A Contribution to the Study of Blood-Cells in Orthoptera

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Özet : Yirmi iki Ortopter türü üzerinde yapılan araştırmalardan elde edilen sonuçlara göre dört tip kan hücresi vardır : 1) Ana hücreler. Bunlar yuvarlak ve sitoplazmayı dolduran bol kromatinli bir nukleusa maliktirler. Bu hücreler mitoz ile bölünür. Bölünme neticesinde tekrar ana hücreler veya prolökositler meydana gelir. 2) Prolökositler. İğ biçimindedirler. Bölündükleri görülmemiştir. Diğer iki tip kan hücresi ile ana hücreler arasında bir geçit safhası teşkil eder. 3) Fagositler ve 4) Granüllü lökositler. Bu iki tip hücre de iğ biçimindedir. Sitoplazmaları boldur. Mitozla bölünmezler. Fakat bazan amitotik olarak çoğaldığını gösteren safhalar müşahede edilmiştir. Fagositlerde granül yoktur. Granüllü lökositlerde bol miktarda granül bulunur.

Bu travayda ayırt edilen dört kan hücresi tipi diğer müelliflerin tasnifleri ile karşılaştırılarak, Ortopterler için bir sinonim cetveli yapılmıştır.

Ana hücreler, prolökositler ve fagositler fagositoz yapmak kabiliyetini haizdirler. Ana hücrelerin fagositoz kabiliyeti en fazladır. Granüllü lökositler bu hassadan mahrumdur.

Bütün kan hücrelerinde sitoplazma bazofil reaksiyonludur.

Asidofil sitoplasmalı önositlere rastlanmamıştır.

Kan hücreleri sayımı on sekiz Ortopter türü üzerinde yapılmış ve aynı türün hücre sayımında ekseriya büyük değişiklikler görülmüştür. Bu değişiklerin vücut suyu veya hemolenf miktarı ile ilgili olabileceği gösterilmiştir.

Aynı türe ait dişi ve erkek fertlerin kan hücre sayıları arasında büyük bir fark yoktur. Bununla beraber dişilerde hücre sayısı ekseriya biraz daha fazladır.

Erginlerde kan hücre tiplerinin yüzde nisbetleri oldukça sabittir.

Mitoz nisbeti çok düşüktür. Hücre sayımında görülen artışı izah edemez. Dipter ve Lepidopter'de olduğu gibi, lökopoietik bir organın mevcut olabileceği fikri ortaya atılmıştır.

Introduction

Many of the previous authors who have studied blood-cells in insects worked on only one or few species. This paper is an attempt to investigate the types, phagocytic activity and number of haemocytes on several species (up to 22) of Orthoptera.

In Part I, different types of blood-cells, their multiplication and phagocytic activity are studied.

In Part II, the results of blood cell counts in the nymphs and adults and percentages of different types of haemocytes in adults are given

Material and method.

The Orthoptera species which are investigated in this paper were all collected around Ankara (Emir gölü) during 1949-1951. The haemocytes were studied on blood smears. The blood was obtained by pricking the cervix which is located dorsally between the head and pronotum. The younger nymphs often released more blood than the older. The smears were fixed in Bouin. If they were allowed to dry in the air, the shape of blood-cells deteriorated and crystals were formed on them. To avoid this, sufficient quantities of Bouin were poured on the smears to cover them completely during fixation, which lasted about an hour. The preparations were then washed thoroughly. They were stained either with May-Crünwald-Giemsa (Panoptic method) or with Haematoxylin-Eosin. In the first case the slides were examined uncovered.

Phagocytic activity of the haemocytes was examined 24—48 hours after injection of the following dyes.

1) 1 % Neutral Red
2) 10 % Indian Ink
3) 0.1 % Carmine
4) 1 % Methylene Blue.

The injections were effected from the ventral side between the thorax and the abdomen. The injected grasshopers were exposed to acetic acid vapours before examination. This prevents the coagulation of the blood. This method was first used in insects by Shull et. al. [16] then by Fischer [7] and Tauber and Yeager[18]: The grasshopper was attached by the hind legs and kept in suspense through a string over acetic acid in a closed bottle. The insect was maintained in this position until it becomes unable to move. The required time for this varies according to the species. The haemolymph was studied between slide and cover without fixation.

The blood-cells were counted on individuals collected every week. The insects of same species were kept together and were fed abundantly during the experiments. They were always counted in succession. The blood was diluted with the following solution in an ordinary pipette used for the Mammalian blood :

0.0081 Mol Nacl
0.002 Mol Kcl
0 001 Mol $Cacl_2$
% 0.0015 Gentian Blue
% 0.125 Glacial Acetic Acid
1000 Cm^3 Distilled Water
The counter slide was a Neubauer-slide type.

I — Types of blood-cells, their growth, multiplication and phagocytic activity.

a) Types of haemocytes.

Examinations of three hundred smears belonging to twenty-two species of Orthoptera permitted the classification of the blood-cells into four groups.

In all of the studied blood-cells the cytoplasm was always basophil. It stained dark-blue or bluish-purle with May-Grünwald-Giemsa. Eosin stained the cytoplasm homogeneously. The mean values for the diameters of these cells are given in Table I. All measures were obtained by counting ten cells for each type of haemocyte.

1) Mother cells.

They are easily recognized by their round shape. Their nucleus almost fills the cell and possesses an abundant quantity of chromatin (Fig. 1). Their long diameter is 12.29 μ and short diameter 10.94 μ. The lowest and highest measures made for long diameter are respectively 5 and 28 μ, and for short diameter 5 and 23 μ (Table I). Mother cells multiply mitotically. The mitosis phases can be best followed on smears stained with Haematoxylin-Eosin (Pl. I). The cell division produces either two new mother cells (Pl. I; Fig. 9) or two proleucocytes. During the division resulting in two proleucocytes, the two

cells are elongated until the end of telophase producing two pear-shaped haemocytes (Pl. I; Figs. 7a, 8a and 9a).

The amount of cytoplasm first increases in the cells as they become older (Fig. 1; F,K), then numerous vacuoles appear in them (Fig. 1; I,K). Finally the cytoplasm begins to dissolve and

