

# Package ‘simcross’

May 9, 2026

**Version** 0.8

**Date** 2026-05-01

**Title** Simulate Experimental Crosses

**Description** Simulate and plot general experimental crosses. The focus is on simulating genotypes with an aim towards flexibility rather than speed. Meiosis is simulated following the Stahl model, in which chiasma locations are the superposition of two processes: a proportion  $p$  coming from a process exhibiting no interference, and the remainder coming from a process following the chi-square model.

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**Depends** R (>= 3.1.0)

**Imports** graphics, stats, Rcpp (>= 0.12.17)

**Suggests** qtl, knitr, rmarkdown, testthat, devtools, roxygen2

**License** GPL-3

**URL** <https://kbroman.org/simcross/>, <https://github.com/kbroman/simcross>

**BugReports** <https://github.com/kbroman/simcross/issues>

**VignetteBuilder** knitr

**LinkingTo** Rcpp

**LazyData** true

**Encoding** UTF-8

**ByteCompile** true

**RoxygenNote** 7.3.3

**NeedsCompilation** yes

**Repository** CRAN

**Date/Publication** 2026-05-01 13:30:02 UTC

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---

AILped

*Example AIL pedigree*

---

### Description

Example matrix describing the pedigree for advanced intercross lines

### Usage

`data(AILped)`

### Format

A data frame with five columns: individual id, mom, dad, sex (0 for females and 1 for males) and generation.

**Source**

Derived from the pedF8 dataset in the QTLRel package, <https://cran.r-project.org/package=QTLRel>

**Examples**

```
data(AILped)
x <- sim_from_pedigree(AILped)
```

---

`calc_Lstar`*Calculate adjusted chromosome length for obligate chiasma*

---

**Description**

Calculate the reduced chromosome length that will give the target expected number of chiasmata when conditioning on there being at least one chiasma on the four-strand bundle.

**Usage**

```
calc_Lstar(L, m = 0, p = 0)
```

**Arguments**

L	Length of chromosome (in cM); must be > 50
m	Interference parameter for chi-square model
p	Proportion of chiasmata coming from no-interference process

**Value**

Adjusted length of chromosome

**See Also**

[cross\(\)](#), [sim\\_meiosis\(\)](#), [sim\\_crossovers\(\)](#)

**Examples**

```
calc_Lstar(100, 0, 0)
calc_Lstar(60, 10, 0.1)
```

---

CCcolors	<i>Collaborative Cross colors</i>
----------	-----------------------------------

---

**Description**

Get the vector of colors for the Collaborative Cross

**Usage**

```
CCcolors(palette = c("new", "original", "official"))
```

**Arguments**

palette            Which version of the colors to use? (New or original)

**Value**

vector of eight colors

**Examples**

```
CCcolors()
```

---

check_pedigree	<i>Check a pedigree for errors</i>
----------------	------------------------------------

---

**Description**

Perform a series of checks on the tabular data for a pedigree, checking for problems

**Usage**

```
check_pedigree(pedigree, ignore_sex = FALSE)
```

**Arguments**

pedigree            Numeric matrix or data frame with four columns: ID, mom ID, dad ID, sex. Sex is coded as 0=female, 1=male. There can be additional columns, but they'll be ignored.

ignore\_sex        If TRUE, ignore the sex values completely (appropriate for hermaphroditic species.)

**Details**

The parents should be listed before any of their offspring. Founders should have 0's for mother and father; all others should have non-zero values for the parents, and the parents should appear in the pedigree. Father should be male and mothers should be female (unless ignore\_sex=TRUE). Individual identifiers should be unique and non-zero. There should be no missing values anywhere. (NAs are allowed in the sex column if ignore\_sex=TRUE.)

**Value**

TRUE (invisibly) if everything is okay; otherwise gives an error.

**See Also**

[sim\\_from\\_pedigree\(\)](#), [sim\\_ril\\_pedigree\(\)](#)

**Examples**

```
tab <- sim_ril_pedigree(7)
check_pedigree(tab)
```

---

collapse\_do\_alleles    *Collapse alleles for simulated DO genotypes*

---

**Description**

When simulating Diversity Outbreds, we need to specify parents 1-16, with 9-16 being the males from strains 1-8. This function collapses replaces alleles 9-16 with 1-8, to make the result ordinary DO-type data.

**Usage**

```
collapse_do_alleles(xodata)
```

**Arguments**

xodata            The sort of detailed genotype/crossover data generated by [sim\\_from\\_pedigree\(\)](#).

**Value**

The input object, with alleles 9-16 replaced by 1-8.

