of tunnels and breeding cells filled with food for the offspring could be marked on the glass. After emergence males and females were first placed in large containers with garden soil and fresh horse dung. An inseminated female was isolated in a glass jar, in the dark, for at least 12 hours,

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and then it was transferred to a cage. It took a female 5–12 hours to build a tunnel 100 to 200 mm deep with 5–10 sausage-like breeding cells hollowed out in it, and it filled these with dung. The female laid one egg into each cell. The rearing was done at 16–20°C. The mean duration of the development of particular stages of three species was as follows: *Geotrupes spiniger* MARSHAM – the egg – 20 days, the first instar – 10 days, the second instar – 12 days, the third instar – 85 days, the pupa – 28 days; *G. stercorarius* (L.) – the course of the development was similar, but the third instar moulted into the pupa after about 170 days; *G. mutator* MARSHAM: the egg – 14 days, the first instar – 7 days, the second instar – 8 days, the third instar – 42 days, the pupa – 28 days.

(Ad 4). The extent to which temperature influences the rate of the development of younger larvae was exemplified by a culture of *Oryctes nasicornis* (L.). This species occurs only locally in Poland, but sometimes in great masses. In central Europe the life cycle took from three to four years, but under laboratory conditions and at a constant temperature of 25°C one generation developed within two years, and at 30°C even within 10 months (HURPIN, FRESNEAU 1964). The rearing was done in various containers, e.g. in aluminium boxes, plastic boxes, buckets, glass jars and terraria. In order to obtain eggs a few pairs of beetles were placed in buckets 12 dec^3 in volume, and three quarters of each were filled with garden soil. Eggs were more likely to be obtained if females had been kept at a lower temperature (from 10 to 15°C). The number of eggs laid was greater if the females had emerged from larvae which had been given dung in addition to rotten wood. The mean number of eggs laid by a female was 50. The success of the culture was fairly good because 75% of the first instar larvae had been reared up to adult stages during 5 months. The larvae were reared singly or in groups. Single larvae were reared in aluminium boxes 130 cm^3 in volume and in polystyrene boxes 240 cm^3 in volume. Groups of larvae were reared in boxes 2 and 5 dec^3 in volume. The bottom of each container was covered with a few centimetres of soil for the larvae to pupate in. The soil was covered with a mixture consisting of five parts of rotten willow or birch wood and one part of fresh cow dung. The content of each container was sprinkled with water every 8 to 15 days.

The author (BURAKOWSKI) reared *O. nasicornis* (L.) larvae in two-litre jars or in terraria covered with a glass pane. The containers were filled with the material in which the larvae had been found in nature. The food material provided was sawdust from an old sawmill heap, rotten leaves mixed with humus and dung. The larvae reared in this way produced pupae and adults in the culture.

According to DONALDSON (1979) an addition of cattle dung to humus has a positive effect on the results of cultures of some species of the subfamily *Cetoniidae*. In the culture only 25% of the larvae which had fed entirely on compost soil underwent pupation, but when compost was mixed with dung the number of pupating larvae reached 70%. Moreover, an increase in the number of larvae per container had a negative effect on the culture. In a 3.5 dec^3 container with 30 larvae only 20–31% of them pupated, whereas 50–76% of larvae

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pupated when there were 10 – 20 individuals per container. The rearing was done at 25 ± 1°C and relative humidity of 60 – 80%. About 20 pairs of beetles were let into cages measuring 75 x 48 x 48 cm enclosed in a wire screen. Each cage contained a dish 240 mm in diameter and 70 mm high filled to the brim with moist pasteurized soil. A piece of cloth, 120 mm wide, was put on the rim to make it possible for the beetles to enter the dish. Two or three times a week the soil was removed, the eggs taken out and put on wet filter paper placed in Petri dishes 90 mm in diameter. The same soil in the containers was used by females for oviposition. During each inspection the soil was moistened with 50 cm^3 of water. The dishes with the eggs were kept in the dark and inspected every day. The newly hatched larvae fed on the filter paper for a week. After that groups of 20 – 30 individuals were transferred to containers 3.5 dec^3 in volume filled with a mixture of loam-sandy soil, compost at least one year old and not very moist cattle dung that was 4 – 15 days old. In order to destroy all unwanted organisms the soil and compost had been pasteurized at 98°C for 20 minutes, and the dung had been cooled down to from 15 to 20°C below zero for at least 24 hours. The mixture of these material was heated to about 25°C and 50 – 80 cm^3 of water were added into each container 3.5 dec^3 in volume. The soil mixture was changed every two weeks while the devolopment of the larvae was being checked. Groups of 10 pupae were transferred to 1 dec^3 containers filled with wet pasteurized soil. The containers were covered with wire gauze caps and the soil was moistened with 20 cm^3 of water twice a week until the first adults appeared.

(Ad 5). Rearing scarab beetles whose larvae feed in ant hills presents no difficulties. Larvae of *Potosia metallica* (HERBST) are usually found either in the lower or in a side layer of an ant hill, beyond the zone penetrated by the ants, or in the wood of stumps on which the ants had built their nest. The author reared larvae in big jars and terraria filled with humus, dry remains of plants from ant hills and pieces of rotten wood. All ants had been carefully removed from this material. The content of the containers was sprinkled with water every 2 – 3 months. Before pupation the larvae built barrel-like pupal cocoons made from the materials they had fed on and from their own excrement in the form of short rods glued on the inside with their secretion. The hatched beetles were fed with diluted syrup of honey or sugar.

(Ad 6). A culture method for species inhabiting the rotten wood of trunks and stumps, the humus at the base of trees and tree hollows does not greately differ from the above described ways.

The author (BURAKOWSKI) reared *Gnorimus octopunctatus* (PODA) of the subfamily *Trichiinae*. This species occurs in forests and its larvae feed in moist humus soil, in rotten trunks of deciduous trees, usually close to the ground. These adults lead a hidden life and avoid sunlight, quite unlike the other species *G. nobilis* (L.) recorded in Poland which can be found on flowers, especially of umbelliferous plants. Five older larvae were found in August in the touchwood of an oak trunk fallen to the ground. They produced 4 adults in May of the following year. A culture of this species is easy. Pieces of decayed and rotting

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wood collected together with the larvae were placed on a 3–5 cm layer of humus in a jar 2 dec^3 in capacity. Two further generations were obtained in the same jar even though the food material had not been changed, no larval excrement had been removed, and only the content of the container had been sprinkled with water every 3–4 months. The adults that had emerged were left in the jar, too. The beetles were given no additional food, they had a possibility to feed exclusively on the material already in the container. The eggs laid by a female in June 1959 produced the first generation in the culture in May 1962, and the second generation was obtained in June 1965. Before pupation the larvae constructed pupal cells surrounded with cocoons. The 5–12 mm thick wall of each cocoon consisted of fine decayed wood held together by larval secretion. The pupal stage lasted for about 10 days. Adults emerged from the pupa were fully coloured within a few days and then they come up to the surface. Males died soon after mating, females survived until July. The culture was terminated after about 6.5 years.

Family: Leaf Beetles (*Chrysomelidae*)

Leaf beetles may be reared successfully only when their morphology, ecology and biology are well known. Adults may be identified on the basis of keys prepared by WARCHAŁOWSKI (1971, 1973, 1978). These keys provide not only the morphological features of different taxa but ecological and bionomic data and the host plants as well.

The larvae of a great number of species, especially those completing their development in soil, have not been studied so far. The existing keys for identifying larvae (HENNING 1938, OGLOBLIN and MEDVEDEV 1971, STEINHAUSEN 1978) make it possible to identify many subfamilies and genera but only a small number of species. Culture is therefore the best way to obtain larvae identified without any doubt. This is done when larvae belonging to a given species are reared from eggs laid by females of a properly identified species. Moreover, the investigator has then great possibilities to make invaluable observations of species whose bionomics is not known.

