COLLEMBOLA CLASS ("SPRINGTAILS")

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The Collembola are Arthropoda which form one class in super-class Hexapoda which are Invertebrata with 3 pairs of legs. Together with mites, Collembola are one of the most abundant of animals in the soils, occurring in all habitat types, on vegetation, in caves, littoral sand and the canopy in all continents. Because of their small size and difficult taxonomy, Collembola are difficult to see for non specialists, which may be the reason why they are still very badly known for most of the general public. So, unlike other groups such as Lepidoptera, there are not "amateurs" collecting Collembola and globally there are only about one hundred specialists on this group. Close to 8 000 species have been described in the world, but it is thought that at least 5 times this number will be discovered. Collembola are characterized by having a ventral tube or collophore, and a jumping organ named the furca or furcula, which are vestiges of abdominal appendixes. Lubbock (1873) has given the scientific name to the group as *Collembola* because of the presence of this ventral tube-collophore from Greek *colle* (glue) and *embolon* (piston). In English Collembola are also known as "springtails" because: furca = tail and spring = jump.

In the vast continent of Africa, we know very little of the biodiversity of Collembola. Indeed, only about 900/1 000 species are know from Africa and Madagascar. Also, in Africa little research has been done on Collembola biology, anatomy, behavior, and ecophysiology. Unfortunately, they are not many African scientists working on this group. Currently working on this class are two scientists in Algeria, one student in Ivory Coast and one in South Africa. This chapter is divided into three parts. The first, is a "General view on Collembola", a presentation of this group, with reference to the lector to Hopkins (1997) for the bibliography. The second is on the "Biodiversity and biogeography", country by country, of this class in Africano-Malagasy Empire, with

about all publications. And the third is the "Role of Collembola in terrestrial ecosystems. Man and Collembola".

1. General View on Collembola

1) Brief historic view

In 350 AC, Aristotle in *Historia animalium* mentioned the name "snow fleas" for the first time. These were actually the species *Isotoma saltans* (Isotomidae) which very numerous on the névés. In 1743, De Geer made the first "scientific" description of a Collembola, *Smynthurus fuscus (=Allacma fusca)* a Symphypleona. In 1758, Linné, in the tenth edition of *Systema naturae*, indicated 10 species of Collembola in the Insecta class, order of Aptera and all in the genus *Podura*. In 1873, Lubbock published the first Monograph on the Collembola. He included 130 species which were well illustrated. This was the beginning of the real scientific "Collenbology". But their study has made good progress only after 1950.

2) Phylogenetic position

The former group of Insects without wings, the "Apterygota", was based on one "symplesiomorphy"; it means a shared primitive character, the absence of wings. Recently, it has been considered that the Hexapoda is divided in two big groups (Figure 1) depending on the position of their mouths parts:

a) The Insecta are Ectognatha, characterized by their mouth parts being on the *outside* of the head. This group includes the winged Insects or Pterygota; the ancients group includes "Thysanoura": Archaeognatha (Machilis) and Zygentoma (Lepisma).
b) The Entognatha, characterized by their mouths parts located *inside* a cavity in the interior of the head, include Diplura, Protura, and Collembola.

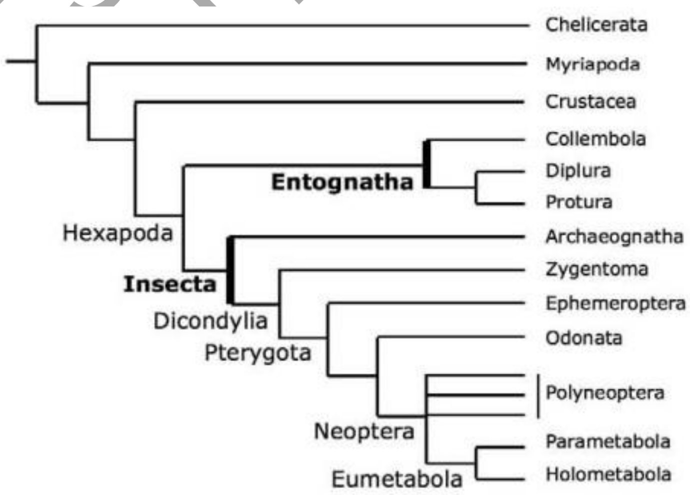

Figure 1. Essay of "reasonable" synthesis in Hexapoda phylogeny (from D'Haese C. - 2004. Phylogénie des hexapodes et implications pour l'hypothèse de leur origine aquatique. *Journal de la Société de Biologie* 198).

3) Morphology

In summary, Collembola are hexapods, entognaths, wingless and of small size, usually from 1 to 3 mm long. The smallest species of Collembola and also the smallest Hexapoda known *Sphaeridia pilleata*, a Symphypeona from Brazil, is 0.12 mm, while the largest species is 1.7 cm *Holacanthella duospina*, a Neanuridae from New-Zealand.

The body structure of the Collembola of a head and 9 postcephalic segments: three thoracic and six abdominal (Figure 3), which are sometimes more or less fused as in the Neelipleona and the Symphypleona groups. The head has a pair of antennae consisting of four segments each, sometimes subsegmented or annulated, always with many setae and sensillae of different length and shape. These setae and sensilla function as sensorial receptors.

