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Beginnings and Organizational Entities in the United States Department of Agriculture, 1854–2006, With Selected Research Highlights

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Abstract

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Entomology has played an important role in the U.S. Department of Agriculture (USDA) since 1862 and prior to that in the Agricultural Division of the U.S. Patent Office beginning in 1854. The science has had organizational status at various levels in the USDA hierarchy. Since its inception it has grown in stature and numbers in research, regulatory, and pest management functions in USDA and has been extended into other branches of government. The first Federal entomologist received his appointment in 1854 as an expert in assembling statistics and other information on seeds, fruits, and insects in the United States. This text presents some of the history of the growth, impact, broadening of responsibility, and implementation of entomology in U.S. organizations and its expansion into research, education, extension, and regulatory functions.

KEYWORDS: Agricultural Research Service, Agricultural Research Administration, Bureau, Department of Agriculture, Department of the Interior, Entomology.

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- enhance the natural resource base and the environment, and
- provide economic opportunities for rural citizens, communities, and society as a whole.

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Preface

The more than 150-year existence of Federal entomology is paved with accomplishment and outstanding scientific leadership.

Entomology in the Federal establishment began before the U.S. Department of Agriculture (USDA) was formed. From a single entomologist hired in 1854 in the Agricultural Division of the United States Patent Office, and later in 1863 in the newly established USDA, Federal entomological research grew to be represented by more than 500 scientists at numerous research laboratories and work sites in the United States and in some foreign countries. At present there are about 400 Federal entomologists in USDA's Agricultural Research Service (ARS). In addition to the research community, quarantine, regulatory, and Federal-State extension and cooperative entomology activities provide vital services to agriculture and to the Nation as a whole. Other Federal organizations such as the Forest Service, Animal and Plant Health Inspection Service, and military establishments also have entomology programs. This entire cadre of Federal entomology expertise started with the single employee mentioned earlier.

Major emphasis in this publication is placed on the transition of entomological research and other entomology programs in Federal government organizations beginning with the first Patent Office entomologist to the present multidisciplinary structure of ARS. Regulatory, quarantine, cooperative Federal/State/extramural, and other programs that have branched off from the original entomological organization or developed independently are discussed within the limits of access to available information.

New and improved crop and animal arthropod pest protection technology has contributed to the ability of the nation's agricultural system to provide food, fiber, and animal and human health protection for the needs of continuing human population growth. A chronological record of the development, progress, and some accomplishments of the entomological organizations within USDA are presented in this document. Some of the early USDA organizational actions and program responsibility changes that affected entomological activity are included here for continuity. Most of the events reported herein have been gleaned from publications and the author's personal knowledge and correspondence with existing and former USDA employees. I have taken information liberally from published materials, but in all cases have made the effort to identify the original sources if they are known.

Many other events and organizational and personnel changes have certainly occurred during the more than 150 years of entomology in the Federal government than are recorded in this manuscript. But without permanent record or recall from the memories of former and present employees or others they may not appear here. Unfortunately, for these and other reasons, many of the details, personalities, heroes, stories and myths that readers remember or have heard about may have been lost for lack of documentation. This is not a unique lament. Osborn's introduction to *Fragments of Entomological History* (1937) refers to the scarcity of records documenting the beginnings of entomology in America. As with other phases of history, much that would be interesting now was not thought at the time to have historic value or lacked an interested party to record the events. Errors and omissions as a result of these occurrences or for other reasons are accepted in this writing as the sole responsibility of the author.

Any opinions, expressed or implied, are those of the author and do not reflect the view of the USDA or any of its components.

Where applicable and possible, dates reported here for occurrences other than publications are those cited as dates of Presidential document signing, Congressional action, USDA Administrator's or Secretary's announcements, or published effective dates of the described events. Calendar dates, when known, were recorded as opposed to fiscal year dates.

Contents

Abbreviations

AAAS	American Association for the Advancement of Science
AAEE	American Association of Economic Entomologists
ADA	Associate Deputy Administrator
AEE	Association of Economic Entomologists
APHIS	Animal and Plant Health Inspection Service
APHS	Animal and Plant Health Service
ARA	Agricultural Research Administration
ARS	Agricultural Research Service
AWPM	areawide pest management
BEPQ	Bureau of Entomology and Plant Quarantine
Bt	*Bacillus thuringiensis* (Berliner)
ESA	Entomological Society of America
FDA	Food and Drug Administration
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
IPM	integrated pest management
NPD	National Program Director
PPQ	Plant Protection and Quarantine
SEA	Science and Education Administration
SY	scientific year (see page 45 for definition)
USDA	U.S. Department of Agriculture

Introduction

American colonists encountered the insect world in their limited agricultural endeavors and also reported nuisance pests (gnats, mosquitoes, lice, and the like) in correspondence to Europe and elsewhere. Occasionally, historians refer to pests and damage to fruits and vegetables, but most accounts suggest little more than an avocational interest in entomology in the United States until the mid-1800s. The earliest entomological reports are vague and uninformative. Little information is recorded on insects economic and agricultural effects. The lack of recognition of serious insect pest problems remains unexplained and speculative, but many authors suggest that the minimal agricultural enterprises of the early colonists and limited commerce between Europe, other countries, and the Colonies delayed exotic pest introductions that are often responsible for insect outbreaks. Also, the earliest colonists were adventurers, hunters, and explorers with little interest in agricultural production. These suggestions partially explain the lack of concern with insect pests and entomology but does not address the lack of attention to these issues in later years, after serious insect problems were recognized and agriculture became of prime importance to the Colonies.

