BASICS OF EXPERIMENTAL DESIGN

From a statistician's perspective, an experiment is performed to decide (1) whether the observed differences among the treatments (or sets of experimental conditions) included in the experiment are due only to change, and (2) whether the size of these differences is of practical importance. Statistical inference reaches these decisions by comparing the variation in response among those experimental units exposed to the same treatment (experimental error) with that variation among experimental units exposed to different treatments (treatment effect). Thus, the three principles of experimental design are:

- **replication**, to provide an estimate of experimental error;
- **randomization**, to ensure that this estimate is statistically valid; and
- **local control**, to reduce experimental error by making the experiment more efficient.

The number of **replications** (sample size) is the number of experimental units that receive each treatment. The sample size should be small enough that negligible treatment differences are not declared statistically significant and large enough that meaningful treatment differences are declared statistically significant. Repeated measurements on the same experimental unit may or may not constitute true replications; treating dependent observations as if they were independent is one of the most common statistical errors found in the scientific literature.

Randomization means the use of a random device to assign the treatments to the experimental units. Randomization prevents the introduction of systematic bias into the experiment and provides the link between the actual experiment and the statistical model that underlies the data analysis. Thus, randomization is essential to the valid use of statistical methods.

Performing the experiment with more care is one way to exert **local control**. For example, the treatments should be applied uniformly and under standardized conditions. However, an experiment can also be made more efficient by the judicious choice of **design structure** and **treatment structure**.

If the experimental units are homogeneous, the treatments can be assigned to units randomly. Although the completely randomized design (CRD) is very flexible and easy to analyze, it is not always possible to obtain enough homogeneous experimental units to make this an efficient design. However, it is often possible to sort the experimental units into homogenous groups (blocks). The arrangement of the experimental units into blocks is the **design structure** of the experiment. There are many types of block designs, including the randomized complete block design, balanced or partially balanced incomplete block designs, and the Latin square design. With all of these designs, the gain in efficiency (compared with the CRD) is expected to outweigh the loss in flexibility and the increased complexity of the statistical analysis.

An experiment with *n* types of treatments (factors), each with two or more levels, is said to have an *n*-way **treatment structure**. For example, an experiment comparing diets with three levels of protein and four levels of fat would have a two-way treatment structure. All possible combinations of the treatment levels (a full factorial treatment structure) may be included in the experiment, or only a subset (a fractional factorial treatment structure). Factorial treatment structures allow the experimenter to study both the main effect of each factor and the interactions among the factors. If the purpose of the experiment is to maximize or minimize the response, experiments that consider only one factor at a time may not find the optimum when interactions are present. Moreover, if there are no interactions, performing one experiment with a factorial treatment structure is equivalent to performing several "one-factor-at-a-time" experiments. This "hidden replication" customarily results in a substantial decrease in the required sample size.

The above appeared in: "College of Veterinary Medicine Research Program News," Volume 1, Issue 2, October 1999.