

Standard Karyotype of the Mouse, *Mus musculus*

COMMITTEE ON STANDARDIZED GENETIC NOMENCLATURE FOR MICE

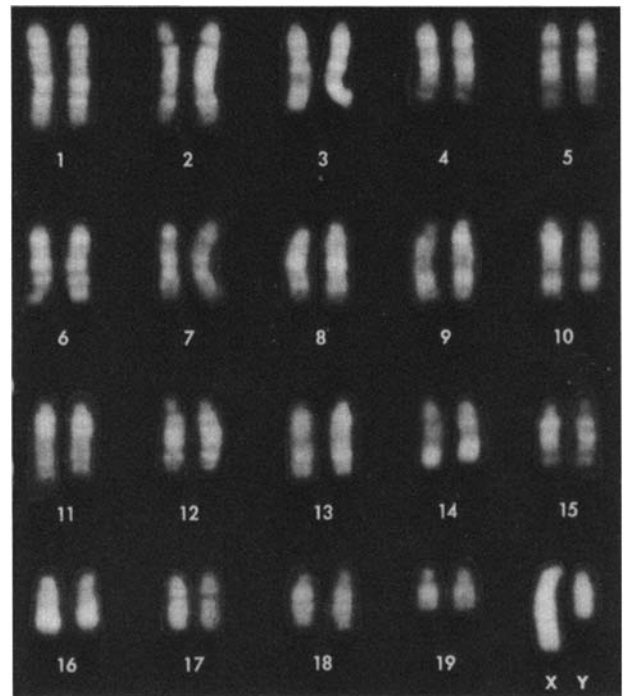
ALL 20 pairs of chromosomes of the mouse can now be individually identified by the use of the banding pattern revealed by quinacrine fluorescent staining or by modified Giemsa staining^{1, 3, 7-16}. Research workers in several different laboratories have contributed to these discoveries. Each group has numbered the chromosomes more or less in the order of descending size. Because of variability in the apparent size of the chromosomes from cell to cell and probably from strain to strain, as well as between members of a pair within a cell, it has been difficult to determine the exact size rank, and, not surprisingly, there are discrepancies between the numbering systems evolved by the different groups.

At least four numbering systems based on length measurements have been published. Dev *et al.*³ measured standard orcein-stained chromosomes, identified by prior quinacrine fluorescent staining, in ten female and six male cells from primary cultures of C57BL/6J embryos. The rank order thus determined differed somewhat from the numbering system given in that paper and used in all the other papers from the same laboratory. Schnedl¹⁵ measured the chromosomes in 100 cells from C3H embryos, using

modified Giemsa staining that produces banding patterns similar to those produced by fluorescent staining. Francke and Nesbitt⁷ determined the average rank of the longer member of each pair of quinacrine-stained chromosomes, using 23 cells from cultures of adult lungs or fetuses in several inbred and random-bred stocks. Buckland *et al.*¹ ranked the chromosomes using measurements of six Giemsa-stained female cells from cultures of blood lymphocytes and kidney fibroblasts of CFE/Q mice.

Since it seems unlikely that further refinements of measuring techniques will yield information of either great esthetic or biological importance, we

FIGURE 1—Quinacrine fluorescent karyotype of a mouse cell from a primary embryonic culture, stained with quinacrine mustard. The chromosomes are arranged and numbered according to the proposed system. (Prepared by V. G. Dev.)