With expanding agricultural horizons, appointments of the first State and Federal professional entomologists in the same year, 1854, did attest to an increasing concern and awareness of the role of insects in the agricultural economy and the harm they could do to the well-being of people. Insect outbreaks affecting cereals and grain, vegetables and fruit, cotton, and forests, as well as increasing understanding in the mid-1800s to the early 1900s of the interaction of insects in the transmission of organisms causing disease in humans and animals, were convincing evidences of need for entomological solutions to pest problems.

Establishment of the United States Department of Agriculture (USDA) and the land-grant college system in 1862 and legislation in 1889 supporting State research experiment stations provided the educational opportunities and the experimental foundations for the growth of entomology and agricultural sciences in general. These actions also positioned the country well for its subsequent growth to becoming a leading agricultural nation of the world. Creation of an agricultural extension organization in 1914 formed the final link for technology transfer to the consumer and stakeholder.

Entomology in USDA expanded its scope of activity with increasing awareness of problems. Increasing levels of Congressional support resulted in research at more than 100 locations to solve high-priority research problems of international importance. The role of the entomological community in World Wars I and II in providing for well-fed United States military forces and agricultural commodity assistance for our allies, as well as protection from insect-related diseases, were well recognized. These accomplishments further increased the value of the science in the public mind.

Discovery of chemicals with effective insecticidal activity during World War II was a boon to mankind in the battle for insect control. These new materials resulted in savings of millions of dollars in annual crop value and lives due to reductions in insect-related disease in humans and animals. Accurate accounts of benefits to humanity are rare or nonexistent, and there may never be a satisfactory way to give full credit for the contribution of insecticides to human welfare.

The effects, as we all know, were not all positive. The adverse results from overuse, misuse, resistance development, and environmental issues are well documented. The issues provided entomologists with unprecedented challenges to develop more effective application technology, alternative use patterns, new and safer chemicals, and integration of chemicals with cultural, biological, behavioral, physical, regulatory, and other alternative methods that are ecologically oriented and socially and environmentally compatible.

The technology to achieve these goals surfaced through scientific breakthroughs in many disciplines. Advances in molecular biology, genetics, biochemistry, and other sciences promise unprecedented depth and scope in investigations leading to progressively higher levels of achievement and understanding of the complexity of agroecosystems. Federal entomologists in the United States and at foreign locations have made significant contributions through research, regulatory, quarantine, and technology-transfer activities that reduced farm and other agricultural production losses and improved animal welfare. Nonetheless, currently estimated damage by insect and mite pests continues to be in the range of 10 to 15 percent with additional yield losses of 10 to 40 percent during post-harvest handling. Costs of insecticides in the United States in recent years have exceeded $2 billion annually. Losses as a result of invasive insect species are estimated at $100 billion annually. There is obviously room for continuing study in agricultural entomology; similar concerns apply to animal welfare and environmental issues. Current programs are making significant progress in developing ecologically oriented approaches to pest control. The future—with advanced genetics, molecular biology, and other new technology—promises novel and exciting new approaches in pest management.

Now is an opportune and appropriate time to record some of past events and accomplishments in Federal entomology that influenced the present state of the art and provide for increasing levels of excellence in the future. Studies to identify arthropods, trace their evolution, define ecological relationships, and describe the importance of pest and beneficial arthropod species and their interactions in ecosystems have provided a firm basis for integrated pest management. Avoiding crop and animal losses to arthropod pests, reducing the cost of pest control, improving crop and animal production, and protecting human health and the environment have been driving forces in the U.S. Department of Agriculture since it was established by Congress in 1862.

Within this text, the beginnings of entomology in the early days of the Colonies and its transition to the present are written to record past accomplishments and provide expectations for the increasing value of future contributions from research that provides solutions to agricultural and environmental problems. Federal entomology, since its inception, benefited from synergistic interactions, cooperations, and communications with other segments of the entomological community in university, State, private industry, and other establishments. The main objective of this publication is to document entomological activity in the Federal government, with particular reference to research, filling some gaps of earlier presentations, and updating information from the mid-1930s to the present. Some tangential entomological events in States, industries, and other Federal agencies are included since they affected and complemented, or in some other way were involved in, Federal efforts.

Historical Reporting of Entomological Events

In the American Colonies and early years of the United States, entomological activities were sparsely documented. Four exceptions very briefly cover colonial times, with detail beginning about 1800 and continuing to the mid-1930s (Howard 1930, Essig 1931, Weiss 1936, Osborn 1937). These four authors are to be applauded for documenting the beginning of the entomological profession in the United States. Howard's *History of Applied Entomology (Somewhat Anecdotal);* Essig's *A History of Entomology;* Weiss's *The Pioneer Century;* and Osborn's *Fragments of Entomological History* are valuable contributions to the recording of personal, local, State, Federal, and some international entomology, accomplishments, and personalities.

In addition, the commemoration of the first 100 years of the Entomological Society of America (ESA) reviewed the emergence of entomology and ESA's role in the environmental movement and the new order of biotechnology and other advanced research (Smith 1989). This review documents the development of the professional societies, their successes and weaknesses in an agriculturally developing nation, and the loss of public confidence with increasing knowledge of the environmental impact of insecticides.

Entomological achievements accomplished through ecologically oriented pest management have dispelled most critics' objections of the science's long-term goals in global ecology. The present document briefly reviews interest in entomology, beginning with the first colonists, as a prelude to the formal pursuit of entomology as a profession in the United States (which began in the late 1800s). Barnes (1985) credited the 1800s American agricultural revolution with providing the first major market for entomological expertise.