The third antennal segment has one sensorial organ or "antennal organ III", more or less complex, typical for Collembola. The mouth parts that are found in a cavity inside the head, are very often chewing, the mandibles have one incisive apical part and one basal chewing part. Only in the group of Poduromorpha, the families of Odontellidae, Brachystomellidae and Neanuridae, have sucking mouth parts.

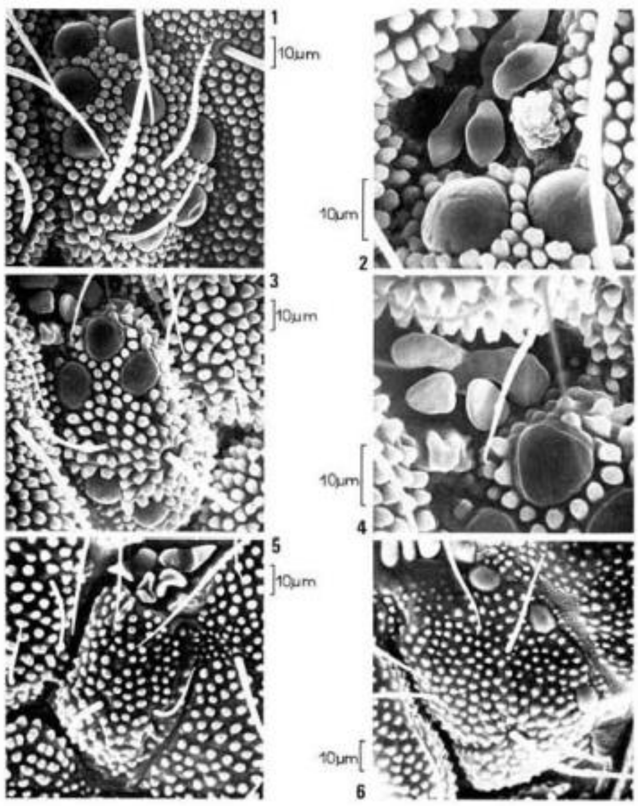

Figure 2. Photos with scanning electron micrograph of area ocular with a complete number of cornulae (8 + 8) or reduced or absent, and postantennal organ near anterior cornulae, in Poduromorpha Hypogastruridae hemiedaphic and cavernicolous respectively (from Thibaud & Massoud - 1973 - Etude de la régréssion des cornéules chez les Collemboles. *Annales de Spéléologie. CNRS* 28)

The head usually has 16 elementary eyes, that is, 8 cornulae on each side (Figure 2). This number is often reduced or sometimes absent (Figure 2), in the species living in soil and in caves (Thibaud, 1970, Thibaud & Massoud 1973; Thibaud 1976). Because of the few number of sensorial cells in their optical lobes the vision in the Collembola, even those with 16 cornulae, may be very reduced.

Between the base of the antennae and ocular area the "postantennal organ" is found (Figure 2), with a variable shape between groups and sometimes also absent in some genera of the families Hypogastruridae, Entomobryidae, Tomoceridae and Sminthuridae. This organ has also one sensorial function for smelling. It is considered by some authors as the Tömösvary organ of the Myriapoda and the pseudoculi of the Protura.

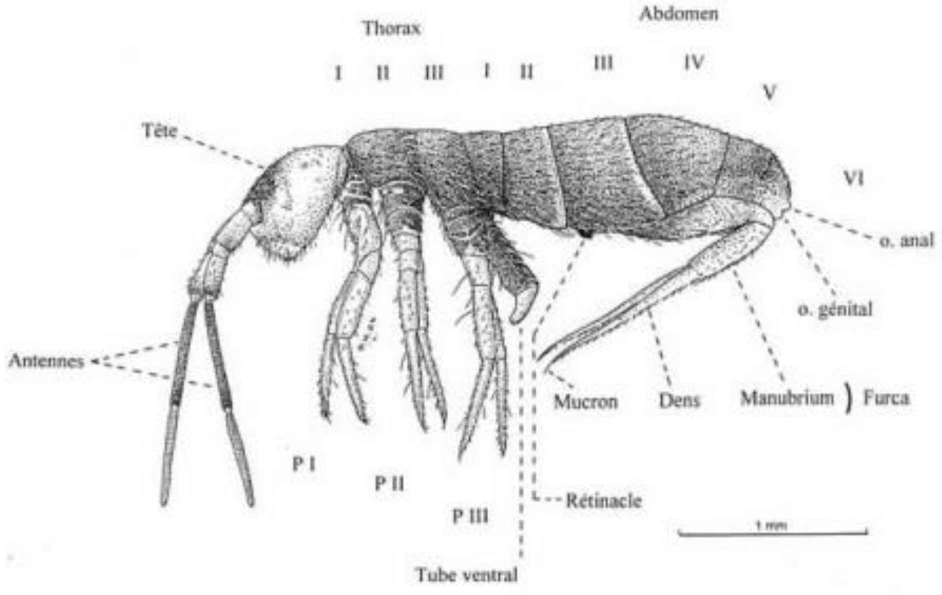

Figure 3. Habitus of *Dicranocentrus chimborazoensis* (Entomobryidae) (L: 3 to 4 mm) (modified from Najt, Thibaud & Mari Mutt - 1998 - Collemboles de l'Equateur III. Entomobryidae: Orchesellinae. *Bulletin du Muséum national d'Histoire naturelle Paris*. 10).