**See Also**

[sim\\_do\\_pedigree\(\)](#), [sim\\_do\\_pedigree\\_fix\\_n\(\)](#), [sim\\_from\\_pedigree\(\)](#)

**Examples**

```
# simulate DO pedigree
tab <- sim_do_pedigree(8)

# simulate genotypes for that pedigree
dat <- sim_from_pedigree(tab)
# collapse to alleles 1-8
dat <- collapse_do_alleles(dat)

# also works with data on multiple chromosomes
```

```
dat <- sim_from_pedigree(tab, c("1"=100, "2"=75, "X"=100), xchr="X")
dat <- collapse_do_alleles(dat)
```

---

 convert2geno

*Convert continuous allele information into marker genotypes*


---

### Description

Convert the continuous crossover location information produced by `sim_from_pedigree` to marker genotypes

### Usage

```
convert2geno(xodat, map, founder_geno = NULL, shift_map = FALSE)
```

### Arguments

xodat	The sort of detailed genotype/crossover data generated by <code>sim_from_pedigree()</code>
map	vector of marker locations; can also be a list of such vectors (one per chromosome), in which case xodat and founder_geno must be lists with the same length.
founder_geno	Optional matrix (size n_founders x length(map)) of founder genotypes. If coded as 1/2 (or 1/3), results are 1/2/3 genotypes. If coded as A/T/G/C/N, results are A/T/G/C/N/H genotypes. If coded as letters A-H for the 8 founders, results are two-letter genotypes AA-HH with 36 possible values.
shift_map	If TRUE, shift genetic map to start at 0

### Value

If founder\_geno is provided or there are just two founders, the result is a numeric matrix of genotypes, individuals x markers, with genotypes 1/2/3 codes for 11/12/22 genotypes.

If founder\_geno is not provided and there are more than two founders, the result is a 3-dimensional array, individuals x markers x alleles, with the third dimensional corresponding to the maternal and paternal allele.

If the input map is a list (the components being chromosomes), then xodat and founder\_geno must be lists of the same length, and the result will be a list of matrices.

### See Also

`get_geno()`, `sim_from_pedigree()`

**Examples**

```

# simulate AIL pedigree
tab <- sim_ail_pedigree(12, 30)
# simulate data from that pedigree
dat <- sim_from_pedigree(tab)
# marker map (could also use sim.map in R/qt1)
map <- seq(0, 100, by=5)
names(map) <- paste0("marker", seq(along=map))
# convert data to marker genotypes
geno <- convert2geno(dat, map)

# AIL with multiple chromosomes
dat <- sim_from_pedigree(tab, c("1"=100, "2"=75, "X"=100), xchr="X")
# marker map
multimap <- list("1"=seq(0, 100, by=5),
                "2"=seq(0, 75, by=5),
                "X"=seq(0, 100, by=5))
for(i in 1:3)
  names(multimap[[i]]) <- paste0("marker", i, "_", 1:length(map[[i]]))
geno <- convert2geno(dat, multimap)

# simulate DO pedigree
tab <- sim_do_pedigree(8)
# simulate data from that pedigree
dat <- sim_from_pedigree(tab)
# simulate founder snp alleles
fg <- matrix(sample(1:2, 8*length(map), repl=TRUE), nrow=8)
# for DO, need female & male founders (to deal with X chr)
fg <- rbind(fg, fg)
# convert dat to SNP genotypes
geno <- convert2geno(dat, map, fg)
# if fg not provided, result is a 3d array
genoarray <- convert2geno(dat, map)

```

---

convert2geno_allchr	<i>Convert continuous allele information into marker genotypes for multiple chromosomes</i>
---------------------	---

---

**Description**

Wrap up of convert2geno to adequate multiple chromosomes.

**Usage**

```

convert2geno_allchr(
  xodat,
  map,
  id = NULL,

```

```

founder_geno = NULL,
return.matrix = TRUE,
shift_map = FALSE
)

```

### Arguments

xodat	The sort of detailed genotype/crossover data generated by <a href="#">sim_from_pedigree_allchr()</a>
map	marker locations, a list with elements for each chromosome
id	ids for which individuals genotypes is desired
founder_geno	Optional list of matrices (one per chromosome) of size n_founders x n_markers, with the founder genotypes. If coded as 1/2 (or 1/3), results are 1/2/3 genotypes. If coded as A/T/G/C/N, results are A/T/G/C/N/H genotypes. If coded as letters A-H (in the case of 8 founders), results are two-letter genotypes AA-HH with 36 possible values.
return.matrix	If FALSE, the result is a list of length n_chrs, otherwise it is converted into a matrix if size length(id) x n_markers.
shift_map	If TRUE, shift genetic map to start at 0

### Value

If founder\_geno is provided or there are just two founders, the result is a numeric matrix of genotypes, individuals x markers, with genotypes 1/2/3 codes for 11/12/22 genotypes. If there are more than two founders and founder\_geno are letters, the result is a character matrix, too.

If founder\_geno is not provided and there are more than two founders, the result is a 3-dimensional array, individuals x markers x alleles, with the third dimensional corresponding to the maternal and paternal allele.

