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On the adaptations to cave life of some different animal groups (first note)

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Abstract. In this paper we present the major and common adaptations to the cave environment of different animal groups. The common features are: anophthalmia, depigmentation, apterism in the case of insects, body shape and ecophysiological adaptations.
Key Words: biospeology, species adaptations, cave life.

Rezumat. În această lucrare prezentăm adaptările, atât majore cât și comune, la viața cavernicolă a diferitelor grupe de animale. Trăsăturile caracteristice sunt: anoftalmia, depigmentarea, apterismul în cazul insectelor, forma corpului cât și unele adaptări eco-fiziologice.
Cuvinte cheie: biospeologie, adaptările speciilor cavernicole, viața subterană.

Introduction. In the current paper we present the major and also common morphological adaptations of some cave animals and mention the ecophysiological adaptations of cave dwelling organisms, adaptations debated by many authors, we have to mention the work of: Barndt (2004); Biswas (2009ab); Bologna et al (1985); Bonzano & Bonzano (1985); Buzilă & Moldovan (2000); Casale et al (2000); Decu & Juberthie (1998); Decu & Racoviță (1994); Giachino et al (1998); Ginet & Decu (1977); Juberthie & Decou (1994, 1998, 2001); Moldovan (1995, 2003a, 2003b); Moldovan et al (2000); Negrea & Boitan (2001); Newton (1998); Perreau (2000); Rohwerder et al (2003); Vandel (1964); Vanin & Masutti (2008); Wilkens (2001).

The food chain in a cave: predators at the top of the chain, detritivores, saprophages and limivores. In the most remote caves, bacteria are the primary producers.

The food chain and energy balance of the chemolithoautotrophically-based ecosystem of the sulphur spring in Movile Cave from Romania is a model system for extraterrestrial life; a first sampling campaign was done by Rohwerder et al (2003). The data presented suggest a close interdependence of sulphur oxidation and reduction as well as carbon dioxide and other C1 compound metabolism in the most biologically active zone of the cave ecosystem, i.e. the floating microbial mats (Rohwerder et al 2003).

Discussion. The evolutionary adaptations of the organisms which inhabit the unusual and fragile ecosystems within caves are of inherent interest to both biologists and laymen. Cave organisms generally develop a high degree of physiological and behavioral adaptation for survival in the subterranean environment (Biswas 2009ab).

The species which are highly endemic to the cave ecosystem, and they are probably in verge of extinction. A serious measure to conserve the whole biodiversity has been suggested in India (Biswas 2009a). Cave fauna are unique and constitute one of the important components of biodiversity. The prevalence of cave organisms (cavernicoles) is always more in wet and longer caves compared to small and dry ones. Cavernicoles continue to evolve in the habitat characterized by complete darkness, constant temperature, high humidity and low predatory pressure (Biswas 2009b).

The species adapted to cave life are divided in: troglophiles and troglobites. Another category, the trogloxenes are accidently found in caves. Troglophiles can spend their entire life in a cave, but these same species can also survive on the surface. Examples of troglophiles are earthworms and spiders and also: bats, spiders, Tricoptera, some butterflies, several Opiliones, foxes, rats, badgers, coleopters, spiders, Orthoptera, Diplopoda, amphibians.

Many troglobites exhibit incredible adaptations to cave environments, such as tiny or non-existent eyes, increased sensory organs and elongated appendages, and reduced or non pigmentation. The species adapted to extreme cave life and that are depending exclusively to cave life, the troglobites are organisms that for all the duration of their life need the hypogean environment; they are species that have achieved such a degree of specialization and physiological modifications that they are living exclusively in the hypogean environment. Almost all the troglobite species are highly endemic.

Adaptations of the Cavernicol Zootaxa. Because of the physical and trophical particularities of the cavernicol environment, in the evolution process the animals turned to have a sum of adaptive features. These features are most evident at paleo-troglobiont taxa, organisms specialized to cavernicol way of life for a long time before other taxa.

In the hypogean environment all is turned to an energetic saving. In fact, the hypogean fauna has indirectly renounced to several "facilitations" typical of the epigean one (eyes, wings, colors etc) (see Figure 1). This genetic saving has been used for the mutations with "facilitations" suitable to lead hypogean life: the lengthening of the antennas and legs is a classic example.