Members of the Committee are: Dr. Margaret C. Green, The Jackson Laboratory, Bar Harbor, Maine, *Chairman*; Dr. Peter Démant, Institute of Experimental Biology and Genetics, Prague; Dr. I. K. Egorov, Institute of General Genetics, USSR Academy of Sciences, Moscow; Dr. Hans Grüneberg, University College, London; Dr. John J. Hutson, Department of Medicine, University of Kentucky, Lexington; Dr. K. Kondo, Department of Animal Genetics, Faculty of Agriculture, Nagoya University; Dr. Mary F. Lyon, MRC Radiobiology Unit, Harwell; Dr. Thomas H. Roderick, The Jackson Laboratory, Bar Harbor, Maine; Dr. M. Sabourdy, (Centre de Sélection et d'Élevage des Animaux de Laboratoires, Orléans-la-Source, *ICLA Representative*); Dr. R. Schmidt, Biologisches Institut des Bereiches Medizin, Jalle; Dr. A. G. Searle, MRC Radiobiology Unit, Harwell; and Miss Joan Staats, The Jackson Laboratory, Bar Harbor, Maine, *Secretary*. The Committee is affiliated with the International Committee on Laboratory Animals (ICLA). The members of the Committee would like to express their appreciation for the support they have received from Drs. Francke, Nesbitt, Schnedl, Buckland, Evans and Sumner, as well as from other persons interested in mouse genetics and cytogenetics, and their particular gratitude to Dr. O. J. Miller and his colleagues who prepared Table I and Figures 1 and 2. Requests for reprints should be addressed to Miss Joan Staats, The Jackson Laboratory, Bar Harbor, Maine 04609.

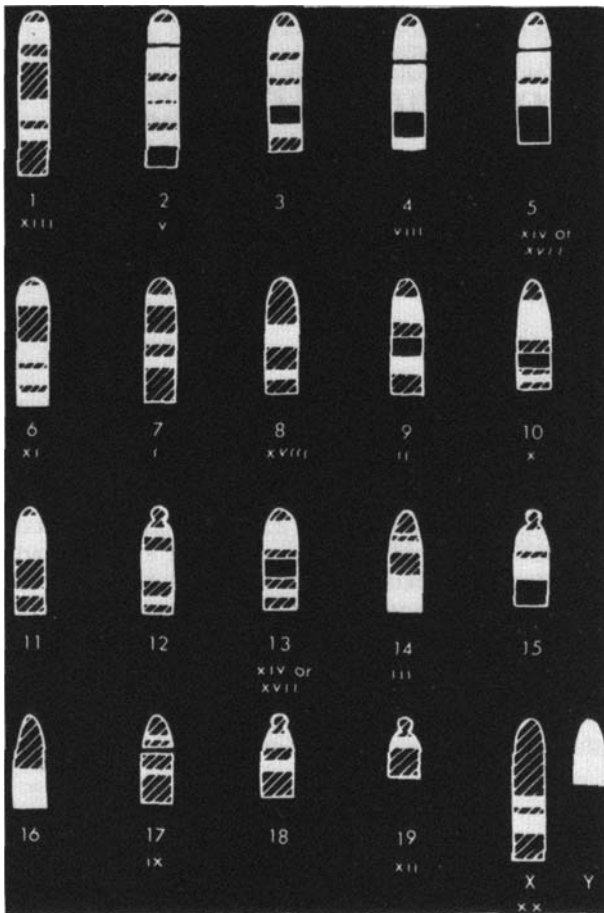


FIGURE 2—Idiogram showing the quinacrine fluorescent banding patterns of the mouse chromosomes, arranged and numbered according to the system proposed here. Linkage assignments are indicated when known. (Prepared by D. A. Miller.)

believe that the time is now appropriate to decide on a single numbering system that we hope will come into universal use. The proposed system shown in the karyotypes and idiogram in Figures 1, 2, and 3 is based on the calculations in Table I. The chromosome corresponding to each number in the four systems^{1, 3, 7, 15} was determined by comparing karyotypes prepared by the four groups of investigators. The two sets of measurements (Dev *et al.*³ and Schnedl¹⁵) were averaged, giving equal weight to each, and the length expressed as a percentage of the haploid female complement. The resulting rank order, which shows general agreement with each of the four systems already published, provides the basis for a standard numbering system for mouse chromosomes.