### See Also

[convert2geno\(\)](#)

### Examples

```

library(qtl)
# marker map
map <- sim.map(len=rep(100, 19), n.mar=10, include.x=FALSE)
# simulate AIL pedigree
tab <- sim_ail_pedigree(12, 30)
# simulate data from that pedigree
dat <- sim_from_pedigree_allchr(tab, map)
names(map) <- paste0("marker", seq(along=map))
# convert data to marker genotypes
id <- which(tab[, "gen"]==12)
geno <- convert2geno_allchr(dat, map, id)

```

---

create_parent	<i>Create a parent object</i>
---------------	-------------------------------

---

**Description**

Create a parent object

**Usage**

```
create_parent(L, allele = 1)
```

**Arguments**

L	chromosome length in cM
allele	vector of integers for alleles, of length 1 or 2

**Value**

A list with two components, for the individual's two chromosomes. Each is a list with alleles in chromosome intervals (as integers) and locations of the right endpoints of those intervals.

**See Also**

[cross\(\)](#), [sim\\_meiosis\(\)](#)

**Examples**

```
create_parent(100, 1)
create_parent(100, 1:2)
```

---

cross	<i>Cross two individuals</i>
-------	------------------------------

---

**Description**

Simulate the cross of two individuals to create a single progeny

**Usage**

```
cross(
  mom,
  dad,
  m = 10,
  p = 0,
  xchr = FALSE,
  male = FALSE,
```

```

    obligate_chiasma = FALSE,
    Lstar = NULL
  )

```

### Arguments

mom	An individual object, as produced by <code>create_parent()</code> or this function.
dad	An individual object, as produced by <code>create_parent()</code> or this function.
m	interference parameter for chi-square model
p	proportion of crossovers coming from no-interference process
xchr	If TRUE, simulate X chromosome
male	If TRUE, simulate a male (matters only if xchr=TRUE)
obligate_chiasma	If TRUE, require an obligate chiasma on the 4-strand bundle at meiosis.
Lstar	Adjusted chromosome length, if obligate_chiasma=TRUE. Calculated if not provided.

### Details

Simulations are under the Stahl model with the interference parameter being an integer. This is an extension of the chi-square model, but with chiasmata being the superposition of two processes, one following the chi-square model and the other exhibiting no interference.

### Value

A list with two components, for the individual's two chromosomes. Each is a list with alleles in chromosome intervals (as integers) and locations of the right endpoints of those intervals.

### See Also

`create_parent()`, `sim_meiosis()`, `sim_crossovers()`, `calc_Lstar()`

### Examples

```

mom <- create_parent(100, 1:2)
dad <- create_parent(100, 1:2)
child <- cross(mom, dad)

```

---

get_geno	<i>Get genotype at a single position</i>
----------	--

---

**Description**

With data on the continuous crossover location information produced by `sim_from_pedigree`, grab the genotype at a given position.

**Usage**

```
get_geno(xodat, position)
```

**Arguments**

xodat	The sort of detailed genotype/XO data generated by <code>sim_from_pedigree()</code>
position	Position (in cM) for which to obtain genotypes

**Value**

A numeric matrix with two columns: the maternal and paternal allele for each individual.

**See Also**

[sim\\_from\\_pedigree\(\)](#), [convert2geno\(\)](#)

**Examples**

```
# simulate AIL pedigree
tab <- sim_ail_pedigree(12, 30)
# simulate data from that pedigree
dat <- sim_from_pedigree(tab)
# get genotype at position 30 cM
geno <- get_geno(dat, 30)
```

---

mouseL_cox	<i>Mouse chromosome lengths</i>
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---

**Description**

Mouse chromosome lengths in cM from the Cox et al. map

**Usage**

```
data(mouseL_cox)
```

**Format**

A numeric vector with lengths in cM for the 20 mouse chromosomes.

**Source**

Taken from Table 1 of Cox et al. (2009) A new standard genetic map for the laboratory mouse. Genetics 182:1335-1344. doi:[10.1534/genetics.109.105486](https://doi.org/10.1534/genetics.109.105486)

**See Also**

mouseL\_mgi

**Examples**

```
data(mouseL_cox)
```

---

mouseL\_mgi

*Mouse chromosome lengths*

---

**Description**

Mouse chromosome lengths in cM from the Mouse Genome Informatics (MGI) standard map.

**Usage**

```
data(mouseL_mgi)
```

**Format**

A numeric vector with lengths in cM for the 20 mouse chromosomes.

**Source**

Taken from Table 1 of Cox et al. (2009) A new standard genetic map for the laboratory mouse. Genetics 182:1335-1344. doi:[10.1534/genetics.109.105486](https://doi.org/10.1534/genetics.109.105486)

**See Also**

mouseL\_cox

**Examples**

```
data(mouseL_mgi)
```

---

plot\_crosslines      *Plot cross lines*

---

### Description

Add lines for a cross

### Usage

```
plot_crosslines(  
  momloc,  
  dadloc,  
  kidsloc,  
  gap = 3,  
  chrlength = 30,  
  cex = 1.5,  
  lwd = 2,  
  arrow_length = 0.1,  
  col = "black",  
  ...  
)
```

### Arguments

momloc	An (x,y) vector with center location for mother
dadloc	An (x,y) vector with center location for mother
kidsloc	Either an (x,y) vector with center location for a kid, or a list of such for multiple kids
gap	Gap arrows and points/rectangles
chrlength	Length of chromosomes
cex	Character expansion for x point
lwd	Line width for points, segments, and arrows
arrow_length	The length parameter in the call to <a href="#">graphics::arrows()</a>
col	Color of lines and points
...	Additional arguments passed to <a href="#">arrows()</a> and <a href="#">segments()</a>

### Value

None.