The thorax (Figure 3) is made up by 3 segments, each with a pair of legs, each subdivided in 6 segments, covered by setae and ending in of more or less long and fine nails or claw.

The abdomen (Figure 3) has 6 segments, some of them with the following ventral appendices:

- The first sternite has the cylindrical "ventral tube", more or less elongated, mainly in the Symphypleona. It has an important role in the ionic and hydrological equilibrium and also for adhering the animal to certain substrates. This ventral tube is always present. It is one unique character in this group (synapomorphy) and defines the Collembola.
- The second sternite has no appendix.

- The third sternite has the "retinacle" (tenaculum), organ where the furcula is attached to.
- The fourth sternite has the "furcula", which gives the characteristic jumping to the Collembola. This jumping organ allows the animal to escape from predators and for dispersal. Good jumpers such as the *Entomobrya,* which measure about 1 mm, can jump more than 16 cm ! In families that live in the soil, such as Onychiuridae and Tullbergiidae, the retinaculum and the furcula, are very reduced or often completely absent.

The impaired genital opening is located in one genital plate in the fifth sternite in both sexes. The anal opening is in the sixth and last abdominal segment, where it is emerges among 3 anal valves.

In the Symphypleona and in the Neelipleona, the thorax and abdomen may have fewer segments by the secondary fusion of some of them.

The habitus of the body and the pigmentation vary very much (Figure 4).

Figure 4. Photos of (from up-down and left-right): *Holacanthella* (Neanuridae), *Allacma* (Sminthuridae), *Neanura* (Neanuridae) with eggs, *Tomocerus* (Tomoceridae), *Cryptopygus* (Isotomidae), *Onychiurus* (Onychiuridae), photos D'Haese (from Thibaud & D'Haese - 2010 – "Le petit Collembolle illustré" . *arvensis* 51).

The cuticle, with little sclerotification, has many and different kinds of epicuticular ornamentations. It has ordinary setae which are mechanic-receptors and the sensillae which are chemo-receptors. The study of the position and the shape of those setae and sensillae is the interest of the "chaetotaxy". That chaetotaxy has become very important for the description of the species and the study of the phylogeny (Figure 5).

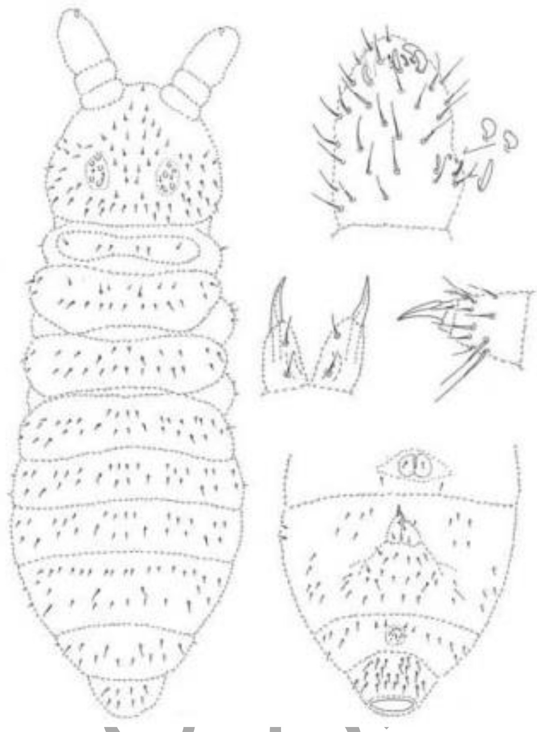

Figure 5. Example of the study of the chaetotaxy in *Paraxenylla piloua* (Hypogastruridae) living in sand-beach (from Thibaud & Weiner - 1997 - Collemboles interstitiels des sables de Nouvelle-Calédonie. *Zoologia Neocaledonia Mémoires du MNHN* Paris 171).

The cuticle of the Onychiuridae has special pores, with the wrong name of "pseudocelles", which at the time of the attack by a predator secrete a repellent liquid which protects them.

4) Classification of Collembola

The Collembola have been divided in 4 orders by Börner (1906), based on their morphology:

- Body elongated and segmented ("Arthropleona"): Poduromorpha and Entomobryomorpha.
- Body round and no clear segmentation ("Symphypleona"): Symphypleona and Neelipleona.

Those 4 orders are subdivided now in 16 super-families:

- Poduromorpha: with thorax I well developed, with 3 super-families: Hypogastruroidea, Neanuroidea and Onychiuroidea.
- Entomobryomorpha: with thorax I reduced, with 3 super-families: Isotomoidea, Tomoceroidea and Entomobryoidea.
- Symphypleona: with abdomen more developed than the thorax, with 9 super-families.
- Neelipleona: with thorax more developed than the abdomen, with 1 super-family Neeliodea.

Note that the recent works on cladistic and molecular systematic have not deeply changed this classification, for more than a century.