Table I also shows the linkage groups known to be identified with particular chromosomes, as shown by segregation of marker genes in translocation heterozygotes. Six chromosomes are still unidentified with linkage groups but it is unlikely that they will

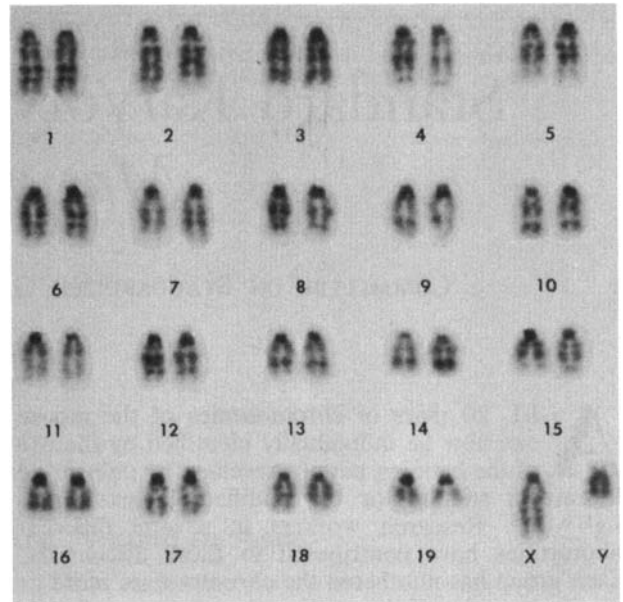


FIGURE 3—Karyotype of a cultured mouse cell prepared by the acetic-saline-Giemsa (ASG) technique. The chromosomes are arranged and numbered according to the proposed system. (Prepared by R. A. Buckland.)

long remain so. Mouse linkage groups have been numbered in order of discovery, and their order shows no similarity to that of the corresponding chromosomes. Once the assignment of linkage groups to specific chromosomes is completed it will be a great convenience to abandon the dual terminology of "linkage group" when referring to linked genes, and "chromosome" when referring to cytologically observed chromosomes, and to speak only of "chromosomes," e.g., *fz* is on chromosome 1; *Ra* is linked to *a* on chromosome 2. There will be no need to retain the term "linkage group" except during the transition period. Relearning a new set of chromosome numbers will require a major effort on the part of geneticists familiar with the present system of linkage group numbers, but once accomplished it will reduce confusion and greatly increase the ease of communication in mouse cytogenetics.

It has been customary to use Arabic numerals for chromosomes and Roman numerals for linkage groups.² The Committee on Standardized Genetic Nomenclature for Mice now recommends that Arabic chromosome numbers be used in place of linkage group numbers as shown in Table I. The transition will have to be gradual, and cannot be complete until all the chromosomes corresponding to all the linkage groups have been identified. In the transition period, the Committee recommends that the form "Chromosome 1 (LG XIII)" be used at least once in each published paper, or more often if needed to avoid misunderstanding.

There is one exception to the use of Roman

numerals for linkage groups, namely, in the symbols for translocations and other chromosome aberrations, where the linkage groups involved are given in Arabic numerals². For example, *T(2;9)138Ca* is a reciprocal translocation between the chromosomes bearing Linkage Groups II and IX. The Arabic linkage group numbers 2 and 9 will be replaced by the Arabic chromosome numbers 9 and 17. When chromosome rather than linkage group numbers are being used in the symbols for chromosome aberrations, this should be stated in some appropriate place in all papers. In addition, the Committee recommends that, when chromosome numbers are being used, they be printed in bold face (indicated in typescript by wavy underline). Thus the above translocation becomes *T(9;17)138Ca*. Within a few years it may be possible to abandon the use of bold-face without risk of misunderstanding.

NOTE ADDED IN PROOF: One of the metacentric translocations of *Mus poschiavinus* (*T4Bnr*) involves chromosome 13 and does not involve chromosome 5¹⁶. It has been found to be linked with extra toes (*Xt*) in LG XIV (B. M. Cattanaeh, Harwell, personal communication). This shows that chromosome 13 carries LG XIV and therefore that chromosome 5 carries LG XVII.