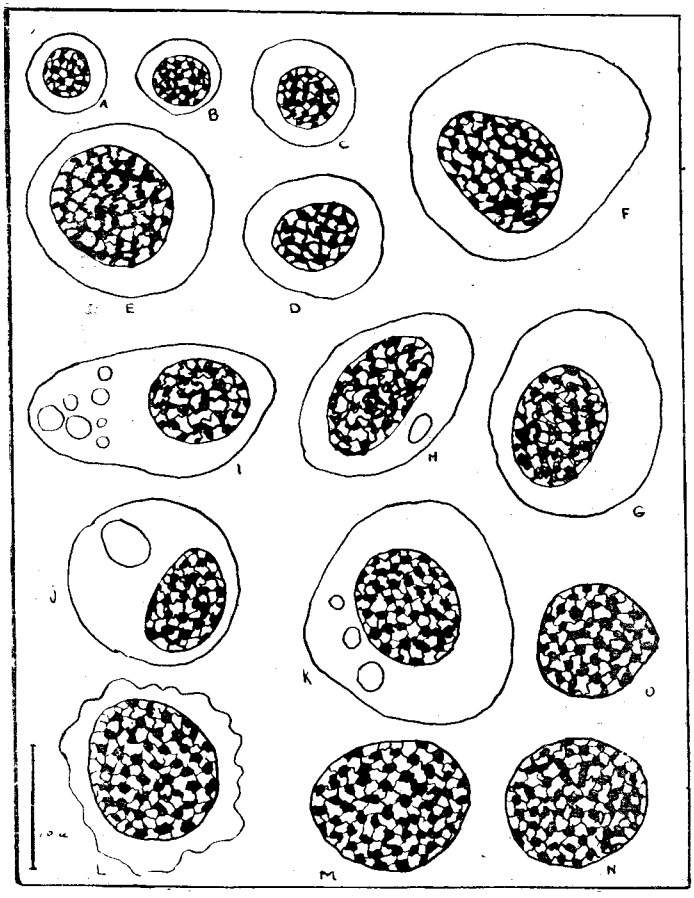

Fig. 1. Mother cells

A: *Platycleis escalerai* Bol., B: *Bradyporus dilatatus* (Stal.), C: *Acrotylus insubricus* (Scop.), D: *Aiolopus strepens* (Latr.), E: *Oedaleus decorus* Germ., F: *Oedipoda coerulescens* (L.), G: *Saga cappadocica* Wern. (E,F,G old mother cells), H: *Bradyporus dilatatus* (Stal.), I: *Glyphotmethis escherichi* (Kr.), J: *Saga cappadocica* Wern., K: *Oedipoda miniata* (Pall.) (H,I,J,K old cells with vacuoles, L: *Saga cappadocica* Wern., an old cell with a partly disappeared cytoplasm, M: *Metromerus coelesyriensis* (G.-T.), N: *Calliptamus barbarus* (Costa), O: *Tisoecetrinus pterostichus* F.W. (M,N,O naked nucleus).

disappears completely (Fig. 1 ; L) leaving a bare nucleus (Fig. 1 ; M,N,O).

2) Proleucocytes.

The proleucocytes issuing from the division of mother cells are either pear-or spindle-shaped (Pl. I ; Figs. 7a 8a and 9a). The long diameter of this spindle-form cells varies between 10—23 μ and the short diameter between 5—14 μ (Fig. 2). The

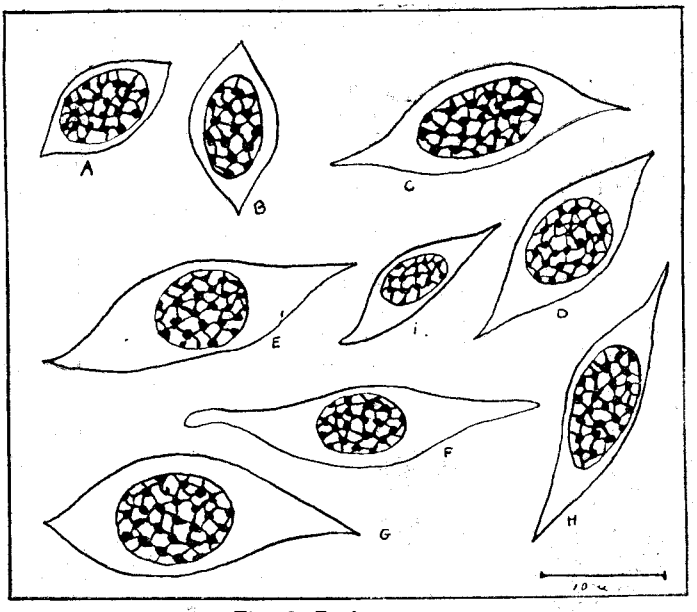

Fig. 2. Proleucocytes

A, B : *Calliptamus barbarus* (Costa.), C : *Oedipoda miniata* (Pall.), D : *Oedipoda schochii* Sauss., E : *Platycleis escalerai* Bol., F : *Calliptamus italicus* L., G : *Dociostaurus brevicollis* (Ev.), H : *Aiolopus strepens* (Latr.), I. *Glyphotmethis escherichi* (Kr.).

mean lenght obtained for the long diameter is 18.52 μ and for the short 7.85 μ (Table I). The cytoplasm appears homogeneous and without vacuoles.

These cells are never observed multiplying. By growing up they form directly phagocytes or granular leucocytes. The proleucocytes may, therefore be considered as an intermadiate form between the mother cells and phagocytes or granular leucocytes.

3) Phagocytes and 4) Granular leucocytes.

Both cells are spindle-formed and do not differ morpho-

logically from each other (Fig. 3—4). Their long diameter varies between 24—49 μ, and the short 7—20 μ. The mean length for the long diameter is 36.12 μ and for the short 10.84 μ (Table I).

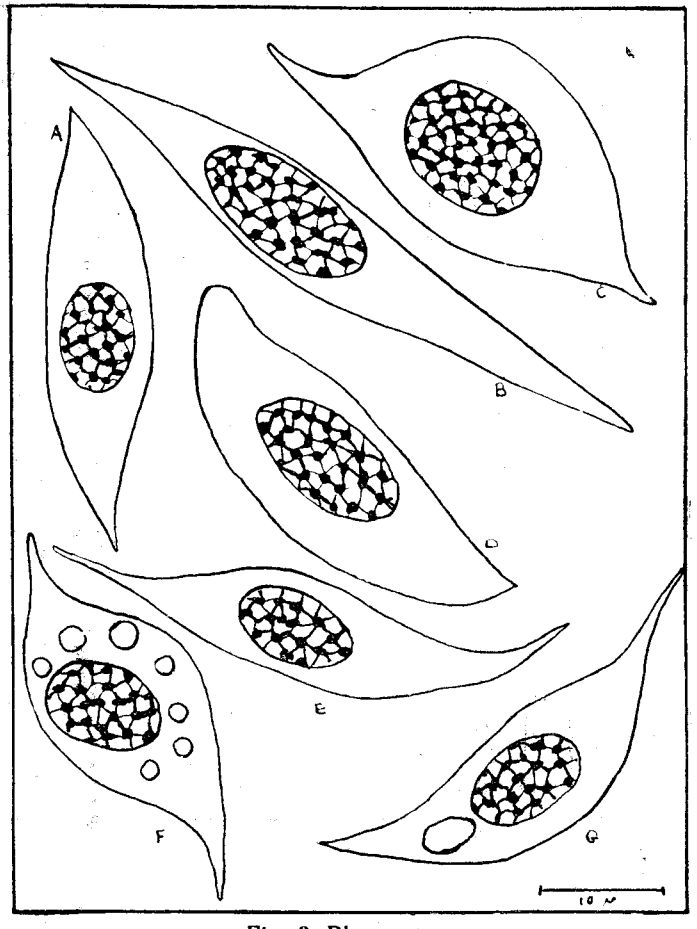

Fig. 3. Phagocytes

A : *Metromerus coelesyriensis* (G.-T.), B : *Calliptamus barbarus* (Costa.), C : *Oedipoda coerulescens* (L.), D : *Acrida anatolica* Dirsh., E, G : *Glyphotmethis escherichi* (Kr.), F : *Saga coppadocica* Wern. (F, G with vacuoles).

The cells contain an abundant quantity of cytoplasm which is sometimes vacuolated.

