

Genetic discontinuity and evolutionary scenario among Neotropical and Old World swift species (Aves: Apodiformes: Apodidae)

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Abstract — The karyotypes of *Streptoprocne biscutata* and *Streptoprocne zonaris* were compared in order to understand the process of karyotype evolution in the family Apodidae in the Neotropical region. The comparisons revealed an extreme similarity between each other although some subtle differences could be also identified and some events that could have gave arise to such differences are purposed. In addition global karyotypical analyses were made involving all of Apodidae taxa with their karyotypes known until nowadays. A wide discussion is also made involving a purpose about the taxonomic status of an Old World Apodidae species and about an understanding concerning the evolutionary scenario of the karyotype through the evolutionary scale of some Apodidae clades.

Key words: Apodidae chromosomes, Apodidae evolution, Apodidae taxonomy, Avian cytogenetics, swifts.

INTRODUCTION

The order Apodiformes is poorly known by the cytogenetic view. Among 428 species known just 5 of them have their karyotypes described. In *Hirundapus caudacutus* the diploid number of 64 chromosomes with 12 macrochromosomes and 52 microchromosomes was observed and another species, *Apus pacificus* was characterized by present $2n=62$ (14 macrochromosomes and 48 microchromosomes – XIAOZHANG *et al.* 1988). *Apus affinis affinis* had its karyotype determined with $2n=\pm 70$ being 7 macrochromosome pairs and 28 microchromosome pairs (YADAV *et al.* 1995).

In the tropical region three species for the genus *Streptoprocne* are recognized: *S. semicolaris* (endemic from Mexico), *S. biscutata* and *S. zonaris* from South America. The karyotypes of South American species were described by Ribeiro *et al.* (2003) and were verified for *S. biscutata* $2n=64$ (18 macrochromosomes and 46 microchromosomes). In *Streptoprocne zonaris* it was verified the existence of a $2n=66$ (18 macrochromosomes and 48 microchromosomes).

Therefore, this paper focuses the understanding concerning the karyotype evolution inside the Neotropical Apodidae (*Streptoprocne biscutata* and *Streptoprocne zonaris*) and between these and the others Apodidae species with their karyotypes known until nowadays, considering that no approach such as the present study is available in the literature.

MATERIAL AND METHODS

The karyotypes of *Streptoprocne biscutata* and *Streptoprocne zonaris* from the Vila Velha Statewide Park, in the city of Ponta Grossa, state of Paraná, Brazil and previously described by Ribeiro *et al.* (2003) were compared.

Were also compared the karyotypes of *Hirundapus caudacutus*, *Apus pacificus* and *Apus affinis affinis* based on the descriptions made available by XIAOZHANG *et al.* (1988) and YADAV *et al.* (1995).

The relative lengths of the macrochromosomes were determined by the procedures described by LEVAN *et al.* (1964). The karyotypical ideograms were made respecting exactly the proportion of chromosomes from the plates published by XIAOZHANG *et al.* (1988), YADAV *et al.* (1995) and RIBEIRO *et al.* (2003). Indeed, the same were still partially modified from the original plates of *Hirundapus caudacutus*, *Apus pacificus* and *Apus affinis affinis* being considered more distinguishable acrocentric pairs (underlined – Figure 1).