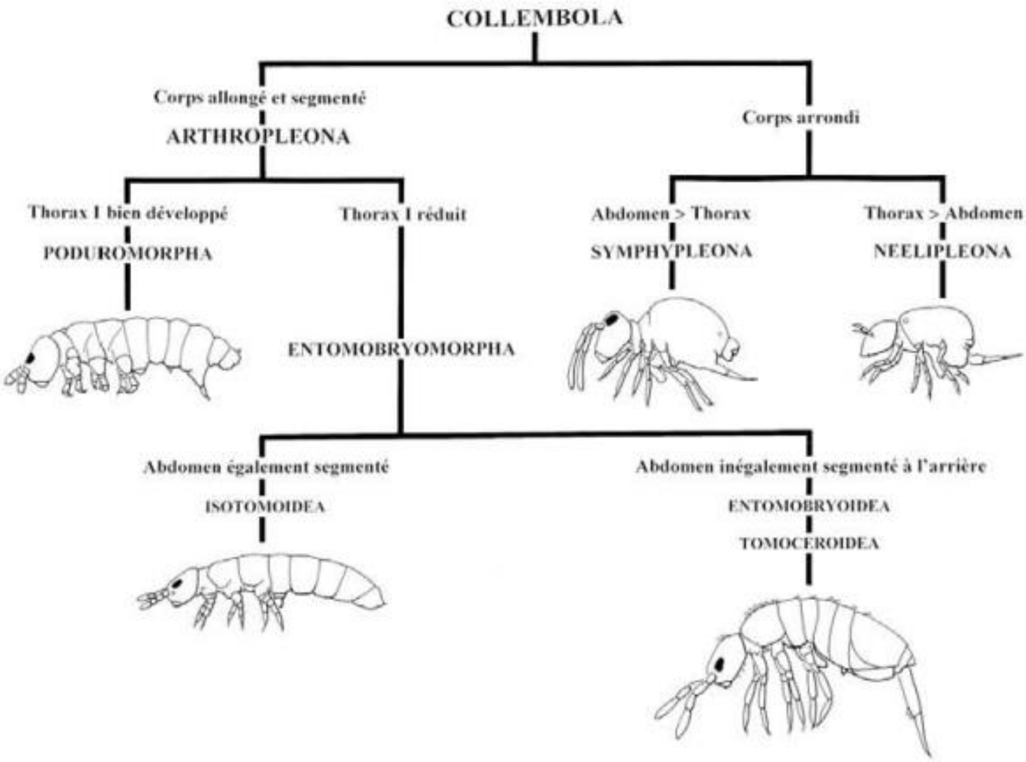

Figure 6. Classification of the Collembola-class (from Thibaud - 2003 - *Titres et Travaux. MNHN*).

5) Paleontology of Collembola

Collembola is the most ancient group of the Hexapoda. The Collembolan fossil *Rhyniella praecursor* discovered at Rhynie, in Scotland, has been dated from the Middle Devonic, close to 400 millions years ago. This species is closely related to present day Neanuridae. After some new studies, it can be said that during the Devonic, there were already at least two lineages of Collembola: the Neanuridae and the Isotomidae, close to the present day species (Greenslade 1988).

Fossil Collembola are also known from the amber of Cretacic and Eocene in Poland, Canada, Mexico and Dominican Republic. Those fossils are well preserved and close to actual species (Poinar 1993), and represent 3.5% of the species found in amber.

The evolutionary explosion of the Collembola then happened very early; then slowed down soon after.

6) Anatomy of Collembola

All the Collembola, even those very small such as those living in sand interstices about 0.2 mm long, present the same internal organs. It is one extraordinary example of "miniaturization" (Figure 7).

The head contains: the mouth pieces, salivary glands, labial nephridiae, anterior digestive tube prolongation of the external cuticle and then submitted to molting process, the brain, the subesophagyc ganglion, the neuro-secretion system with few cells in the *corpora allata* and one aortic sleeve.

The body contains: body fat, one muscular system very complex, one circulatory system or dorsal "heart", the nervous chain, made by three thoracic ganglions and one abdominal fused with the metathoracic, ovaries or testicles, the digestive median tube endodermic which is totally changed in each molting, the posterior digestive tube ectodermic and also dependent on molting. Collembola have no abdominal nephridia.

Most of the species of the Collembola have a cuticular respiration system. Only the Actaletidae (Entomobryomorpha) and most of the Symphypleona have developed a respiratory system with trachea, which has allowed them to live on the vegetation and even on the tree canopy. Some species of Symphypleona also have their cuticle with a hydrophobic wax. That is why without doubt it is in the composition of their hemolymph where the explanation most be searched about their extraordinary water retention.