### See Also

[plot\\_ind\(\)](#)

**Examples**

```

mom <- create_parent(100, 1:2)
dad <- create_parent(100, 3:4)
kids <- lapply(1:4, function(junk) cross(mom, dad))
plot(0,0, type="n", xlim=c(0, 100), ylim=c(0,100),
     xaxt="n", yaxt="n", xlab="", ylab="")
loc <- list(c(25,75), c(75,75), c(12.5,25), c(37.5,25), c(62.5, 25), c(87.5,25))
plot_ind(mom, loc[[1]])
plot_ind(dad, loc[[2]])
for(i in 1:4) plot_ind(kids[[i]], loc[[i+2]])
plot_crosslines(loc[[1]], loc[[2]], loc[3:6])

```

plot\_ind

*Plot an individual***Description**

Add an individual, as a pair of chromosomes, to a plot

**Usage**

```

plot_ind(
  ind,
  center,
  chrlength = 30,
  chrwidth = 3,
  gap = 3,
  col = CCcolors(),
  border = "black",
  lend = 1,
  ljoin = 1,
  allborders = FALSE,
  ...
)

```

**Arguments**

ind	An individual object, as output by <code>create_parent()</code> or <code>cross()</code>
center	(x,y) vector for the center of the individual
chrlength	Length of chromosomes (Can be a vector of length 2, in which case the two chromosomes will be different lengths, aligned at the top. This is for the X chromosome.)
chrwidth	Width of chromosomes
gap	Gap between chromosomes
col	Vector of colors
border	Color for border

lend	Passed to <code>graphics::rect()</code>
ljoin	Passed to <code>graphics::rect()</code>
allborders	If TRUE, put borders around all segments
...	Additional arguments passed to <code>rect()</code>

**Value**

None.

**See Also**

`plot_crosslines()`

**Examples**

```

mom <- create_parent(100, 1:2)
dad <- create_parent(100, 3:4)
kid <- cross(mom, dad)
plot(0,0, type="n", xlim=c(0, 100), ylim=c(0,100),
     xaxt="n", yaxt="n", xlab="", ylab="")
loc <- list(c(25,75), c(75,75), c(50,25))
plot_ind(mom, loc[[1]])
plot_ind(dad, loc[[2]])
plot_ind(kid, loc[[3]])
plot_crosslines(loc[[1]], loc[[2]], loc[[3]])

```

---

sim_4way_pedigree	<i>Simulate pedigree for 4-way intercross</i>
-------------------	---

---

**Description**

Simulate a 4-way cross, among four inbred lines (a table of individual, mom, dad, sex)

**Usage**

```
sim_4way_pedigree(ngen = 1, nsibs = 100)
```

**Arguments**

ngen	Number of intercross generations (1 or 2)
nsibs	Vector with number of siblings in the sibships in the last generation.

**Details**

We start with a set of 4 individuals (representing four inbred lines), and make a pair of crosses to generate a pair of heterozygous individuals. These are then crosses to generate a set of F1 individuals. If `ngen==1`, we stop there, with `sum(nsibs)` individuals in this last generation. If `ngen==2`, we generate `length(nsibs)` male/female pairs of F1 offspring; these are intercrossed to generate a set of sibships, with lengths defined by the values in `nsibs`. Individuals in the last generation are alternating female/male.

**Value**

A data frame with five columns: individual ID, mother ID, father ID, sex, and generation. Founders have 0 for mother and father ID. Sex is coded 0 for female and 1 for male.

**See Also**

[sim\\_from\\_pedigree\(\)](#), [sim\\_ril\\_pedigree\(\)](#), [sim\\_do\\_pedigree\(\)](#), [sim\\_ail\\_pedigree\(\)](#)

**Examples**

```
# 100 F1s between heterozygous parents
tab <- sim_4way_pedigree(1, 100)
# could also do this
tab2 <- sim_4way_pedigree(1, rep(10, 10))

# 120 F2s in 10 sibships each of size 12
tab3 <- sim_4way_pedigree(ngen=2, rep(12, 10))
```

---

sim\_ail\_pedigree      *Simulate AIL pedigree*

---

**Description**

Simulate a pedigree for advanced intercross lines (a table of individual, mom, dad, sex)

**Usage**

```
sim_ail_pedigree(
  ngen = 12,
  npairs = 30,
  nkids_per = 5,
  design = c("nosib", "random")
)
```

**Arguments**

ngen	Number of generations of outbreeding
npairs	Number of breeding pairs at each generation
nkids_per	Number of offspring per pair for the last generation
design	How to choose crosses: either random but avoiding siblings, or completely at random

## Details

Advanced intercross lines (AIL) are generated from a pair of inbred lines. We cross them and then cross the F1 to generate npair breeding pairs. The subsequent ngen outbreeding generations then proceed by crossing a male and female from the preceding generation (mated completely at random, with design="random", or avoiding siblings, with design="nosib"). Each breeding pair gives a single female and a single male to the next generation, except at the last generation nkids\_per offspring are mated, in equal numbers male and female. (If nkids\_per is an odd number, the number of males and females in each sibship will differ by one, alternating between sibships, with one additional female and then one additional male.