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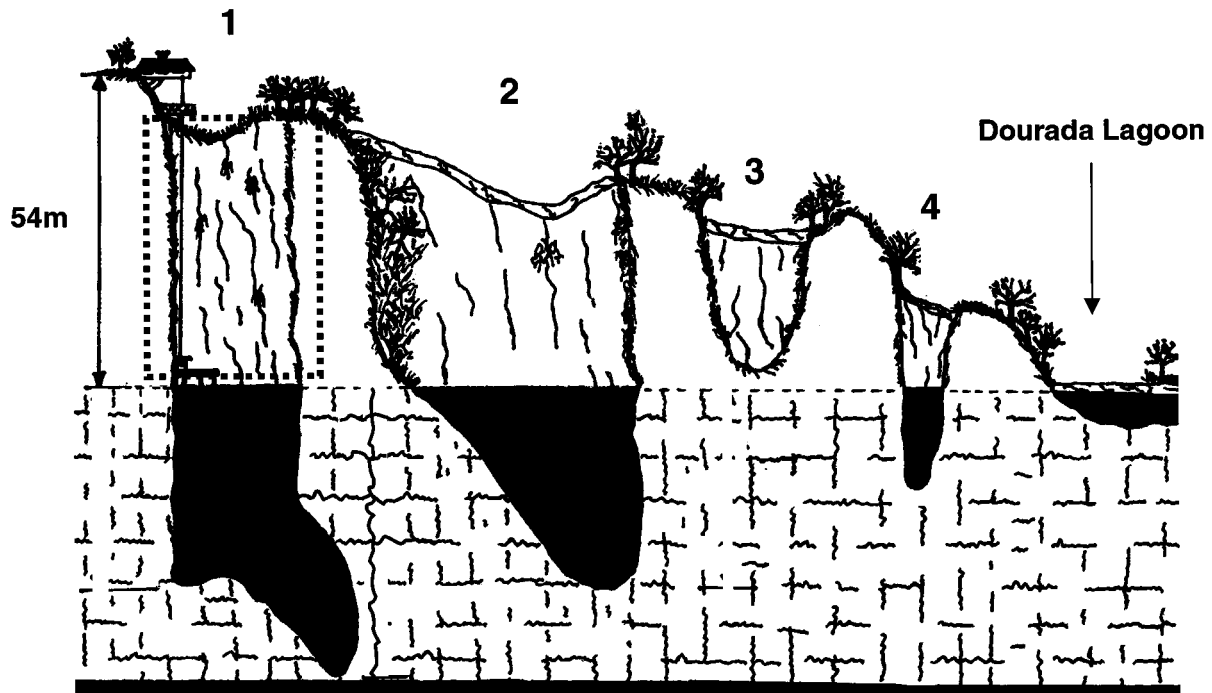


Fig. 1 — Scheme representing the Furnas Complex at the Statewide Park of Vila Velha, Ponta Grossa, state of Paraná, South of Brazil. The dotted square (Fuma 1) detaches the capture place of *Streptoprocne biscutata* and *S. zonaris*. Modified from MATOSO *et al.* (2002).

The purposes about the evolutionary scenario (Figure 3) of the karyotype through some Apodidae clades were elaborated considering the cladogram proposed by LEE *et al.* (1996) as the evolutionary basis for our considerations.

RESULTS AND DISCUSSION

The karyotypes of *Streptoprocne biscutata* and *Streptoprocne zonaris* revealed a variation in the diploid number ranging to ± 2 chromosomes (Ribeiro *et al.*, 2003).

When their partial karyotypes are compared it is still possible to observe the clear similarity between both karyotypes. Some punctual differences are also present and are represented by the presences of an additional submetacentric pair in *S. biscutata* and an additional acrocentric pair in *S. zonaris* as it was previously described by Ribeiro *et al.* (2003).

According to Ribeiro *et al.* (2003) probably very few chromosomal rearrangements would be involved in the karyotype differentiation of the South American *Streptoprocne* species and it seems that the occurrence of karyotypical homeostasis may be a feature within the genus (Figure 1) suggesting that *Streptoprocne* can be a monophyletic genus. Nevertheless, several hypotheses could be still developed concerning the origin of these punctual differences.

Among them two could be considered concerned with the occurrence of these punctual differences between the *Streptoprocne* species.

The first hypothesis, but not necessarily the most probable one, given its complexity and double direction would be the occurrence of a pericentric inversion involving probably the larger acrocentric pair of *Streptoprocne zonaris* and the larger submetacentric pair of *S. biscutata* (Figure 2A). This purpose of involvement of these chromosomes in the process mentioned above is supported by the idea of a similarity in the relative lengths of their submetacentric and acrocentric pairs (Figures 1 and 2). The second hypothesis and probably the most consistent one, given the requirement of the least cellular energy, would be the occurrence of a large deletion in the short arm of one of the submetacentric pairs (3rd or 4th pairs – Figure 2B) of *S. biscutata* giving rise probably to an acrocentric pair (7th or 8th pairs – Figure 2). Such ideas related to the target (submetacentrics indicated in *S. biscutata* – Figure 2) as much as the result (acrocentrics indicated in *S. zonaris* – Figure 2) of that deletion are also based on the fact that the relative lengths of the long arms of the 3rd and the 4th pairs (submetacentrics) of *S. biscutata* are quite similar to the relative lengths of the mentioned acrocentrics of *S. zonaris*. In addition the resulting acentric fragments could be confused with