When stained with May-Grünwald-Giemsa, one can see that some of these cells are granular and the others non-granular. Big granules cover a large part of the cytoplasm in granular

cells. They are stained reddish-violet (Fig. 4). It will be seen below that the non-granular cells have a phagocytic power, whereas the others have not. The name phagocyte is, therefore,

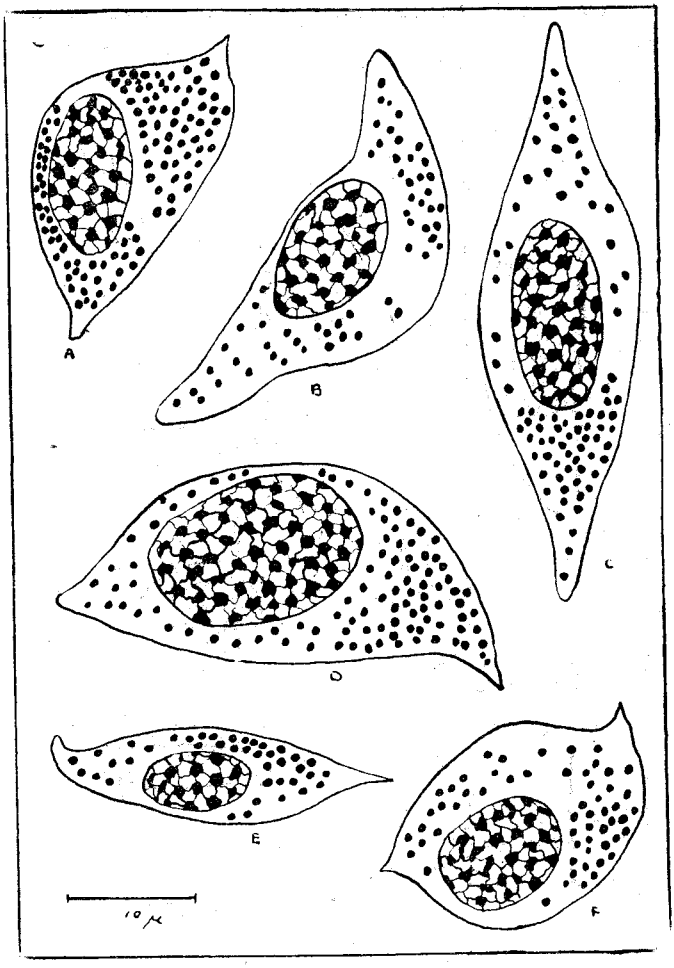

Fig. 4. Granular leucocytes

A : *Calliptamus tenuicersis* Tarb., B : *Acrida anatolica* Dirsh., C : *Oedipoda coerulescens* (L.), D : *Calliptamus barbarus* (Costa.), E : *Platycleis escalerai* Bol., F : *Oedaleus decorus* Germ.

adopted in this paper for the first ones and granular leucocytes for the second ones as was proposed by Mathur and Soni [11].

The phagocytes and the granular leucocytes were never observed dividing mitotically. But some aspects of the division

in these cells leave no doubt that an amitotic multiplication may occur in some of the phagocytes and probably granular leucocytes (Fig. 5): The nucleus first divides into two parts, then the cytoplasm stretches out producing two new spindle-form cells. The last phase of this division closely resembles that

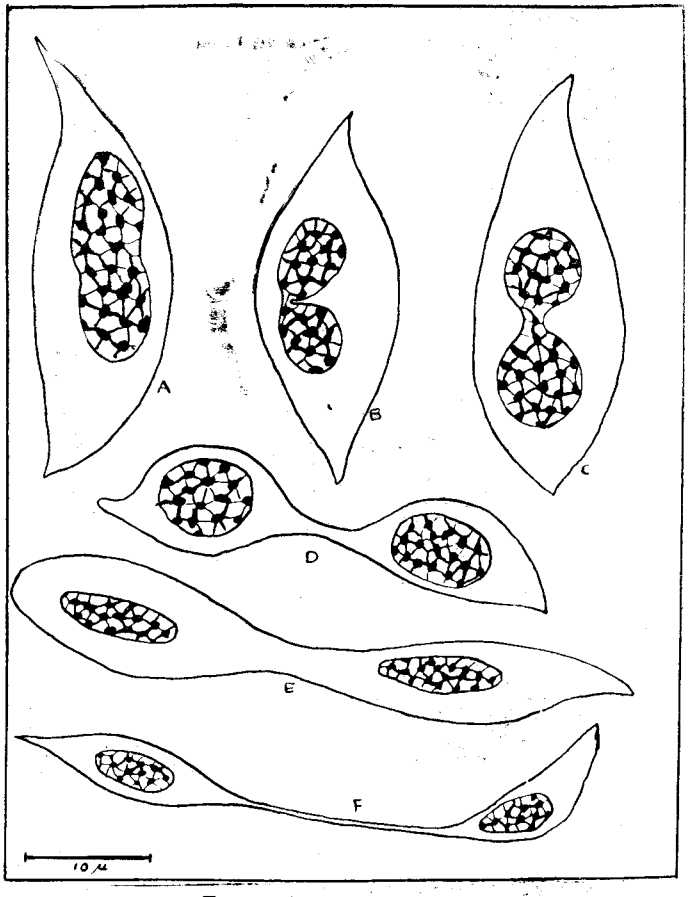

Fig. 5. Amitotic division

A, B: *Oedipoda miniata* (Pall.), C: *Metromerus coelesyriensis* (G.—T.), D: *Calliptamus barbarus* (Costa.), E: *Thisoecetrinus pterostichus* F.W., F: *Bradyporus dilatatus* (Stal).

of a mitotic multiplication in a mother cell producing two proleucocytes (Fig. 5; F). But during the amitotic division of phagocytes or granular leucocytes the nucleus is always quiescent and its membrane never disappears, whereas in dividing

mother cells the chromosomes may be sometimes distinguished even after the new cells are separated from each other and the nucleus membrane not yet formed (Pl. 1; Fig. 9). Direct division was observed in eight species.