On account of their food requirements leaf beetles may be divided into three basic bioecological groups. The most numerous oligophagous group includes species feeding on several related plant genera of one family, or of two families in exceptional cases. The second, less numerous group, includes species feeding on plants belonging to one genus. The third group includes species (in Poland about 20) feeding exclusively on one plant species.

Females oviposit on parts of plants above the ground or into the soil within the range of the root system. Larvae either feed freely on the surface of fragments of plants or burrow tunnels in the stems, trunks and roots or mine into leaves. Most species (in Poland) have one generation a year; two generations occur more seldom. In most species metamorphosis takes place in soil or on its surface under fragments of plants. Larvae of certain species pupate on above-the-ground

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parts where they are hitched with the last segment of their abdomen. Many leaf beetles can cause damage to cultivated herbaceous plants, bushes, fruit and forest trees. The potato beetle, *Leptinotarsa decemlineata* SAY, and certain species of the genus the flea beetle *Phyllotreta* STEPH. and of *Psylliodes* LATR. are grave pests.

The subject of this and of the following chapter is not so much a description of cultures of different species but a presentation of some ideas introduced. It is not difficult to rear leaf beetles in the laboratory or, still better, in the field, if older larvae, pupae or adults are found. Cultures from egg to imago are more difficult but worth while.

Leaf beetles found in the field are carried to the laboratory very carefully together with whole plants or with fragments only. Rearing is conducted in terraria or big jars covered with a fine mesh screen, gauze or muslin. The botton of these containers is covered with a few centimetres of soil to provide insects pupating in soil with conditions similar to natural ones. The plants on which leaf beetles feed must be put into a bottle or glass with water and these are firmly fixed in the soil in the jar (Fig. 12). The mouth of the bottle round the twig is stoppered with cotton wool or, if the plant is in a glass, a paper funnel is inserted upside down. A few strips of paper or cloth are fixed to the neck of the bottle or to the funnel to give those insects that have fallen off a possiblity to climb on to the plant again. Every few days the water in the bottle and the plants are changed and excrement removed.

This is a method for short-term cultures. Jars do not provide sufficient aeration and water drops settling on the glass together with the excrement impossible to be completely removed may bring about the development of mould or diseases of the larvae. Jars may be replaced by cages made of screen, bells or caps made of gauze, cylinders made of glass or from sheets of plastic. These structures, covered with gauze at the top but

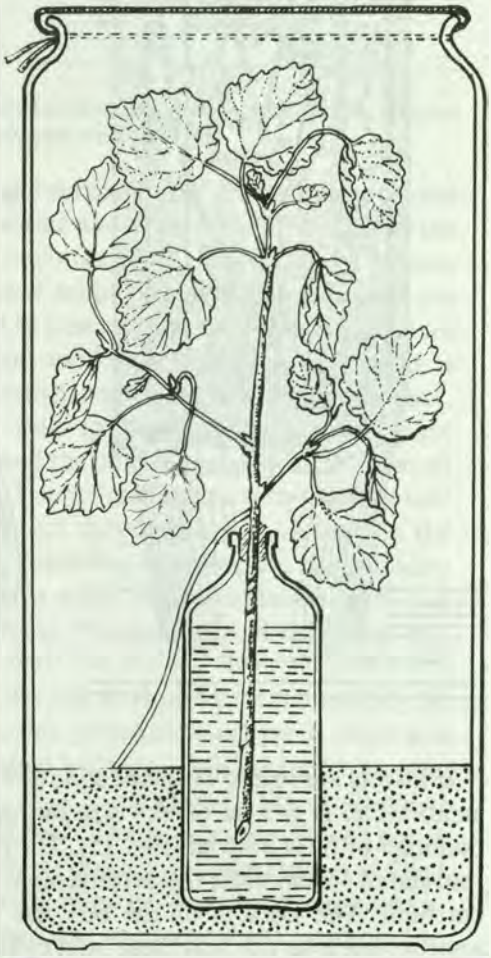

Fig. 12. A culture of herbivorous beetles on a plant put into a bottle placed in a bigger container.

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open at the bottom are placed in shallow small boxes, bigger Petri dishes or flower pots filled with moist soil. Instead of immersing the plant directly in water its stalk may be pulled through the hole in the bottom of the flower pot kept over a vessel with water. The bottom of the flower pot must be covered with soil, sand and moss and the plant with a cap made of gauze stretched over a wire framework. The lower part of the cap must be fixed to the upper part of the flower pot with rubber tape or cord (Figs 13, 14).

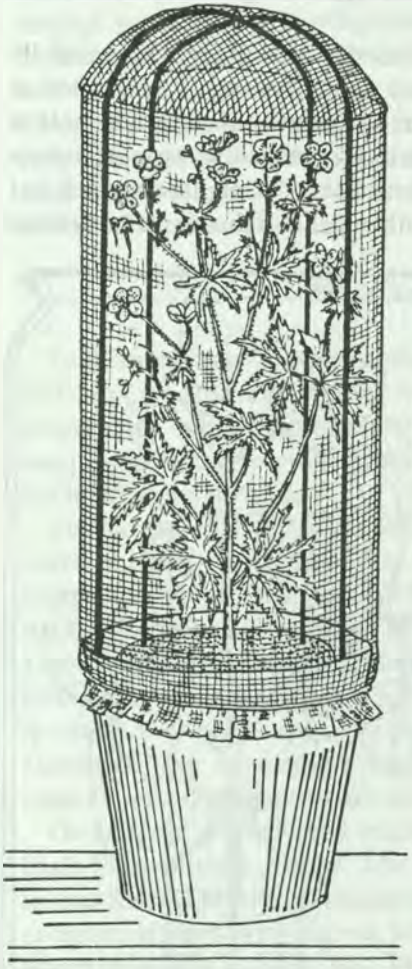
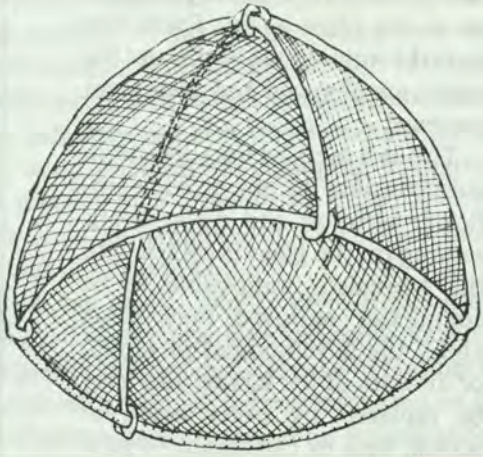


Fig. 13. A culture of herbivorous beetles on a plant growing in a flower pot and protected by a muslin bag on a wire frame.

Fig. 14. A screen bell for covering host plants for herbivorous beetles.



If insects are reared on plant shoots it is convenient to have a specially made small table. It can be of any size but adapted to the number of jars and the diameter of their bottom (Fig. 15). The edges of such a table are protected with thin slats 4 – 6 cm wide; this arrangement forms a shallow open box on legs 6 – 10 cm high. The bottom of the box has holes 1 – 2 cm in diameter, made at appropriate intervals and these hold cylinders. The box is filled with soil and the

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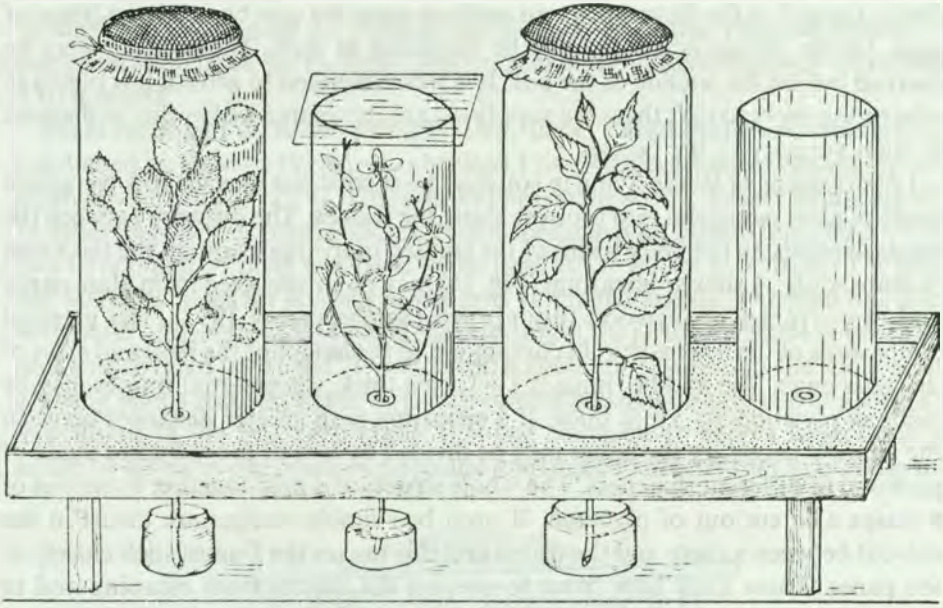