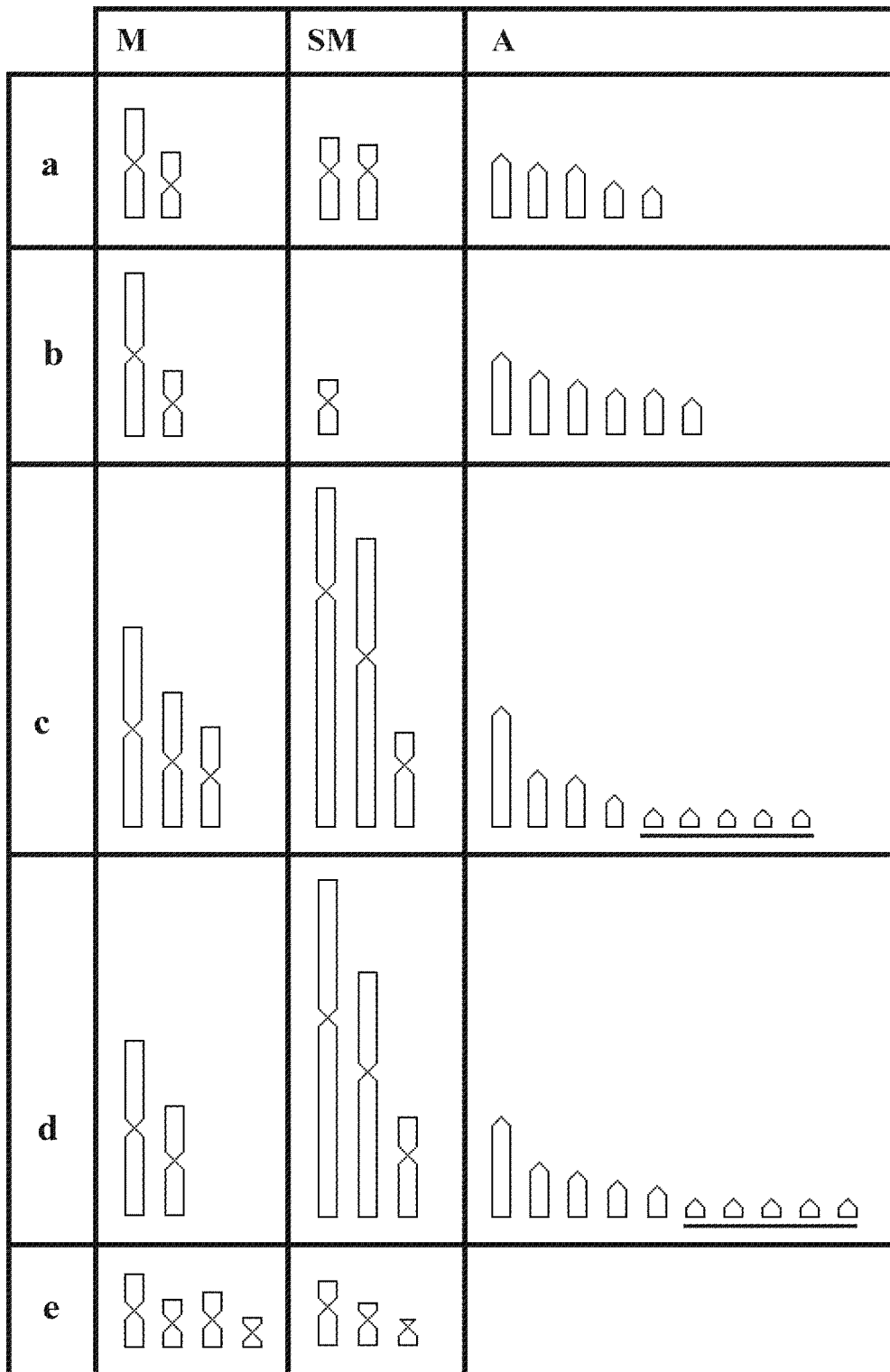


Fig. 2 — Idiogram representing the summary of the karyotypical data known for the Neotropical and Old World Apodidae species: *Streptoprocne biscutata* (a); *Streptoprocne zonaris* (b); *Apus pacificus* (c); *Hirundapus caudacutus* (d); *Apus affinis affinis* (d). M= metacentrics; SM= submetacentrics; A= acrocentrics.