Colonial Entomology, Agriculture, and Insect Pests

In spite of the lack of specific information, there are numerous historical referenes to the foundations of agriculture and the subsequent role of entomology in early New World agriculture. John Rolfe of Jamestown, VA, experimented with tobacco as early as 1613; and in Jamestown and Plymouth, MA, early settlers learned from Native Americans how to grow corn (Baker et al. 1963), beans, and potatoes (Moore 1967). Also at Jamestown, mulberry trees were identified by early settlers soon after their arrival in 1607 (Edwards 1940). Silkworm [*Bombyx mori* (L.)] eggs were imported from Italy, France, and Spain by the Virginia Company. In 1619, the Virginia Company required each man in the colonies to plant six mulberry trees a year for 7 years in anticipation of a developing silk industry (Edwards 1940). Silk was produced in all of the original colonies except Maryland (Senechal 2005).

In other areas, South Carolina settlers experimented with many tropical crops to find varieties that were suited to the area. When the first settlement was established in Georgia, an experimental garden was established, and a botanist was hired to collect in the West Indies and Central and South America plants having recognized potential for adaptation and use in the new Colony. Honeybees (*Apis mellifera* Linnaeus), as well as attempts to establish sericulture, were introduced into Massachusetts in early colonial days (Montgomery 1955). Apiculture developed into an active, productive industry in the United States; honeybee research began later to provide state-of-the-art technology and improve beekeeping efficiency.

The attempts to establish a long-term sericulture industry during colonial times and thereafter were not successful despite some limited success in the late 1800s in New York, New Jersey, Connecticut, and California (Bollman 1872). In the late 1890s, Congress made a special appropriation to promote silk culture in the United States. This was largely the result of an effort by James Wilson, then Secretary of Agriculture, to develop a household silk products culture in the South to improve economic conditions. Interest in sericulture revived briefly in the 1930s in California (Montgomery 1955), but it was also short-lived. Reasons for the lack of success have not been elaborated, but it appears that few Americans had either patience with the detail required for silkworm rearing or the delicate touch required before automation for unreeling the single strand of silk from the cocoon (Senechal 2005).

The limited crop production in the early American Colonies did not suffer seriously from insect attack, according to Howard (1930), Osborn (1937), and Davis (1952). This may be, but it was not particularly long after the first settlers arrived until insect problems were recognized. There is a lack of documentation of the economic effects of insect infestations, and authors have left confusing histories, or no records at all, of the importance of insects. However, the occasional records mentioning insects in colonial times suggest more than idle concern for entomology in the early days of American colonization.

Native insects that attacked native plants were known to adapt to new varieties brought by settlers as well as those plants developed from seeds or cuttings (Waite et al. 1926). It also was common knowledge that some plant materials brought from abroad were insect-infested and diseased. Slingerland and Crosby (1924) reported that John Hull in 1661 observed that for 4 years cankerworms devoured most of the apples in Boston. In addition, reports of nuisance pest aggravations were common in early letters from the Colonies to England (Weiss 1936). Personal correspondence, local newspapers, and other documents also mentioned gnats, mosquitoes, bedbugs [*Cimex lectularis* Linnaeus], and other aggravating insects. Mention of several species of nuisance insects (gnats, mosquitoes, flies, etc.) were found in reports by John Josselyn on his travels through the Colonies in 1638–1639 and 1663–1671 (Felter 1927).

Angoumois grain moth [*Sitotroga cerealella* (Olivier)] was recognized as a pest in 1728, and other established pests reported in the 18th century were webbing clothes moth [*Tineola bisselliella* (Hummel)], codling moth [*Cydia pomonella* (Linnaeus)], Hessian fly [*Mayetiola destructor* (Say)], pear sawfly [*Caliroa cerasi* (Linnaeus)], and oystershell scale [*Lepidosaphes ulmi* (Linnaeus)] (Sasscer 1940); but few serious widespread insect devastations were recorded. Baird (1917) found reports of oak trees stripped bare by insects in 1791 in Vermont and 1797 in Virginia. Parker (1954), in a similar manner, found documentation of grasshoppers attacking crops in Massachusetts Colony in 1740. Many local insect outbreaks were probably recorded only by word-of-mouth and quickly forgotten.

Records have been found of primitive attempts by early settlers to prevent insect damage—for example, building 9-foot fences to exclude plum curculio [*Conotrachelus nenuphar* (Herbst)] or hanging dead mice in trees for plum curculio to lay their eggs in, in preference to fruit (Waite et al. 1926). Other recommendations involved burning brimstone, tobacco, leather, rags, and other materials to repel pests. Drilling holes in fruit trees and filling them with sulfur, salt, calomel, or other materials was practiced to taint the plant sap and make it unpalatable for fruit-eating insects. These early attempts were ineffective because of the materials used; but with increased knowledge of plants and insect biology and physiology, repellents and systemic insecticides would in the future become a reality for management of some pests.

Henshaw (1895) listed the following numbers of papers and authors on economic entomology published through 1854:

Year	Number of papers	Number of authors
before 1800	11	10
1801–1810	4	4
1811–1820	24	18
1821–1830	42	18
1831–1840	32	2
1841–1845	46	19
1846–1850	74	28
1851–1854	53	12
1854	14	7

In the papers published from 1771 to 1840, 48 injurious insects or groups of insects were discussed.

