Multiple randomizations

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Designing a simple experiment:
Fisher (1935), Cox (1958), Nelder (1965)

t treatments $\longrightarrow$ b blocks of t plots each

systematic design AND randomization

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    4.1 Randomized-inclusive randomizations
    4.2 Unrandomized-inclusive randomizations

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Concepts and terminology

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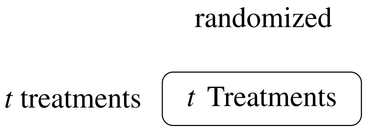

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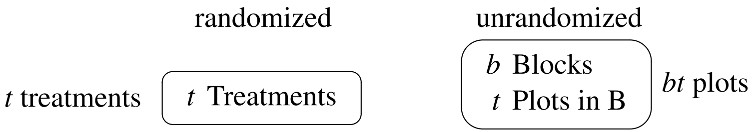

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A panel shows a poset block structure: a list of factors,
their numbers of levels,
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b Blocks
t Plots in B

bt plots

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$B \wedge P =$ generalized factor whose levels are all combinations of the levels of B and P.

"P is nested in B" means that $B \wedge P$ is a meaningful factor but P is not.

t treatments | t Treatments

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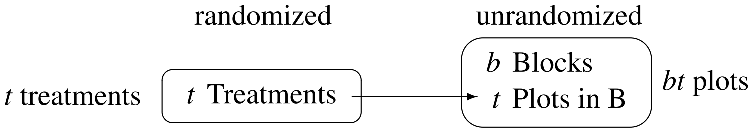
First phase of a sensory experiment (Brien, 1983)



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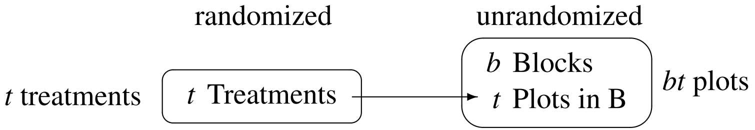

Systematic design: each treatment once per block

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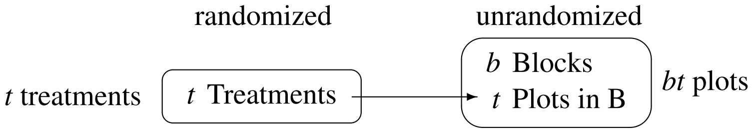

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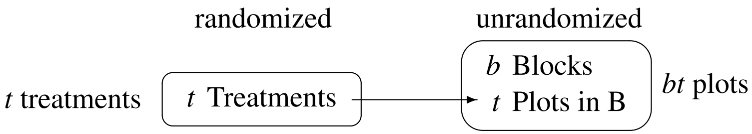

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The arrow from the randomized tier to the unrandomized tier indicates both

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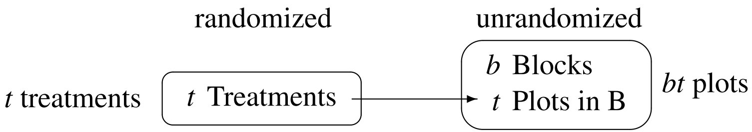
First phase of a sensory experiment (Brien, 1983)



Systematic design:	each treatment once per block
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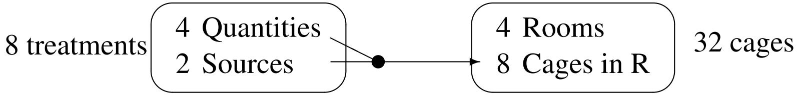
The arrow from the randomized tier to the unrandomized tier indicates both

- a systematic design (with extra explanation if necessary)
- the randomization: permute the (names of the) objects in the unrandomized set by a permutation chosen at random from among all those that preserve the relevant structure.

A poultry-feeding experiment



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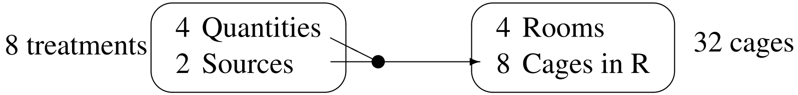

How do we read this diagram?

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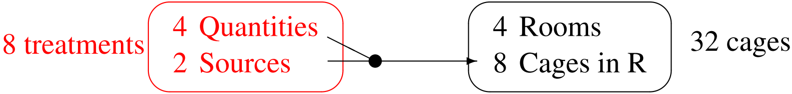

How do we read this diagram?

- There are 8 treatments:
  all combinations of 4 quantities and 2 sources of protein.

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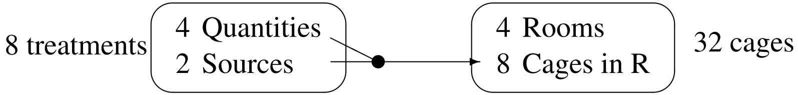

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- There are 8 treatments:
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- ● denotes the generalized factor $Q \wedge S$ with 8 levels.

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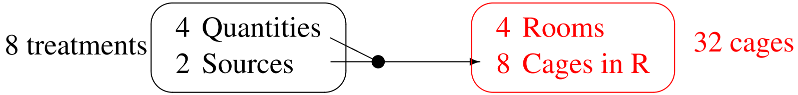

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- There are 4 rooms; each room contains 8 cages of chickens.

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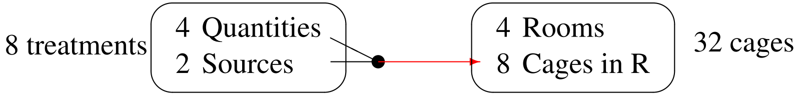

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- The systematic design allocates each level of $Q \wedge S$ to one cage in each room.

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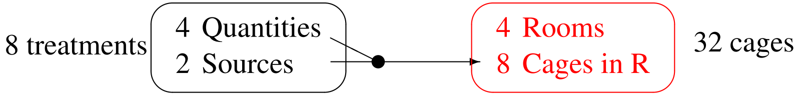

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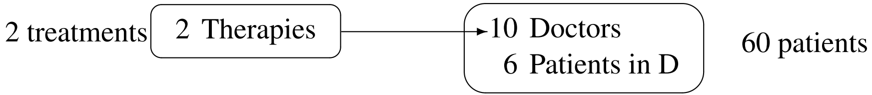
- (Rooms are randomized);
  and cages are randomized within rooms.