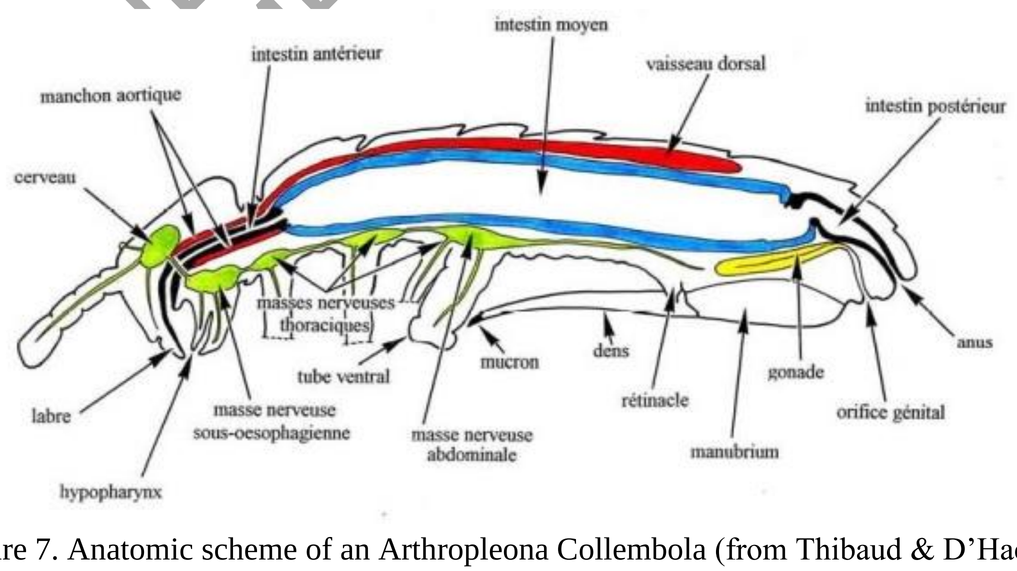

Figure 7. Anatomic scheme of an Arthropleona Collembola (from Thibaud & D'Haese - 2010 - «Le petit Collembolle illustré». *arvensis* 51).

7) Reproduction of Collembola

In Collembola there are always two sexes isolated: male and female. Usually there are not morphological differences between both sexes, except the shape of the genital opening. Nevertheless, in some species of Entomobryomorpha such as in the families Actaletidae, Coenaletidae, some species of the genus *Seira*, and most of the Sminthurididae (Symphypleona), the males have secondary sexual characters on the antennae, legs and abdomen; and some females of the Symphypleona have anal appendices and long setae.

Usually the male puts one spermatophore in the shape of a drop, usually on one stick, thus the reproduction happens without mating. The size of the spermatophores varies depending on the species from 50 µm to 1 mm. In most of the species, the laying of the spermatophores and the fertilization of the female are by chance.

However, in many species of Entomobryomorpha and Symphypleona, lying of the spermatophore is stimulated by the presence of the females and in some species there is a "mating" behavior.

In very few cases the laying of the spermatophore and its reception is with the participation of both sexes. It can happen when:

- The male very actively pushes the female forwards over the spermatophores, as in *Podura aquatica* (Poduridae),
- The male has primitive nuptial parade, and then it "entoure" the female with a "barrier" of spermatophores, as in *Dicyrtomina minuta* (Dicyrtomidae),
- The male and the female have a real nuptial parade with the succession of interactions of stimuli-answer and the transport of the male by the female while the male clasps the female antennae with its own antennae, then he deposits a spermatophore and the female takes it, as in *Sminthurides aquaticus* (Sminthurididae).

Parthenogenesis is known in several species of genera *Mesaphorura, Neanura, Folsomia* and *Isotoma*.

Eggs and embryonic development

Eggs are often laid in very small batches of 8 to 50 eggs (Figure 4), but sometimes isolated as in *Tomocerus* (Tomoceridae). Depending on the species, one female can lay from 1 to 10 times during her lifetime. Eggs are spherical with an average diameter from 0.1 to 0.3 mm, with the surface smooth or with ornamentation, depending on the taxa. Sometimes the eggs are covered by excrement, as in the *Dicyrtomina* (Dicyrtomidae), in order to stand the dry biotope. Some species, mainly those that are epigeous, have special types of eggs which can stand the difficult climatic periods.

The embryonic development varies between species and depends on the environmental conditions and temperatures: from 3 days just to 2 months, but in general it takes about 2 weeks.

8) Postembryonic development

Collembola are "ametabols", which means they do not pass by one metamorphose. From the egg hatches one juvenile of the first instar, is morphologically almost identical to the adults, but smaller. This juvenile will begin to grow during molting, and the number of molting varies depending on the species, just to reach sexual maturity, and will continue molting throughout its life. The chaetotaxy develops, little by little, by the addition of setae in each molting, from juvenile to the adult.

The postembryonic development varies upon the environmental conditions, from 1 week to 5 months, but in general from 1 to 2 months.

9) Life cycle and longevity

The life cycle, from egg to egg, takes approximately 2 months to 1 year.

The longevity may vary, from 3 months to 3 years, depending of the species. Life cycles are longer for species living in the mineral soil and those living in caves.

In addition, Collembola store less water and more fat in their bogy when they are older as found in many other Arthropods.

10) Intermolting cycle of adults

The presence of molting in adults is a primitive character of Collembola, which is shared with other "Apterygota" and some Myriapodes, Arachnids and Crustaceans. After molting, the size neither the morphology change. The length of the intermolting cycle varies, depending on the environmental conditions and the species, from 4 days to 2 months, in general from 1 week to 1 month.

During its adult life, one Collembola can molt from 20 to 60 times according to species. This explains why the Collembola have regular alternative periods of fasting and feeding during all their life. This is very important in ecology, as one Collembola can be consider as inactive in the saprophagy system, about 20 to 30 % of its life! This phenomenon is never considered in the global ecological studies.