In some of the studied species the nucleus is sometimes seen

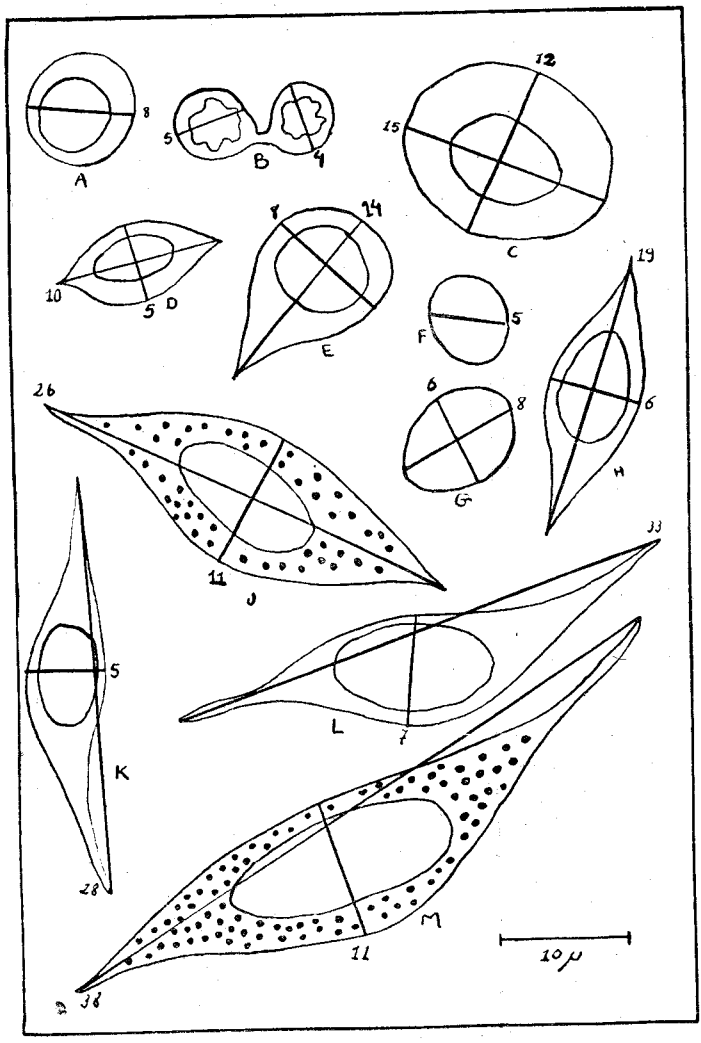

Fig. 6. Diameters of haemocytes

A, C: Mother cell, B: Mitotic division in mother cell, D, H: Proleucocytes, E: A newly shaped proleucocyte, G, F: Naked nucleus, J, M: Granular leucocytes, K,L: Phagocytes.

to be lobate. A lobate nucleus may be formed by a simple and a temporary fragmentation. But it is probable that some of these nuclei may represent the beginning of an amitotic division.

The oenocytoids which are present in other groups of insects with an uniform acidophil cytoplasm were not observed in the investigated species. The Fig. 6 represents the diameters of haemocytes and the Pl. II the various types of blood-cells.

b) Phagocytosis.

The phagocytic power of the blood-cells was studied on the following species: *Acrida anatolica*, *Oedipoda miniata*, *Oedaleus decorus* and *Calliptamus barbarus pallidipes*. The phagocytosis depends on the size of the injected particles.

The particles of neutral red, which are the biggest of the dyes used, were ingested in few numbers. The mother cells may take up to 10-12 particles (Fig. 7). The particles of the indian ink, which are the smallest of the dyes injected, fill nearly all the cytoplasm covering even the nucleus (Fig. 8). Finally the particles of carmine and methylene blue which have an intermediate size between neutral red and indian ink, were taken up moderatly. The mother cells may ingest several particles of carmine (Fig. 9 and 10).

The ingested particles were usually seen around and on the nucleus.

The mother cells appear to be the most active phagocytes. The proleucocytes and phagocytes have also a good phagocytic power. But the granular leucocytes, which do not differ morphologically from the phagocytes — except the presence of granules in their cytoplasm — are not capable of taking up the injected particles.

II.— Blood-cell counts.

The blood corpuscles were counted on 1181 specimens belonging to eighteen species. As the different nymphal stages could not be studied separately in all these species the results were, therefore, assembled under three rubrics: (i) Nymphs (except for the last nymphal stage), (ii) preadults and (iii) adults. The nymphs and preadults, ranging from one to fourty specimens for each species, were investigated. Twenty adult males and females for each species were examined.

The mean and maximal and minimal values of total cell counts in a cubic millimetre are given in Table II, III, IV.

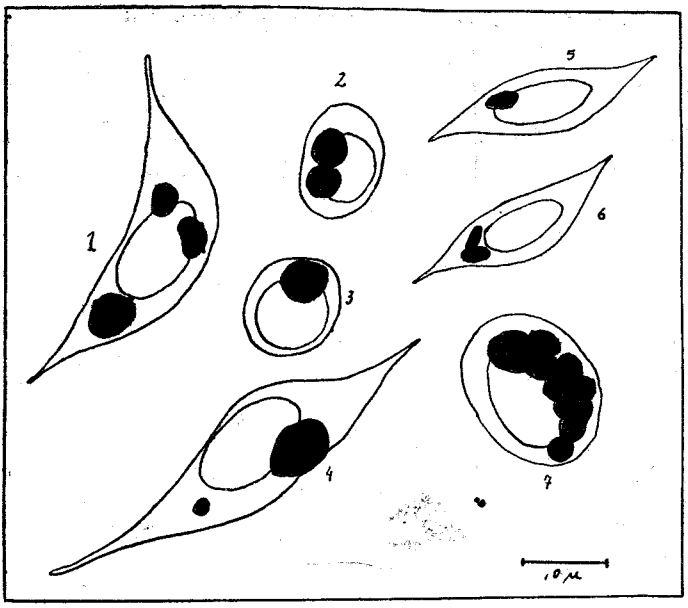

Fig. 7. Ingested particles of neutral red in mother cell (2,3,7), proleucocytes (5,6), phagocytes (1,4).
1,2,3: *Acrida anatolica* Dirsh. (after 24 hours), 4: *Calliptamus barbarus pallidipes* Chopard. (after 48 hours), 5,6,7: *Oedaleus decorus* Gern. (after 24 hours)

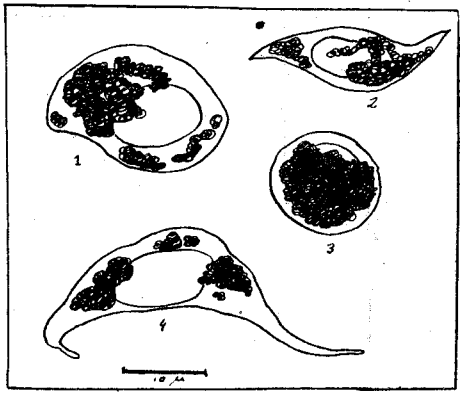

Fig. 8. Ingested particles of indian ink in mother cell (1,3) proleucocytes (2), and phagocytes (4).
1,2: *Oedipoda miniata* (Pall.) (after 24 hours), 3: *Calliptamus barbarus pallidipes* Chopard. (after 24 hours), 4: *Oedaleus decorus* Gern. (after 24 hours)

1) Range of variation in individual counts.

The number of circulating blood-cells may vary enormously in the nymphs of the same stage and adults belonging to the same species. The highest variation was obtained in *Calliptamus barbarus* (3000—32500, nearly 1/11). The lowest variation was

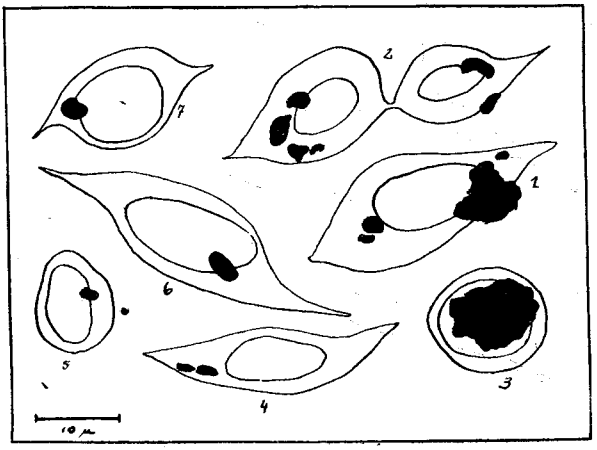

Fig. 9. Ingested particles of carmine in mother cell (3,5), proleucocytes (4,7) and phagocytes (1,2,6).
1, 2: *Oedipoda miniata* (Pall.) (after 24 hours), 3,4,5: *Calliptamus barbarus pallidipes* Chopard. (after 36 hours), 6,7: *Oedaleus decorus* Germ, (after 36 hours).

