MEMOIRS OF THE COLLEGE OF SCIENCE, KYOTO IMPERIAL UNIVERSITY, SERIES B,
VOL. X, NO. 5, ART. 15, 1935

Studies on Reptilian Chromosomes
IV. Chromosomes of *Takydromus* spp. (Lizards)

By

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With 89 Text-figures

(Received October 10, 1934)

Of the members of the family Lacertidae, *Lacerta muralis, L. agilis, L. vivipara, L. viridis* and *Tropidosaurus algiris* have been studied by MATTHEY ('29, '31) as regards the chromosome-complex. His studies are confined to the chromosomes of males. Recently, OGUMA ('34) worked on both sexes of *L. vivipara*.

In the present study, male chromosome-complexes of three kinds of *Takydromus* are dealt with: *T. tachydromoides* (SCHLEGEL) from the vicinity of Kyoto, *T. formosanus* BOULENGER and *T. septentrionalis* GÜNTHER from Formosa. The preliminary accounts of the present study were published in 1928 and 1931 (a).

Material and method

The materials were obtained from individuals in breeding season, May and June. The spermatogenetic cycle in these lizards is somewhat different from that in *Eumeces latiscutatus* (NAKAMURA '30). An abundance of mitotic figures may be found in various stages of germ-cells in the testes during the breeding season.

For fixation of chromosomes, the modified CHAMPY'S solution concentrated 1.5 times as strong as the original formula, was employed. This fixative has been recommended for chromosomes of several other reptiles by MATTHEY ('31), KEENAN ('32) and NAKAMURA ('27–'32). In the present study also, it gave very satisfactory results in every case. The chromosomes are preserved with sharply defined outlines and there is no sign of the fusion which makes detailed observation difficult. In *T. tachydromoides*, however, the chromosomes are slightly more shrunken than in those of the other two species; but even such shrinkage does not impede observation. The materials were then treated in the usual way and the sections were stained with HEIDENHAIN's hæmatoxylin.

Observations

The chromosome-complexes of these three kinds of lizards are so much alike that it is hardly possible to distinguish the equatorial plates of the three species. So that they are described here all together.

Spermatogonium

In the prophase of either the primary or the secondary spermatogonia the ordinary process of condensation of chromosomes takes place. MATTHEY ('29) describes in *Lacerta* spp. a remarkable difference in the condensation process of certain chromosomes between the

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Explanation of Text-figures

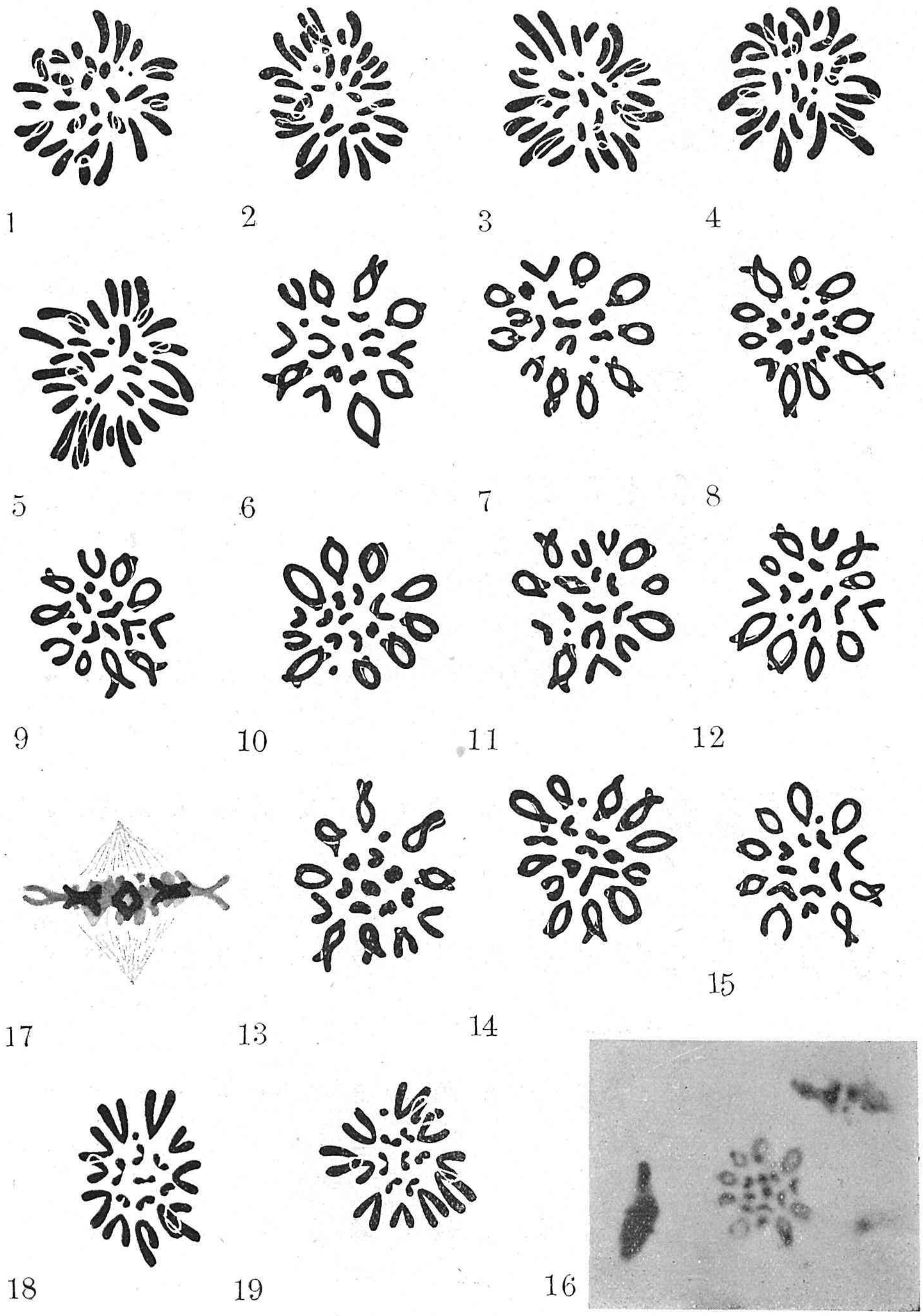
All figures are drawn with the aid of camera lucida, using Zeiss 1.5 mm. apochromatic oil-immersion objective and a K. 18 ocular, tube-length 16 cm., at a level about 25 mm. below the stage.