Parks (1954) reported that by 1854 a few pests were causing serious damage in Ohio. Of particular concern were hessian fly, plum curculio, aphids, and codling moth. Forest tent caterpillar [*Malacosoma disstria* Hübner], cucumber beetle [*Diabrotica undecimpunctata howardi* Barber], peach tree borer [*Synanthedon exitiosa* (Say)], and periodical cicada [*Magicicada septendecim* (Linnaeus)] were also mentioned in the literature as pests in the late 1700s and early 1800s.

Evidence suggests that there was individual interest in entomology during the early development of the country, but organized entomology in the United States was slow to develop before 1855. Lack of recognition of the value of the science may have contributed to the lack of interest as suggested by some authors. Lack of agricultural colleges or Federal or State agricultural institutions to present factual entomological information was surely an important factor. The positive effect of these organizations on the importance of the science after 1862 is certain.

Agricultural Growth and Federal Explorations

Colonel Landon Carter was credited with writing the first paper dealing with economic entomology in the United States (Howard 1930). Carter's paper, published in *Transactions of the American Philosophical Society* in 1771, was entitled "Observations concerning the fly weevil, that destroys wheat, with some useful discoveries and conclusions regarding the propagation and progress of that pernicious insect, and methods to be used to prevent the destruction of the grain by it." *

During the Revolutionary War and shortly thereafter, changes in the insect pest situation began to be recognized. This appears to support geographical isolation of the American Colonies and limited commerce as factors limiting interest in development of entomology. W.D. Peck's paper, published in 1795 in *Massachusetts Magazine,* was entitled "The description and history of the cankerworm" (Davis 1952).* Pests of squash and pumpkin such as chinch bug [*Blissus leucopterus leucopterus* (Say)] (thought to be indigenous to the country) and the introduced pests hessian fly, codling moth, and Angoumois grain moth, began to receive attention as important factors limiting fruit and grain production.

Entomology found its value in its practical application of knowledge to preventing crop yield losses. With increasing agricultural production, additional insect pests began to appear, and the importance of entomological study began to be recognized. Devastations by locust, chinch bug, and Colorado potato beetle [*Leptinotarsa decemlineata* (Say)] in the early 1800s; spread of boll weevil [*Anthonomus grandis grandis* Boheman] in the late 1800s; and documentation of the relationships between mosquitoes and yellow fever and malaria in the late 1800s and early 1900s did much to highlight the importance of entomology to the welfare of society. Serious outbreaks of yellow fever during colonial times resulted in suffering, death, and major concern for the welfare of the Colonies. Within a short time additional information on other insects' relation to diseases of humans and animals further elevated the status of entomology as an important science.

* "Fly weevil" was a common name for Angoumois grain moth, and "cankerworm" a shortened version of spring cankerworm [*Paleacrita vernath* (Peck)].

Incidental interest in entomology at the Federal level first appeared indirectly in the form of financial support for insect collections in association with early explorations in the United States to collect and catalog information on birds, mammals, and reptiles during 1819–1821 and later (Osborn 1937). Thomas Say (1787–1834), often referred to as the Father of American Entomology (Say himself favored Friedrick V. Melsheimer with the title) was an important member of several federally supported expeditions to southwestern and western areas of the continent to collect specimens of interest to natural history (Osborn 1937, Weiss 1936). Melsheimer, mentioned above, published the first book on American entomology in 1806 (Osborn 1937). Say published on hessian fly as early as 1816, peachtree borer in 1828, and cotton leafworm [*Alabama argillacea* (Hübner)] in 1828. His reports on the exploration's findings were published in *Proceedings of the American Philosophical Society of Philadelphia*. [The society was organized in 1743 under the leadership of Benjamin Franklin (Knoblauch et al. 1962).] Osborn (1937) suggested that if Say is the "Father of American Entomology," surely Melsheimer should be the "Grandfather of American Entomology."

Federal funding and Congressional support were also provided in the early 19th century for the Smithsonian Institution. The Smithsonian Institution was established by Congress on August 10, 1848, as a trust from funds bequeathed to the United States from James Smithson, an English scientist. The purpose of the institution, per Smithson's bequest, was to "increase and diffuse knowledge among men." The institution performs, as part of its responsibilities, the essential work of insect preservation, identification, and systematics research as well as study of evolution and species diversity. Entomology in the Smithsonian Institution was initiated in the early days of its formation. Federal funding for this effort was a milestone in recognition of entomology at the national level. The program became formal with the appointment in 1881 of Charles V. Riley (Division of Entomology Chief) as Honorary Curator and with transfer of USDA insect collections to the Smithsonian the same year.

Early American Agricultural Interests

Agricultural practices in the early American Colonies, despite experimentation by individuals, remained basically the same as "Old World" crop production methods (Baker et al. 1963). However, the basic crops grown and the forms of tillage that dominated colonial agriculture for more than 200 years were those of Native Americans as adopted by the settlers (Sauer 1941). Following the American Revolution, many of the new Nation's leaders were farmers or came from farm backgrounds, and they were interested in improving agricultural production. Recognition of need for improvements in agriculture in the New World was inspired by the agricultural revolution in England during the 18th century and an overall increasing European interest in science (Wiser and Bowers 1981).

Two well-known agricultural groups established by progressive farming interests in the United States were the Philadelphia Society for Promoting Agriculture and the South Carolina Society for Promoting Agriculture. Both societies were organized in 1785. Their objectives and those of other philosophical societies were to exchange information, communicate scientific improvements, and improve early American agriculture (Weiss 1936). Thereafter, societies with similar interests were developed in New York in 1791, Massachusetts in 1792, and Connecticut in 1794 (Knoblauch et al. 1962). Thus, during colonial times and shortly thereafter interests and progress in agriculture were largely a product of the societies that were established to exchange information, though it appears that the societies did little to advance entomology (Barnes 1985).

