Paper presented at The First Arctic Ungulate Conference,
Nuuk, Greenland, 3-8 September, 1991.

Expanded abstract

The phylogenetic relationship of the muskox and takin based on high resolution, G-banded, chromosome analysis

M. Pasitschniak-Arts[1], P. F. Flood[2], S. M. Schmutz[3], S. Tedesco[2] and B. Seidel[4]

[1] Department of Biology, [2] Department of Veterinary Anatomy, and [3] Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 0W0.

[4] Tierpark Berlin-Friedrichsfelde, Am Tierpark 125, D-1136 Berlin, Germany

Key words: muskox, takin, chromosomes, G-banded karyotypes

Rangifer, 12 (3) 203-205

Muskoxen, *Ovibos moschatus*, currently inhabit parts of the Canadian mainland tundra, numerous Arctic islands, regions of Alaska, Norway, Sweden, northern and eastern Greenland, and the Taymyr Peninsula (Lent, 1988). The takin, *Budorcas taxicolor*, is an Asian species presently found in mountainous areas of west central China, Burma, Bhutan and India (Jia-Yan, 1989; Neas and Hoffman, 1987). Both species appear to have originated from a common ancestor in Asia and exhibit morphological similarities. Muskoxen apparently dispersed from north central Asia to North America during the Illinoian glaciation (Jia-Yan, 1989).

Both the muskox and the takin are members of the Bovidae. The species in this family often have markedly different diploid numbers of chromosomes, but the fundamental number (number of chromosome arms) differs only from 58 to 62 (Hsu and Benirschke, 1967-1977; Wurster and Benirschke, 1968). The consistency in the number of chromosome arms suggests Robertsonian fusion, or the joining of chromosomes at their centromeres, to be a dominant phenomenon in the evolution of the Bovidae.

The relationship of the muskox to other members in the Bovidae is somewhat unclear. Many related genera of bovids adapted to colder climates are now extinct, leaving only the muskox and takin (Jia-Yan, 1989; Lent, 1988; Neas and Hoffman, 1987). Despite the apparent close relatedness of the two species, banded karyotypes of the muskox and takin have yet to be compared.

In the Bovidae, individual autosome pairs cannot be reliably distinguished using conventional staining (Lin *et al.*, 1977), but they have been identified using G-banding (Wang and Federoff, 1974) in a variety of species (Evans *et al.*, 1973; Lin *et al.*, 1977). High resolution or elongated banding techniques have further improved resolution and facilitated chromosome comparisons (Mensher *et al.*, 1989).

The object of our research was to compare the individual chromosomes of the muskox and takin, and to determine the cytotaxonomic relationship of the two species using high resolution G-banding. Karyotypes were prepared from blood samples from three male muskoxen and two female takin: the muskoxen are part of

a captive research herd at the University of Saskatchewan (Flood *et al.*, 1984), and the takin are kept at Tierpark Berlin-Friedrichsfelde, Germany. Jugular blood was drawn into sterile heparinized evacuated tubes, kept at room temperature, and set up as soon as possible after collection. Ten to 20 drops of whole blood, 0.2 ml of pytohemaglutinin, and 10.0 ml of Ham's F-10 medium were added to sterile culture flasks and incubated in an atmosphere of 5 % CO_2 at 37° C for three days (Schmutz and Moker, 1989). After a short 10 to 15 minute treatment with colcemid, the cells were suspended in a hypotonic solution (0.75M KCl) for 15 minutes, and fixed in Carnoy's fixative (3:1 methanol: glacial acetic acid) overnight. The following day, the cells were washed three times in fresh fixative and several drops of cell suspension were placed on glass slides, air dried, and stored at room temperature for seven days. Chromosomes were banded in a 5 % trypsin solution, and stained in 3 % Giemsa staim The chromosomes from the photographed spreads were paired and arranged in decreasing order of size. Individual chromosomes in any chosen karyotype showed slightly different degrees of elongation and thickness owing to the variable effects of trypsin treatment.

The karyotype of the muskox consists of 12 biarmed and 34 acrocentric autosomes, a large acrocentric X and a small metacentric Y chromosome (Tietz and Teal, 1967). The karyotype of the takin is similar, but has eight biarmed and 42 acrocentric autosomes, a large acrocentric X and small metacentric Y (Hsu and Benirschke, 1967–1977).