11) Influence of factors from the environment

a) Temperature

Temperature for eggs, juveniles and adults of the *European* Collembola are:

- The *lower lethal temperatures* are in general from - 1 to - 4°C, and for some of them - 10°C. Certain species of Onychiuridae and Isotomidae live in the *Antarctic* continent such as *Cryptopygus antarcticus*, or in Spitzberg, or on the glaciers, can lower their freezing point to -30°C. This is due to the production of one "antifreeze agent" in their tissues.

- The *upper lethal temperatures* vary from 25 to 30°C according to the species, but more rarely for some up to 50°C.

In *Europe*, the *thermal optimum* varies from 8 to 16°C. In the *Tropics*, it is higher and varies from 22 to 32°C (in Guadeloupe-Lesser Antilla: Thibaud & Oliveira 1989). Collembola are thus animals rather *eurythermes* with rather broad thermal tolerance.

b) Humidity

The *hydrometrical optimum* for Collembola is from 90 to 100% of *relative humidity of the air*: they are thus *stenogroby* animals, that is, with weak tolerance for the changes of relative humidity of the air. It is important to remember that the majority of the species of Collembola have a cuticular respiration. This cuticular permeability allows the respiratory exchanges and facilitates the body hydrous transfers. Only the family of the Actaletidae (Entomobryomorpha) and the majority of Symphypleona have a respiratory tracheal system, a special cuticule and a special hemolymph, which enabled them to live out of the ground in the herbaceous air layer.

The majority of Collembola from *soil* tolerate the drying of the substrate only after the point of permanent fading (pF = 4.2): they are thus *eurydrobic* animals. They flee the substrate before the point of maximum hygroscope is reached, that is after the departure of capillary water and at the time when it still in the interstices of the substrate a relative humidity of the air of almost 100%. It is impossible for these animals to use the water of the substrate which determines their escape. Even subjected to a strong drying in depth ground always constitutes an excellent protective medium thanks to its hydrous reserves usable by these animals.

Collembola are thus ready more desiccation tolerant than previously thought. It should not be confused "resistance to the drying of the substrate" and "resistance to a hydrometrical deficit of the air".

c) Semi-aquatic life

Certain species, especially those from *soil or caves in Europa*, have eggs immersed in water develop normally and hatch under water. This possibility of eggs to survive under water confers to some Collembola a great resistance to the floods and a capacity of dissemination by water. Many species of Collembola, especially those of the deep soil and caves, thus have a possibility of "semi-aquatic life" (Thibaud 1970).

This enables us to better imagine the life of these animals in the marshy forests of the Carboniferous. At the appearance of broad-leaved trees, end inferior Cretaceus, with humus covered the ground, Collembola have colonized the ground and the underground to occupate the available niches. Certain Collembola are true "living fossil", or "panchronic species", with great ecophysiological adaptations that permit these species to cross the geological era in preserve the facies (habitus) of the earliest ancestors.

12) Collembola diet

The majority of Collembola are *polyphagous*. They feed on organic remains: foliar parenchyma, wood in decomposition, animal excrement and, especially, pollen, algae, mycelium and spores of mushrooms-fungi and bacteria. They are thus *detritivorous* and they play a considerable part in the processes of biological breakdown as we will see it further.

13) Predators and parasites of Collembola

The predators of Collembola are centipedes, spiders, opilionids, pseudoscorpions, mites, and several insects as flies (Diptera), beetles (Coleoptera) and ants (Formicidae). Also some vertebrates that can predate on Collembola include lizards, frogs and birds. This big role of trophic Collembola as a resource remains often neglected in ecology.

The internal parasites of Collembola include Microsporidies and other Protozoa, Gregarins and Nematodes.

14) Population density, Biomass and Metabolism

The *density* of Collembola is very variable according to the biotopes. When they are present, this density varies from 1 000 to 1 000 000 specimens per m ^{2}, with averages from 10 000 to 100 000 (Hopkin 1997). The *fresh weight* of adult Collembola varies from 0.2 mg to 1.5 mg according to the species (Vannier & Thibaud 1984). The *dry weight* of adults varies from 0.05 mg to 0.3 mg according to the species (Vannier & Thibaud 1984). The *biomass*, for 50 000 individuals per m^2, varies from 10 g to 75 g/weight fresh and from 2.5 g to 15 g/dry weight (Hopkin 1997). The *biomass* of Collembola from *soil* would represent from 1 to 10% of the biomass of the fauna of the soil fauna. The *metabolism* of their populations would be also from 1 to 10% of the metabolism of soil fauna. Collembola would thus represent from 0.4% to 3% of the *energy* of the terrestrial ecosystems.

15) Habitats and life forms

Collembola have invaded all the terrestrial biotopes of our planet. They are found close from seashore to the eternal snow with more than 7 700 m elevation, and even in the Antarctic. They are distributed under all the climates and at all the latitudes. They generally live in forest in the litter, the humus, the first centimeters of the soil. Some of them are adapted to the cavernicolous life, others to interstitial life in sandy environments and the deserts. Only the Entomobryoidea and Symphypleona have the flexibility of the wet ground and invaded the epigeic air and the vegetation.