Fig. 15. A culture of herbivorous beetles on cut plants kept in cylinders and big jars without bottoms and placed on a small table with soil.

upper rims of the cylinders are flush with the surface of the soil. A twig is passed through the cylinder to a container with water under the table. The stalk in the upper opening of the cylinder is wrapped in cotton wool. Jars without a bottom or cylinders are placed on a thus prepared table. The jars and cylinders are covered with a pane, screen or gauze kept in place with a rubber band. Such an arrangement ensures good ventilation and moderate humidity, excrement is easily removed with a feather-duster or a brush, and access to the insects is easy. When the larvae are leaving the plant in order to pupate in soil it is necessary either to push the containers to the bottom of the box or to transfer the larvae to special containers where they will pupate. Larvae and pupae with a soft cuticle which are hidden in soil or in plant tissues are very sensitive to changes in the humidity of their habitat. In order to avoid moulding in drying out the humidity of the substratum must be maintained at a more or less constant level and ventilation must be appropriate. According to HEIKERTINGER (1926) burnt but not glazed flower pots are the best containers for rearing. They may be filled with soil and plants can be either sown or planted. In flower pots the soil may be covered with a piece of clay and a layer of fine gravel, then the pot is filled with moderately wet soil. Prior to that the soil must be thoroughly inspected in order to remove any undesirable invertebrates. It is good to use stiff cardboard to very thoroughly before any plants are planted. The hole in the flower pot is covered with with a piece of clay and a layer of fine gravel, then the pot is filled with moderately wet soil. Prior to that the soil must be thoroughly inspected in order ot remove any undesirable invertebrates. It is good to use stiff cardboard to

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divide the soil in the flower pot into sections were the number and condition of eggs, larvae, pupae or adults may be inspected in turn. The sections may be marked out on the outside of the pot. It is recommended to grow a few plants in other containers so that there is a supply in case any plants wither due to diseases or high voracity of the beetles.

Observations of larvae living in soil may be carried out in a shallow terrarium made of glass panes slid into grooves along the frames. The distance between the panes depends on the body width of the studied individuals and on the thickness of plant roots. A similar terrarium (Fig. 16) may be constructed from glass panes and three frames of plywood fitting them (SZCZERBAKOW 1957). The external dimensions of the frames should correspond to the length of the base and sides of the glass pane. The middle frame is 1 – 1.5 cm thick, the external frames may be made of plywood 3 – 5 mm thick. If a terrarium with greater distances between the panes is necessary the panes may be divided by two or more frames made of plywood of different thickness. The whole structure is held together by means of 6 clasps also cut out of plywood. If need be suitable wedges are thrust in the cut-out between a clasp and the frame and this makes the frames stick closely to the panes. There must be a cover to prevent the beetles from escaping and to maintain the right humidity. In a culture of dendrophagous beetles the inner part of the middle frame must be protected with a sheet belt.

It is easy to rear species whose life cycle is relatively short. These are species whose adults overwinter and they mature sexually in spring, after some supplementary feeding. The embryonic development takes more or less from 6 to

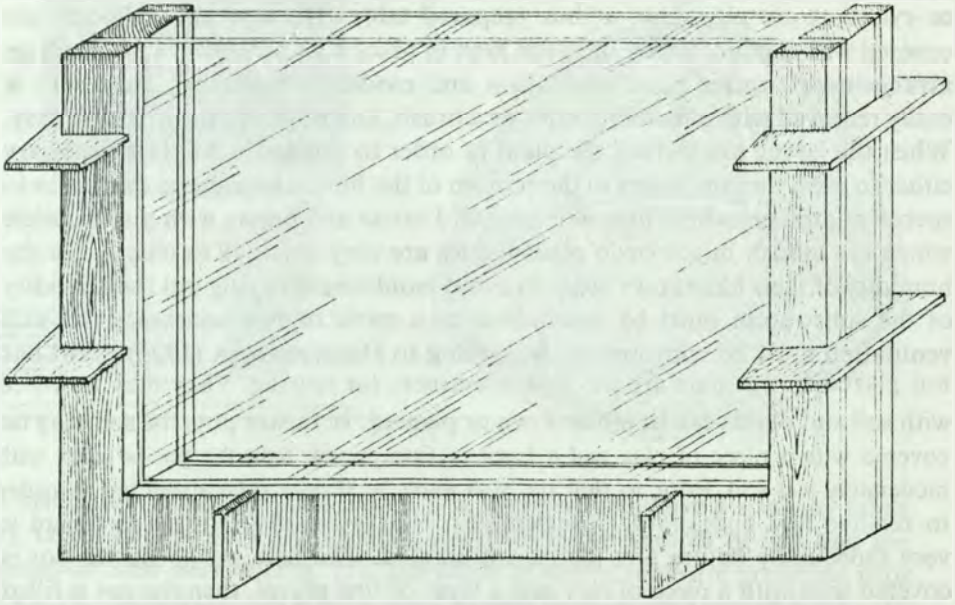

Fig. 16. A diagram of a shallow terrarium made from plywood and glass panes used for rearing soil larvae.

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10 days, the larval stage 2 – 3 weeks, the pupa 1 – 3 weeks. The development of one generation from the moment eggs are laid until the adult emerges takes from 4 to 8 weeks.

Mass rearing of *Gastroidea viridula* DEG. under the laboratory conditions was conducted by RENNER (1970). He obtained 12 – 14 generations within one year at a temperature of 25 – 26°C. This species lives on the sorrel, *Rumex obtusifolius* L. In order to grow this plant RENNER built a concrete pool 140 cm long, 60 cm wide and 80 cm high. A plate was fixed in the pool 10 cm above its bottom. The plate had 40 round holes for holding flower pots 12 cm in diameter. The pool was filled with water and its surface touched the bottoms of the pots. The plane between the pots was covered with sand. Through the holes in the flower pots the roots of the growing plants reached water. In such a culture one female gave rise to about 200 individuals of the new generation. It is not advisable to keep a large stock of adults or larvae in one container because due to their voracity they may cause too

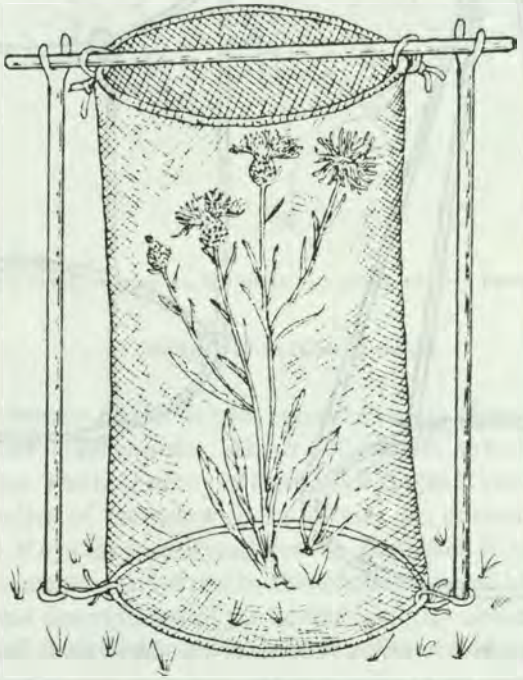

Fig. 17. A field cap for covering plants invaded by herbivorous beetles.

much damage to the plant. In order to limit feeding on the plant the soil in the container should be strewn with twigs of the host plants. The number of eggs laid on a given plant must be controlled. This is done in two ways: either the females that have already laid some eggs are transferred to other rearing cages or a part of an egg batch is carried to other containers together with the part of the plant it has been on.