As indicated by its generic name, *Ovibos*, the muskox is believed to have characteristic in common with both sheep and cattle, but has more serological similarities to sheep and goats than to cattle and bison (Moody, 1958). Nevertheless, the metacentric chromosomes of the muskox differ from the metacentrics of sheep, and therefore must have arisen independently (Heck, Wurster and Benirschke, 1968).

Our G-banded chromosome analysis showed that the largest four pairs of metacentric chromosomes of the muskox matched the four metacentrics of the takin reasonably well (Fig. 1). Extensive similarity in the banding patterns of the X chromosomes of the two species were also clearly evident. When the acrocentric chromosomes of the muskox were compared with the corresponding acrocentrics of the takin, many of these chromosomes were found to have homologous banding patterns.

During evolution, the tendency appears to be towards fewer but larger chromosomes (Benirschke and Kumamoto, 1991). Since Robertsonian fusion has been a consistent mechanism in karyotype evolution in the Bovidae (Evans *et al.*, 1973), we propose that ancestral acrocentrics corresponding to the takin's smallest four pairs of chromosomes underwent Robertsonian fusion, resulting in the formation of the two smallest metacentric pairs in the muskox.

Fossil records, anatomical characteristics, and climatic adaptations of the muskox and takin disclose remarkable similarities between the two animals (Jia-Yan, 1989; Lent, 1988; Neas and Hoffman, 1987). Our high resolution chromosome analysis revealed considerable likeness in chromosome morphology and banding patterns in the two species, supporting a close phylogenetic relationship between the two.

References

Benirschke, K. and **Kumamoto, A. T.** 1991. Mammalian cytogenetics and conservation of species. – *Journal of Heredity* 82: 187–191.

Evans, H. J., Buckland, R. A. and **Summer, A. T.** 1973. Chromosome homology and heterochromatin in goat, sheep and ox studied by banding techniques. – *Chromosoma* 42: 383–402.

Flood, P. F., Rowell, J. E., Glover, G. J., Chaplin, R. K. and **Humphreys, S.** 1984. The establishment of a small research herd of captive muskoxen. – *Biological Papers University of Alaska Special Report* 4: 170–172.

Heck, H., Wurster, D. and **Benirschke, K.** 1968. Chromosome study of members of the subfamilies Caprinae and Bovinae, family Bovidae; the muskox, ibex, aoudad, Congo buffalo and gaur. – *Zeitschrift für Saugetierkunde* 33: 172–179.

Hsu, T. C. and **Benirschke, K.** 1967–1977. *An atlas of mammalian chromosomes.* Vol. I–X. – Springer Verlag, New York.

Jia-Yan, W. 1989. The systematics and distribution of the takin. – *In: Proceedings of the Second International Muskox Symposium, Saskatoon, Sask., Canada 1–4 October 1987.* Edited by: P. F. Flood. – National Research Council of Canada, Ottawa.

Lent, P. C. 1988. Ovibos moschatus. – *Mammalian Species* 302: 1–9.

Lin, C. C., Newton, D. R. and **Church, R. B.** 1977. Identification and nomenclature for G-banded bovine chromosomes. – *Canadian Journal of Genetics and Cytology* 19: 271–282.

Mensher, S. H., Bunch, T. D. and **Maciulis, A.** 1989. High-resolution G-banded karyotype and idiogram of the goat: a sheep-goat G-banded comparison. – *The Journal of Heredity* 80: 150–155.

Moody, P. A. 1958. Serological evidence on the relationships of the muskox. – *Journal of Mammalogy* 39: 554–559.

Neas, J. F. and **Hoffman, R. S.** 1987. Budorcas taxicolor. – *Mammalian Species* 277: 1–7.

Schmutz, S. M. and **Moker, J.** 1989. Impact of a 1;29 Robertsonian translocation on a herd of purebred beef cattle. – *Canadian Journal of Animal Science* 69: 891–896.

Tietz, W. J. and **Teal, J. J.** 1967. Chromosome number of the muskox *(Ovibos moschatus).* – *Canadian Journal of Zoology* 45: 235–237.

Wang, H. C. and **Federoff, S.** 1974. Trypsin technique to reveal G-bands. – *In: Tissue culture methods and applications.* Edited by: P. F. Kruse, Jr. and M. K. Pattersen, Jr. – Academic Press, New York, pp 782–787.

Wurster, D. H. and **Benirschke, K.** 1968. Chromosome studies in the superfamily Bovidae. – *Chromosoma* 25: 152–171.

Manuscript accepted 30 june, 1992.