Theor Appl Genet (1992) 84:986–989

Chromosome polymorphism in *Ateles geoffroyi* (*Cebidae; Primates; Mammalia*)

S. Herzog [1], A. Herzog [2], H. Höhn [2], B. Matern [3], and W. Hecht [2]

[1] Abteilung für Forstgenetik und Forstpflanzenzüchtung, Georg-August-Universität, Büsgenweg 2, D-W-3400 Göttingen, Federal Republic of Germany
[2] Fachgebiet Veterinärmedizinische Genetik und Zytogenetik, Justus-Liebig-Universität, W-6300 Giessen, Federal Republic of Germany
[3] Zoological Gardens of Frankfurt am Main, W-6000 Frankfurt am Main, Federal Republic of Germany

Received December 20, 1991; Accepted January 27, 1992
Communicated by F. Mechelke

Summary. The karyotype of *Ateles geoffroyi* (*Cebidae*; *Primates*; *Mammalia*) was studied using G- and C-banding techniques, and standardized idiograms are proposed. A polymorphism of chromosome 3 due to a pericentric inversion has been identified for the first time. Genetic analysis of this polymorphism showed Mendelian inheritance.

Key words: *Primates* – *Ateles geoffroyi* – Karyotype – Pericentric inversion – Inheritance

Introduction

Early investigations on the karyotype of *Ateles geoffroyi* (black-handed spider-monkey) revealed a chromosome number of $2n = 34$ with conventional staining techniques: the autosomes consist of 15 meta- or submetacentric pairs as well as one acrocentric pair. Both gonosomes have been described to be metacentrics (Hsu and Benirschke 1968). This latter study, on two animals, confirmed the results of Bender and Mettler (1958) and Chu and Bender (1961) who in their investigations on different species of *Ateles*, found identical karyotypes as far as the autosomes and the X-chromosome were concerned. However, in more recent papers, the male gonosome has been described to be a small acrocentric, whereas Hsu and Benirschke (1968) found it to be a metacentric. Moreover, Egozcue et al. (1969) found two dimorphic autosome pairs in a single male by conventional staining techniques.

A karyotype analysis by means of G- and C-banding techniques as well as a systematic description of the bands of each chromosome in accordance with an international standard has not yet been performed. The purpose of the investigation reported in the present paper was to study the karyotype of *Ateles geoffroyi* by means of G- and C-banding techniques, with special regard to the formerly described chromosome polymorphisms, and to propose a standardized idiogram.

Correspondence to: S. Herzog

Materials and methods

In order to obtain the metaphase chromosomes, blood lymphocyte cultures of nine specimens (including a complete family of seven individuals) from the Zoologischer Garten Frankfurt am Main (FRG) were prepared by means of standard culture techniques. The metaphase chromosomes were studied by modified G- and C-banding techniques (Sumner et al. 1971; Seabright 1972) and photographed at a 1,000-fold magnification under oil immersion.

The schematic representation of the chromosomes follows the International System for Human Cytogenetic Nomenclature (Standing Committee on Human Cytogenetic Nomenclature 1985), by which the chromosomes are visualized as consisting of a continuous series of light and dark bands. The designation of the chromosomes according to their centromeric positions is in accordance with Nagl (1980).

Results

The somatic, diploid chromosome set of all nine animals consisted of 34 chromosomes, namely 32 autosomes and two gonosomes (2n = 34, XX respectively XY). Figures 1 and 2 show a proposal for the G- and C-banded idiograms of *Ateles geoffroyi*. The bands and landmarks were drawn from the photos of the chromosomes of all animals following the ISCN (1985). All autosomes exhibit distinct C-bands of varying sizes. The nombre fondamental (N.F.) is 64; however chromosome pair no. 16 as well