The followings main life forms can be distinguished:

- Epiedaphic, living above the ground on the vegetation: Entomobryoidea (Figure 8) and Symphypleona. They are well pigmented, with well developed antennas, eyes, legs and furcula. They can also live in the canopy, especially in tropical forests, where they are still one of the dominant groups (6 to 7%).

- Hemiedaphic, living in the litter and the first centimeters of soil: Poduromorpha and Isotomidae (Figure 8). Intermediate forms.
- Euedaphic, living in the deep ground: Onychiuridae (Figure 8) and Tullbergiidae. They lack pigmentation, with their antennas, eyes, legs and furcula reduced and even often absent for eyes and furcula.

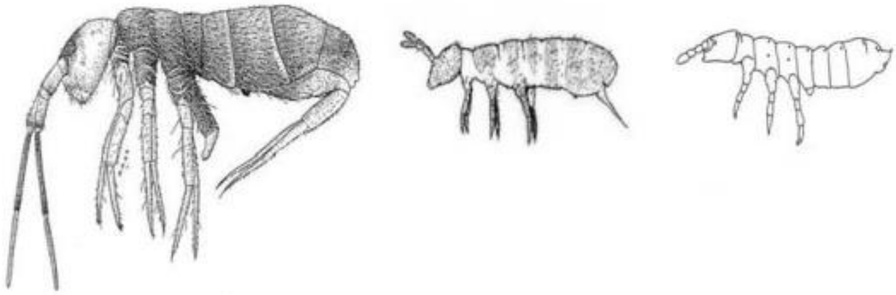

Figure 8. Habitus of 3 life-forms: left, epiedaphic *Dicranocentrus chimborazoensis* (Entomobryidae); middle, hemiedaphic *Folsomia candida* (Isotomidae); right, euedaphic *Onychiurus* sp. (Onychiuridae) (modified from Najt, Thibaud & Mari Mutt - 1988 - Collemboles de l'Equateur III. Entomobryidae: Orchesellinae. *Bulletin du Muséum national d'Histoire naturelle* Paris. 10, and from Thibaud & Massoud - 1986 - Insecta: Collembola. in *Stygofauna Mundi*. Leiden).

- The interstitial species living in sand in "supra littoral zone" (psammobiontes), can be in littoral or continental sands in all continents (Greenslade 1981; Massoud & Thibaud 1985; Christian & Thibaud 1988; Thibaud 2007), especially along Africa and Madagascar coasts (Thibaud 1993, ...2012; Barra 1995, ...2002). They approach euedaphic and lack pigment, often without eyes and furcula, with the short appendices, but with the very flexible body in order to penetrate between the grains of sand without break up its structure (Figure 9). These include certain species of Hypogastruridae, Neanuridae, Tullbergiidae, Isotogastruridae and Isotomidae.

Figure 9. Littoral sand under a binaucular-microscope, where you can see three *Friesea anophthalma* (Neanuridae) and one Acarina (Nematalycidae) *Gordialycus* (from

Thibaud - 2007 - Recent advances and synthesis in biodiversity and biogeography of arenicolous Collembola. *Annales de la Société entomologique de France* 43).

- Troglobites (real cavernicolous), they live exclusively in the caves, such a genera: *Ongulonychiurus, Tritomurus, Bessoniella, Troglopedetes* and *Arrhopalites* all in *Europa*_(Figure 10). They lack pigment and eyes, but often with lengthened appendices: furcula, legs, claws and sensillae are long and fine. However, their adaptation to the cavernicolous life is especially biological and ecophysiological (in *Europa*: Thibaud 1986; Thibaud & Vannier 1987; Thibaud & Deharveng 1994).

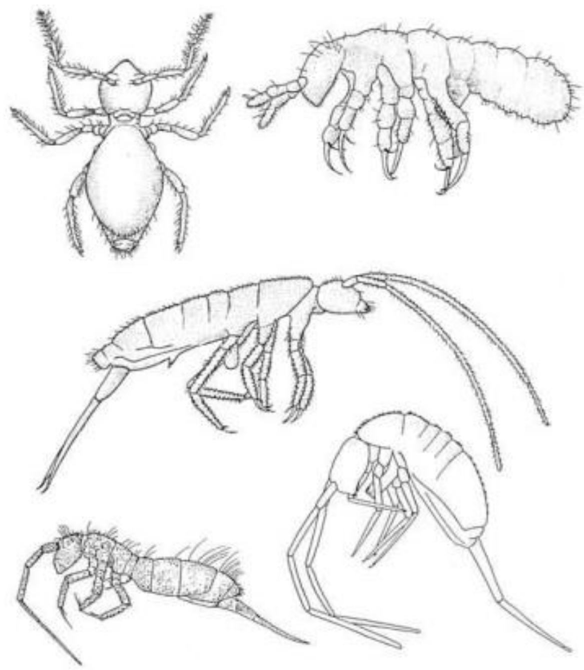

Figure 10. Habitus of troglobites Collembola: Up in left, *Arrhopalites pygmaeus* (Arrhopalitidae) from numerous European caves; up in right, *Ongulonychiurus colpus* (Onychiuridae) from caves in Spain; in middle, *Tritomurus falcifer* (Tomoceridae) from caves in Pyrenees France; down in left, *Bessoniella procera* (Orchesellinae) from caves in Pyrenees France; down in right, *Troglopedetes delamarei* (Paronellidae) from a cave in Cuba. (from Thibaud & Deharveng - 1994 - Collembola. *Encyclopaedia Biospeologica Moulis-Bucarest*).