A clinical trial (R. F. White, 1975)



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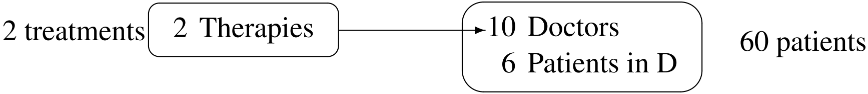

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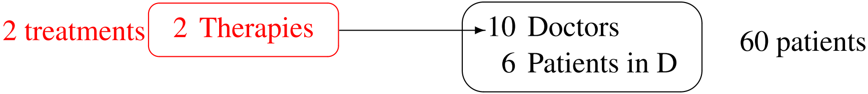

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- There are 2 therapies.

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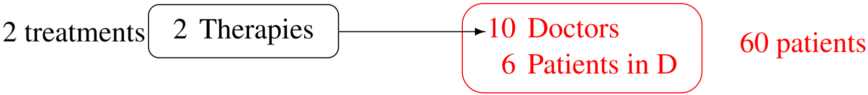

How do we read this diagram?

- There are 2 therapies.
- There are 10 doctors; each doctor has 6 patients.

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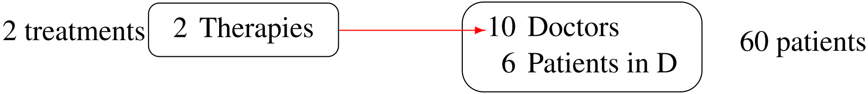

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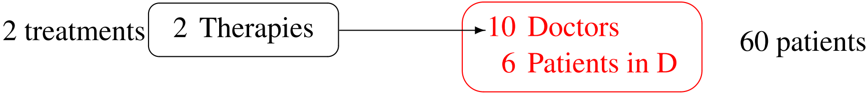
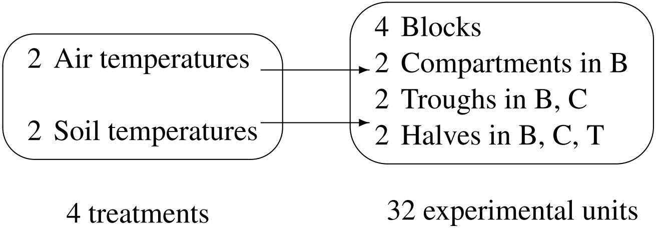


How do we read this diagram?

- There are 2 therapies.
- There are 10 doctors; each doctor has 6 patients.
- The systematic design allocates each therapy to 5 doctors.
- Doctors are randomized;
  (and patients are randomized within doctors).

A greenhouse split-split plot experiment (R. Mead, 1988)



Two arrows but a single randomization

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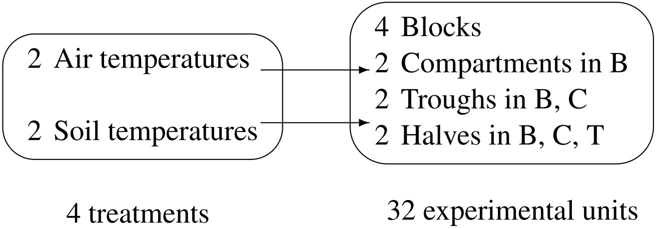

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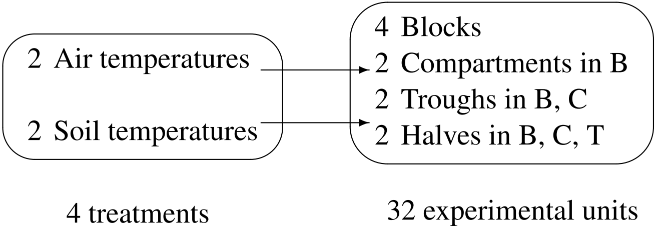

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- Each air temperature is allocated to one compartment in each block, and each soil temperature to one half of each trough.

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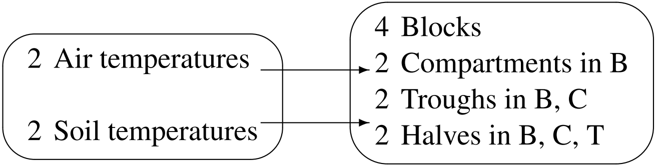


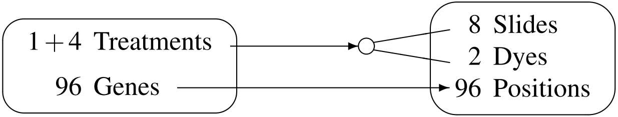
4 treatments

32 experimental units

Two arrows but a single randomization

- There are 4 blocks; each block contains 2 compartments; each compartment contains 2 troughs, each split into 2 halves.
- Each air temperature is allocated to one compartment in each block, and each soil temperature to one half of each trough.
- Blocks are randomized; compartments are randomized within blocks; troughs are randomized within compartments; and halves are randomized within troughs.

A micorarray experiment



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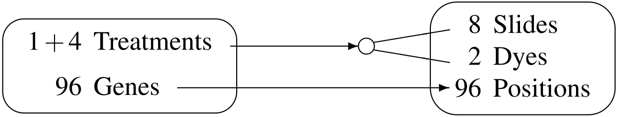
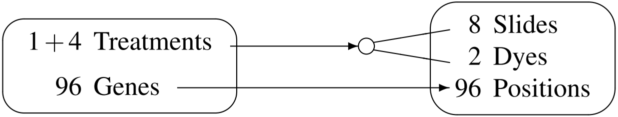


- There is 1 ‘control’ treatment (labelled 0) and 4 other treatments.