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A culture of species hibernating as larvae is more troublesome, lasts for many months and requires more patience of the investigator. Adults appear in May or June and larvae emerge in late summer or in autumn. For the period of overwintering the containers with larvae should be placed in an unheated room or, better still, buried in soil in a shaded place. A board put on top of the soil will protect the containers from too much precipitation and a layer of leaves from great changes in temperature.

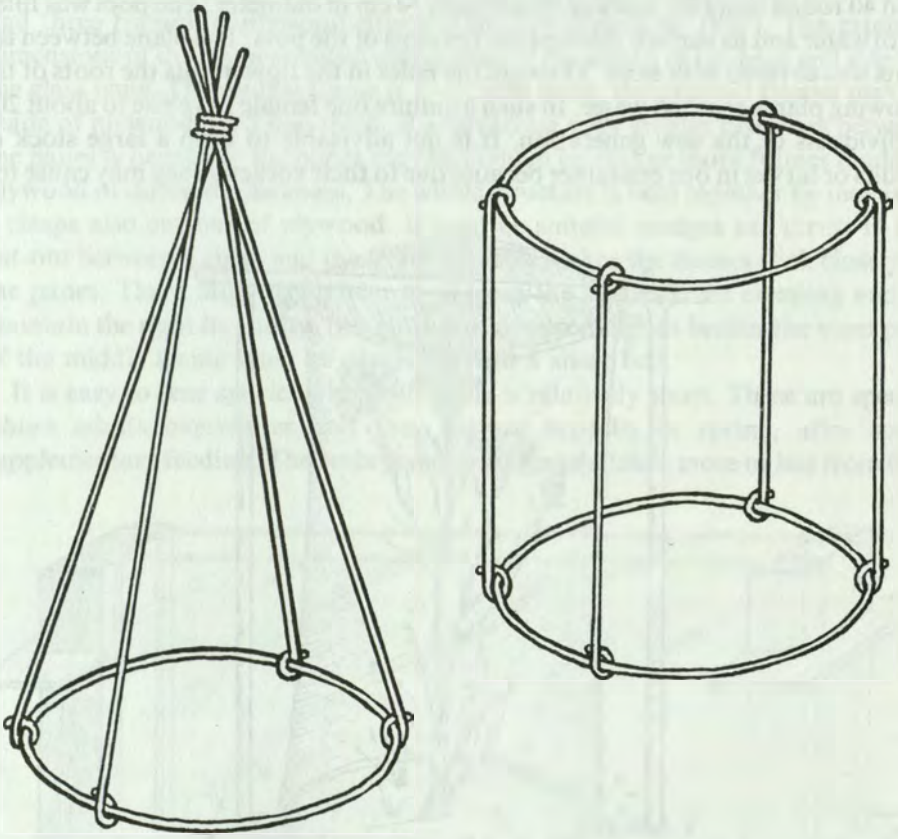

Fig. 18. Wire frames with muslin for covering individual host plants for herbivorous beetles.

Bells and caps (Figs 17, 18), insulators (Fig. 19) in the form of bags and sleeves made of gauze are used both for rearing done in flower pots and for observations of herbivorous beetles in nature. Before any insulators are fixed it is necessary to check very carefully whether the plants are free from predators and parasites of the beetles to be reared. Cultures in insulators must be inspected fairly often, especially in the case of species whose larvae complete their metamorphosis in soil. Last stage larvae leaving the plants or lying in the bags must be taken out and placed in rearing containers with soil.

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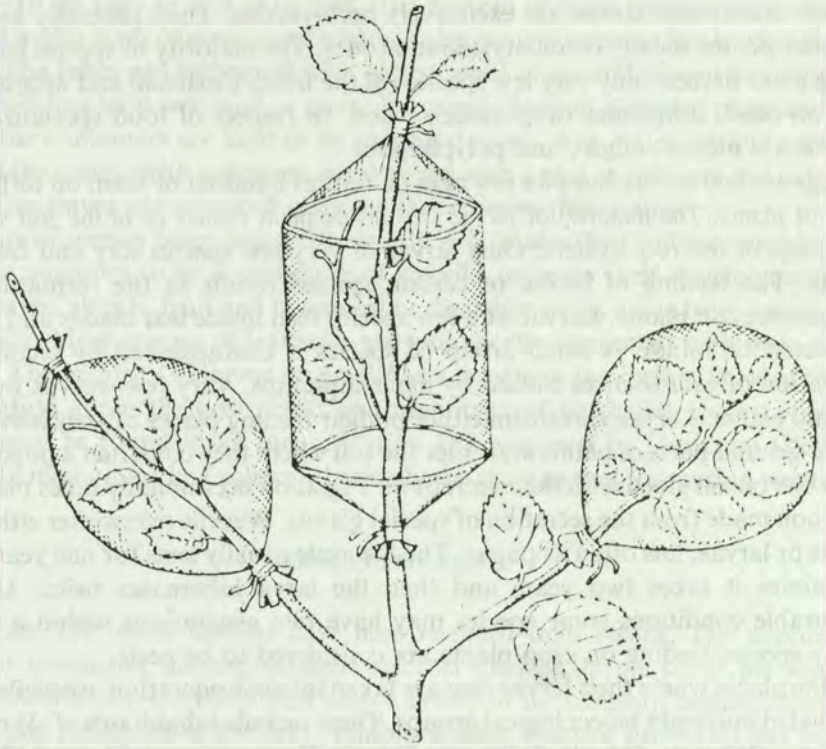

Fig. 19. Muslin insulators put on the parts of a plant invaded by herbivorous beetles.

Family: Weevils (*Curculionidae*)

In respect of the number of identified species the family of weevils comes second to the rove beetles *Staphylinidae*. About 850 species have been recorded from Poland up till now. The taxonomy of their adult stages is known very well thanks to long-term studies of Stanisław SMRECZYŃSKI, an outstanding expert in this group of beetles. Keys for identifying weevils, published from 1965–1976, were the effect of the research carried out by this scientist. These keys provide not only the morphological descriptions of particular taxa but also concise information on the ecology and host plants of most species of the family of weevils that occur in Poland. These data are therefore indispensable to an investigator of weevils. However, the bionomics and the younger larvae are still known rather poorly. SCHERF's paper (1964) is one of the pioneer publications in this field of studies. In the general part the author presented all the developmental stages, the morphology of larvae and pupae, the number of generations, and outlined a culture method. The main part includes a key for identifying larvae to genera, and in some genera to a species, with information about the host plants, manner of feeding, the developmental stages and the bionomics of a great number of species.

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Both adults and larvae are exclusively herbivorous. They generally live on vascular plants, mostly on dicotyledonous ones. The majority of species feed on living plant tissues, only very few species (of the tribes *Cossonini* and *Magdalini*) feed on dead, sometimes fungi-ridden wood. In respect of food specialization weevils are mono-, oligo-, and polyphagous.

Eggs are laid in batches of a few eggs or several hundred of them on different parts of plants. The majority of larvae live inside plant tissues or in the soil within the range of the root system. Only larvae of very few species stay and feed on plants. The feeding of larvae of certain species results in the formation of excrescences on plants. Larvae of a few species feed inside leaf blades and form characteristic mines. A small group of species is characterized by secondary utilization of excrescences caused by hymenopterans. Very few weevils live on aquatic plants. Larvae transform either in their feeding places or they leave the above-ground parts of plants and enter the soil where they construct a pupal cell from bits of soil glued with their secretions. Pupation occasionally takes place in a cocoon made from the secretion of special glands. Weevils overwinter either as adults or larvae, less often as pupae. The life cycle usually lasts for one year, but sometimes it takęs two years and then the larva hibernates twice. Under favourable conditions some species may have two generations within a year. Many species feeding on crop plants are considered to be pests.