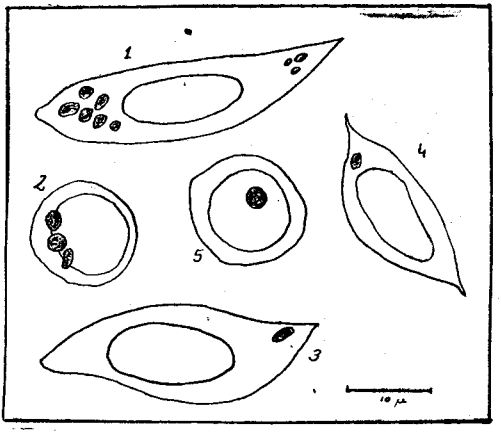

Fig. 10. Ingested particles of methylene blue in mother cell (2,5), proleucocytes (4), and phagocytes (1, 3).
1, 2: *Oedipoda miniata* (Pall.) (after 24 hours), 3,4,5: *Calliptamus barbarus pallidipes* Chopard. (after 36 hours).

found in *Saga* (7500—26250, between 1/3 and 1/4, Table IV). This variation is due, as is generally accepted, to the fact that the circulating corpuscles may adhere to the walls of the dorsal vessel or body cavity.

2) The range of variation in the number of haemocytes during growth.

The Tables II, III, IV show that the number of haemocytes varies during growth in the same species. But this variation seems not to be constant. The number of corpuscles per cubic millimetre may either increase (*Decticus*) or decrease (*Oedipada miniata*) as the nymph grows up. It must be, however, noted that in the majority of species becoming adult early in summer the adult possess more blood-cells than the nymphs (*Platycleis, Decticus, Bradyporus* and *Pyrgodera*), whereas in the species growing up late in summer and early in autumn the adults have less haemocytes than the nymphs (*Acrida, Oedipoda miniata, Oe. coerulescens, Calliptamus barbarus pallidipes* and *C. barbarus*).

3) The number of haemocytes in relation to the sex.

In the majority of the studied species, the number of blood-cells was found slightly higher in the female nymphs and adults than in the male individuals. However this is not constant. In four species (*Saga, Decticus, Bradyporus* and *Glyphotmethis*), the male nymphs and adults had more haemocytes than the female insects (Tables II, III, IV).

4) Percentage of haemocytes.

The ratio of three types of blood-cells[1], which are described above, was effected on eighteen adult species, and then the percentage was calculated. The results are given in Table V. This table shows that the percentage of three types of haemocytes is rather constant in all studied species. The mother cells have the lowest percentage. The proleucocytes have a percentage lying between those of mother cells and phagocytes + granular leucocytes, but always nearer to the first ones. Finally, the phagocytes and the granular leucocytes together possess the highest percentage.

Table V summarizes the results obtained in eighteen species.

[1] The phagocytes and the granular leucocytes were counted without discrimination during these experiments.

The percentage of mother cells is 17 %, the proleucocytes 28 %, the phagocytes and the granular leucocytes together 55 %.

5) Percentage of dividing mother cells.

The percentage of dividing mother cells was studied to see whether the increase in the number of blood-cells during growth may be fulfilled by mitosis. This percentage was investigated by examining 6176 mother cells in nine nymphs belonging to three different species. The percentage of dividing cells was always very low, varying between % 0.2 — % 0.6 (Table VI).

Discussion and conclusions

As it was emphasized at the beginning, the purpose of the present paper is to study the blood-cells of Orthoptera in a large number of species.

Types of blood-cells: The four types of haemocytes, which are described in twenty-two species, coincide with the types adopted by Mathur and Soni in *Schistocerca* [11].

The blood-cells of Orthoptera are classified differently by different authors. A synonymy of these classifications is given in Table VII.

The observation that the cytoplasm of an old mother cell generally disappears leaving a naked nucleus, agrees with that of the two authors mentioned above. A large number of naked nuclei were also observed by Millara in *Acrida* [18].

Multiplication of blood-cells: Our observation that the first type of blood-cells divide mitotically confirms the findings of many previous authors. The divided mother cells produce either new mother cells or proleucocytes.

The other types of haemocytes, namely the proleucocytes, the phagocytes and the granular leucocytes were never seen dividing mitotically. This confirms the observation of previous authors. [10, 14, 15, 19].

A direct cell division was first observed by Cuénot in some phagocytes of *Grillus* [5]. Vosseler only once saw an amitotic division in *Eugaster* [21]. According to Berlese the blood-cells multiply mitotically in young insect larvae and by amitosis subsequently [4]. But Mathur and Soni working on *Schistocerca* [11] were not able to observe an amitotic division.

The observations made in eight species in the present paper leave no doubt that a direct division occurs sometimes in the phagocytes and probably granular leucocytes of these species.

The sizes found for the haemocytes (mother cells 8—12 μ, proleucocytes 18 μ and phagocytes and granular leucocytes 40 μ) agree with those of Mathur and Soni in *Schistocerca* [11].

All the blood-cells were found to have a strong basophil cytoplasm staining dark blue with May-Grünwald-Giemsa. Only the inclusions of the granular leucocytes dye reddish-violet with the same stain. Blood-cells with an acidophil cytoplasm, as the oenocytoids of the other groups of insects, were not found in any of the studied species. These results agree with those of Mathur and Soni [11] and other authors.

Phagocytosis: The phagocytic power, which is studied in four species, exists in all blood-cells except in the granular leucocytes. The mother cells seem to be the most active in taking up the injected particles. Our results confirm those of Rooseboom in *Carausius*, who observed a phagocytosis in all haemocytes except the granular leucocytes [15]. Ermin, who investigated *Periplaneta* saw a phagocytic power in all blood-cells [6]. But this author did not make a discrimination between the phagocytes and the granular leucocytes. The results of other authors concerning the phagocytosis are given in Table VII.

Blood-cell counts: A large range of variation in individual cell counts was already observed in Orthoptera, as in other groups of insects, by previous authors [11,17,18,21]. These fluctuations were considered, by these authors, to be in connection with the ecdysis and oviposition periods. Moreover the corpuscles may attach themselves to the wall of the vessels and cease to circulate as in the wings of the cockroach [22]. It was established, however, by the authors mentioned above, that the numbers of haemocytes increase as the nymph grows up. The average for adults is higher than for the nymphs.

The present author's counts (1181 counts), which were carried out on newly collected nymphs, preadults and adults of eighteen species, showed great changes in the number of haemocytes: The number of blood-cells per cubic millimetre may either increase or decrease during growth according to the species. In the species becoming adult early in summer, the adults possess

more blood-cells than the nymphs. Whereas for those growing up late in summer and early in autumn, the adults have less haemocytes than the nymphs. As a species was always collected at the same locality the higher or lower numbers might be due to the environmental conditions. According to Haber the blood volume diminishes in the specimens of *Blatella* if they are fed with dry food in a dry habitat; well fed individuals, on the other hand, contain more blood and bleed easily[8]. According to Mellanby the blood has water-storing powers [12].