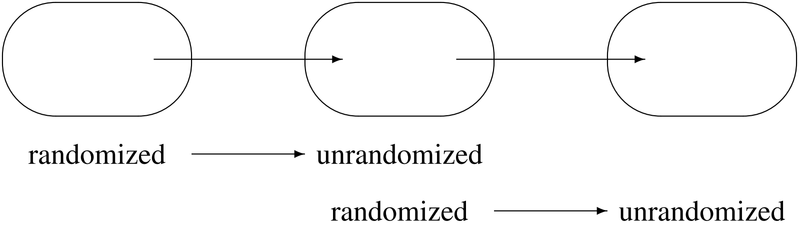
A micorarray experiment



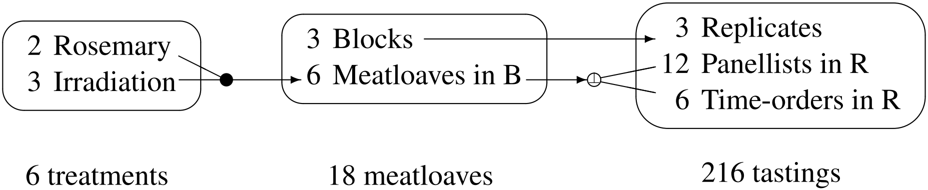
- There is 1 ‘control’ treatment (labelled 0) and 4 other treatments.
- ○ shows that we need to know a specific (non-orthogonal) design for the allocation of the treatments to the dye-slide combinations, such as

	slides							
	1	2	3	4	5	6	7	8
red	0	1	0	2	0	3	0	4
green	1	0	2	0	3	0	4	0

Composed randomizations: Order does not matter



A two-phase sensory experiment (T. B. Bailey, 2003)



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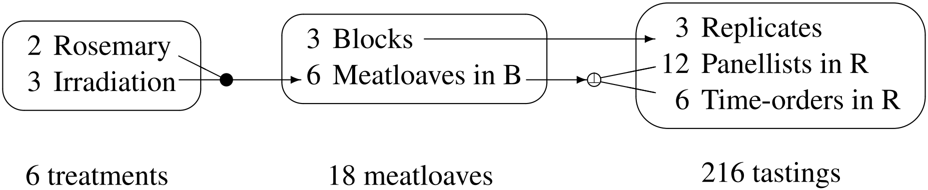

The first phase uses a complete-block design

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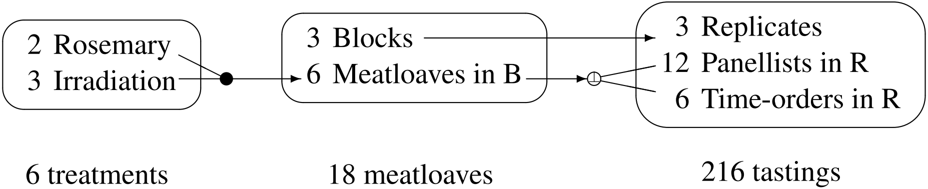

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The second phase uses an orthogonal design, indicated by ⦶ : two 6×6 Latin squares in each replicate

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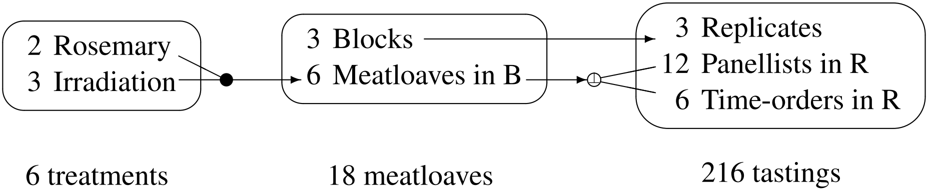

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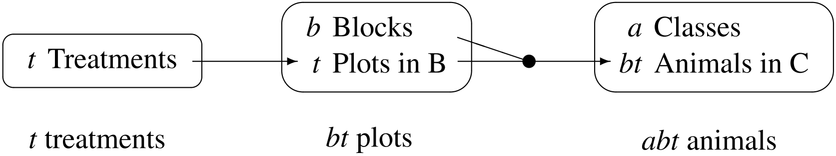
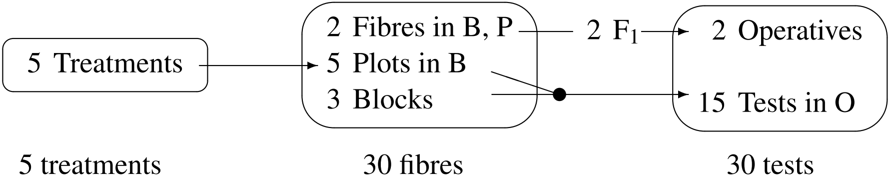
No knowledge of the outcome of the first randomization is needed in order to perform the second.

A continuous grazing experiment (Brien and Demétrio, 1998)



A single-phase experiment with two randomizations

Cotton fibres (D. R. Cox, 1958)



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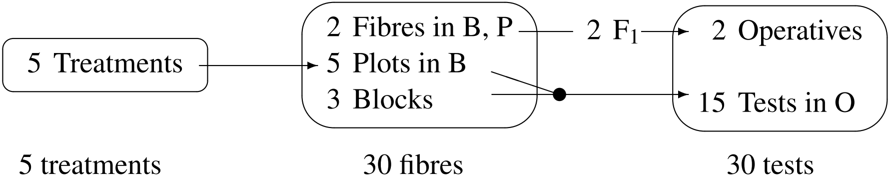

The first phase uses a complete-block design.

In the second phase, 2 fibres of cotton are sampled from each plot, and each operative tests one fibre per plot.

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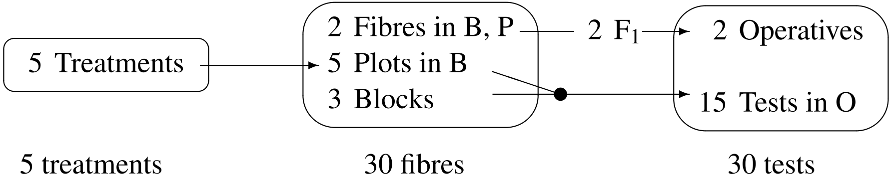

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—shown outside the panel
—levels randomized independently in each plot

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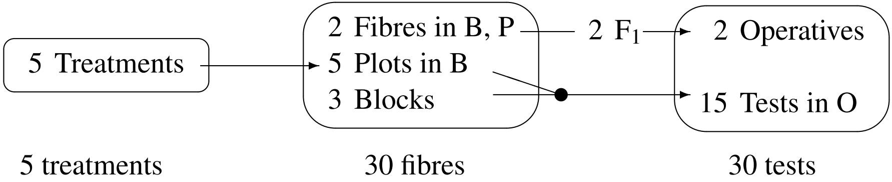

