

## Lesson 1: The Scientific Method

Agricultural biotechnology is a rapidly expanding area of research. This growth makes the documentation of research methods, procedures, and results vitally important. With so many researchers exploring the applications of agricultural biotechnology, proper research methods and proper documentation of those methods is necessary. The scientific method helps researchers organize their experiments and allows other researchers to duplicate their work, which adds credibility to the results. Patent applications have been rejected or slowed due to poor documentation of research or poor research methods, both of which make replicating the research difficult. This lesson will outline the proper method of designing biotechnology research efforts.

### **The Scientific Method**

The scientific method is a way of addressing scientific questions that provides a rational and structured system for research. A single biotechnology research effort may cost hundreds of thousands of dollars or more. A solid research approach is necessary to ensure the wise use of funds. Biotechnology researchers use the time-tested structure of the scientific method when conducting research.

The scientific method used by biotechnology researchers has six major parts. The first step in using the scientific method is to identify the problem to be investigated in a problem statement. The problem statement expresses the general purpose of the research. Knowledge about the problem or question for which an answer is being sought is required. The problem must be stated in such a way that it will lead to experimentation that will solve the problem. A sample problem statement is "Some plants in a corn field have yellow leaves."

After the problem has been identified, the second step is an investigation into previous research to identify alternate explanations or solutions to the problem. This activity leads into the third step of the scientific method, which involves formulating a hypothesis, or educated guess, about the anticipated outcome of the research. The hypothesis is essential, since experiments are developed to validate or invalidate this statement. It must be a focused and detailed statement that can be tested for accuracy. A hypothesis for the problem statement in the preceding paragraph is "Nitrogen deficiency causes the corn plants' leaves to be yellow." Since the hypothesis will direct the methods of experimentation, the hypothesis is the most important statement made by the researcher.

The fourth step is to design an experiment that will accurately test the hypothesis. This step is also a critical step. If the hypothesis is correct but poor experimental methods are used to test it, the chance of obtaining usable results is reduced. Selecting experimental methods for research requires knowledge of the available testing procedures and their advantages and limitations.

The fifth step of the scientific method is to conduct the experiment and collect data. When experimentation is complete, the final step is to draw conclusions about the success of the experiment by analyzing the information it provides. Based on this information, the researchers will accept or reject the hypothesis. The results of the experiments are examined, and evidence about answers to the original problem is detailed. As a part of this step, the limitations of the research results must also be explained. The conclusions collected must be supported by evidence in order to be valid.

Many researchers must add an additional step to this process. After the experiments have been chosen to test the hypothesis, researchers generally have to write a proposal. This proposal is directed at one or more funding agencies that provide funding to support research efforts. Researchers who work for private companies do not normally write a formal proposal, but they must still convince the company that the proposed research is worthwhile.

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### **Importance of the Scientific Method**

A logical question to ask when discussing the scientific method is simply, “Why is the scientific method important for research?” Three main reasons for its importance exist. First, the scientific method provides a logical approach to solving a problem. Scientific research, including research in biotechnology, is essentially a search for the unknown. The search for an unknown requires a basic, comprehensive search beginning from a given point. The scientific method helps researchers to analyze the known information and to select the best way to find the desired answers. Second, the scientific method is important because it helps force researchers to examine their research objectively. The structure of the scientific method aids in identifying alternative answers to research questions since the researchers must carefully examine existing research in the area of interest. A final reason that the scientific method is important is that its use allows other researchers to repeat the experiments. Other researchers need to be able to duplicate the results of an experiment before its validity can be fully established. Research that follows the scientific method is more easily understood than research that does not follow that structure. Research must follow the scientific method to gain professional credibility.

### **Laboratory Notebooks**

Laboratory notebooks serve an important function in biotechnology research. Notebooks provide a detailed account of the day-to-day activities of the experimental process. These notes are vital in examining directions for future research and for proving that specific research was done at a set time, which is required for patent applications. When research is not successful, researchers often review laboratory notebooks so that new research efforts can better address the problem. A notebook should be bound and written using permanent ink. It should also be complete, covering actual activities and all observations made. The laboratory notebook should have a cover that identifies the subject of the research and a table of contents.

Information from individual experiments is recorded on laboratory sheets. These sheets contain six major sections. The first section is for the title of the experiment, the date, and the name(s) of the investigator(s). The second section should briefly describe the purpose of the experiment. A list of materials needed should be included next. The procedures for the experiment should be outlined in the fourth section. These procedures should be detailed and include specific quantities of substances used, as well as the precise methods of using them. The next section should be a record of experimental results in the form of data and observations. Finally, the conclusions drawn from the research are recorded at the end of the laboratory sheet.

### **Summary**

The scientific method is an important tool in research for biotechnology. Without the logical structure of the scientific method, research would involve a blind search for answers. The six parts of the scientific method help researchers organize their research efforts and increase the likelihood of success. The laboratory notebook is an important source of documentation for researchers. This notebook should be a complete, day-to-day account of the research.

### **Credits**

Peterson, Dennis R., and Thomas Relberger. *Biotechnology in Agriculture*. Stillwater, Okla: Mid-America Vocational Curriculum Consortium, Inc., 1992.

Raven, Peter H., and George B. Johnson. *Understanding Biology*. St. Louis: Mosby, 1988.