If the places where their larvae feed are taken into consideration, weeveils may be divided into eight bioecological groups. These include inhabitants of: 1) roots, 2) shoots, 3) leaves, 4) buds, 5) flowers, 6) fruit, 7) excrescences, 8) wood. Out of the 537 species of weevils studied by SCHERF (1964) the majority belonged to those feeding in shoots (122) and roots (119); 81 belonged to those feeding on fruit, 72 — on leaves and 58 — in excrescences. A small group was made up of those feeding on wood (36), flowers (29) and buds (20).

Rearing certain species is troublesome because of their specific ecological and food requirements. Cultures of weevils may generally be based on the directions already given for other families of beetles. A few pieces of supplementary information are given here.

Larvae feeding in thick roots, bulbs and rhizomes may be reared on parts of these cut out and changed from time to time in order to make observation possible. Larvae feeding on flowers and unripened fruit are very sensitive to being transferred. It is therefore best to dig out the whole plant together with a big clod of earth, put it into a flower pot and place it in a rearing container. Ripe fruit with larvae feeding in it is put into a coarse mesh sieve in a container with moist soil which will serve the larvae at the time of their metamorphosis. Species living on riverside and aquatic plants are reared in aquaria-terraria constructed in a way like the one described for hydraenid and water scavenger beetles (Fig. 4).

A culture of weevils mining in living plant tissues must be conducted with great care because the leaves or other fragments of plants invaded by mining beetles must be kept fresh. Parts of plants with mines are placed in tightly closed containers. Each larva is reared individually in a glass tube 2–3 cm in diameter

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and 6–10 cm high or in a Petri dish. The bottom of these receptacles must be covered with a layer of moist sand where the larvae will pupate after leaving their mines. The tubes are stoppered with cotton wool plugs and placed in a closed glass container with wet sand or moss. Rearing is done in a shaded place and in winter the containers are kept in an unheated room. Any water settling on the walls of the vessels with mines can be removed with a pair of tweezers and cotton wool. The leaves are removed after the larvae leave their mines.

Larvae of species belonging to the family *Attelabidae* (leaf rollers) considered by some scientists to be a subfamily of weevils, undergo their development in buds, leaves, shoots, fruit and in conical or cigar-like tubes made from leaves by the adults. Most species of leaf rolls are biologically connected with trees and bushes. The majority of larvae of *Attelabidae* pupate in the surface layer of soil. Information about the host plants and bionomics of particular species of leaf rollers may be found in an idendification key prepared by CMOLUCH (1979). A culture method for leaf rollers is basically the same as that for rearing weevils.

FINAL REMARKS

To date, 120 beetle families have been recorded from Poland. The directions given for conducting cultures of some selected families do not cover the whole subject. Even within the fairly well known family of the longhorn beetles, *Cerambycidae*, the bionomics of the very common species *Vadonia livida* (F.) has been explained only recently. This has been done on the basis of results of cultures carried out in the laboratory, which have found confirmation in field observations. Within the group of over 200 species belonging to Polish longhorn beetles the prevailing majority undergo their development in above-ground parts of plants, mainly trees and bushes. For many decades, different publications have included incorrect information that larvae of *Vadonia livida* (F.) feed on the wood of dead branches of deciduous trees, especially those of oak. According to the author (BURAKOWSKI 1979a) this species completes its preimaginal development in soil, among the dead plant remains infested by a white mycelium the larvae feed on. In another family – *Throscidae* – larvae of *Trixagus dermestoides* (L.) living in soil feed on the mycorrhized rootlets of trees (BURAKOWSKI 1975) and not on wood tissues, as has been suggested by other authors. Thanks to laboratory cultures the author has managed to follow the life cycle of this species and collect interesting bionomical data.

All the above examples show how great a role rearing plays in discovering unknown facts on the life of beetles, in confirming and supplementing chance observations in the field and in filling the gaps in the knowledge of particular life cycles.

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REFERENCES

ADASHEVICH B. P. 1970. Razvedenie *Aleochara bilineata* (*Coleoptera, Staphylinidae*) v laboratorii. Zool. Zh., Moskva, **49**: 1081–1083.

BLUME R. R., AGA A. 1975. *Onthophagus gazella*: Mass rearing and laboratory biology. Environ. Entomol., Baltimore, **4**: 735–736.

BOROWSKI S. 1960. *Geotrupes stercorosus* (SC.) (*Coleoptera, Scarabaeidae*) w Białowieskim Parku Narodowym. Fragm. faun., Warszawa, **8**: 337–365.

BRYSON H. R. 1926. A method for rearing wireworms (*Elateridae*). J. Kansas ent. Soc., Manhattan, Kans., **2**: 15–21.

BURAKOWSKI B. 1962. Biologia oraz opis larwy *Ampedus elegantulus* (SCHÖNH.) (*Coleoptera, Elateridae*). Fragm. faun., Warszawa, **10**: 47–62.

BURAKOWSKI B. 1971. Sprężyki (*Coleoptera, Elateridae*) Bieszczadów. Fragm. faun., Warszawa, **17**: 221–272.

BURAKOWSKI B. 1975. Development, distribution and habits of *Trixagus dermestoides* (L.), with notes on the *Throscidae* and *Lissomidae* (*Coleoptera, Elateroidea*). Ann. zool., Warszawa, **32**: 375–405.

BURAKOWSKI B. 1976. Rozmiazgowate – *Pythidae*, omiękowate – *Lagriidae*, cisawkowate – *Alleculidae*. In: Klucze do oznaczania owadów Polski, XIX, 88–90, 76 pp.

BURAKOWSKI B. 1979a. Immature stages and bionomics of *Vadonia livida* (F.) (*Coleoptera, Cerambycidae*). Ann. zool., Warszawa, **35**: 25–42.

BURAKOWSKI B. 1979b. Sprężyki (*Coleoptera, Elateridae*) Pienin. Fragm. faun., Warszawa, **24**: 185–226.

BURAKOWSKI B. 1986. The life-cycle and food preference of *Agonum quadripunctatum* (DE GEER). In: Feeding behaviour and accessibility of food for carabid beetles. Vth Meeting Europ. Carabidol., Stara Brda Pilska, September 13–15, 1982. Warsaw agric. Univ. Press, Warszawa, pp. 35–39.

BURAKOWSKI B., MROCZKOWSKI M., STEFAŃSKA J. 1971–1991. Chrząszcze *Coleoptera*. In: Katalog fauny Polski, Warszawa, part XXIII. Vol. 1 – Piśmiennictwo, 1971, 183 pp.; vol. 2 – Biegaczowate – *Carabidae*, part 1. 1973, 233 pp.; vol. 3 – Biegaczowate – *Carabidae*, part 2, 1974, 430 pp.; vol. 4 – *Adephaga* prócz *Carabidae*, *Myxophaga*, *Polyphaga: Hydrophiloidea*. 1976, 307 pp.; vol. 5 – *Histeroidea* – *Staphylinoidea* prócz *Staphylinidae*, 1978, 356 pp.; vol. 6 – Kusakowate – *Staphylinidae*, part 1. 1979, 310 pp.; vol. 7 – Kusakowate – *Staphylinidae*, part 2. 1980, 272 pp.; vol. 8 – Kusakowate – *Staphylinidae*, part 3. 1981, 330 pp.; vol. 9 – *Scarabaeoidea*, *Dascilloidea*, *Byrrhoidea* i *Parnoidea*. 1983, 294 pp.; vol. 10 – *Buprestoidea*, *Elateroidea* i *Cantharoidea*. 1985, 401 pp.; vol. 11 – *Dermestoidea*, *Bostrychoidea*, *Cleroidea* i *Lymexyloidea*. 1986, 243 pp.; vol. 12 – *Cucujoidea*, part 1. 1986, 226 pp.; vol. 13 – *Cucujoidea*, part 2. 1986, 278 pp.; vol. 14 – *Cucujoidea*, part 3. 1987, 309 pp.; vol. 15 – *Cerambycidae* i *Bruchidae*. 1990, 312 pp.; vol. 16 – *Chrysomelidae*, part 1. 1990, 279 pp.; vol. 17 – *Chrysomelidae*, part 2. 1991, 227 pp.