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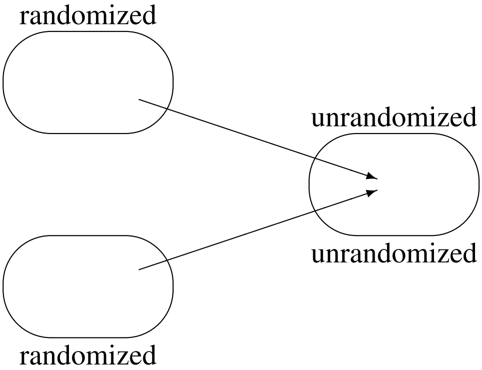
Randomization is not consonant: Fibres are nested in Blocks $\wedge$ Plots
Tests are nested in Operatives

Coincident randomizations: Order does not matter

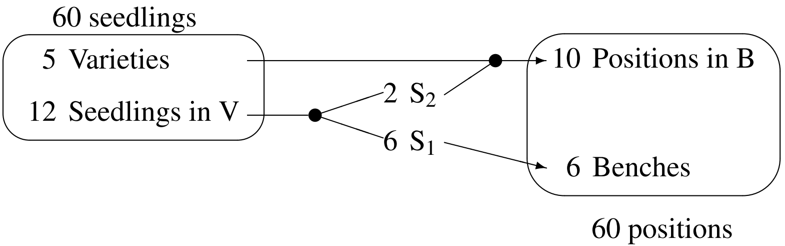


Levels of some factors from the two randomized tiers are associated by randomization.

Some effect from one randomized tier is confounded with some effect from the other randomized tier.

A plant experiment

12 seedlings of each of 5 varieties are put into individual pots; these 60 pots are randomly assigned to 6 benches in such a way that there are 2 seedlings of each variety on each bench.



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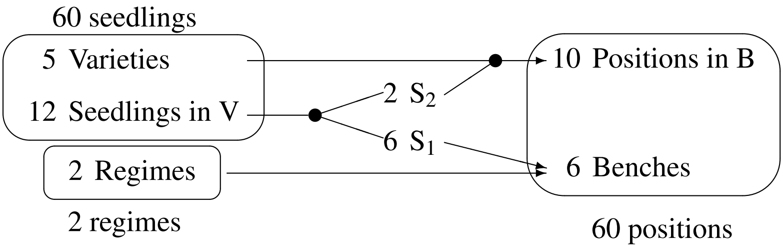

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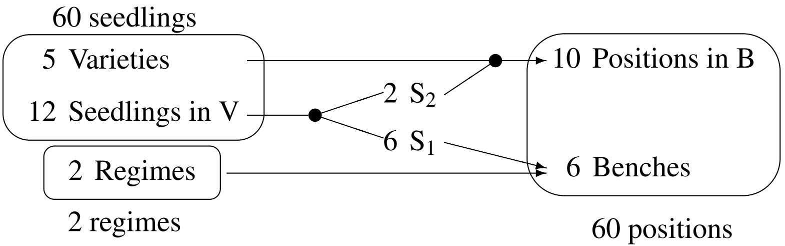
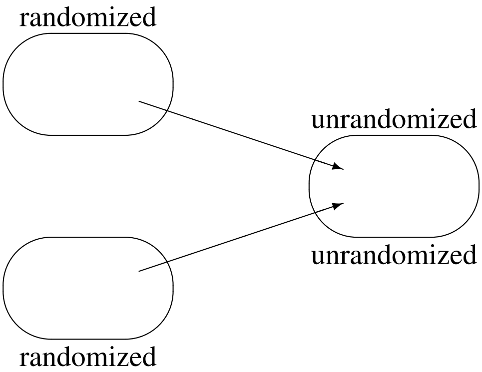


$$S_1 \wedge S_2 = \text{Seedlings}$$

1 df for Seedlings in Varieties is confounded with Regimes.

Independent randomizations: Order does not matter

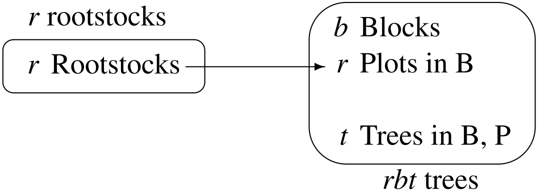


All combinations of levels of the factors from the two randomized tiers occur.

There is no confounding of effects from the two randomized tiers.

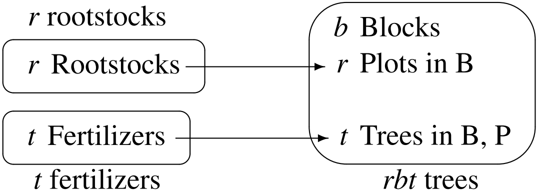
Superimposed experiment using split plots

A randomized complete block experiment with b blocks is set up to investigate the yield differences between r rootstocks for orange trees, each plot containing t trees.

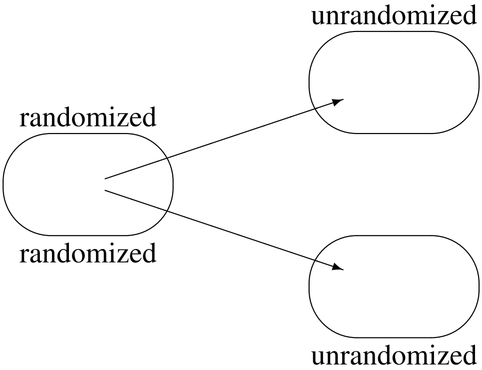


Superimposed experiment using split plots

A randomized complete block experiment with b blocks is set up to investigate the yield differences between r rootstocks for orange trees, each plot containing t trees.
After several years of running this initial experiment, it is decided to incorporate t fertilizer treatments by randomizing them to the t trees in each plot.



Double randomizations: Order does not matter

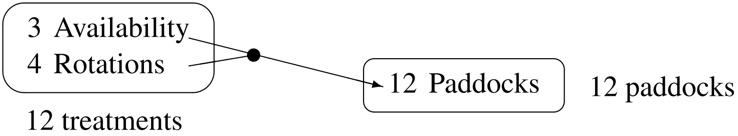


One unrandomized set has the same size as the doubly randomized set; the other contains the observational units.