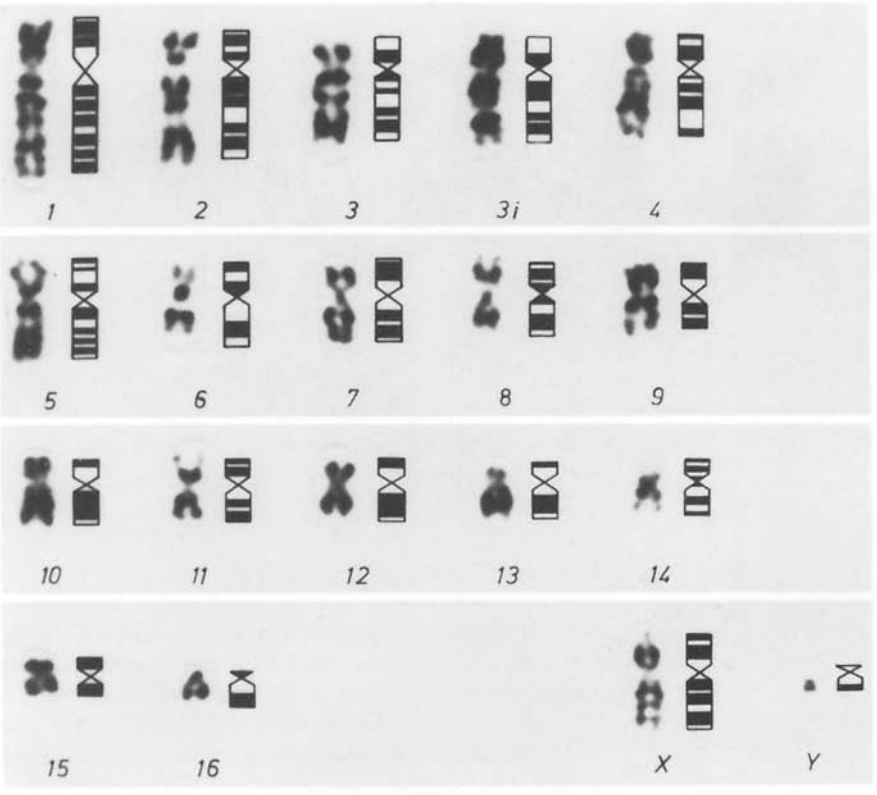

Fig. 1. Photographic and schematical representation of the G-banded idiogram of *Ateles geoffroyi*

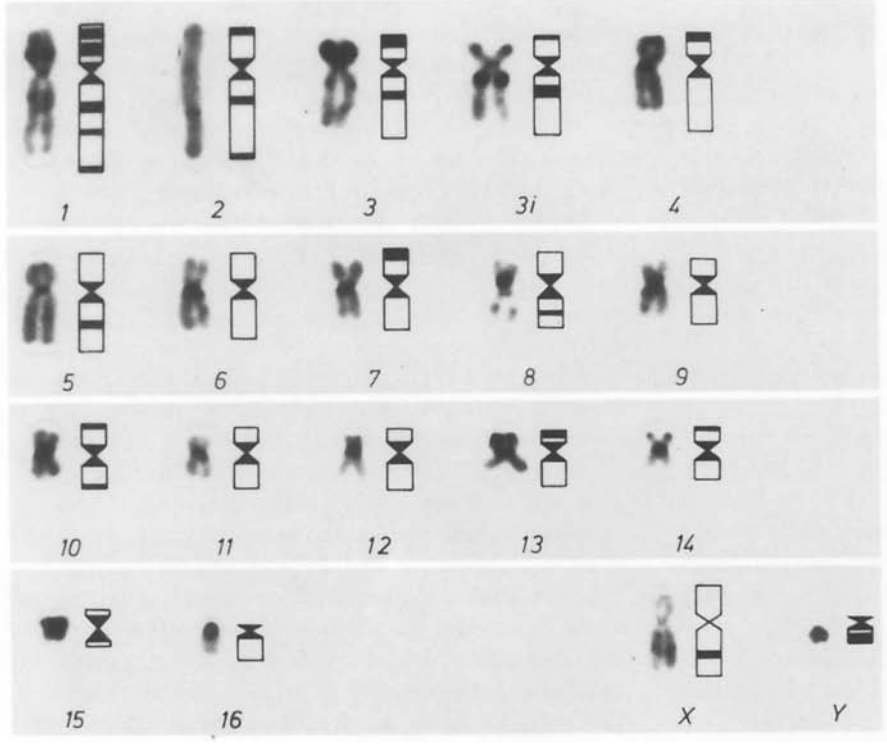

Fig. 2. Photographic and schematical representation of the C-banded idiogram of *Ateles geoffroyi*