In fact it was observed by the present author that the nymphs of the species feeding in spring had a less viscous blood than the adults living early in summer. On the contrary the nymphs of the species rearing late in summer had rather viscous blood. These variations in volume probably bring about changes in the concentration of corpuscles by concentrating or diluting the blood. It may be concluded from these counts that the number of haemocytes in a nymph or adult is closely related to the water content of these individuals.

Percentages of haemocytes: The study of the percentages of three types of haemocytes (mother cells, proleucocytes and phagocytes + granular leucocytes) indicates that the ratio of the blood-cells is very constant in the studied eighteen adult species, although they have very different total cell counts as is mentioned above. This suggests that either the evolution of the haemocytes from mother cells toward granular leucocytes follows strictly the same principle in all species, or the different kinds of blood-cells are formed in a constant ratio within a leucopoietic organ, which was recently found in some Lepidoptera and Diptera [2,3].

The fact that the percentage of the dividing mother cells is very low (% 0.2 — % 0.6) indicates that this process alone cannot explain the increase of the number of blood-cells. It is highly probable that a leucopoietic organ intervenes during a rapid increase of the cells.

Summary

1 — The types of blood-cells, their pagocytic power and their counts are studied in Orthoptera.

2 — Observsations are made on twenty-two species for the classification of blood-cells. They are divided into four groups: a) Mother cells, b) Proleucocytes c) Phagocytes and d) Granular leucocytes. All these cells have a basophil cytoplasm.

3 — The mother cells divide mitotically giving either new mother cells or proleucocytes. The grown up proleucocytes are transformed directly into phagocytes and granular leucocytes.

4 — A direct division of the phagocytes and probably granular leucocytes is observed in eight species.

5 — Phagocytosis is investigated on four species. Execpt for granular leucocytes, all the blood-cells may take up the injected particles. The mother cells seem to be the most active phagocytes.

6 — 1181 total blood-cell counts were effected on eighteen species. There is a considerable variation in the number of haemocytes.

7 — This variation is probably related to the blood volume of the insect. In the species becoming adult early in summer the adult possesses more blood-cells than the nymphs. Whereas for those growing up late in summer and early in autumn, the situation is reversed.

8 — The number of blood-cells is slightly higher in the majority of the female nymphs and adults than in the males.

9 — The percentage of the types of blood-cells is very constant. The percentage of mother cells is 17 %, the proleucocytes 28 %, the phagocytes and the granular leucocytes 55 %.

10 — The percentage of the dividing mother cells varies between 0.2 % and 0.6 %.

Acknowledgments

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TABLE I.

Diameters of the blood-cells. Ten haemocytes are mesured for each type of cells

Species	Mother cells		Proleucocytes		Phagocytes and granular leucocytes	
	Short Diameter	Long Diameter	Short Diameter	Long Diameter	Short Diameter	Long Diameter
Acrida anatolica Dirsh.	11.1	11.9	7.6	18.3	10.2	36.3
Acrotylus insubricus (Scop.)	13.5	14.2	6.6	17.9	10.0	34.9
Aiolopus strepens (Latr.)	9.1	11.3	7.7	18.4	10.8	34.8
Bradyporus dilatatus (Stal.)	10.8	11.8	7.5	18.0	10.7	34.3
Calliptamus barbarus (Costa.)	11.7	12.9	8.2	18.0	11.7	35.8
Calliptamus italicus L.	11.3	12.3	8.7	18.3	12 5	34.3
Calliptamus tenuicersis Tarb.	12 5	14.6	8.9	18 0	11.6	34.7
Decticus verrucivorus L.	11.3	12.6	8 1	18.4	10.5	36 8
Dociostaurus brevicollis (Ev.)	11.6	12.6	7.3	18.2	9.5	32.9
Glyphotmethis escherichi (Kr.)	9.4	11.2	6.4	17.7	9.3	34.3
Glyphotmethis heldereichi(Br.-W.)	11.2	12.1	7.5	17.6	10.4	35.6
Isophya nervosa Ramme.	12.2	12.4	8 0	16.6	11.9	34.9
Metromerus coelesyriensis (G.-T.)	11.8	12.6	8.5	17.0	10.9	37.9
Oedaleus decorus Germ.	10.6	12 5	9.2	18 0	12.3	34.7
Oedipoda coerulescens (L.)	12.7	15.2	8.3	17.7	13.4	35.7
Oedipoda miniata (Pall.)	11.8	12.7	7.2	17.4	11.2	36.6
Oedipoda schochii Sauss.	11.3	12.0	7.7	16.2	10.1	36.3
Platycleis escalerai Bol.	9 8	11.7	7.9	17.9	10.5	33.7
Poecilimon uvarovi Ramme.	9.2	10.1	6.6	15.5	10.1	32.1
Pyrgodera armata F. W.	10.9	12.0	8 1	18.4	10.0	35.9
Saga cappadocica Wern.	8.8	10.4	6.0	17.5	10.3	35 7
Tisoecetrinus pterostichus F. W.	10.1	11.4	10.7	20.2	10.4	34.6
Lowest and highest values for diameter	5—23	5—28	5—14	10—23	7—20	24—49
Average for diameters	10.94	12.29	7.85	18.52	10.84	36.12

TABLE II.

Total cell counts in the nymphs.
(The cell counts of the last nymphal stage are given in Table III)

Species	NYMPHS					
	Individuals used (♀)	Average for ♀	Individuals used (♂)	Average for ♂	Average for both sexes	Lowest and highest number of haemocytes
Acrida anatolica Dirsh.	20	16575	20	16262	16418	7500—49000
Bradyporus dilatatus (Stal.)	6	11503	7	12928	12215	6000—28750
Calliptamus barbarus pallidipes Chopard.	20	15040	20	9885	12462	2000—27000
Decticus verrucivorus L.	1	14500	2	22750	18625	13500—32000
Oedaleus decorus Germ.	20	16237	20	13160	14698	4000—34000
Oedipoda miniata (Pall.)	20	15950	20	14280	15115	7000—24500
Platycleis escalerai Bol.	1	12500	3	11833	12166	11500—12500
Poecilimon uvarovi Ramme.	20	22737	20	18362	20549	7500—49000
Saga cappadocica Wern.	4	16750	3	17633	17191	14000—22000
Average for studied species		15755		15232	15493	

TABLE III.

Total cell counts in the preadults.

Species	PREADULTS					
	Individuals used (♀)	Average for ♀	Individuals used (♂)	Average for ♂	Average for both sexes	Lowest and highest number of haemocytes
Acrida anatolica Dirsh.	20	16807	20	14612	15709	4500—36000
Bradyporus dilatatus (Stal.)	1	17500			17500	
Calliptamus barbarus (Costa.)	1	13000			13000	
Calliptamus barbarus pallidipes Chopard.	20	13360	20	13300	13330	4000—22000
Decticus verrucivorus L.	6	20000	2	23000	21500	8750—31500
Oedaleus decorus Germ.	20	15490	20	13628	14559	5500—28000
Oedipoda coerulescens (L.)	7	16877	3	15666	16271	7500—24000
Oedipoda miniata (Pall.)	20	10888	20	10062	10475	6000—20000
Platycleis escalerai Bol.	7	21000	7	17928	19464	4750—36000
Poecilimon uvarovi Ramme.	20	24487	20	16931	20709	4500—50000
Pyrgodera armata F. W.	3	9500	1	9000	9250	8000—12500
Saga cappadocica Wern.	5	13050	8	13187	13118	6500—19250
Average for studied species		15996		14731	15363	

TABLE IV.