Degenerate case of randomized-inclusive randomization.

An improperly replicated rotational grazing experiment

Combinations of 3 levels of availability and 4 rotations are applied completely at random to 12 paddocks.



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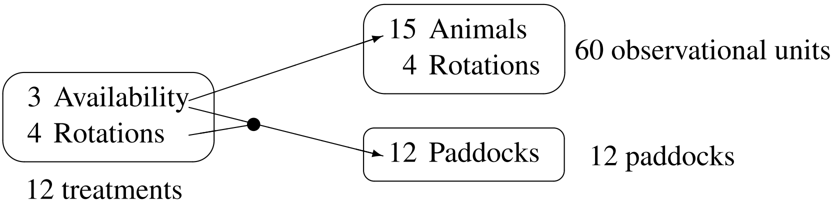
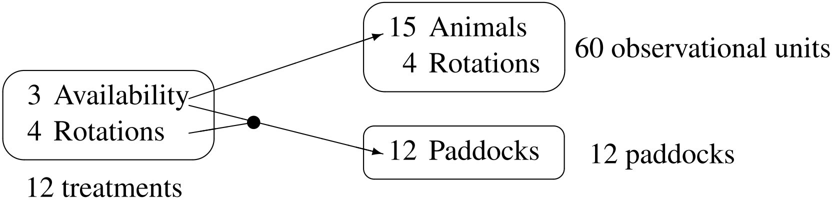
Also, the levels of availability are assigned completely at random to 15 animals so that each level of availability is assigned to 5 animals.



An improperly replicated rotational grazing experiment

Combinations of 3 levels of availability and 4 rotations are applied completely at random to 12 paddocks.
Also, the levels of availability are assigned completely at random to 15 animals so that each level of availability is assigned to 5 animals.
The 5 animals are then grazed together in sequence on the 4 paddocks assigned to that level of availability; the sequence of 4 paddocks is determined by the rotations assigned to them.



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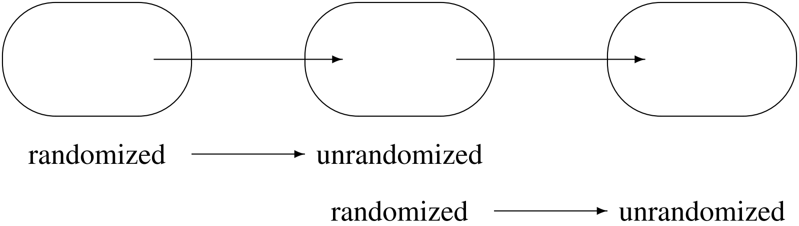
Randomized-inclusive randomizations: Order does matter



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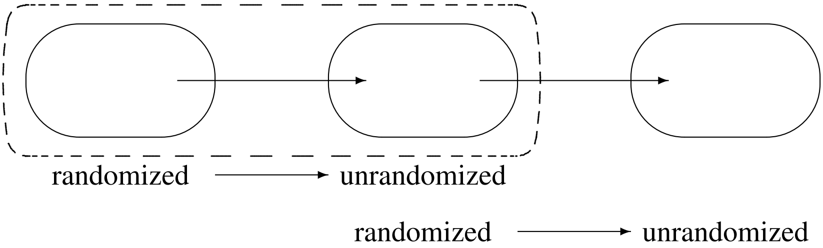
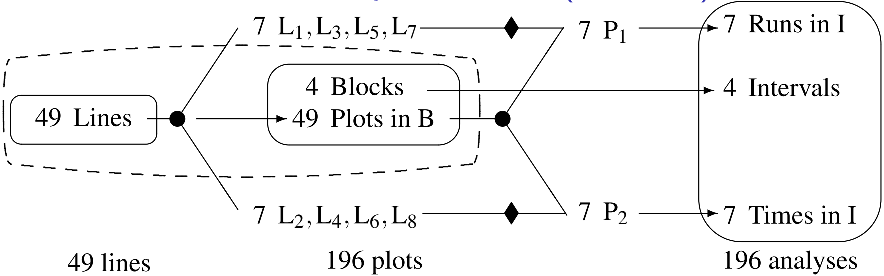


The dashed box shows the pseudotier.

A Two-Phase Wheat Variety Trial (Haskard)



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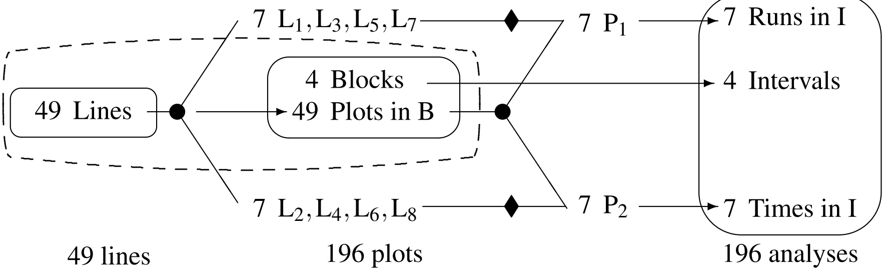

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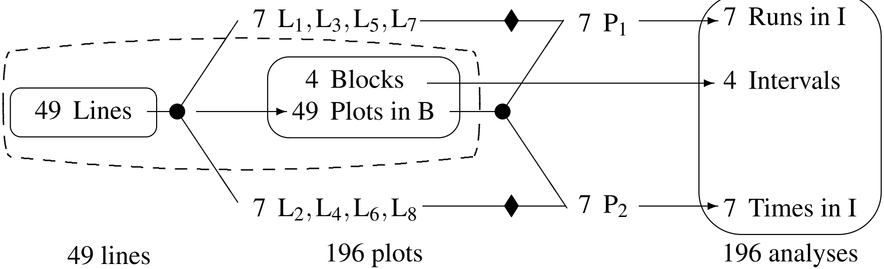