## Value

A data frame with five columns: individual ID, mother ID, father ID, sex, and generation. Founders have 0 for mother and father ID. Sex is coded 0 for female and 1 for male.

## See Also

[sim\\_from\\_pedigree\(\)](#), [sim\\_ril\\_pedigree\(\)](#), [sim\\_do\\_pedigree\(\)](#), [sim\\_4way\\_pedigree\(\)](#)

## Examples

```
tab <- sim_ail_pedigree(12, 30)
```

---

sim\_ail\_pedigree\_fix\_n

*Simulate AIL pedigree with fixed n*

---

## Description

Simulate a pedigree for advanced intercross lines (a table of individual, mom, dad, sex) so that the last generation reaches a desired sample size n

## Usage

```
sim_ail_pedigree_fix_n(  
  ngen = 12,  
  nkids_per = 5,  
  nsample_ngen = 150,  
  npairs = NULL,  
  method = c("last2", "sub2"),  
  design = c("nosib", "random")  
)
```

**Arguments**

ngen	Number of generations of outbreeding
nkids_per	Number of offspring per pair for the last generation
nsample_ngen	Number of individuals desired at the last generation
npairs	Number of breeding pairs at each generation. If missing, we use 30 when method="last2" and 300 when method="sub2".
method	Method used to generate pedigree: either expand at the last two generations or generate a pedigree with a large number of pairs and select a subset to have the desired sample size.
design	How to choose crosses: either random but avoiding siblings, or completely at random

**Details**

The default value for npairs depends on the choice of method. For method="last2", we use a default of npairs=30; for method="sub2", we use a default of npairs=300.

**Value**

A data frame with five columns: individual ID, mother ID, father ID, sex, and generation. Founders have 0 for mother and father ID. Sex is coded 0 for female and 1 for male.

**See Also**

[sim\\_from\\_pedigree\(\)](#), [sim\\_ril\\_pedigree\(\)](#), [sim\\_ail\\_pedigree\(\)](#), [sim\\_do\\_pedigree\(\)](#), [sim\\_4way\\_pedigree\(\)](#), [sim\\_do\\_pedigree\\_fix\\_n\(\)](#)

**Examples**

```
tab <- sim_ail_pedigree_fix_n(12)
```

---

sim\_crossovers

*Simulate crossover locations using the Stahl model*

---

**Description**

Simulate crossover locations on a single meiotic product using the Stahl model.

**Usage**

```
sim_crossovers(L, m = 10, p = 0, obligate_chiasma = FALSE, Lstar = NULL)
```

**Arguments**

L	length of chr in cM
m	Interference parameter (m=0 is no interference)
p	Proportion of chiasmata from no-interference mechanism (p=0 gives pure chi-square model)
obligate_chiasma	If TRUE, require an obligate chiasma on the 4-strand bundle at meiosis.
Lstar	Adjusted chromosome length, if obligate_chiasma=TRUE. Calculated if not provided.

**Details**

Chiasma locations are a superposition of two processes: a proportion p exhibiting no interference, and a proportion (1-p) following the chi-square model with interference parameter m. Crossover locations are derived by thinning the chiasma locations with probability 1/2.

Simulations are under the Stahl model with the interference parameter being an integer. This is an extension of the chi-square model, but with chiasmata being the superposition of two processes, one following the chi-square model and the other exhibiting no interference.

**Value**

Numeric vector of crossover locations, in cM

**References**

Copenhaver, G. P., Housworth, E. A. and Stahl, F. W. (2002) Crossover interference in arabidopsis. *Genetics* **160**, 1631–1639.

Foss, E., Lande, R., Stahl, F. W. and Steinberg, C. M. (1993) Chiasma interference as a function of genetic distance. *Genetics* **133**, 681–691.

Zhao, H., Speed, T. P. and McPeck, M. S. (1995) Statistical analysis of crossover interference using the chi-square model. *Genetics* **139**, 1045–1056.

**Examples**

```
x <- sim_crossovers(200, 10, 0)
x <- sim_crossovers(200, 10, 0.04)
x <- sim_crossovers(100, 0, 0, obligate_chiasma=TRUE)
```

---

sim_dof1_pedigree	<i>Simulate pedigree for F1 between diversity outbreeds and another inbred line</i>
-------------------	---

---

### Description

Simulate a pedigree for a set of DOF1 individuals: the F1 offspring of a set of diversity outbred mice and another inbred strain (such as a mutant line).