Text-figs. 1–33. Chromosomes of *T. septentrionalis*. 1–5, the chromosomes of the spermatogonia; 6–15, the tetrads of the first spermatocytes; 16, the photomicrograph of the tetrads shown in Text-fig. 15; 17, the side view of the equatorial plate of the first spermatocyte; 18 and 19, the daughter complexes of the first spermatocyte tetrads in the anaphase; 20–27, the dyads of the second spermatocytes; 28, the spermatogonial chromosomes, which are paired into the supposed synaptic mates (from Text-fig. 15); 29–32, the linear alignments of four sets of the tetrads (from Text-figs. 7, 8, 10 and 15); 33, the same of the dyads (from Text-fig. 25).

Text-fig. 34–70. Chromosomes of *T. formosanus*. 34–39, the chromosomes of the spermatogonia; 40–51, the tetrads of the first spermatocytes; 52 and 53, the daughter complexes of the first spermatocyte tetrads in the anaphase; 54–63, the dyads of the second spermatocytes; 64 and 65, the daughter complexes of the second spermatocyte dyads in the anaphase; 66, the spermatogonial chromosomes, which are paired into the supposed synaptic mates (from Text-fig. 38); 67–69, the linear alignments of four sets of the tetrads (from Text-figs. 42, 45 and 50); 70, the same of the dyads (from Text-fig. 58).

Text-figs. 71–89. Chromosomes of *T. tachydromoides*. 71–75, the chromosomes of the spermatogonia; 76–80, the tetrads of the first spermatocytes; 81–84, the dyads of the second spermatocytes; 85 and 86, the daughter complexes of the second spermatocyte dyads in the anaphase; 87, the spermatogonial chromosomes, which are paired up into the supposed synaptic mates (from Text-fig. 71); 88, the linear alignment of the tetrads (from Text-fig. 77); 89, the same of the dyads (from Text-fig. 82).

Text-figures. 1–19.