Epigean Diptera exists in caves at depths of 800-900m; this is a demonstration that these bugs have the particular organs that allow them to find one's way in the dark for great distances (Figure 2)

1. The General Morphological Adaptations. Troglobiont zootaxa are characterized through a specific habitus which defines a so called cavernicol type. The main morphological features which occur to this are:

a. Anophthalmia – in correspondence with their life in an environment which is characterized by the absence of light, the troglobiont zootaxa are often without functional eyes. Visual function is realized step by step and in some species the eyes are shortened or absent (anophthalmic species). In some extreme cases regression affects also the nervous centers of the view sense. The absence of eyes is compensated by the capacity of the tegument to perceive light, capacity known as dermatological sensitiveness and the presence of some tactile and olfactive organs (see Figures 1-2).

b. Depigmentation - unrelated with the loss of sense of vision, troglobiont zootaxa are characterized also by their absence of tegumentary pigment. Because of this fact, most of the species are white, sometimes even translucid. It is considered that depigmentation is favorised by the atrophy of the visual sense organ and also due to the low temperature and high moisture.

For exemple, the pigmentation in absolute darkness individuals of both fish cave species mention by (Wilkens 2001) are pale. When kept for some months under daylight conditions they will develop greyish pigmentation (Wilkens 2001). This is caused by the light induced development of melanin in the melanophores; however, in comparison to the surface species the number of melanophores, which still are able to perform physiological color change, is reduced by about 50% (Wilkens 2001).

In the case of fish mentioned by Wilkens (2001), the ancestor of the cave species was possibly a troglophile, already perfectly adapted to life in darkness, similar to *R. Laticauda*. As a consequence, only few newly developed morphological adaptations to cave life can be found in the cave fishes. There is neither an improvement of the lateral line sensory system nor of structure and quantity of the electro-sensitive organs. The main adaptations focus on prerequisites for survival under food scarcity, such as the detection of food by the elongation of barbels and increased fat storage (Wilkens 2001) (see Figure 2). For exemple, Coleopters like in the genus *Trechus*, the functional eyes

have a semispherical configuration, in the *Duvalius* the reduction of the visual organ become much more evident and in the *Agostinia* genus the eyes are totally disappeared.
c. Apterism - is characterized by absence of the wings, in the case of insects, at the species which would normally have (Insecta, Coleoptera). There are, even here, some intermediate stages when we assist to a reduction of the wings, case of small winged (microptera) insects. Between three adaptative characters mentioned until now there is a statistical correlation on troglobiont coleopterans defined by the term of ADA characters (Anophthalmia-Depigmentation-Apterism).

An important morphologic modification in several insects, is the apterism (the absence of wings). In Diptera, with external membraneous wings, the apterism of the cavernicoles is evident, like in *Chionea alpina* (Diptera, Fam. Limoniidae) (Figure 2).
d. Morphology of the body (body shape) - the cavernicol type could be characterized by a gracil body as well as an elongation of appendix (legs and antennae). In the case of coleopterans, thinness affects only anterior part of the body, while the abdomen has the tendency to become globular, phenomenon known as false physiogastry. Troglobiont coleopterans have a normal abdomen, and only elytron are cambered, sheltering underneath a chamber full of air which preserves humidity necessary to tegumentary respiration processes.

The length of the legs and the appendages in artropods is an advantage, the antennas and palps of many hypogean arthropods are provided with a well developed sensitive apparatus, specific structures, biochemically locating the food or other individuals of the same or different species. This is also the case of *Leiodidae* and *Cholevinae* (Newton 1998; Perreau 2000) that are numerous in the subterranean environment, representing 30% of all known underground beetles (Decu & Juberthie 1998). They populate caves, as well as the fissure network and even the layers of the soil. The subfamily shows a mixture of archaic, plesiomorphic and derivate together with ultra-specialized, autapomorphic features (Giachino et al 1998). Some of these evolved features refer to the parts of the mouth, like the maxillary palpi with 3 articles, the last becoming very small and conical to the ultra-specialized species, or the mandibles, generally very regular in form that are modified as adaptation to the semi-aquatic way of life. This mixture of new and old features is also the consequence of the presence in this group of species with different degrees of adaptation to the underground life, from endogean to hypogean species, or from species that can be encountered only at the entrance of the caves to those that are found exclusively in the deepest passages (Casale et al 2000; Moldovan et al 2004).

The feeding is the main problem of every species. Due to the ecological niche which they occupy, every arthropod species has a suitable buccal apparatus: ex. the jaws of the *Carabidae* or to the mouth apparatus of the Diptera (flies) and of the *Lepidoptera* (butterflies).

Cholevinae representatives are detritivorous or saprophagous, feeding on organic matter more or less decomposed, deposited on the substrate (walls and stalagmites of the caves) or stored in the sediment deposits of the caves or the cracks, and decayed epigean or subterranean animals. Therefore the mouthparts show an adaptation relevant to these trophic niches (Moldovan et al 2004).