### Usage

```
sim_dof1_pedigree(
  ngen = 12,
  npairs = 144,
  ccgen = rep(4:12, c(21, 64, 24, 10, 5, 9, 5, 3, 3)),
  nkids_per = 5,
  design = c("nosib", "random")
)
```

### Arguments

ngen	Number of generations of outbreeding
npairs	Number of breeding pairs at each generation
ccgen	Vector of length npairs, with the number of generations for each CC line. If length 1, it is repeated to a vector of length npairs.
nkids_per	Number of offspring per pair for the last DO generation (each will be crossed to produce one F1)
design	How to choose crosses: either random but avoiding siblings, or completely at random

### Details

Diversity outbred (DO) mice are generated from a set of 8 inbred lines. We need two individuals from each line (one female and one male) as the order of the initial crosses will be randomized; for example, sometimes the individual from line 1 will be a mother and sometimes a father. The founders are numbered 1-8 for the females from the 8 lines, and 9-16 for the corresponding males.

Diversity Outbred mice are generated by first creating a panel of partially-inbred 8-way RIL (the so-called pre-CC, for pre-Collaborative Cross). The ccgen argument specifies the number of inbreeding generations for each of the CC lines. We generate a pre-CC line for each of the npairs breeding pairs, and generate a sibling pair from each as the starting material.

The subsequent ngen outbreeding generations then proceed by crossing a male and female from the preceding generation (mated completely at random, with design="random", or avoiding siblings, with design="nosib"). Each breeding pair gives a single female and a single male to the next generation, except at the last generation nkids\_per offspring are mated, in equal numbers male and female. (If nkids\_per is an odd number, the number of males and females in each sibship

will differ by one, alternating between sibships, with one additional female and then one additional male.

The default for ccgen is taken from Figure 1 of Svenson et al. (2012).

We assume that the F1 offspring are all from a cross DO female x line 17 male, and so the last generation of the DO is taken to be all females.

### Value

A data frame with seven columns: individual ID, mother ID, father ID, sex, generation, a TRUE/FALSE indicator for whether DO or pre-DO, and a TRUE/FALSE indicator for whether DOF1. Founders have 0 for mother and father ID. Sex is coded 0 for female and 1 for male.

### References

Svenson KL, Gatti DM, Valdar W, Welsh CE, Cheng R, Chesler EJ, Palmer AA, McMillan L, Churchill GA (2012) High-resolution genetic mapping using the mouse Diversity Outbred population. *Genetics* 190:437-447

### See Also

[sim\\_from\\_pedigree\(\)](#), [sim\\_ril\\_pedigree\(\)](#), [sim\\_ail\\_pedigree\(\)](#), [sim\\_4way\\_pedigree\(\)](#)

### Examples

```
tab <- sim_dof1_pedigree(8)
```

---

sim_do_pedigree	<i>Simulate a pedigree for Diversity Outbred mice</i>
-----------------	---

---

### Description

Simulate a pedigree for generating Diversity Outbred (DO) mice (a table of individual, mom, dad, sex).

### Usage

```
sim_do_pedigree(  
  ngen = 12,  
  npairs = 144,  
  ccgen = rep(4:12, c(21, 64, 24, 10, 5, 9, 5, 3, 3)),  
  nkids_per = 5,  
  design = c("nosib", "random")  
)
```

**Arguments**

ngen	Number of generations of outbreeding
npairs	Number of breeding pairs at each generation
ccgen	Vector of length npairs, with the number of generations for each CC line. If length 1, it is repeated to a vector of length npairs.
nkids_per	Number of offspring per pair for the last generation
design	How to choose crosses: either random but avoiding siblings, or completely at random

**Details**

Diversity outbred (DO) mice are generated from a set of 8 inbred lines. We need two individuals from each line (one female and one male) as the order of the initial crosses will be randomized; for example, sometimes the individual from line 1 will be a mother and sometimes a father. The founders are numbered 1-8 for the females from the 8 lines, and 9-16 for the corresponding males.

Diversity Outbred mice are generated by first creating a panel of partially-inbred 8-way RIL (the so-called pre-CC, for pre-Collaborative Cross). The ccgen argument specifies the number of inbreeding generations for each of the CC lines. We generate a pre-CC line for each of the npairs breeding pairs, and generate a sibling pair from each as the starting material.

The subsequent ngen outbreeding generations then proceed by crossing a male and female from the preceding generation (mated completely at random, with design="random", or avoiding siblings, with design="nosib"). Each breeding pair gives a single female and a single male to the next generation, except at the last generation nkids\_per offspring are mated, in equal numbers male and female. (If nkids\_per is an odd number, the number of males and females in each sibship will differ by one, alternating between sibships, with one additional female and then one additional male.

The default for ccgen is taken from Figure 1 of Svenson et al. (2012).