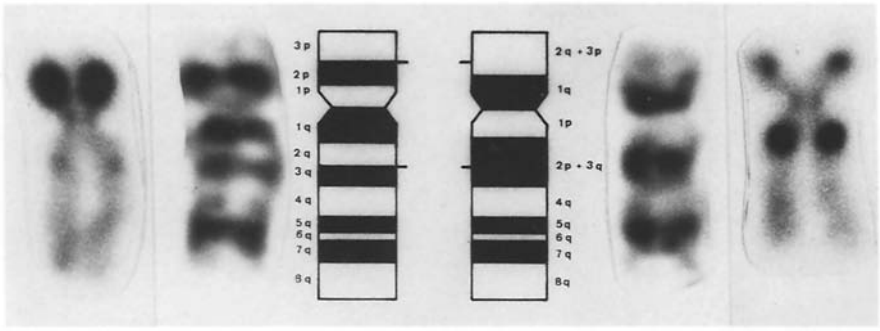

Fig. 3. C- and G-banded chromosome 3 (*left*) and 3i (*right*) of *Ateles geoffroyi*, as well as a schematical G-banded representation

Table 1. Relative chromosome length ($\bar{x}$, as percentage of the total length of the diploid autosome set) of *Ateles geoffroyi* revealed by the measurement of 22 haploid chromosome sets

Pair	$\bar{x}$ (p-arm)	s_x	Range	$\bar{x}$ (q-arm)	s_x	Range
1	1.9	0.24	1.4–2.3	4.0	0.21	3.7–4.4
2	1.7	0.14	1.4–1.9	3.5	0.15	3.2–3.7
3	1.3	0.17	1.0–1.7	2.9	0.15	2.7–3.3
4	1.4	0.17	1.1–1.7	2.7	0.24	2.2–3.0
5	1.6	0.14	1.4–1.8	2.4	0.24	1.9–2.9
6	1.4	0.18	1.0–1.8	1.9	0.27	1.5–2.5
7	1.5	0.16	1.2–1.8	1.7	0.18	1.3–2.0
8	1.3	0.27	0.9–1.8	1.7	0.20	1.5–2.2
9	1.2	0.15	1.0–1.5	1.4	0.21	1.0–1.7
10	1.0	0.13	0.8–1.3	1.6	0.23	1.2–2.1
11	1.0	0.15	0.8–1.4	1.4	0.20	1.1–1.6
12	0.9	0.13	0.7–1.2	1.5	0.21	1.0–1.8
13	0.9	0.16	0.5–1.2	1.4	0.17	1.0–1.6
14	0.9	0.12	0.7–1.2	1.2	0.18	0.9–1.5
15	0.7	0.12	0.5–0.9	0.7	0.12	0.6–0.9
16	0.1	0.05	0.0–0.1	1.2	0.15	1.0–1.5
X	1.5	0.24	1.0–1.9	2.2	0.36	1.3–2.6
Y	0.1	0.05	0.0–0.1	0.8	0.28	0.4–1.0

Table 2. Segregation results of polymorphic chromosome pair number 3 in a family of *Ateles geoffroyi*. For phenotypes, see Fig. 3

Mating type	Off-spring (total)	Off-spring[a] "3,3"	Off-spring[a] "3,3i"	Off-spring[a] "3i,3i"	Exact level of significance
3,3 × 3,3i	5	2 (2.5)	3 (2.5)	0 (0)	0.81

[a] Expected number in parentheses

as the male gonosome show only very short p-arms, which are not unequivocally measurable or even detectable. Relative chromosome arm lengths and centromeric indices are shown in Table 1.