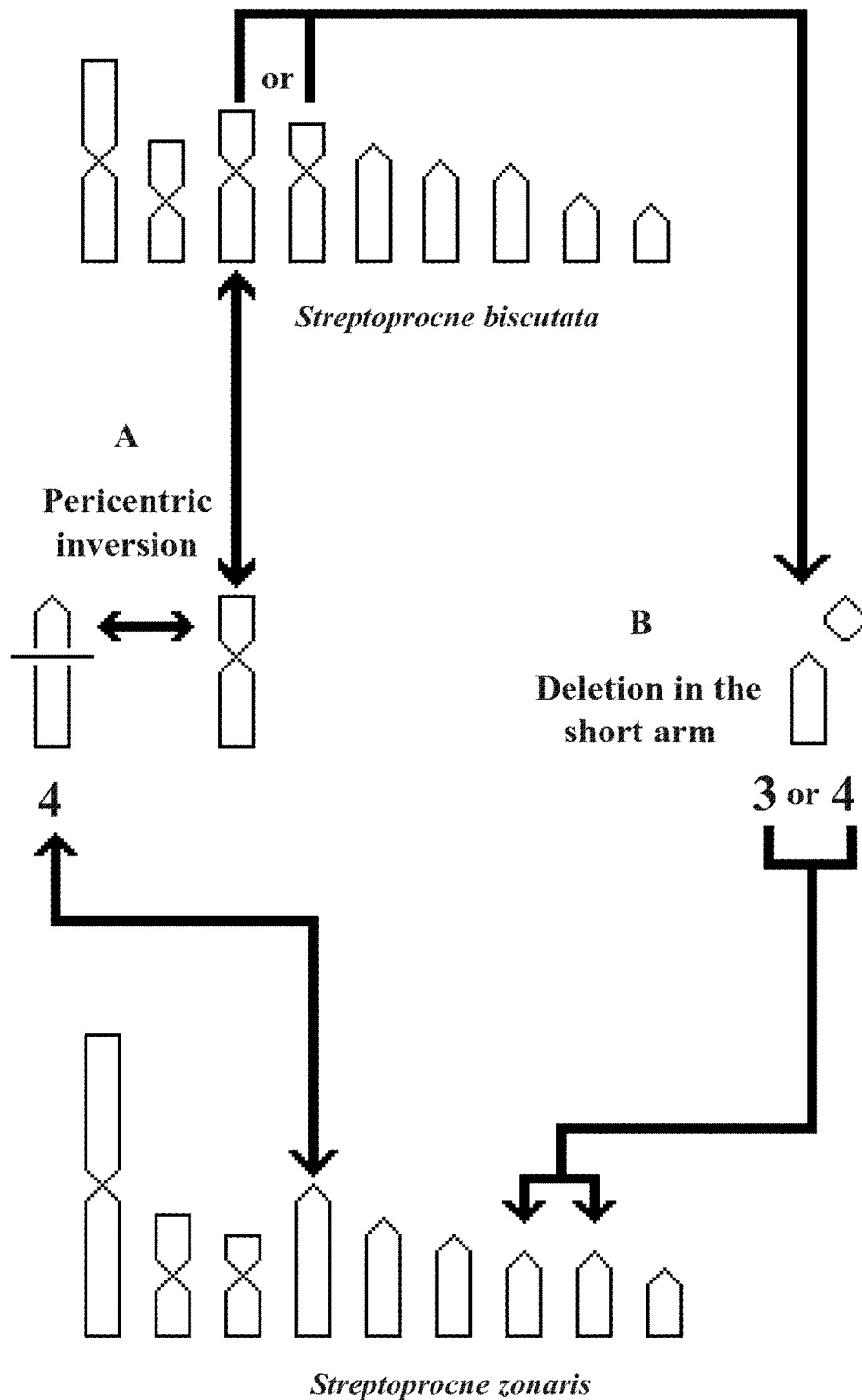


Fig. 3 — Scheme representing the possible chromosomal rearrangements involved in the karyotype evolution between the studied species of *Streptoprocne*.

microchromosomes and it would determine the variation of ± 2 chromosomes found in the diploid number of both species.