Cholevinae are a group of beetles with many cave representatives that are mainly detritivorous or saprophagous. Some species show modifications of the mouthparts on account of their dietary niche, being adapted to a semi-aquatic way of life, or on account of the degree of adaptation to the life in caves. Differences are obvious also among the genera, and cave species that are at the same level of adaptation. The main modifications concern the shape and structure of the different parts, as well as their length and the disposal of hairs, bristles and setae. The adaptation to an aquatic dietary niche has modified the mandibles, which acquired a spoon-like form to bring water near the mouth, the lacinia taking on the role of stirring and the galea of filtering the organic part (Moldovan et al 2004).

2. Ecophysiological Adaptations. Close aboard of the morphological particularities, troglobiont zootaxa have also a series of ecophysiological adaptations as follow: low rate of metabolism, stenothermia, stenohigrobiosis, continuous activity (absence of nictemeral rhythm) and particularities of the reproduction cycle.

Some insects are sensitive also to airflows and are equipped with bristles encircled from cells that inform them in case of dehydration danger. The smell is very developed. The velocity with which the *Leptodirinae*, and some aquatic organisms, reach the smelling decoys, also from considerable distances, is a clear indication of their sense of smell.

The metabolism of the cavernicol fauna has suffered some modifications, the oxygen consumption decreases: the life in the caves is much less animated, there are less biodiversity.

The nictemeral and seasonal rhythms vanish; all the biological rhythms slow down, also to an insufficient and sporadic food regimen.

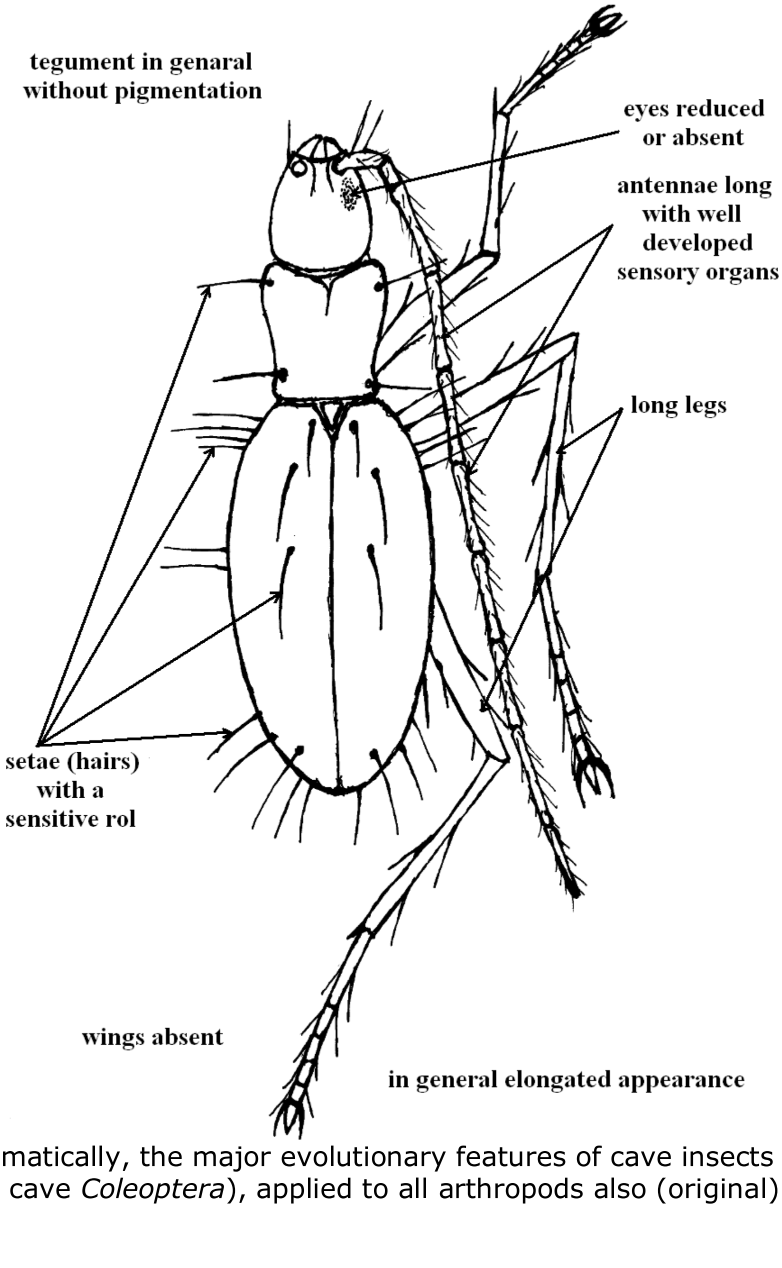


Figure 1. Schematically, the major evolutionary features of cave insects (modeled after cave *Coleoptera*), applied to all arthropods also (original)