Both G-banding and C-banding reveals that the studied population is polymorphic for a pericentric inversion of the proximal q-arm of chromosome 3 (Fig. 3).

The hypothesis of Mendelian inheritance of this chromosome polymorphism was tested using the family data available for seven specimens (Table 2).

Discussion

The karyotype of *Ateles geoffroyi* has been described by means of G- and C-banding techniques, and this has enabled us to make a proposal for the respective standard karyotypes.

A chromosome polymorphism of chromosome pair 3 has been observed for the first time. It is due to a pericentric inversion involving the p- and the proximal q-arm. Neither chromosome length nor even the centromeric index are changed by this inversion. Genetic analysis of a complete family provides evidence for the Mendelian inheritance of the chromosome polymorphism. This allows its use as a genetic marker system, e.g. in studies of mating behaviour. In fact, the present study provides evidence that one elder male (α-male) is the father of all the offspring in the enclosure.

The polymorphism of chromosome pair 3 found in the present study of *Ateles geoffroyi* is not identical to that observed by Egozcue et al. (1969) as it does not lead to any alteration in chromosome length or centromeric index. However, *Cebidae* are known to have unstable karyotypes. Chromosomal rearrangements found in the genera *Cebus* and *Lagothrix* give rise to intraspecific chromosome polymorphisms (Freitas and Seuánez 1982; Garcia et al. 1983; Mudry de Pargament 1985; Clemente et al. 1987). The comparative study of the latter authors found the polymorphisms to be due only to differences in the amount of interstitial or terminal heterochromatin. Moreover, Clemente et al. (1987) showed that the interfaces between heterochromatin and euchromatin can be labile regions prone to breakage and rearrangements. Evidently, the polymorphism described in the present study is not due to the loss of heterochromatin (see Fig. 3), which explains the lack of differences in chromosome length between the two types of chromosome 3. However, the breakage points for the inversion corre-

spond to the interfaces between heterochromatin and euchromatin. This means that the mechanism of the chromosome rearrangement in *Ateles geoffroyi* fits into the recent concept of karyotype evolution of *Primates*.

References

Bender MA, Mettler LE (1958) Chromosome studies of primates. Science 128:186

Chu EHY, Bender MA (1961) Chromosome cytology and evolution in primates. Science 133:1399

Clemente IC, Garcia M, Ponsá M, Egozcue J (1987) High-resolution banding studies in *Cebus apella, Cebus albifrons,* and *Lagothrix lagothricha*: Comparison with the human karyotype. Am J Priamtol 13:23–36

Egozcue J, Perkins F, Hagemenas F, Ford DM (1969) The chromosomes of some platyrrhini (*Callicebus, Ateles* and *Saimiri*). Folia primatol 11:17–27

Freitas L, Seuánez H (1982) Chromosome heteromorphisms in *Cebus apella*. J Hum Evol 10:173–180

Garcia M, Miró R, Ponsá M, Egozcue J (1983) Constitutive heterochromatin polymorphism in *Lagothrix logothricha cana, Cebus apella* and *Cebus capucinus*, Am J Primatol 4:117–126

Hsu TC, Benirschke K (1968) An atlas of mammalian chromosomes. Folio 2:98

Mudry de Pargament MD, Labal de Vinuesa ML, Brieux de Salum S (1985) Quantitative estimation of heteromorphism in C-bands of *Cebus apella*. J Hum Evol 14:693–698

Nagl W (1980) Chromosomen. Paul Parey, Berlin Hamburg

Seabright M (1972) The use of proteolytic enzymes for the mapping of structural rearrangements in the chromosomes of man. Chromosoma 36:204–210

Standing Committee on Human Cytogenetic Nomenclature (1985) An international system for human cytogenetic nomenclature. Karger, Basel

Sumner AT, Evans HJ, Buckland RA (1971) New technique for distinguishing between human chromosomes. Nat New Biol 232:31–32