Thomas Jefferson, Benjamin Franklin, and George Washington were members of the Philadelphia Society (Fletcher 1959). Washington's Mount Vernon estate cultivated the spirit of scientific research. He worked to conserve his soil, diversified crops, and pioneered the use of new machinery. Similarly, to improve American agriculture Franklin and Jefferson brought back accounts of agricultural inventions and new agricultural materials from their travels in Europe. Jefferson was a farmer, and he used his Monticello estate in Virginia as an experimental farm (Baker et al. 1963).

Though the groundswell of interest and recognition of need for research to provide new knowledge for the American farmer began with these and other early colonists, formal authority and responsibility for scientific activity in Federal agricultural research would not be implemented until the late 1800s. The growing need for agricultural study was probably helped by such advances as the invention of the steam-powered printing press in 1811, which resulted in the ability to produce inexpensive newspapers, magazines, and other publications for dissemination of agricultural information (Barnes 1985). The most important agriculture publications of the time were *Cultivator, Country Gentleman,* and *American Agriculturalist*. Damage caused by insects were frequently reported in local news outlets.

Federal Financial Support for Agriculture

The beginnings of Federal entomology in the United States obviously followed closely the early development of public and governmental agricultural interests. Formal focus on support for entomological and other agricultural sciences at the Federal level paralleled people's activities, interests, and needs that were essential to the establishment of the United States and the growing requirement of the new country to provide food, fiber, and a healthy environment for its people. Formation of USDA was a result of a long series of changes and improvements in American farming (Baker et al. 1963).

The American Revolution brought an awakening of the peoples' need to become a self-sustaining country. As the new country's first President, George Washington retained his interest in agriculture and in agricultural advances from England. Information was provided him through his continuing correspondence with two English farm leaders, Arthur Young and Sir John Sinclair (Edwards 1937). Young was the first secretary and Sinclair the first president of an English Board of Agriculture established in 1793 to survey the conditions of British agriculture and advise farmers of progress and needs. Sinclair became aware of Washington's pending retirement and advised him to recommend a Board of Agriculture, or some similar institution, with agriculture societies for correspondence in the capital of each State. On December 7, 1796, in his last annual message to Congress, Washington urged the creation of a board of agriculture.

Washington's request that the government support agriculture—the livelihood of the majority of the population—brought forth in Congress a ringing declaration on the need for government to develop information for the agricultural community. In spite of this enthusiastic response by Congress and urgings of important figures of the time such as John Quincy Adams and others, a Federal agricultural department would not become a reality until 1862, 66 years after Washington identified farmers' need for help.

A House of Representatives committee did recommend, on January 11, 1797, the first proposal that an American Society of Agriculture be formed with a secretary to be paid by the government. The proposal never came to vote. Though this action stimulated development of a number of additional State and local agricultural organizations, Congress did not respond with appropriated Federal funds until March 3, 1839. On that date, $1,000 was designated for 1 year to collect agricultural statistics and for other agricultural purposes. This action followed establishment of the United States Patent Office on July 4, 1836, with appointment of Henry L. Ellsworth as commissioner. Ellsworth's efforts in collecting and distributing seed to farmers at his own expense, his report to Congress, and requests for support for agriculture were major factors in the 1839 appropriation. Additional appropriations of $1,000 in 1842, $2,000 each in 1843 and 1844, and $3,000 in 1845 were a result of Ellsworth's continuing efforts. Funding for agriculture on an annual basis was sporadic for several years thereafter. Ellsworth's interest in agriculture was whetted by the many applications being submitted to the Patent Office for improved agricultural tools. He apparently established the Agricultural Division of the Patent Office to accommodate the patent applications for agricultural inventions and for seed collection (Moore 1967).

U.S. Patent Office and Professional Entomology's Beginnings at Federal and State Levels

The Patent Office became part of the newly established Department of the Interior on March 3, 1849. Federal entomology had its beginning when Townend Glover, an entomologist, was appointed on June 14, 1854, to the Agricultural Division of the Patent Office to collect statistics on seeds, fruits, and insects (Fernald 1896, table 1). He served in that capacity until 1859, when he resigned to teach entomology at the Agriculture College of Maryland. It is surprising to the author that Glover has not been given the title of "Father of Federal Entomology." His work on seeds, fruits, and insects and curatorship of his natural history collection following his resignation in 1859 apparently continued until he was again hired following establishment of USDA and transfer of responsibilities of the Agricultural Division of the Patent Office to the new Department. In effect, the Agricultural Division of the Patent Office became the Department of Agriculture (Moore 1967).

In the first half of the 19th century, interest in entomology increased in the States because of increases in damage and recognition of the influence of pest insects on crop growth and production. Thaddeus W. Harris published his report on *The Insects of Massachusetts Injurious to Vegetation* in 1841. Harris' work was authorized by a State commission from which he received $175 (Montgomery 1955). Thus, Harris probably became the first person in the United States to be monetarily rewarded for work in entomology. Accordingly, he has been called the "Father of Economic Entomology" (Smith 1989). His writings identified and provided remedial suggestions for over 50 injurious insect species. This number would increase to 209 by 1925, 85 of which attacked fruit crops (Waite et al. 1926).

Asa Fitch's appointment in 1854 in the State of New York followed the New York State Legislature's approval in 1853 of $1,000 for examination of insects injurious to vegetation (Howard 1930). Thus, the year 1854 has special meaning to entomologists. Fitch's appointment for $1,000 in New York and that of Glover for an unknown amount by the Federal government in the same year may have been the first action recognizing entomology as a profession. However, W.D. Peck was employed in 1805 at Harvard University to lecture on natural history (Osborn 1937). It is difficult to believe, with his interests, that entomological information was not part of the curriculum. As a librarian at Harvard, T.W. Harris also taught an entomology course from 1831–1842, but attendance was voluntary.