Although the karyotypical data are very scarce in the family Apodidae it is perfectly possible to analyze

some questions concerning the contributions of cytogenetics in the taxonomy of biological groups.

Among the Apodidae species with their karyotypes recognized are stood out those from, *Apus pacificus*, *Hirundapus caudacutus*, *Apus affinis affinis*,

Streptoprocne biscutata and *Streptoprocne zonaris* (XIAOZHANG *et al.*, 1988; YADAV *et al.*, 1995; RIBEIRO *et al.*, 2003). Indeed, it is possible to observe an extreme homeostasis related to the maintenance of the karyotypical macrostructure with a large number of acrocentric chromosomes followed by submetacentrics and metacentrics (Figure 1).

Comparing the karyotypes from *Apus pacificus* and *Hirundapus caudacutus* it is possible to observe a remarkable similarity between their karyotypical macrostructures (Figure 1). The group of submetacentrics is characterized by the extreme conservation in number, morphology and ratio of chromosomes. Punctual differences are present in the metacentric and acrocentric groups: (a) *Apus pacificus* present a third metacentric pair absent in *Hirundapus caudacutus* and (b) *Hirundapus caudacutus* present an additional acrocentric pair in relation to *Apus pacificus* (XIAOZHANG *et al.*, 1988).

These differences could be explained by the occurrence of a pericentric inversion in the third metacentric pair of *Apus pacificus* followed by a large terminal deletion in the resulting acrocentric pair.

The inverse sense of such rearrangements would be also possible but it would not be the most acceptable hypothesis considering that besides the occurrence of a pericentric inversion, duplication should be also considered.

Striking karyotypical differences are observed between the karyotypes of *Apus pacificus* and *Apus affinis affinis* (Figure 1). Therefore, it is completely impracticable any inference about how many and which mechanisms would be involved in the obscure relationship between such karyotypes, contrarily to what is expected to be observed between species from the same genus.

The occurrence of homeostasis at the karyotypical macrostructure among species from the same genus seems to be a phenomenon occurring frequently in vertebrates, being possible to verify such occurrence since freshwater fishes to small rodents. As an example, the chromosomal data made available for species and lineages belonging to Trichomycteridae (one of the most basal families of Neotropical freshwater catfishes) point out to an extreme maintenance of the karyotypical macrostructures being these composed by similar numbers of metacentrics, submetacentrics, subtelocentrics and acrocentrics (TORRES *et al.*, 1998; BORIN & MARTINS-SANTOS, 1999; 2000; TORRES *et al.*, 2002; SATO *et al.*, 2003). The same situation may be also observed among the species belonging to the genus *Bolomys* (a genus comprising small Neotropical rodents). Among four studied species (*B. obscurus*, *B. temchuki*, *B. amoenus* and *B. lasiurus*) all of them present the same $2n=34$ and the same fundamental number [34] (GARDNER & PATTON, 1976; BIANCHI & MERANI, 1984; VITULO *et al.*,