Text-figures. 20–33.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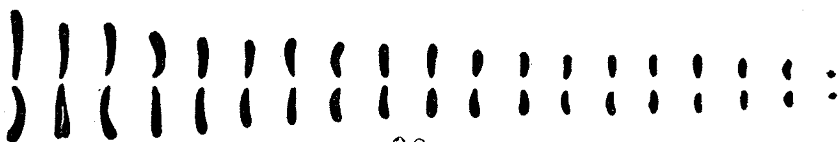
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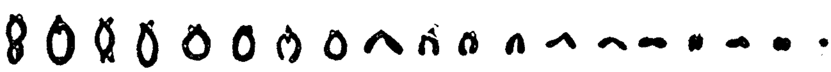
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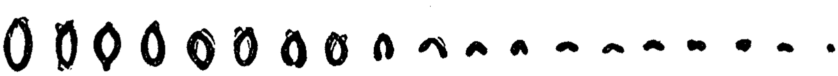
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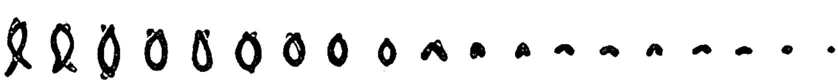
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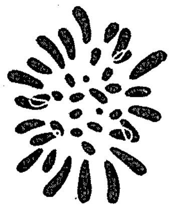
Text-figures 34–53.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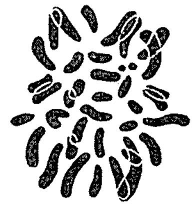
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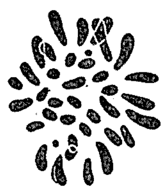
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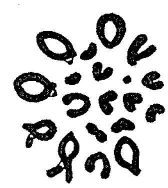
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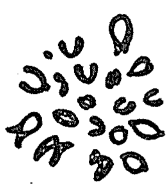
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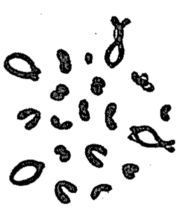
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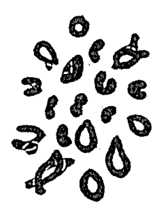
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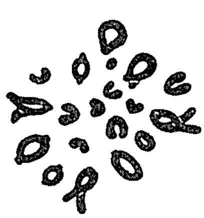
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Text-figures 54–70.


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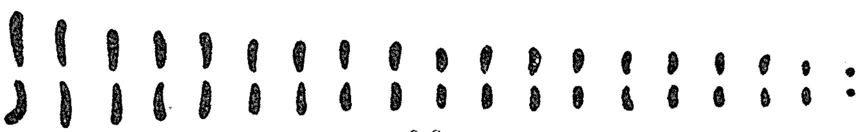
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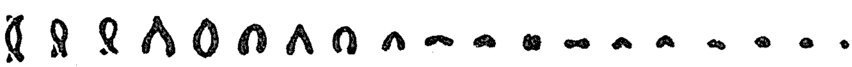
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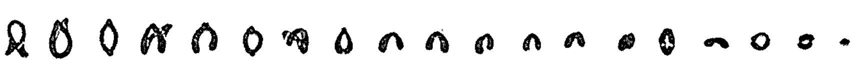
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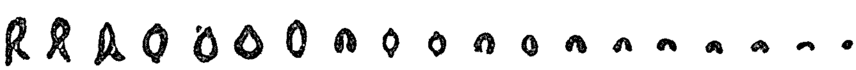
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Text-figures 71–89.


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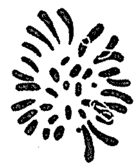
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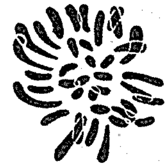
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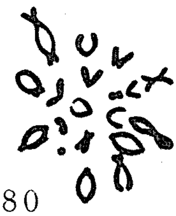
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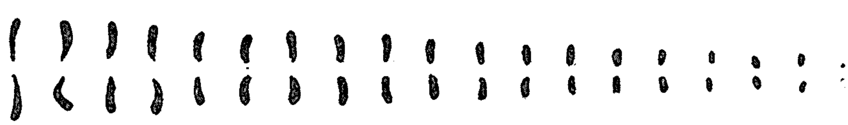
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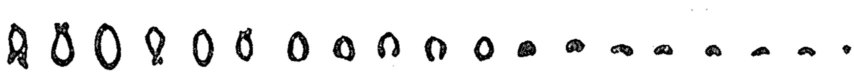
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primary and the secondary spermatogonia. In *Takydromus* spp., however, no such difference occurs, the primary spermatogonia being distinguished from the secondary only by the relative size of the nuclei.

In the metaphase 38 chromosomes appear in the equatorial plate (Text-figs. 1–5, *T. septentrionalis*; 34–39, *T. formosanus*; 71–75, *T. tachydromoides*). They consist of 36 chromosomes of various sizes and two minute dot-like chromosomes which are clearly distiguished from the rest by their small size and dot-like shape in the equatorial plate as well as in the prophase nucleus. The other 36 chromosomes have terminal spindle-fibre attachment and are of intergrading sizes, so that it is almost impossible to sort them into such categories as macro- and micro-chromosomes as we have done in some other lizards and snakes (MATTHEY, NAKAMURA, loc. cit. and PAINTER '21). Text-figs. 28, 67 and 88 are serial alignments of spermatogonial chromosomes of the three kinds of lizards according to their relative magnitudes. The synaptic mates cannot be assorted with accuracy and the pairing up of the chromosomes in these figures is merely a matter of approximation; but it is beyond doubt that there is no synaptic mate which is composed of heteromorphic members.