Congressional Actions Affecting Agricultural Development and Science

Three United States legislative acts of importance to entomology and American agriculture were passed in 1862. These acts provide for an efficient and productive Federal-State agricultural community able to feed and clothe people and protect animal and plant health in the United States and many other nations. USDA was established as a result of the Agriculture Organic Act passed by Congress and signed by President Abraham Lincoln on May 15, 1862 (Baker et al. 1963, Rasmusson and Baker 1962). The new law established at the seat of Government of the United States, a Department of Agriculture, the general designs and duties of which were to acquire and to diffuse among the people of the United States useful information on subjects connected with agriculture, and to procure, propagate, and distribute among the people new and valuable seeds and plants.

The Homestead Act, approved by Lincoln on May 20, 1862, opened half a continent to the plow (Stefferud 1962). The Act provided 160 acres of public land to the head of a family after the land had been cleared, improved, and lived on for 5 years. Though need for agricultural colleges had been expressed in the 1840s (Knoblauch et al. 1962), passage of the Act primed the pump again in recognizing need to provide agricultural information, education, and technology transfer to American farmers. Michigan established the first agricultural college in 1855, seven years before the Morrill Land Grant Act (Knoblauch et al. 1962). Funding for the college was supported by endowments and private donations.

The Morrill Land Grant Act, passed by Congress on July 2, 1862, donated public land to States for establishment of colleges to benefit American agriculture and mechanic arts. The Act provided the opportunity for educational facilities to provide knowledge to improve agricultural technology. Iowa in 1862 was the first State to accept funding for establishment of a college under the Morrill Land Grant Act (Baker et al. 1963). Massachusetts Agricultural College became a reality in 1863 (University of Massachusetts 2005). Indiana accepted the Morrill Act land grant funds in 1865, selected the college site in 1869, and registered its first students in 1874 (Deay 1955). By 1872, 35 States had received the endowment of land scrip prescribed in the Act (Watts 1872).

A milestone in development of entomology as a science in the experiment stations was establishment of the first entomology department in 1874 at Cornell University under the leadership of John H. Comstock. Formation of agricultural educational systems nationwide had major influence on development of agricultural and other sciences, including entomology. Though the Morrill Act provided facilities for teaching of agricultural science, it would be 25 years before State agricultural experiment stations with research responsibilities would become a reality in the land grant agricultural system.

Following passage of the Land Grant Act, some farm leaders and government officials questioned the need for experiment station research as part of the academic community. Others stressed that research was a vital component that provided scientific knowledge essential to improving agriculture. The extended debates concerning the issues of agricultural research delayed development of State experiment stations until the Hatch Act, which provided Federal aid, passed on March 2, 1887. The Morrill Act created the essential teaching link for providing knowledge to equip scientists with the tools for research implementation, but the long wait for facility funding to complete the circle from teaching to research implementation was frustrating to the scientific community.

Interest in agricultural research and the experiment station concept began in Europe and was first fostered in America through the philosophical societies. The European initiative to put scientists to work for agriculture began in the 1840s (Knoblauch et al. 1962). The experiment station concept in America was first adopted in 1856 in New York by early American agricultural enthusiasts following their experiences in experiment stations in England, Scotland, and Germany. Connecticut, in 1875, provided financial support to establish the first agricultural experiment station in the United States at Wesleyan University, Middletown, CT. California also established an experiment station in 1875, as did North Carolina in 1877, Massachusetts in 1878, and New York and New Jersey in 1880 (Moore 1967). Iowa established its experiment station on March 2, 1888. Fourteen State experiment stations were established before the 1887 passage of the Hatch Act.

Much later, on May 8, 1914, the Smith-Lever Act provided that extension work be administered cooperatively by USDA and State agricultural colleges. This Act provided for instruction and practical demonstrations on agriculture and home economics in communities and provided agricultural information through field demonstrations, publications, and other methods. The means to bring new agricultural research information to consumers and stakeholders on a timely basis was finally established. Memoranda of understanding between USDA and States firmly established that all extension work with USDA funding would be carried out through the State colleges of agriculture.

Entomology research and other entomology programs in the land grant university systems, private educational institutions, and agricultural and other associated industries paralleled that occurring at the in-house Federal level. Histories of State entomologists from the mid-1800s and experiment station entomology activities through 1937 were published by Howard (1930) and Osborn (1937). Also, much of the background and leadership of these and other entomologically oriented organizations during 1889 to 1939 is presented in the proceedings of the Joint Session of the American Association of Economic Entomologists (AAEE) with the Entomological Society of America (ESA) in the "Symposium of Fifty Years of Entomological Progress" (*Journal of Economic Entomology*, vol. 33, 1940) and by various contributors in the *Bulletin of the Entomological Society of America* 1989 (vol. 3) that deals with the centennial celebration of the society's founding.

Additionally, Smith (1989) traced and reviewed important events affecting ESA from 1889 to 1989. His stated objective was to review the setting in which the discipline of entomology emerged in the United States. Smith's presentation accomplished many things, including commendation and congratulation for some of the outstanding past and contemporary Federal and State leadership and constructive identification of areas of need and improvement. He also provided a retrospective of the first 100 years of ESA and its predecessor organization, an invaluable assessment of entomology as a science, and its internal conflict with implementation of its developed technology and the associated responsibility for the environment.