Total cell counts in the adults.

Species	ADULTS					
	Individuals used (♀)	Average for ♀	Individuals used (♂)	Average for ♂	Average for both sexes	Lowest and highest number of haemocytes
Acrida anatolica Dirsh.	20	12187	20	9752	10969	3000—23000
Bradyporus dilatatus (Stal.)	20	18805	20	18975	18940	10250—50000
Calliptamus barbarus (Costa.)	20	11335	20	10452	10893	3000—32500
Calliptamus barbarus pallidipes Chopard.	20	7950	20	7700	7825	2250—18000
Caliptamus tenuicercis Tarb.	20	10197	20	10115	10156	3000—28250
Decticus verrucivorus L.	20	24625	20	28062	26343	7000—62500
Dociostaurus brevicollis (Ev.)	20	14630	20	13800	14215	5500—40500
Dociostaurus hauensteini (Bol.)	20	9755	20	8527	9141	3500—22500
Glyphotmethis escherichi (Kr.)	20	8397	20	8726	8561	2500—17000
Isophya nervosa Ramme.	20	15002	20	14715	14858	7000—28000
Metromerus coelesyriensis (G.-T.)	20	11175	20	9232	10203	3000—24000
Oedaleus decorus Germ.	20	9812	20	8650	9231	4000—2.000
Oedipoda coerulescens (L.)	20	8662	20	7587	8124	3000—17500
Oedipoda miniata (Pall.)	20	9330	20	8120	8725	3000—18000
Platycleis escalerai Bol.	20	24917	20	22600	23758	7000—63000
Poecilimon uvarovi Ramme.	20	16916	20	16462	16689	6500—39500
Pyrgodera armata F. W.	20	19530	20	16220	17875	4050—37000
Saga cappadocica Wern.	13	15050	12	15625	15337	7500—26250
Average for studies species		15098		14621	14859	

TABLE V.

Percentage of the types of blood-cells in adults. They are obtained by cointing five hundred cells for each species.

Species	Mother cells	Proleuco-cytes	Phagocytes and granular leucocytes
Acrida anatolica Dirsh.	18	26	56
Bradyporus dilatatus (Stal.)	15	29	56
Calliptamus barbarus (Costa.)	19	29	52
Calliptamus barbarus pallidipes Chopard.	16	29	55
Calliptamus tenuicersis Tarb.	16	29	55
Decticus verrucivorus L.	15	31	54
Dociostaurus brevicollis (Ev.)	21	26	53
Glyphotmethis escherichi (Kr.)	21	29	50
Isophya nervosa Ramme.	18	26	56
Metromerus coelesgriensis (G.-T.)	18	30	52
Oedaleus decorus Germ.	16	24	60
Oedipoda coerulescens (L.)	18	29	53
Oedipoda miniata (Pall.)	16	26	58
Oedipoda schochii Sauss.	19	28	53
Platycleis escalerai Bol.	15	24	61
Poecilimon uvarovi Ramme.	18	30	52
Pyrgodera armata F. W.	16	29	55
Saga cappadocica Wern.	17	28	55
Average for studies species	17	28	55

TABLE VI.

Ratio for mitotic division.

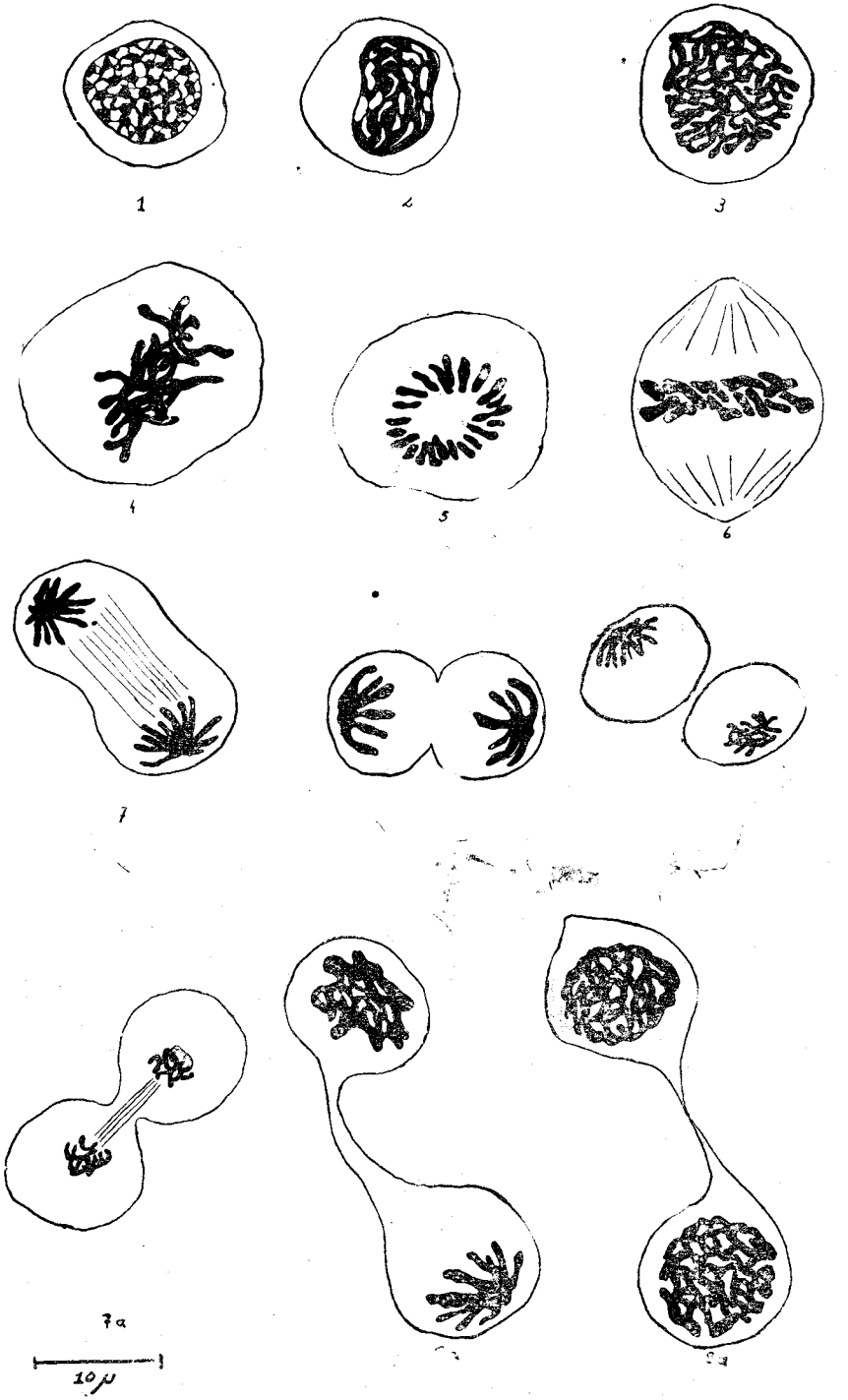
Species	Number of mother cells counted	Mother cells in mitosis	Ratio for %
♀ *Acrida anatolica Dirsh.*	602	2	‰ 6
♀ „ „	575	1	‰ 3
♀ „ „	826	2	‰ 2
♂ *Calliptamus tenuicersis* Tarb.	1054	3	‰ 3
♂ „ „	678	3	‰ 5
♀ „ „	348	2	‰ 6
♀ „ „	580	1	‰ 2
♀ „ „	556	2	‰ 4
♀ *Oedaleas decorus* Germ.	957	2	‰ 2
Conversion of ratio for %	6176		‰ 2—‰ 6

TABLE VII.