**Value**

A data frame with six columns: individual ID, mother ID, father ID, sex, generation, and TRUE/FALSE indicator for whether DO or pre-DO. Founders have 0 for mother and father ID. Sex is coded 0 for female and 1 for male.

**References**

Svenson KL, Gatti DM, Valdar W, Welsh CE, Cheng R, Chesler EJ, Palmer AA, McMillan L, Churchill GA (2012) High-resolution genetic mapping using the mouse Diversity Outbred population. *Genetics* 190:437-447

**See Also**

[sim\\_from\\_pedigree\(\)](#), [sim\\_ril\\_pedigree\(\)](#), [sim\\_ail\\_pedigree\(\)](#), [sim\\_4way\\_pedigree\(\)](#)

**Examples**

```
tab <- sim_do_pedigree(8)
```

---

sim\_do\_pedigree\_fix\_n *Simulate a pedigree for Diversity Outbreds for a target sample size*

---

### Description

Simulate a pedigree for Diversity Outbred (DO) mice (a table of individual, mom, dad, sex) so that the last generation reaches a desired sample size.

### Usage

```
sim_do_pedigree_fix_n(
  ngen = 12,
  nkids_per = 5,
  nccgen = 15,
  nsample_ngen = 150,
  npairs = NULL,
  method = c("last2", "sub2", "fixcc"),
  design = c("nosib", "random"),
  selc.method = c("byfamily", "byindiv")
)
```

### Arguments

ngen	Number of generations of outbreeding
nkids_per	Number of offspring per pair for the last generation
nccgen	The number of generations for each CC line, only used when method is not "fixcc".
nsample_ngen	Number of individuals desired at the last generation
npairs	Number of breeding pairs at each generation. If missing, we use 30 when method="last2" and 300 when method="sub2".
method	Method used to generate the pedigree: either expand at the last two generations or generate a pedigree with a large number of pairs and then select a subset to have the desired sample size. With method="fixcc", we use the pre-CC generations as performed at the Jackson Lab.
design	How to choose crosses: either random but avoiding siblings, or completely at random
selc.method	Method used to select the individuals from last generation.

### Details

The default number of breeding pairs depends on the chosen method. With method="last2", the default is npairs=30; with method="sub2", the default is npairs=300; with method="fixcc", npairs is ignored and is fixed at 144.

**Value**

A data frame with six columns: individual ID, mother ID, father ID, sex, generation, and TRUE/FALSE indicator for whether DO or pre-DO. Founders have 0 for mother and father ID. Sex is coded 0 for female and 1 for male.

**See Also**

[sim\\_from\\_pedigree\(\)](#), [sim\\_ril\\_pedigree\(\)](#), [sim\\_ail\\_pedigree\(\)](#), [sim\\_do\\_pedigree\(\)](#), [sim\\_4way\\_pedigree\(\)](#), [sim\\_ail\\_pedigree\\_fix\\_n\(\)](#)

**Examples**

```
tab <- sim_do_pedigree_fix_n(8)
```

---

sim_from_pedigree	<i>Simulate genotypes for pedigree</i>
-------------------	--

---

**Description**

Simulate genotypes along one chromosome for a pedigree

**Usage**

```
sim_from_pedigree(
  pedigree,
  L = 100,
  xchr = FALSE,
  m = 10,
  p = 0,
  obligate_chiasma = FALSE
)
```

**Arguments**

pedigree	Matrix or data frame describing a pedigree, with first four columns being individual ID, mom ID, dad ID, and sex (female as 0, male as 1).
L	Length of chromosome in cM (or a vector of chromosome lengths)
xchr	If TRUE, simulate X chromosome. (If L is a vector, this should be a vector of TRUE/FALSE values, of the same length as L, or a character string with the name of the X chromosome, in L.)
m	Crossover interference parameter, for chi-square model (m=0 corresponds to no interference).
p	proportion of crossovers coming from no-interference process
obligate_chiasma	If TRUE, require an obligate chiasma on the 4-strand bundle at meiosis.

**Value**

A list with each component being the data for one individual, as produced by the `cross()` function. Those results are a list with two components, corresponding to the maternal and paternal chromosomes. The chromosomes are represented as lists with two components: an integer vector of alleles in chromosome intervals, and a numeric vector of locations of the right-endpoints of those intervals; these two vectors should have the same length.

If the input `L` is a vector, in order to simulate multiple chromosomes at once, then the output will be a list with length `length(L)`, each component being a chromosome and having the form described above.

**See Also**

`check_pedigree()`, `sim_ril_pedigree()`, `sim_ail_pedigree()`, `sim_from_pedigree_allchr()`

**Examples**

```
# simulate AIL pedigree
tab <- sim_ail_pedigree(12, 30)
# simulate data from that pedigree
dat <- sim_from_pedigree(tab)
# simulate multiple chromosomes
dat <- sim_from_pedigree(tab, c("1"=100, "2"=75, "X"=100), xchr="X")
```

---

sim\_from\_pedigree\_allchr

*Simulate genotypes for pedigree for multiple chromosomes*

---

**Description**

Simulate genotypes along all chromosomes for a pedigree. This is a wrap up of `sim_from_pedigree`.