- "Marine" (thalassobiontic), pledged species in the more or less salted littoral mediums in "intertidal zone", such *Anurida maritima*, *Friesea valeriae*, *Weinera ghislaineae*, *Halisotoma maritima*, and genera *Anuridella*, *Isotogastrura*, *Archisotoma*. Besides the structure and the ornamentation of their cuticule, the adaptation to this medium is especially ecophysiological, in order to tolerate higher salinity (Owojori et al 2009) and the osmotic pressure (Witteveen et al 1987).
- "Fresh water surface" (epineustonic), species living on the surface of the fresh water tablecloths such *Podura aquatica*, *Sminthurides* and *Isotomurus.* In addition to their hydrophobic cuticle, they present claws and mucrons more or less modified for walking and jumping on water. Some of these species can carry out their entire life cycle on the water surface.

- Termitophyl and myrmecophyl, living in the termites nest or in ants nest, especially in *Africa* (in *Ivory Coast*: Delamare 1948): 130 blind and unpigmented species of the Cyphoderidae (Entomobryompopha) of which the half are in the cosmopolitan genus *Cyphoderus*. The species, less numerous, in a more specialized genus, like *Colobatinus* (Figure 11) and *Cyphoderinus*, have sucking mouth parts and are living, in commensal, with termites in the closed environment of termites nest in numerous populations.

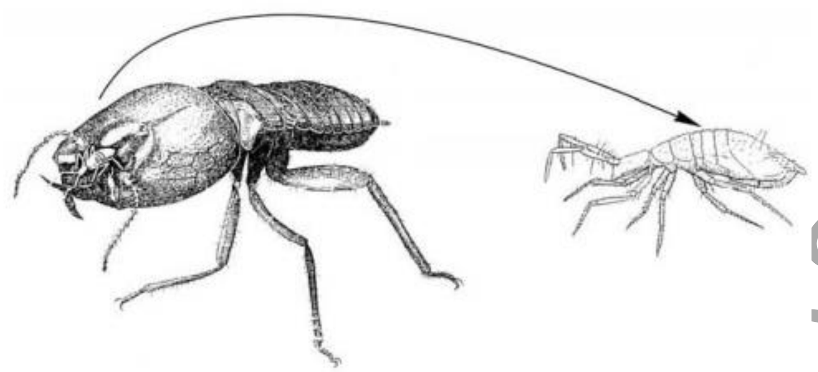

Figure 11. African Collembola *Colobatinus* (Cyphoderidae) on the head of a soldier of *Bellicositerma* (Termite), in position to catch the food when a worker goes to give food to a soldier (modified from Delamare Deboutteville - 1948 - Recherches sur les Collemboles termitophiles et myrmécophiles. *Archives de Zoologie expérimentale et générale*. 85).

16) Dispersion of Collembola

The dispersion of these small animals is done by walking and the jumping (from 200 to 300 m per day for *Hypogastrura socialis* on snow), by air and wind (in the "air plankton": up to 2 000 m of altitude; Berland 1937), birds and other animals, the water of the torrents and the rivers, transoceanic "rafts" (Thibaud 1970, ...2007; Coulson *et al* 2002), and through human activity ("introduced species").

17) "Gatherings" of Collembola

Some species such in *Europa*, *Anurida maritima* (Neanuridae) and *Actaletes neptuni* (Actaletidae), in the zone of the tides; *Isotoma saltans* (Isotomidae) "the louse of the glaciers", on the snow; *Ceratophysella sigillata* and *Hypogastrura socialis* (Hypogastruridae), and in South America (*Brazil*) *Seira* (Entomobryidae), gather sometimes in spectacular colored spots from 1 to more than 300 m²! They are grouped up to million individuals for still unknown reasons, perhaps due to the high reproduction rates due to the exceptional climatic and nutritional conditions.

18) Ecomorphosis, Epitoky and Cyclomorphosis

- "*Ecomorphosis*": Under certain climatic conditions, high temperature and low hygroscopy, especially in spring in the *Mediterranean Region*, some species of Hypogastruridae and Isotomidae can have reduced nutritional and respiratory activities at the time of one or several juvenile stages. They develop morphological modifications such as a regression of the mucron and the oral parts, development of spines on the abdomen. They also present internal modifications, atrophies digestive tract and gonads, accumulation of greasy substance and granules of excretion. This temporary metabolic crisis is started by the inhibition of the *corpora allata* to produce juvenile hormone. This absence plunges the organization in a physiological context enabling them to escape the vicissitudes from the hot and dry season. All these modifications are reversible at the end of the ecomorphosis.

- "*Epitoky*": When some of these changes, such as the reduction of the mucron and of the anal spines, reduction or enlarging of certain silks, occur during the reproductive cycle it is known as epitoky.
- "*Cyclomorphosis*": When some of these changes occur in a regular seasonal cycle it can be called cyclomorphosis. This happens in certain species of *Isotoma* (Isotomidae) which then present a form of summer and another form of winter.

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Biographical Sketch

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