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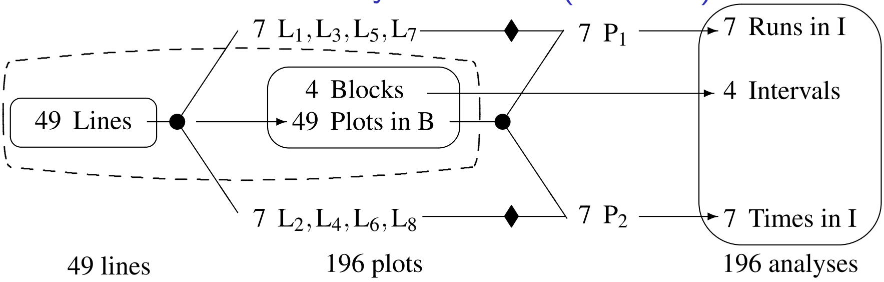

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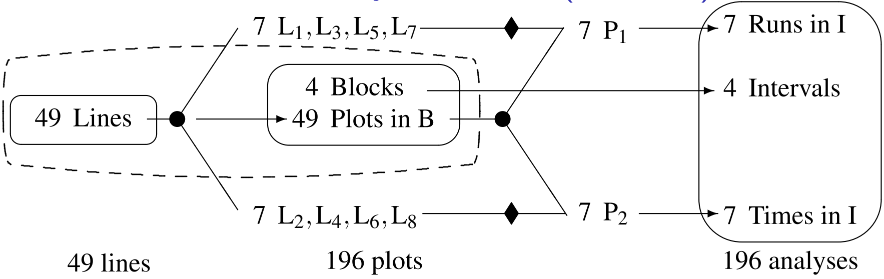

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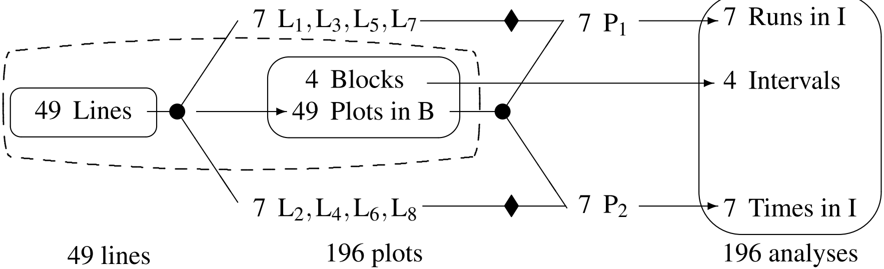

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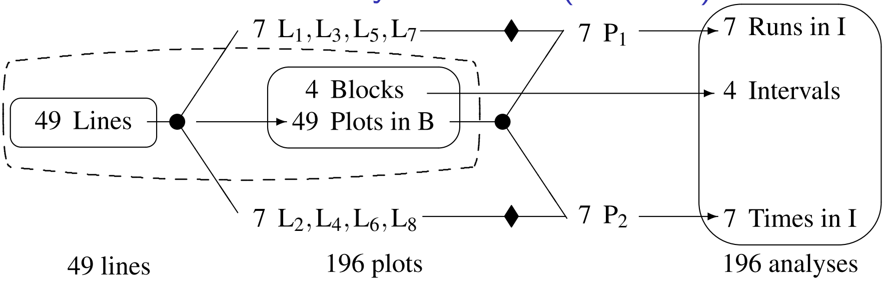

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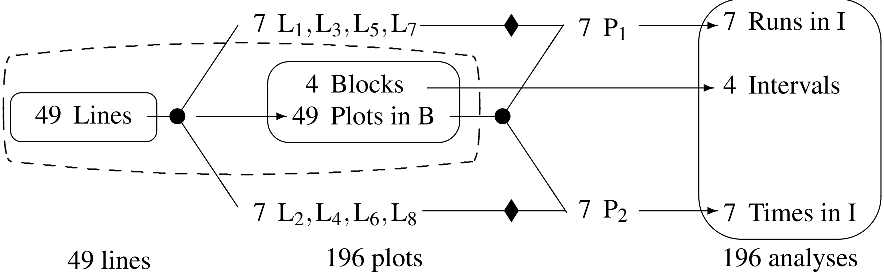

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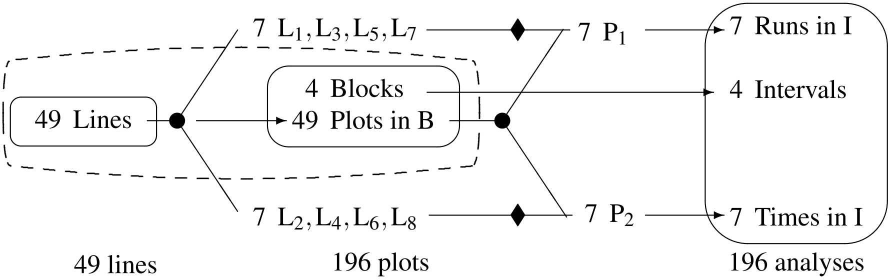

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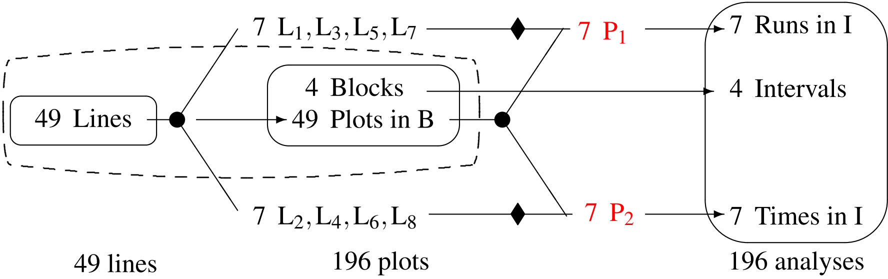

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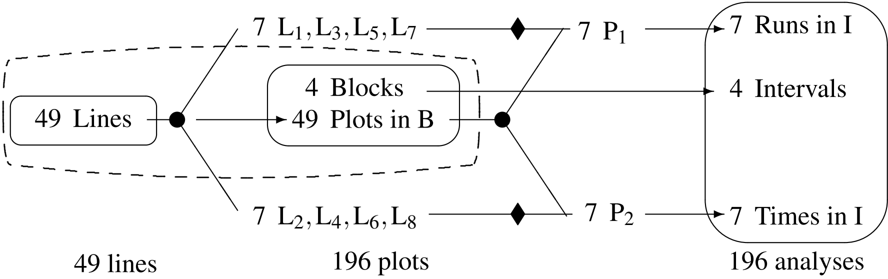