United States Department of Agriculture (USDA)

As a result of the Organic Act, USDA was formed on May 15, 1862, and Isaac Newton was sworn in as the first Commissioner of Agriculture on July 1, 1862. His staff (nine employees) were the members of the former Agricultural Division of the United States Patent Office, Department of the Interior. (For comparison and perspective, USDA in 2004 employed about 110,000 people.) The Organic Act charged the Commissioner of Agriculture with the responsibility to acquire and preserve all information on agriculture that he could by means of books, correspondence, and scientific experiments.

Scientific efforts in the early years of USDA were useful, but very little bona fide research was done before 1890 (Moore 1967). Most of the scientists were kept busy on service work—analyzing soils, marl, manure, and crops; classifying plants; making observations on crops and insects; trying new crops; and answering inquiries from farmers. Commissioners appointed in the early developmental stages of USDA were not research oriented, and the slow Federal progress in developing research programs encouraged the States to expand the State experiment station system. This complex of events probably does much to explain the issues of duplication of effort and research responsibilities of State and Federal organizations that remain in never-ending debate (Knoblauch et al. 1962).

Heads of USDA were designated Commissioners until February 9, 1889, when the Department was elevated to Cabinet level and the Secretary title was adopted (Baker et al. 1963).

Newton defined objectives in his first report for USDA:

- Collecting, arranging, and publishing statistical and other useful agricultural information
- Introducing valuable plants and animals
- Answering inquiries of farmers regarding agriculture
- Testing agricultural implements
- Conducting chemical analyses of soils, grains, fruits, plants, vegetables, and manures
- Establishing a professorship of botany and entomology
- Establishing an agricultural library and museum

These objectives were similar to those outlined by Congress in establishing USDA. Glover's talents and his work in the Patent Office were known to Newton, and he was hired in the new USDA. The first botanist in the department, Charles C. Parry, was not hired until 1872.

USDA in 1863 consisted of six rooms that were formerly the offices of the Agriculture Division in the Patent Office Building (Rasmussen and Baker 1962). These rooms housed a horticulturist, a chemist, an entomologist (Glover), a statistician, an editor, and 24 other employees.

A propagating garden in Washington, DC, between Madison and Adams Drives and Fourth and Sixth Streets, and areas between Independence and Constitution Avenues and 12th and 14th Streets, served as an experimental farm. The latter property was transferred to USDA when the army no longer needed it as a cattle yard. Funds appropriated in 1867 financed the 1868 construction of the USDA building, which served as headquarters until 1930. Congressional appropriations in 1897 and 1912 provided for construction of portions of the current Department buildings to accommodate some of the nearly 14,000 employees that made up the Department staff by 1912.

Arlington Farm, 400 acres in Rosslyn, VA, was established by an Act of Congress in 1900 that transferred the land from the War Department to USDA. The site was used by the Bureau of Plant Industry until 1941, when it was transferred back to the War Department for construction of the Pentagon. On-site Arlington Farm experimental work was transferred to Beltsville, MD, in 1941.

The Beltsville facility began with the purchase of 475 acres of land in 1910 to be used as a demonstration farm for the Bureau of Animal Industry. Beltsville ultimately became the present day Agricultural Research Center of more than 10,000 acres. In 1934, the Secretary of Agriculture announced plans for several Bureaus to conduct activities at Beltsville. Work on animal diseases in Bethesda, MD; experimental greenhouse plant propagation on the Washington Mall between 13th and 14th streets; bee culture at Somerset, MD; and insect control at Takoma Park, MD, were specifically mentioned for relocation to Beltsville. Beltsville became the Beltsville Research Center in 1934, the first of several name changes: National Agricultural Research Center, Beltsville Research Center again, Agricultural Research Center, and Beltsville Agricultural Research Center. Since 2000, it has been the Henry A. Wallace Beltsville Agricultural Research Center.

USDA's activities were not fully accepted by all in the Federal establishment as a high priority for government (Moore 1967). In the early years of USDA, Senate debates following submittal of a bill to elevate the organization to Cabinet level suggested that Cabinet posts were for essential government activities and that fostering agriculture was in no sense essential to the government of the country.

USDA's Division of Entomology

Until the early 1900s, USDA consisted of the Bureaus of Animal Industry and Weather, which conducted some research. Other scientific work, including entomology, took place in discipline-oriented, problem-solving divisions. The head of each division and Bureau reported directly to the Commissioner, and later

Secretary, of Agriculture. As the first Commissioner of Agriculture, Newton formed the Division of Entomology with Glover as Federal Entomologist (Baker et al. 1963). Glover served as Federal Entomologist until 1878 (Dodge 1888).

Glover's interest in establishing a museum meshed nicely with the charge for USDA from Congress and one of the Commissioner's objectives. The natural history collections assembled by Glover during his time in the Patent Office formed the base for the Agricultural Museum established by Commissioner Newton on August 1, 1864 (Baker et al. 1963). The collection was housed in USDA until 1905, when it was taken over by the Smithsonian Institution and other organizations. The insect collections of the Agricultural Museum had been transferred to the Smithsonian in 1881.