On the equatorial plane, the chromosomes lie with their points of fibre-attachment towards the centre; the comparatively large chromosomes are arranged in the periphery of the plate and the rest are scattered in the central area. Those in the periphery vary from 20 to 27 in number; the two dot-like ones are almost always in the central area.

First spermatocyte

The behavior of chromosomes during the growth period seems to be quite ordinary. The leptotene nucleus contains very fine threads besides nucleoli. As the nucleus increases in size, the threads become more distinct and oriented to one side of the nucleus. Then conjugation takes place. MATTHEY ('29) recognised in *Lacerta* a remarkable convergence of threads to one side of the nucleus in early prophase, but no such condition was found in my materials. When the pachytene stage is reached, the nucleus has grown to its maximum size and the threads have become thicker and lost their definite orientation. In these stages a deeply stained body, heart-shaped or bipartite, is found near the nuclear surface. I have found a body of similar appearance in the nuclei of the corresponding stages of some other reptiles and identified it as the karyosome.

But it is not very certain whether in this case it is a true karyosome or not. This body seems to remain through the later stages. Each pachytene thread breaks up into two fine threads twisted together. As the condensation takes place the threads assume the characteristic feature of tetrads.

In the metaphase 19 tetrads are scattered well apart in the equatorial plate. These tetrads are of various shape and size, being double or single rings with or without lateral prominence, horse-shoes, V's or heart-shaped; one is particularly minute (Text-figs. 6–16, *T. septentrionalis*; 40–51, *T. formosanus*; 76–80, *T. tachydromoides*). Text-figs. 29–32, 67–69 and 88 are eight sets of the tetrads arranged in series according to their sizes. The number of ring-tetrads varies from 7 to 9 in *T. septentrionalis*, from 4 to 10 in *T. formosanus* and from 7 to 12 in *T. tachydromoides*. We thus see that there is a tendency for larger tetrads to become ring-tetrads. Certain larger ring-tetrads have often long prominences, and the largest two may form double rings. On the equatorial plane the larger tetrads which are mostly rings, usually occupy the peripheral position and the smaller ones the central. The former are from 10 to 13 in number in all the species. Exceptionally the smallest dot-like tetrad takes a peripheral position together with the larger ones. Text-fig. 17 is the side view of the equatorial plate where all tetrads lie on one plane, there being no displacement of the tetrad.

In the anaphase each tetrad divides into two daughter V-shaped or bipartite halves which go to the poles simultaneously (Text-figs. 18 and 19, 52 and 53). Neither precession nor succession occurs in well preserved materials.

Second spermatocyte

In the second spermatocyte 19 dyads appear in the equatorial plate (Text-figs. 20–27, *T. septentrionalis*; 54–63, *T. formosanus*; 81–86, *T. tachydromoides*). Of these dyads one is clearly distinguishable from the rest by its dot-like form and small size. The others are V-shaped or bipartite dyads, each of which is composed of two rod-like monads united at the proximal end. These dyads are perpendicular to the equatorial plane and some of them appear as single rods in the polar views, one arm of the V overlying the other. In the equatorial plate most of the dyads come in the centre and 12 to 17 dyads form a circle. The smallest one is found in the periphery as in the proceeding division. All the dyads divide when the anaphase sets in and each spermatid receives 19 monads.

Remarks

As stated above the chromosome-complexes of the three species of *Takydromus* are identical with one another. They consist of 38 chromosomes, of which 18 pairs appear to have terminal spindle-fibre attachment and the remaining single pair are dot-like chromosomes. In the structure and arrangement of tetrads and dyads on the equatorial plates also, the three species show no difference. In other members of the family Lacertidae MATTHEY has found very similar chromosome-complexes in several species of *Lacerta* and *Tropidosaurus algiris*, so that such chromosome-complex seems to be of general occurrence in the lacertid lizards. It is rather remarkable, that OGUMA ('34) has found 36 chromosomes in *Lacerta vivipara*, whereas MATTHEY found 38 in the same species. Comparing the chromosome-complexes recorded in the papers of the two authors we find that the complex in OGUMA's material does not include a pair of dot-like chromosome which is very conspicuous in MATTHEY's material and other lacertid lizards. As regards the lacking of these minute chromosomes in OGUMA's material, he is of opinion that they have been obliterated as the lizard has been distributed from Europe to Saghalien.