Synonymy of haemocyte classifications in Orthoptera

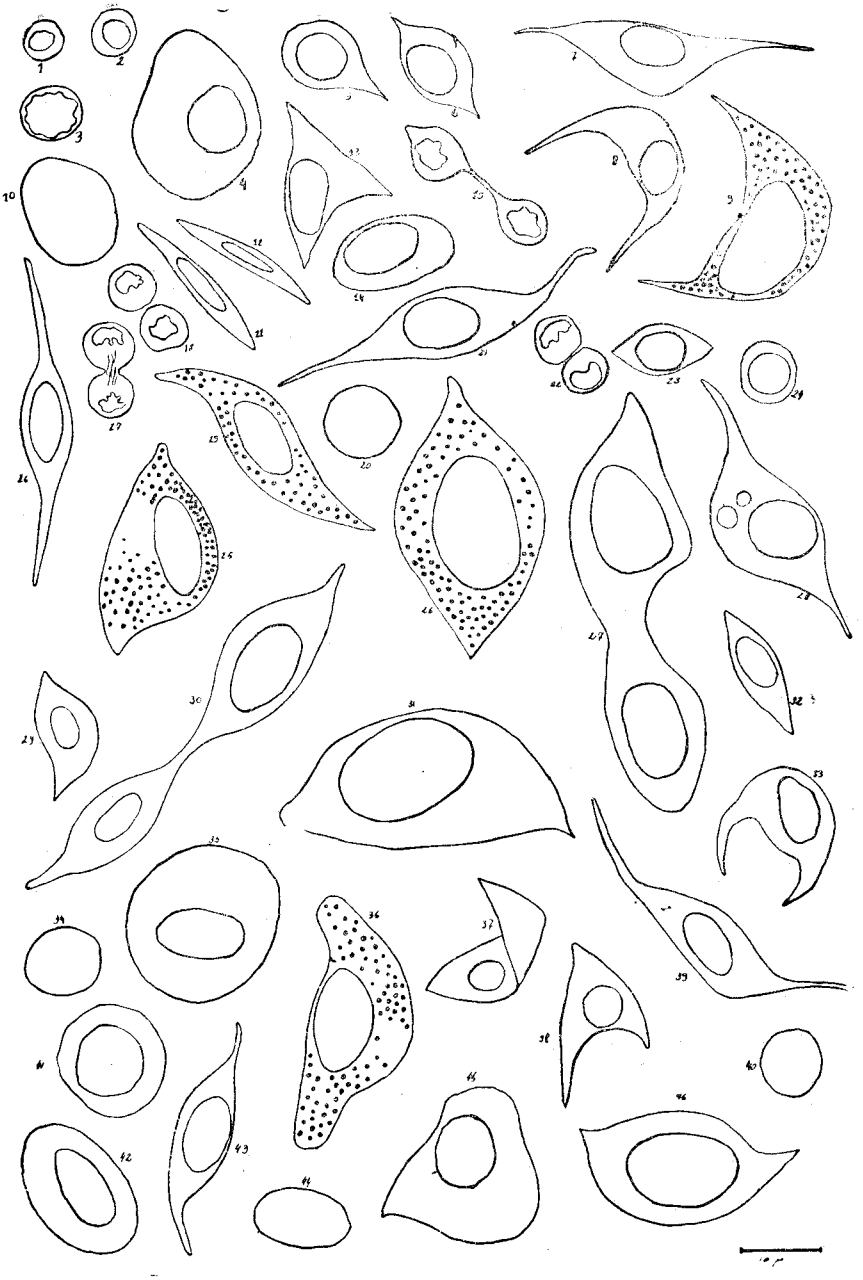
Authors	Studied species	Types of blood-cells				
Cuénot (1895)	*Grillus*	Germinative cells	—	Phagocytes *	Granular amybocytes	Degenariting cells
Hollande (1911)	*Grillus*	Proleucocytes	—	Phagocytes *	Granular leucocytes	—
Ermin (1936)	*Periplaneta*	Prolymphocytes *	Intermediate forms *	Large lymphocytes *		—
Mathur-Soni (1937)	*Schistocerca*	Mother cells	Proleucocytes	Phagocytes *	Granular leucocytes	—
Rooseboom (1937)	*Carausius*	Proleucocytes * Macronucleocytes *	—	Micronucleocytes *	Granular leucocytes	—
Lepesme (1938)	*Schistocerca, Locusta, Acridium, Phamphagus*	Macronucleocytes (Germinative cells)	—	Micronucleocytes * (Phagocytes)	Macronucleocytes (Germinative cells)	—
Millara (1947)	*Acrida*	Round cells	Young leucocytes	Spindle-formed * phagocytes	—	—
Ögel (1954)	Twenty two species	Mother cells *	Proleucocytes *	Phagocytes *	Granular leucocytes	—

* Cells endowed with a phagocytic power.



Mitotic division of the mother cell.

Fig. 1. Mother cell in rest, 2. Early prophase, 3. Late prophase, 4. Metaphase, 5. Anaphase (dorsal view), 6. Anaphase (lateral view), 7.—7a. Late anaphase, 8.—8a. Telophase, 9. Newly shaped mother cells, 9a. Newly shaped proleucocytes.



Various types of haemocytes in Ortoptera.

1, 2, 4, 14, 24, 35, 41, 42: Mother cells, 3: Early prophase, 17: Late anaphase, 15: Telophase, 18, 22: New mother cells, 5: A newly shaped proleucocytes, 6, 11, 12, 23, 29, 32: Proleucocytes, 9, 19, 25, 26, 36: Granular leucocytes, 7, 8, 13, 16, 21, 28, 31, 33, 37, 38, 39, 43, 45, 46. Phagocytes, 27, 30: Amitotic division.

36, *Acrida anatolica* Dirsh, 8, 9, 11, 12, 14, 15, 16· 39: *Bradyporus dilatatus* (Stal.), 5, 31, 40, 43: *Calliptamus barbarus* (Costa.). 10, 25, : *Calliptamus tenuicersis* Tarb., 44: *Dociostaurus brevicollis* (Ev.) 1, 2, 3, 7, 21, 22, 23, 28, 33, 37, 39, 45: *Glyphotmethis escherichi* (Kr.), 34; *Metromerus coelesyriensis* (G.-T.), 30: *Oedaleus decorus* Germ., 4, 19, 26, 27, 41: *Oedipoda coeralescens* (L.), 35, 42: *Oedipoda minita* (Pall.), 32, 46: *Oedipoda*