**Usage**

```
sim_from_pedigree_allchr(
  pedigree,
  map,
  m = 10,
  p = 0,
  obligate_chiasma = FALSE
)
```

**Arguments**

pedigree	Matrix or data frame describing a pedigree, with first four columns being individual ID, mom ID, dad ID, and sex (female as 0, male as 1).
map	marker locations, a list with elements for each chromosome

**m** Crossover interference parameter, for chi-square model ( $m=0$  corresponds to no interference).

**p** proportion of crossovers coming from no-interference process

**obligate\_chiasma**  
If TRUE, require an obligate chiasma on the 4-strand bundle at meiosis.

**Value**

A list with each component being the result from `sim_from_pedigree`, of length same as `map`.

**See Also**

[check\\_pedigree\(\)](#), [sim\\_ril\\_pedigree\(\)](#), [sim\\_ail\\_pedigree\(\)](#) [sim\\_from\\_pedigree\(\)](#)

**Examples**

```
library(qtl)
# marker map
map <- sim.map(len=rep(100, 19), n.mar=10, include.x=FALSE)
# simulate AIL pedigree
tab <- sim_ail_pedigree(12, 30)
# simulate data from that pedigree
dat <- sim_from_pedigree_allchr(tab, map)
```

---

sim\_meiosis

*Simulate meiosis*

---

**Description**

Output a random meiotic product from an input individual.

**Usage**

```
sim_meiosis(parent, m = 10, p = 0, obligate_chiasma = FALSE, Lstar = NULL)
```

**Arguments**

**parent** An individual object, as output by [create\\_parent\(\)](#) or [cross\(\)](#)

**m** interference parameter for chi-square model

**p** Proportion of chiasmata coming from no-interference process.

**obligate\_chiasma**  
If TRUE, require an obligate chiasma on the 4-strand bundle at meiosis.

**Lstar** Adjusted chromosome length, if `obligate_chiasma=TRUE`. Calculated if not provided.

### Details

Simulations are under the Stahl model with the interference parameter being an integer. This is an extension of the chi-square model, but with chiasmata being the superposition of two processes, one following the chi-square model and the other exhibiting no interference.

### Value

A list with alleles in chromosome intervals (as integers) and locations of the right endpoints of those intervals.

### References

Copenhaver, G. P., Housworth, E. A. and Stahl, F. W. (2002) Crossover interference in arabidopsis. *Genetics* **160**, 1631–1639.

Foss, E., Lande, R., Stahl, F. W. and Steinberg, C. M. (1993) Chiasma interference as a function of genetic distance. *Genetics* **133**, 681–691.

Zhao, H., Speed, T. P. and McPeck, M. S. (1995) Statistical analysis of crossover interference using the chi-square model. *Genetics* **139**, 1045–1056.

### See Also

[create\\_parent\(\)](#), [cross\(\)](#), [sim\\_crossovers\(\)](#), [calc\\_Lstar\(\)](#)

### Examples

```
ind <- create_parent(100, 1:2)
prod <- sim_meiosis(ind)
```

---

sim_ril_pedigree	<i>Generate a ril pedigree</i>
------------------	--------------------------------

---

### Description

Generate a pedigree for multi-way recombinant inbred lines (a table of individual, mom, dad, sex)

### Usage

```
sim_ril_pedigree(  
  ngen = 20,  
  selfing = FALSE,  
  parents = 1:2,  
  firstind = max(parents) + 1  
)
```

**Arguments**

ngen	Number of generations of inbreeding
selfing	If TRUE, use selfing
parents	Vector of the parents' IDs. Should be integers, and length must be a power of 2 (i.e., 2, 4, 8, ...)
firstind	Positive integer to assign to the first child. Must be greater than <code>max(parents)</code> .

**Value**

A data frame with five columns: individual ID, mother ID, father ID, sex, and generation. Founders have 0 for mother and father ID. Sex is coded 0 for female and 1 for male.

**See Also**

[sim\\_from\\_pedigree\(\)](#), [sim\\_ail\\_pedigree\(\)](#), [sim\\_do\\_pedigree\(\)](#), [sim\\_4way\\_pedigree\(\)](#)

**Examples**

```
tab <- sim_ril_pedigree(7)
```

---

where\_het

*Find heterozygous regions*

---

**Description**

Find regions of heterozygosity in an individual

**Usage**

```
where_het(ind)
```

**Arguments**

ind	An individual object, as output be <a href="#">create_parent()</a> or <a href="#">cross()</a>
-----	---

**Value**

A matrix with two columns; each row indicates the start and end of a region where the individual is heterozygous

**See Also**

[sim\\_from\\_pedigree\(\)](#), [convert2geno\(\)](#)

**Examples**

```
mom <- create_parent(100, 1:2)
dad <- create_parent(100, 1:2)
child <- cross(mom, dad)
where_het(child)
```

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