In my previous studies I have called attention to the fact that the males of some snakes and lizards have isomorphic sex-chromosomes, which consist of short rod-like chromosomes of identical size and shape. I have also stated that the question whether these isomorphic sex-chromosomes are really homologous or not should be settled only after the female chromosomes are worked out. Recently, OGUMA ('34) studied the chromosome-complexes of both sexes of *Lacerta vivipara* and found that the female has one X-chromosome while the male has two X's. These X-chromosomes are, as I expected, short rod-like ones, which are the 10th pair in the serial alignment according to size. In the males of *Takydromus* spp. the chromosome-complex is very similar to that of *Lacerta* spp. and each chromosome seems to have a homologous mate, so that it is likely that the 10th pair represent the sex-chromosomes. This pair are short rod-like chromosomes as in *L. vivipara*. In other species of *Lacerta*, MATTHEY first asserted that a pair of small dot-like chromosomes should be XX pair; in later studies, however, he does not recognize the sex-chromosome at all. As these lizards have a generalized chromosome-complex for the lacertid lizards, one short rod-like pair in each chromosome-complex represents most probably the homologous pair of the sex-chromosomes.

The chromosome-complex of the three kinds of *Takydromus* may be formulated as $36+X+X=38$.

Basing his statement on extensive studies of saurian chromosomes, MATTHEY ('33) has given the basal number of chromosomes in reptiles as 48 and states that in the lacertid lizards certain 12 of the larger chromosomes correspond each to two chromosomes of the fundamental complex. Accordingly, the theoretical number of the lacertid chromosome-complex is 50, and *L. vivipara* studied by OGUMA has 48 chromosomes coinciding strictly with the basal number. MATTHEY's assumption seems to account for the diversities of chromosome-complexes found in reptiles, but in his work due consideration has not been given to the sex-chromosomes. The presence of sex-chromosomes in reptiles is shown in the excellent work by OGUMA on the male and female chromosome-complexes of *L. vivipara*. MATTHEY's assumption thus seems to need some modification. Let us take the chromosome-complex of *Eumeces latiscutatus* (NAKAMURA '31) and *Lacerta* for example. In *Eumeces*, the chromosomes may be sharply divided into 12 macro- and 14 micro-chromosomes; of these the 12 macro-chromosomes are V-shaped. In MATTHEY's assumption these 12 chromosomes correspond to certain 12 rod-like chromosomes of *Lacerta* or 24 chromosomes of the fundamental complex which are associated two by two at one end, while the remaining 12 rod-like chromosomes found in *Lacerta* represent 24 dot-like ones of the fundamental complex united in pairs. If a pair of the micro-chromosomes of the fundamental complex of the male are assumed to be the sex-chromosomes, they should form multiple sex-chromosomes in lacertid lizards, i. e. each is composed of one sex-chromosome and one autosome of the fundamental complex. Accordingly, the male chromosome-complex of *L. vivipara* studied by OGUMA should be formulated as $34A+XA+XA=36$, while in the female complex one X is missing and the formula should be given as $34A+XA+A=36$. As the female of this lizard has 35 chromosomes consisting of 34 autosomes and one X, this assumption is evidently incompatible with the fact. Or, if a pair of the macro-chromosomes are assumed to be the sex-chromosomes, a pair of the V-shaped macro-chromosomes in *Eumeces* should be expected to be multiple chromosomes. In *Eumeces*, however, I have recognized a pair of short rod-like chromosomes as the sex-chromosomes. Though my study furnished no evidence as to the female chromosome-complex, it seems probable that this lizard has sex-chromosomes similar to those of *Lacerta*, because the two lizards are closely related in their systematic position. Consequently, as far as these lizards are concerned, MATTHEY's view should be modified as follows ;—of the 38 chromosomes of the lacertid lizards 24 correspond to 24 of the fundamental complex, the two sex-chromosomes correspond to two of the latter, and 12 of the former to 22 of the latter, 20 chromosomes of the latter have fused two by two while two remain unfused. So the chromosome number in these lacertid lizards is to be given as 48.

Summary

1. The chromosome-complexes of the males of the three species of *Takydromus* are very much alike and are practically identical with those of other lacertid lizards.

2. The chromosomes are 38 in number, of which one pair is minute dot-like ones and the remaining 18 pairs are rod-like and of intergrading sizes.

3. A pair of the short rod-like chromosomes represent the sex-chromosomes. These consist of two X-chromosomes which are distributed through the mitotic divisions into the resulting spermatids. The males of these lizards are, accordingly, homogametic.

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