Summary

The Committee on Standardized Genetic Nomenclature for Mice recommends that:

1. The chromosomes of the mouse shall be designated by the numbers shown in the first column of Table I. The chromosome corresponding to each number is identified cytologically as shown in Fig-

ures 1, 2, and 3, and genetically, where known, by the linkage group it bears.

2. As soon as feasible, chromosome numbers in Arabic should be used in place of the corresponding linkage group numbers. Until the use of chromosome numbers for linkage groups becomes firmly established, the form "chromosome 1 (LG XIII)" should be used at least once in each published paper.

3. In symbols for chromosome aberrations Arabic chromosome numbers printed in bold face (wavy underline in transcript) should be used for the chromosomes involved. In published papers it should also be stated that chromosome numbers are meant, not linkage group numbers.

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Table I. Chromosomes of the mouse listed in order of recommended standard chromosome number, corresponding to decreasing length as computed by averaging the measurements of Dev et al.³ and Schnedl¹⁵

Recommended standard chromosome number	Linkage group		Dev et al. ³		Schnedl ¹⁵		Dev et al. & Schnedl average	Francke & Nesbitt ⁷ No.	Buckland et al. ¹ No.
	No.	Ref.	No.*	% of haploid compl.	No.	% of haploid compl.			
1	XIII	11, 12	1	7.27	1	7.14	7.20	1	2
2	V	10, 12	2	6.97	2	6.80	6.88	2	1
3		12	4	6.04	3	6.16	6.10	3	5
4	VIII	12	5	5.89	4	5.89	5.89	4	3
5	XIV or XVII	10, 14	3	5.98	6	5.63	5.80	5	4
6	XI	10, 11	6	5.51	5	5.74	5.62	6	6
7	I	8, 9, 12	8	5.51	7	5.36	5.43	7	7
8	XVIII	10, 12	9	5.00	9	5.01	5.00	8	12
9	II	11, 12, 13	10	4.85	8	5.07	4.96	10	11
10	X	12	7	4.86	10	4.80	4.83	9	10
11			11	4.77	12	4.49	4.63	12	8
12			14	4.68	11	4.58	4.63	11	9
13	XIV or XVII	10, 12, 14	13	4.35	13	4.42	4.38	13	13
14	III	5, 6, 11, 14	12	4.46	15	4.16	4.31	14	14
15		5, 6, 11, 14	15	4.03	14	4.31	4.17	15	17
16		12	17	3.82	17	3.91	3.86	16	18
17	IX	11	16	3.56	16	3.92	3.74	17	15
18		12	18	3.79	18	3.61	3.69	18	16
19	XII	4, 11, 12, 13	19	2.62	19	2.67	2.65	19	19
X	XX	8, 9	X	6.03	X	6.33	6.18	X	X
Y			Y	2.75	Y	2.69	2.72	Y	Y

* This is the numbering system used in references 9, 10, 11, and 12, not the ranking based on length.

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1972 Key Lecture Announced

The ninth Wilhelmine Key lecture, sponsored annually by the American Genetic Association, will, on the occasion of the 25th Anniversary of the founding of the American Institute of Biological Sciences, be cosponsored by the Genetics Society of America. Owing to scheduling conflicts during the 1972 meeting of AIBS (August 28-September 1) at the University of Minnesota in Minneapolis, and to avoid competing lectures

that should interest many of those attending the meetings, the AGA's annual Key lecture and the GSA's traditional keynote address will be combined as a single, jointly sponsored program. Dr. James F. Crow, University of Wisconsin, will present the Key lecture-Keynote address on Tuesday evening, August 29. His topic will be "The dilemma of nearly neutral mutations: How important are they for evaluation and human welfare?"