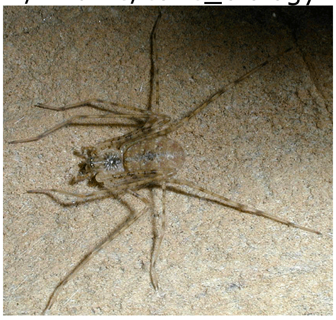
These cave animals perfect usually the tactile sensibility, as it is demonstrated by the particular development of the specific receptors, like the trichobotres (bristle-hairs) of the pseudoscorpiones or the sensory hairs of the *Coleoptera* and other insects. The lengthening of the antennas and of special bristles can be observed in these organisms and renders these animals also most sensitive to the minimum airflows (Figures 1-2).

a


A terrestrial isopod (photo: Joel Despain) http://www.nps.gov/archive/seki/snrm/wildlife/cave_biology.htm

b

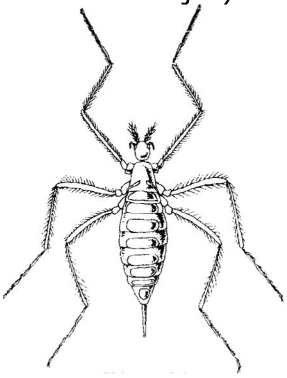

A troglophile species *(Orthoptera)* (photo: Dave Bunnell) http://www.goodearthgraphics.com/virtcave/cave_life/cave_life.html

c


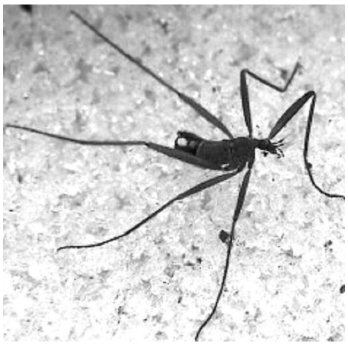
Cave spider, *Hypochilus petrunkevitchi* (photo by J. Krejca).

d

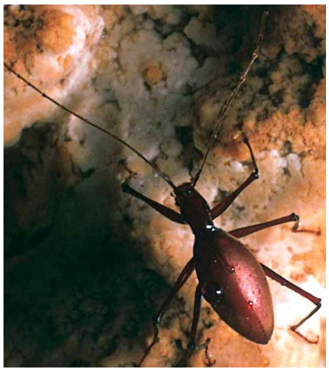

Hadeonoecus subterraneus (Orthoptera) (Photo by Rick Olson)

e


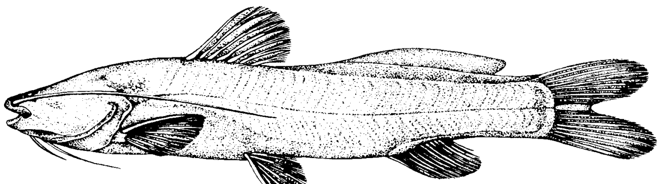
Chionea alpina (Diptera) http://digilander.libero.it/enrlana/

f


C. alpina (from Barndt 2004)

g


Hadesia vasiceki – Coleoptera (Photo: I. Sivec, from Moldovan et al 2004)

h


Rhamdia zongolicensis (from Wilkens 2001)

i


Proteus sp. – Amphibia, from istrianet.org)

Figure 2. A few representative species to the cave ecosystem (internet)

The legs usually are lengthened, while the membraneous wings of the troglobite insects are very reduced or lack at all (Figure 1). The sensitive structures can be the hairs positioned in very precise points on the exoskeleton of many Coleopters like in *Doderotrechus sp.* (a troglobite *Coleoptera*, Fam. *Carabidae*).

Faille et al (2010) suggested that the monophyly of all the highly modified subterranean species, in his case the species of *Pyrenees* (Col. Carabidae) strongly suggests a single origin of their shared character states: loss of eyes, apterism, depigmented body, a subterranean life, and a requirement for high levels of humidity (e.g. Jeannel 1926; Vannier & Thibaud 1971).

Conclusions. As much as a group of organisms are profoundly bounded of their life style (in this case cave environment), their characters (which were discussed in this paper) as anophthalmia, apterism, depigmentation are more pronounced or significantly developed. This is nothing more as one of the laws of evolution applied in the general nature context of the ecological niche.

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