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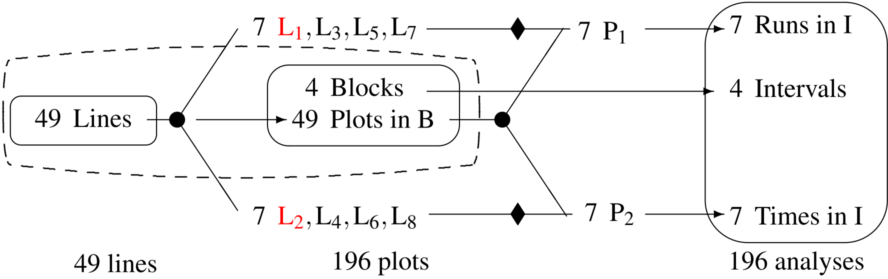

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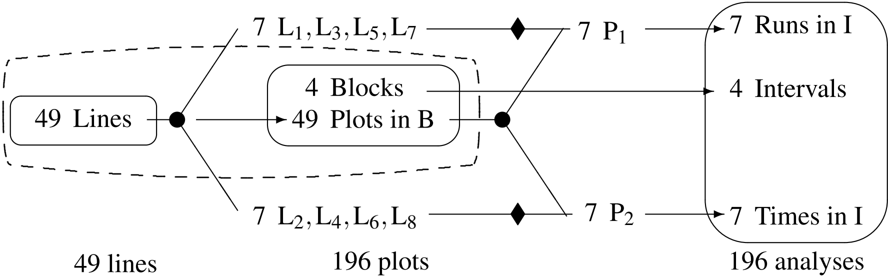

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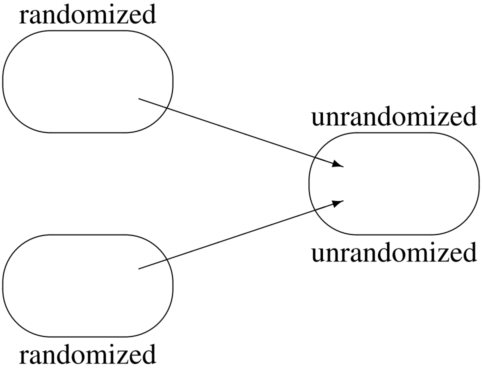
- ♦ shows that P_1 is defined by L_1 in the first block, ...

Unrandomized-inclusive randomizations: Order does matter



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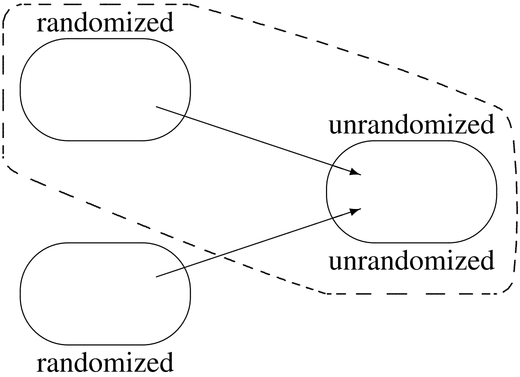

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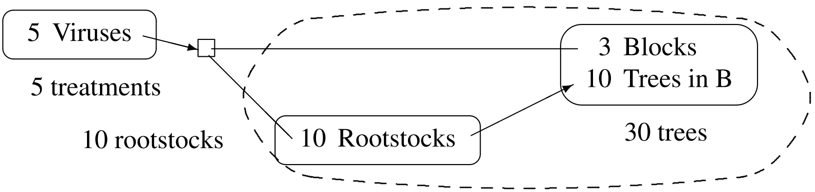
Superimposed Experiment in a Row-Column Design (Freeman, 1959)



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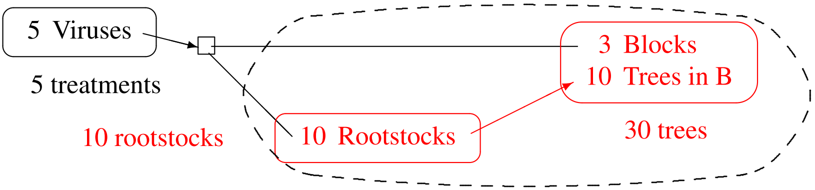

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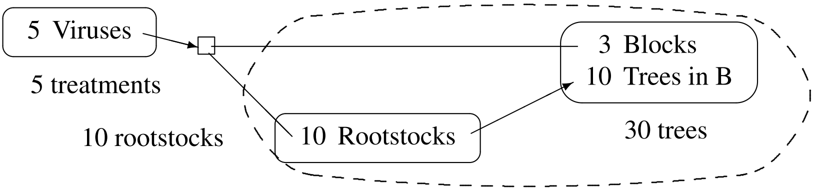

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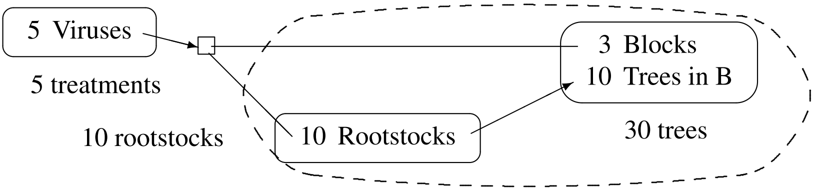

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- In the superimposed experiment, both the systematic design and the method of randomization are constrained by the outcome of the first randomization.