BURAKOWSKI B., NOWAKOWSKI E. 1981. Click beetles (*Coleoptera, Elateridae*) of Warsaw and Mazovia. Memorabilia zool., Warszawa, **34**: 165–180.

BURGESS A. F. 1911. *Calosoma sycophanta*: Its life, history, behavior, and successful colonization in New England. Bull. U. S. Dep. Agric. Ent., Washington, D. C., **111**: 1–94.

BURMEISTER F. 1939. Biologie, Ökologie und Verbreitung der europäischen Käfer auf systematischer Grundlage. I. Band: *Adephaga*. I. Familiengruppe: *Caraboidea*. Krefeld, 307 pp.

BYZOVA Ju. B. 1964. Semejstvo *Silphidae* – mertvoedy. In: Opredielitel obitajushchikh v pochve lichinok nasekomykh. (ed. M. S. GILJAROV), Moskva, 213–225 pp.

CANNON K. F., ROBINSON W. H. 1982. An artificial diet for the laboratory rearing of the old house borer, *Hylotrupes bajulus* (*Coleoptera*: *Cerambycidae*). Canad. Entomol., Ottawa, **114**: 739–742.

CHRZANOWSKI A. 1927. Pewne dane z biologii i ekologji niektórych *Elateridae* (*Agriotes obscurus* L.) i nowe metody ich zwalczania. Dośw. Rol., Warszawa, **3**: 1–52.

CMOLUCH Z. 1979. *Rhinomaceridae*, *Attelabidae*. In: Klucze do oznaczania owadów Polski. Warszawa, XIX, 96–97, 60 pp.

CUTHBERT F. P. 1962. A method of rearing southern potato wireworm. J. econ. Ent., Menasha, Wisc., **55**: 262–263.

http://rcin.org.pl

CZECHOWSKI W., PISARSKI B. 1991. Laboratory methods for rearing ants (*Hymenoptera, Formicoidea*). Memorabilia zool., Warszawa, 45, 32 pp.

DAVIS J. J. 1915. Cages and methods of studying underground insects. J. Econ. Ent., Menasha, Wisc., **8**: 135–139.

DAVIS G. R. F. 1958. Note on survival and feeding of newly hatched larvae of *Ctenicera aeripennis destructor* (BROWN) (*Coleoptera*: *Elateridae*). Ann. ent. Soc. America, Columbia, Miss., **51**: 51–52

DAVIS G. R. F. 1959a. A method for rearing larvae of *Ctenicera aeripennis destructor* (BROWN) (*Coleoptera*: *Elateridae*) aseptically in test tubes. Ann. ent. Soc. America, Columbia, Miss., **52**: 173–175.

DAVIS G. R. F. 1959b. Effects of sterilized soil and of starvation on growth and survival of larvae of *Ctenicera aeripennis aeripennis* (KBY.) (*Coleoptera*: *Elateridae*). Ann. ent. Soc. America, Columbia, Miss., **52**: 537–539.

DAVIS G. R. F. 1961. Effects of variations in casein and dextrin content of a synthetic diet on larvae of *Ctenicera aeripennis destructor* (BROWN) (*Coleoptera*: *Elateridae*). Ent. exper. appl., Amsterdam, **4**: 273–276.

DELKESKAMP K. 1930. Biologische Studien über *Carabus nemoralis* MÜLL. Z. Morphol. Ökol., Berlin, **19**: 1–58.

DOLIN V. G. 1964. Lichinki zhukov-schelkunov (provolochniki) evropejskoj chasti SSSR, Kiev, 207 pp.

DONALDSON J. M. 1979. Laboratory rearing technique for *Pachnoda sinuata flaventris* (*Coleoptera*: *Scarabaeidae*) and other cetoniid larvae. J. ent. Soc. S. Afr., Pretoria, **42**: 137–142.

EMDEN F. I. 1958. Über die Larvenmerkmale einiger deutscher Byrrhidengattungen. Mitt. dtsch. ent. Ges. (Berlin), **17**: 39–40.

ENE I. M. 1942. Experimentaluntersuchungen über das Verhalten des Maikäferengerlings (*Melolontha* spec.). Z. angew. Ent., Berlin, **29**: 529–600.

FAASCH H. 1968. Beobachtungen zur Biologie und zum Verhalten von *Cicindela hybrida* L. und *Cicindela campestries* L. und experimentalle Analyse ihres Beutefangverhaltens. Zool. Jb. Syst., Jena, **95**: 477–522.

FREUDE H., HARDE K. W., LOHSE G. A. et al. 1964–1983. Die Käfer Mitteleuropas. Bd. 1–11. Krefeld.

FRIEDERICHS H. F. 1931. Beiträge zur Morphologie und Physiologie der Sehorgane der Cicindelinen (*Col.*). Z. Morphol. Ökol., Berlin, **21**: 1–172.

FUJIYAMA Sh., TAKAHASHI F. Studies on the self-regulation of life cycle in *Anomala cuprea* HOPE (*Coleoptera*: *Scarabaeidae*). 1. The effects of constant temperature on the developmental stages. Mem. Coll. Agr. Kyoto Univ., **104**: 23–30.

GAEDIKE R. 1969. Bibliographie der Elateridenlarven-Literatur der Welt. Beitr. Ent., Berlin, **19**: 159–266.

GALTSOFF P. S., LUTZ F. E., WELCH P. S., NEEDHAM J. G. et al. 1959. Culture methods for invertebrate animals. New York, XXXII, 590 pp.

GILJAROV M. S. (ed.). 1964. Opredelitel' obitajushchikh v pochve lichinok nasekomykh. Moskva, 919 pp.

GÓRNY M. 1975. Zooekologia gleb leśnych. Warszawa, 311 pp.

HEIKERTINGER F. 1926. Der Gartentopf als Insektenzuchtgerat. Koleopt. Rdsch., Wien, **12**: 177–191.

HENNIG W. 1938. Übersicht über die Larven der wichtigsten deutschen Chrysomelinen *(Coleoptera)*. Arb. physiol. angew. Ent., Berlin-Dahlem, **5**: 85–138.

HEYMONS R., LENGERKEN H. Studien über die Lebenserscheinungen der *Silphini (Coleopt.)*. Z. Morphol. Ökol., Berlin, **20** (1931): 691–706; **24** (1932): 259–287; **25** (1932): 534–548; **28** (1934): 469–479.

HEYMONS R., LENGERKEN H., BAYER M. Studien über die Lebenscheinungen der *Silphini* (*Coleopt.*). Z. Morphol. Ökol., Berlin, **6** (1926): 287–332; **9** (1927): 271–312; **10** (1928): 330–352; **14** (1929): 234–260: **17** (1930): 262–274; **18** (1930): 170–188.

http://rcin.org.pl

HILDT L. F. 1910. Wskazówki zbierania owadów tęgopokrywych. Warszawa, 39 pp.

HOLSTE G. 1915. *Calosoma sycophanta* L. Seine Lebensgeschichte und Gewohnheiten und seine erfolgreiche Ansiedlung in Neuengland. Eine Besprechung nebst einigen Bemerkungen über *Calosoma inquisitor* L. Z. angew. Ent., Berlin, **2**: 413–421.