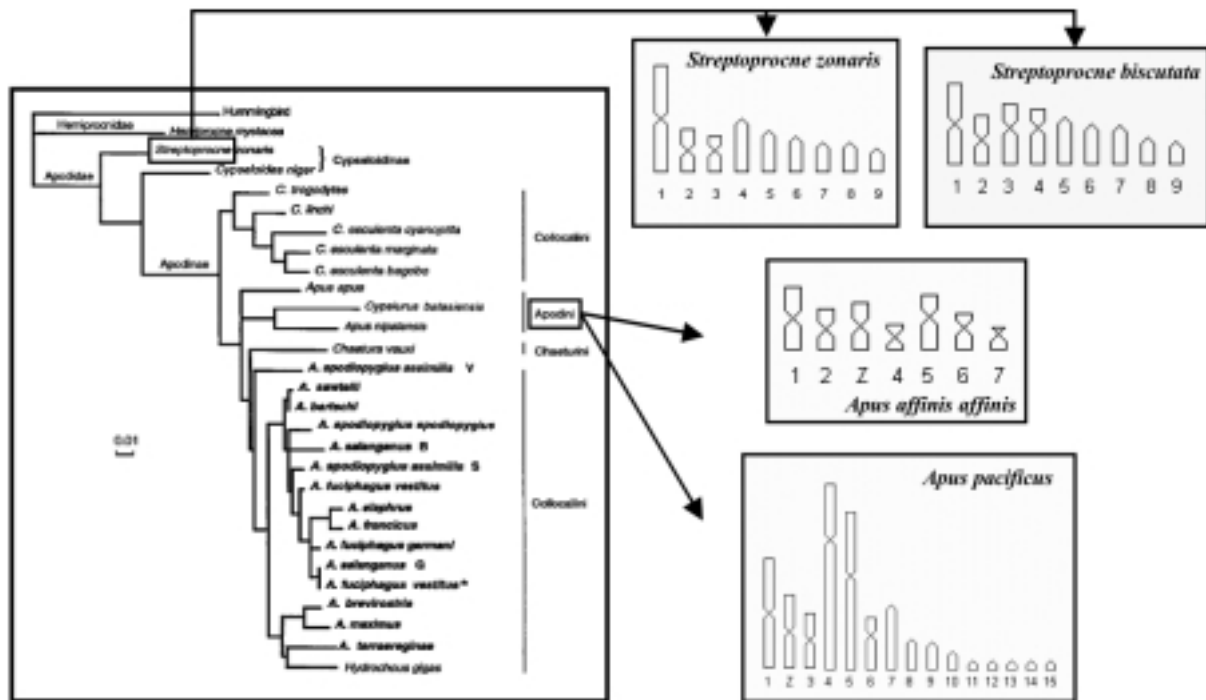


Fig. 4 — A perspective about the evolutionary scenario of the karyotype showing the genetic discontinuity along some Apodidae clades. Modified from Lee *et al.* (1996).

1986; SBALQUEIRO, 1989; SVARTMAN & ALMEIDA, 1993; LIMA & KASAHARA, 2003).

Therefore, considering the remarkable similarity and punctual differences pointed out between the karyotypes from *Apus pacificus* and *Hirundapus caudacutus* and the extreme differences verified here within the genus *Apus* (Figure 1), probably a taxonomic revision in the genus would be necessary. This suggestion is also supported by the hypothesis of phylogenetic relationship purposed for some Apodidae species (LEE *et al.*, 1996) that shows that the genus *Apus* is not monophyletic as it was previously suggested by RIBEIRO *et al.* (2003) and corroborated by the present analyses (Figure 3).

According to LEE *et al.* (1996) the subfamily Cypseloidinae is more basal than Apodinae and hence than the tribe Apodini. Thus, the karyotypical macrostructure (metacentrics + submetacentrics + acrocentrics) observed for the genus *Streptoprocne* (Ribeiro *et al.*, 2003) could be probably the primitive state of the karyotype for family Apodidae (Figure 3) being distinctive for two of the three Neotropical *Streptoprocne* species (Cypseloidinae – Figures 1) and partially maintained in Apodinae as shown in the Figures 1 and 3 for *Apus pacificus*. Furthermore the hypothesis of the genetic discontinuity occurring among Neotropical and Old World Apodidae species may be also corroborated by the data composing the Figure 4. Thus, it is clearly possible to observe the lack of karyotypical homeostasis occurring during the evolutionary process of Apodidae.

Other remarkable features are those related to an eventual increase of chromosomes in size. It seems that a great increase in genome size have occurred in the evolutionary process of Apodidae being made evident comparing the ratio of chromosomes between *Streptoprocne zonaris* and *Apus pacificus* (Figure 1). Thus, events of duplication possibly could be involved in the rising of the subfamily Apodinae (Figure 3).

Several of these presented purposes could be surely corroborated by the accumulation of the karyotypical and genome size data from the family Apodidae mainly those from *Streptoprocne semicolaris* (endemic from Mexico), from the genus *Cypseloides* and from another groups from the subfamily Apodinae such as those the tribes Collocaliini and Apodini.

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