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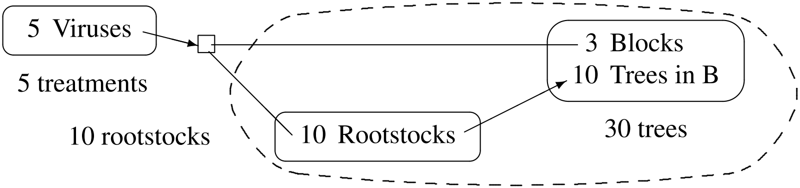

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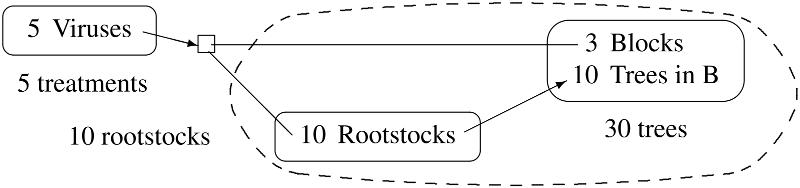

- □ shows that we need to know a specific (non-orthogonal) design for the allocation of the virus treatments to the block-rootstock combinations (from different tiers), such as

		Rootstocks									
		1	2	3	4	5	6	7	8	9	10
	I	A	B	A	C	D	C	B	E	E	D
Blocks	II	D	E	B	D	E	A	C	C	A	B
	III	E	A	C	E	B	D	D	B	C	A

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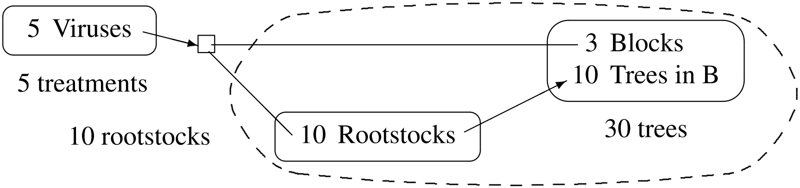

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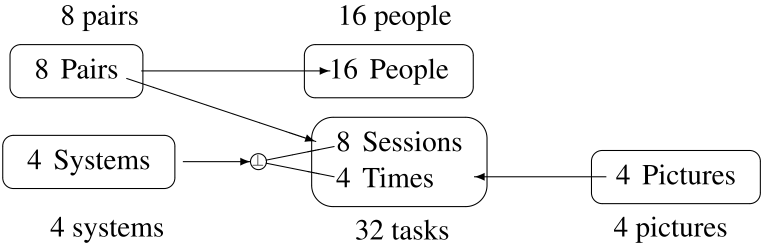
- Randomize this design by randomizing blocks and randomizing rootstocks independently.

Three or more randomizations

All these ideas extend to three or more randomizations
(four or more tiers)
in a straightforward way.

Testing new telephone systems (Lewis and Russell, 1998)



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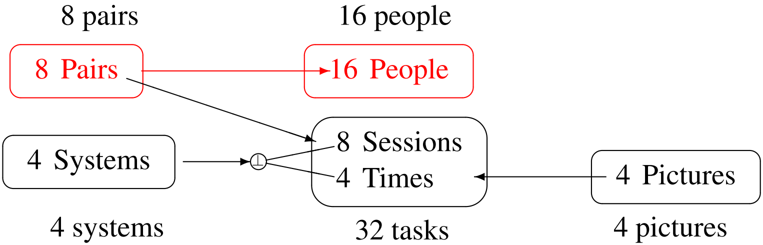

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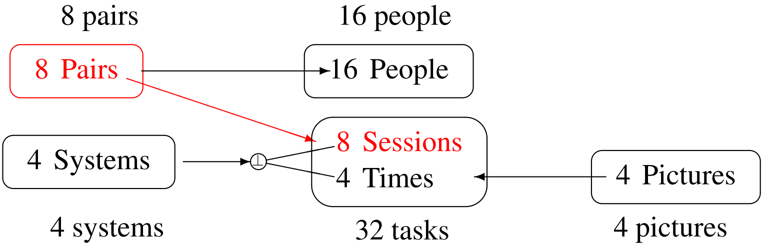

- 16 people are divided into 8 pairs.
- Each pair attends for 1 session, . . .

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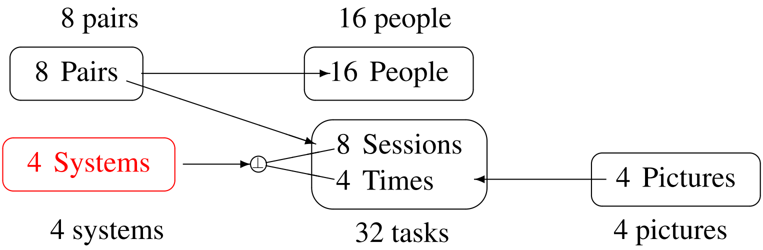

- 16 people are divided into 8 pairs.
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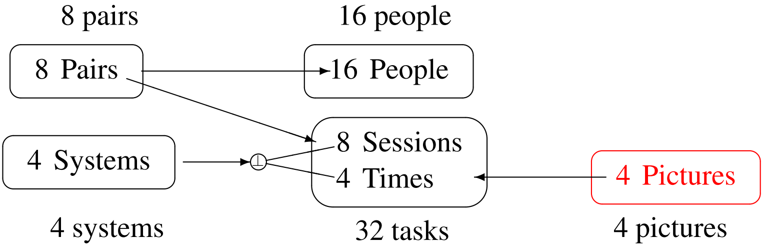

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- . . . one person looking at a picture and describing it to the other.

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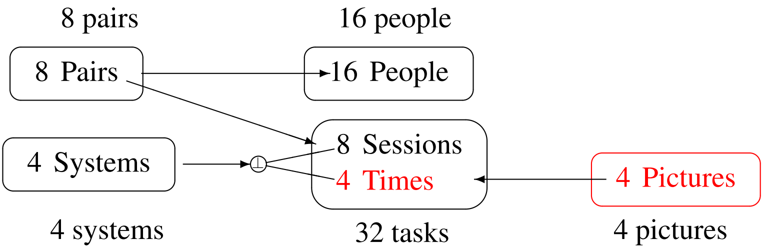

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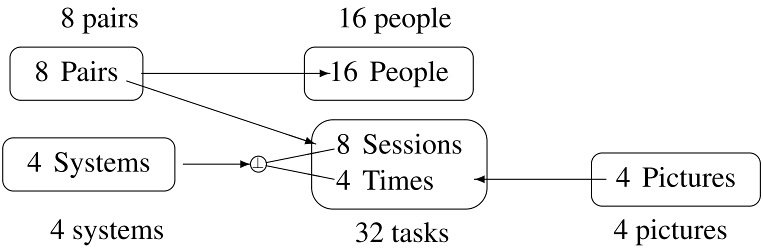

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- ⊥ indicates two 4×4 Latin squares.

Read all about it!

Multiple randomizations
(with discussion)
C. J. Brien and R. A. Bailey
Journal of the Royal Statistical Society, Series B
68 *(2006)*
pages 571–609.