HORION A.: Faunistik der deutschen Käfer. Bd. I – *Adephaga* – *Caraboidea*. 1941, 463 pp.; Bd. II – *Palpicornia* – *Staphylinoidea* (ausser *Staphylinidae*). 1949, XXIII + 388 pp.; Bd. III – *Malacodermata, Sternoxia* (*Elateridae* bis *Throscidae*). 1953, XVIII + 340 pp.; Bd. IV – *Sternoxia* (*Buprestidae*), *Fossipedes, Macrodactylia, Brachymera*. 1955, XXI + 280 pp.; Bd. V – *Heteromera*. 1956, XIV + 336 pp.; Bd. VI – *Lamellicornia* (*Scarabaeidae* – *Lucanidae*). 1958, XXIII + 343 pp.; Bd. VII – *Clavicornia*. 1. Teil (*Sphaeritidae* bis *Phalacridae*). 1960, VIII + 346 pp.; Bd. VIII – *Clavicornia*. 2. Teil (*Thorictidae* bis *Cisidae*), *Teredilla, Coccinellidae*. 1961, XVI + 375 pp.; Bd. IX – *Staphylinidae*. 1. Teil. *Micropeplinae* bis *Euaesthetinae*. 1963, XII + 412 pp.; Bd. X – *Staphylinidae*. 2. Teil. *Paederinae* bis *Staphylinae*. 1965. XV + 335 pp.; Bd. XI – *Staphylinidae*. 3. Teil. *Habrocerinae* bis *Aleocharinae*. 1967, XXIV + 419 pp.; Bd. XII – *Cerambycidae* – Böckkäfer. 1974, XVI + 228 pp.

HŮRKA K. 1971. Die Larven der mitteleuropäischen *Carabus*- und *Procerus*-Arten. Rozpr. české Akad. Véd, Praga, **81**: 1–136.

HURPIN B. 1964. Élevage des vers blancs ou larves do *Melolontha melolontha* L. (*Col. Scarabaeidae*). Rev. Path. Vég., Paris, **43**: 153–177.

HURPIN B., FRESNEAU M. 1964. Elevage de deux Dynastides, *Oryctes nasicornis* L., *Phyllognathus silenus* F. (*Coleopt. Scarabaeidae*). Rev. Path. Veg., Paris, 43: 75–96.

JANSSEN W. 1963. Untersuchungen zur Morphologie, Biologie und Ökologie von *Cantharis* L. und *Rhagonycha* ESCHSCH. (*Cantharidae, Col.*). Z. wiss. Zool., A. Leipzig, **169**: 115–202.

KARPIŃSKI J. J., MAKÓLSKI J. 1954. Biegaczowate (*Carabidae, Coleoptera*) w biocenozie lasu Białowieskiego Parku Narodowego. Pr. Inst. bad. Leśn., Warszawa, **5**: 105–136.

KIRCHNER H. 1927. Biologische Studien über *Carabus cancellatus* ILLIG. Z. Morphol. Ökol., Berlin, **7**: 489–534.

KLAUSNITZER B. 1978. Ordnung *Coleoptera* (Larven). In: Bestimmungsbücher und Bodenfauna Europas. Lief. 10. Berlin, VI + 378 pp.

KLEMPERER H. G. 1978. The repair of larval cells and other larval activities in *Geotrupes spiniger* MARCHAM and other species (*Coleoptera, Scarabaeidae*). Ecol. Ent., Oxford, **3**: 119–131.

KLEMPERER H. G. 1979. An analysis of the nesting behaviour of *Geotrupes spiniger* MARSHAM (*Coleoptera, Scarabaeidae*). Ecol. Ent., Oxford, **4**: 133–150.

KULT K. 1947. Klič k určováni brouků čeledi *Carabidae* Československé republiky. Ent. Přiručky, Praha, 20, 199 pp.

LABITTE A. 1916. Longévité de quelques insectes en captivité. Bull. Hist. nat., Paris, **22**: 105–113.

LAFRANCE J. 1963. New apparatuses and rearing techniques for the study of wireworms (*Coleoptera*: *Elateridae*) in organic soils of Southwestern Quebec. Canad. Entomol., Ottawa, **95**: 1–6.

LAFRANCE J. 1964. New apparatus and rearing techniques for the study of wireworms (*Coleoptera*: *Elateridae*) in organic soils. Canad. Entomol., Ottawa, **96**: 123.

LANE M. C. 1924. Simple methods of rearing wireworms. J. Econ. Ent., Menasha, Wisc., **17**: 578–582.

LARSSON S. G. 1939. Entwicklungstypen und Entwicklungszeiten der dänischen Carabiden. Ent. Medd., København, **20**: 277–560.

LARSSON S. G. 1968. Sandspringere og Løbebiller (*Cicindelidae* og *Carabidae*). Larverne. In: Danm. Fauna, København, **76**: 282–433.

LEITNER E. 1943. Morphologische und entwicklungsbiologische Untersuchungen an Laüfkafern der Gattung *Trechus*. (Ein Beitrag zur Frage der Artbildung). Zool. Jb. Anat., Jena, **68**: 227–272.

LENGERKEN H. 1921. *Carabus aurarus* L. und seine Larve. Arch. Naturg., Leipzig, **87** (A): 31–112.

LINDROTH G. H. 1945. Die fennoskandischen *Carabidae*. I. Spezieller Teil. Göteborgs Vetensk. Samg. Handl., Göteborg, (B) **4**: 1–709.

LIPKOW E. 1966. Biologisch-Ökologische Untersuchungen über *Tachyporus*-Arten und *Tachinus rufipes* (Col., *Staphyl.*). Pedobiologia, Jena, **6**: 140–177.

http://rcin.org.pl

LIPKOW E. 1982. Lebensweise von *Philonthus*-Arten und andere *Staphylinidae* (*Coleoptera*) des Dungs. Drosera, Kiel, 1982, **1**: 47–54.

LOMAKIN V. I. 1981. Soderzhanie *Trogophloeus bilineatus* (*Coleoptera, Staphylinidae*) v laboratornykh uslovijakh. Zool. Zh. Moskva, **60**: 609–611.

MANK H. G. 1923. The biology of the *Staphylinidae*. Ann. ent. Soc. America, Columbia, Miss., **16**: 220–237.

MEDVEDEV S. J. 1952. Lichinki plastinchatousykh zhukov fauny SSSR. Opredel. po Faune SSSR, Leningrad, 47, 343 pp.

MOON R. D., LOONIS E. C., ANDERSON J. R. 1980. Influence of two species of dung beetles on larvae of fly. Envir. Ecol., Baltimore, **9**: 607–612.

MROCZKOWSKI M. 1955. Omarlicowate – *Silphidae*. In: Klucze do oznaczenia owadów Polski, Warszawa, XIX, 25, 29 pp.

MROCZKOWSKI M. 1958. Otrupkowate – *Byrrhidae, Nosodendridae*. In: Klucze do oznaczania owadów Polski, Warszawa, XIX, 50–51, 30 pp.

NETOLITZKY F. 1921. Züchtung von *Bembidion* – Larven. Ent. Bl., Schwabach, **17**: 140–141.

NUNBERG M. 1949. Wpływ składu drzewostanu na faunę chrząszczy z rodziny biegaczowatych (*Carabidae, Col.*). Rozpr. Spraw. Inst. bad. Leśn., Warszawa, **58**: 1–29.

OERTEL R. 1924. Biologische Studien über *Carabus granulatus* L. Zool. Jb. Syst., Jena, **48**: 299–366.

OGLOBLIN D. A., MEDVEDEV L. N. 1971. Lichinki zhukov-listoedov (Coleoptera, Chrysomelidae) evropejskoj chasti SSSR. Opredel. po Faune SSSR, Leningrad, 106, 123 pp.

PAULIAN R. 1941. Les premiers états des *Staphylinoidea* (*Coleoptera*). Etude de morphologie comparée. Mém. Mus. Hist. Nat., Paris, **15**: 1–361.

PETERSON A. 1934. A manual of entomological equipment and methods. Ann. Arbor, Mich. E. Brothers, 21 + XIII pp., 138 tt.

PIEKARCZYK K. 1966. Badania fizjograficzne nad drutowcami (*Elateridae*) w Polsce. Pr. nauk. Inst. Ochr. Rośl. Poznań, **7**: 9–95.

POTOCKAJA V. A. 1967. Opredelitel' lichinok korotkonadrylykh zhukov (*Staphylinidae*) evropejskoj chasti SSSR. Moskva, 120 pp.

REITTER E.: Fauna Germanica. Die Käfer des Deutschen Reiches. Stuttgart. I. Bd. – 1908; II. Bd. – 1909; Bd. – 1911; IV. Bd. – 1912; V. Bd. – 1916.

RENNER K. 1970. Die Zucht von *Gastroidea viridula* DEG. (*Col., Chrysomelidae*) auf Blättern und Blattpulversubstraten von *Rumex obtusifolius* L. Z. angew. Ent., Berlin, **65**: 131–146.

RUDOLPH K. 1974. Beitrag zur Kenntnis der Elateridenlarven der Fauna DDR und der BRD. (Eine morphologisch-taxonomische Studie) Zool. Jb. Syst., Jena **101**: 1–151.

SCHERF H. 1964. Die Entwicklungsstadien der mitteleuropäischen Curculioniden (Morphologie, Bionomie, Ökologie). Abh. Senckenberg. Naturf. Ges., Frankfurt a. M. **506**: 1–335.

SCHERNEY F. 1959. Unsere Laufkäfer, ihre Biologie und wirtschaftliche Bedeutung. Wittenberg, 79 pp.

SCHUCH K. 1938. Laboratorium Untersuchungen über den Lebenslauf des Maikäfers (*Melolontha melolontha* L.). Arb. physiol. angew. Ent., Berlin-Dahlem, **5**: 166–177.

SHAROVA I. Ch. 1958. Morfo-ekologicheskie tipy lichinok zhuzhelic (*Carabidae*). Zool. Zh., Moskva, **39**: 691–708.

SHAROVA I. Ch. 1964. Semejstvo *Carabidae* – Zhuzhelicy. In: Opredelitel' obitajushchikh v pochve lichinok nasekomykh. (ed. M. S. GILJAROV), Moskva, 112–195 pp.

SMRECZYŃSKI S.: Ryjkowce – *Curculionidae*. In: Klucze do oznaczania owadów Polski, Warszawa, XIX, 98a – Wstęp i podrodzina *Apionidae*. 1965, 80 pp.; 98b – Podrodziny *Otiorrhynchinae, Brachyderinae*. 1966, 130 pp.; 98c – Podrodziny *Tanymecinae, Cleoninae, Tanyrhynchinae, Hylobiinae*. 1968, 106 pp.; 98d – Podrodzina *Curculioninae* (I). 1972, 195 pp.; 98e – Podrodzina *Curculioninae* (II). 1974, 180 pp.; 98f – Podrodzina *Curculioninae* (III). 1976, 115 pp.

STEBNICKA Z.: Żukowate – *Scarabaeidae*. In: Klucze do oznaczania owadów Polski, Warszawa, XIX, 28a – Grupa podrodzin: *Scarabaeidae laparosticti*. 1976, 196 pp.; 28b – Grupa podrodzin: *Scarabaeidae pleurosticti*. 1978, 63 pp.

http://rcin.org.pl

STEINHAUSEN W.1978. Bestimmungstablle für die Larven der *Chrysomelidae* (partim). In: B. KLAUSNITZER. Ordnung *Coleoptera* (Larven). Bestimmungsbücher zur Bodenfauna Europas. Lief. **10**: 336–340.

STIPRAJS M. A. 1961. Vyrashchivanie zhuzhelic roda *Carabus* L. Fauna Latv. SSR, Riga, **3**: 147–162.

STIPRAJS M. A 1964. Vyrashchivanie shesti vidov zhuzhelic roda *Carabus*. Fauna Latv. SSR, Riga, **4**: 97–108.

SUBKLEW W. 1934. Eine neue Zucht- und Versuchsanlage für Bodenschädlinge. Anz. Schädlingsk., Berlin, **10**: 83–85.

SZAFER W., KULCZYŃSKI S., PAWŁOWSKI B. 1953. Rośliny polskie. Opisy i klucze do oznaczania wszystkich gatunków roślin naczyniowych rosnących w Polsce bądź dziko, bądź też zdziczałych lub częściej hodowanych. Warszawa, XXVIII + 1020 pp.

SZCZERBAKOW B. 1957. Owady jako przedmiot zajęć szkolnych. Warszawa, 354 pp.

SZUJECKI A. 1961. Kusakowate – *Staphylinidae*. In: Klucze do oznaczania owadów Polski, Warszawa, XIX, 24b – Myśliczki – *Steninae*. 1961, 72 pp.; 24c – Kiepurki – *Euasthetinae* i żarlinki – *Paederinae*. 1965, 74 pp.; 24d – Wydłużaki – *Xantholininae*. 1976, 42 pp.; 24e – Kusaki – *Staphylininae*. 1980, 164 pp.

SZUJECKI A. 1965. Obserwacje nad rozwojem i biologią *Philonthus fuscipennis* (MANN.) (*Coleoptera, Staphylinidae*). Fragm. faun., Warszawa, **12**: 165–173.

SZUJECKI A. 1966. Zależność między wilgotnością wierzchniej warstwy gleb leśnych a rozmieszczeniem kusakowatych (*Staphylinidae, Col.*) na przykładzie nadleśnictwa Szeroki Bór w Puszczy Piskiej. Folia for. pol., Warszawa, S. A., **12**: 5–156.

SZUJECKI A. 1980. Ekologia owadów leśnych. Warszawa, 603 pp.

ŚWIECIMSKI J. 1957. The role of sight and memory in food capture by predatory beetles of the species *Cicindela hybrida* L. (*Coleoptera, Cicindelidae*). Pol. Pismo ent., Wrocław, **26**: 205–232.

TENENBAUM S. 1923. *Coleoptera* – Chrząszcze. In: Podręcznik do zbierania i konserwowania zwierząt należących do fauny polskiej, 5 – Owady, Warszawa, pp. 101–119.

THIEM H. 1951. Über Erfahrungen bei der Aufzucht von Engerlingen. Verh. dtsch. Ges. angew. Ent. 11. Mitgl. vers. München 1949, pp. 77–95.

THIELE H. U. 1977. Carabid beetles in their environments. Berlin, Heidelberg, New York, 369 pp.

VOGEL W., ILIĆ B. 1953. Der Einfluss der Temperatur bei der Verpuppung der Engerlinge von *Melolontha vulgaris* F. Mitt. schweiz. ent. Ges., Schaffhausen, Bern, Lausanne, **26**: 265–276.

WALSH G. B., DIBB J. R. (eds.). 1954. A Coleopterist's Hand-book. Amat. Ent., London, **11**: 1–120.

WARCHALOWSKI A.: Stonkowate – *Chrysomelidae*. In: Klucze do oznaczania owadów Polski, Warszawa, XIX, 94a – Część ogólna i podrodziny: *Donaciinae, Orsodacninae, Criocerinae, Clytrinae, Cryptocephalinae, Lamprosomatinae* i *Eumolpinae*. 1971, 113 pp.; 94b – Podrodziny: *Chrysomelinae* i *Galerucinae*. 1973, 79 pp.; 94c – Podrodziny: *Halticinae, Hispinae* i *Cassidinae*. 1978, 157 pp.

WHITE E. B., LEGNER E. F. 1966. Notes on the life history of *Aleochara taeniata*, a Staphylinid parasite of the house fly, *Musca domestica*. Ann. ent. Soc. America, Columbia, Miss., **59**: 573–577

WILLE H., WILDBOLZ T. 1953. Beobachtungen über die Eiablage des Maikäfers und die Entwicklung des Engerlings im Laboratorium. Mitt. schweiz. ent. Ges., Schaffhausen, Bern, Lausanne, **26**: 219–224.

ZACHARUK R. Y. 1962. Distribution, habits and development of *Ctenicera destructor* (BROWN) in Western Canada, with notes on the related species *C. aeripennis* (KBY.) (*Coleoptera: Elateridae*). Canad. J. Zool., Ottawa, **40**: 539–552.

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