Glover's contribution to development of the Agricultural Museum had far-reaching effects in support of the Smithsonian Institution. His many duties and responsibilities as Curator of Natural History Collections severely compromised his ability to do original entomological study, but his 1865 report to the Commissioner of Agriculture on the potential importance of European insect introductions into the United States and the need to inspect all plant materials entering the country was a landmark in concern for exotic pest problems (Howard 1930, Rainwater and Parencia 1981). Glover's warning, as history records, was completely justified. Recent estimates suggest that invasive species cost the American public more than $100 billion annually (Faust 2001). Until 1800 only about 36 insects were identified as invasive species (Simberloff 1986, Simberloff et al. 1997, Sakai et al. 2001). Capinera (2002) reported that Europe was the principal origin of nonindigenous vegetable pests in North America. Establishment of invasive species in the United States peaked during 1850–1899. Recently the increasing importance of invasive species was recognized in the establishment of the Invasive Species Council in 1999 by Presidential Executive Order 13112. The objective of the council is to develop an Invasive Species Management Plan (Faust 2001).

Charles V. Riley, the second Federal Entomologist, had established a reputation for excellent entomological work as the State Entomologist of Missouri prior to his appointment in USDA. Riley's concern for the effects of the Rocky Mountain locust [*Melanoplus spretus* (Walsh)] outbreak on the economy of grain-producing States gained him early national recognition. His actions were instrumental in getting the 1876 Congress to appropriate money to establish the United States Entomological Commission in 1877 (Baker et al. 1963). In his 1874 annual report to the State of Missouri, Riley devoted considerable time to describing the depredations of grasshoppers, which resulted in losses of millions of dollars each year. He suggested that Congress establish a commission to attend to grasshopper, chinch bug, cotton leafworm, and other insects causing widespread damage. Riley further suggested that commission members be chosen by the National Academy of Science and approved by the Secretary of the Treasury (Howard 1930).

Two bills were introduced in Congress in early 1876 providing $5,000 per year for each of five scientists. Neither bill passed, but a more modest appropriation was approved in March 1876 providing $18,000 to the Director of the Geological Survey to be spent by three scientists to investigate Rocky Mountain locust. Reduced appropriations of $10,000 were approved in both 1878 and 1879. The purpose of the commission was to study grasshoppers, which were causing severe damage to rangeland and other vegetation in the West. Riley served as its first chief. Other commission members were Alpheus Packard and Cyrus Thomas. The commission produced seven bulletins: two on grasshoppers; one each on cotton leafworm, Hessian fly, and chinch bug; a general index to reports and insects of Missouri; and the last a treatise on insects injurious to forest and shade trees.

Riley had become so well known as a national entomological figure that he was appointed to succeed Glover as Federal Entomologist in June 1878. Riley brought Theodore Pergrande and Eugene A. Schwartz with him from Missouri and also hired Leland O. Howard from Cornell in 1878 to assist in entomological work. Howard would become chief of the division and Bureau in later years.

Cotton leafworm had become a serious cotton pest. During his first year as Federal Entomologist Riley hired John H. Comstock, then teaching at Cornell University, as a special agent to work with him in the summer of 1878 on the cotton leafworm problem. Work on cotton leafworm and other cotton insects was later transferred to the United States Entomological Commission. Riley resigned as Federal Entomologist in March 1879 but retained his office as Chief of the Entomological Commission until March 1881. He also continued working on cotton insects and published on cotton leafworm and bollworm [*Helicoverpa zea* (Boddie)] in entomological commission reports.

From 1879 to 1881, Comstock, on leave of absence from Cornell**,** served as Federal Entomologist. He continued to work on the reports of the cotton leafworm from observations made in 1878 in cooperation with Riley. In 1881, Riley returned to the Division of Entomology and remained chief until 1894. All functions of the Entomological Commission were gradually absorbed into the Division of Entomology (Osborn 1937). Comstock's influence on many phases of entomology following his return to Cornell University is legendary. Much has been speculated on how his continued leadership would have affected development and direction of entomology at the Federal level had he remained chief of the Division of Entomology.

Most of the division's entomological work following Riley's return focused on chinch bug, Hessian fly, codling moth, plum curculio, hop aphid [*Phorodon humuli* (Schrank)], and grasshoppers (Howard 1930). Entomology at the Federal level, however, was expanding rapidly. The division broadened its scope with the hiring of Albert Koebele in 1882, Daniel W. Coquillet in 1885, Charles L. Marlatt in 1888, and Francis Chittenden in 1891. Koebele distinguished himself with his work on biological control, Coquillet on citrus insects, Marlatt on insecticides and application equipment, and Chittenden on truck crop entomology.

Interestingly, Howard (1930) reported that for a brief period, a Branch of Ornithology was an organizational entity of the Division of Entomology. The organization later became the Division of Economic Ornithology and Mammalogy from 1886 to 1896 and the Division of Biological Survey from 1896 to 1905. The reason for assigning ornithology to the Division of Entomology remains unknown, but appears to have been related to an interest in the value of birds to farmers as destroyers of injurious insects. Also, and probably more importantly, the American Ornithologist's Union, with Riley's help, obtained a $5,000 appropriation for study of the English sparrow problem and therefore the money was designated for the Division of Entomology.

With increased responsibility for research on bird and animal migration, the Bureau of Biological Survey was established on July 1, 1905. Research expanded further to include wildlife conservation and environmental interactions. Ultimately on July 1, 1939, the Bureau of Biological Survey was transferred to the Department of the Interior and merged with the Bureau of Fisheries to become the Fish and Wildlife Service (Moore 1967).

At some time during the early days of the Division of Entomology and for many years thereafter, "agents" were commissioned in various areas to perform high-priority tasks related to important entomological issues of the time that needed verification or additional information. Some of the earliest references to agents temporarily hired for special entomology tasks date from Riley's tenure. During the period of 1881 to 1885 the Division of Entomology budget increased from $7,000 to $42,900 (Dupree 1957). Some of the funds apparently were expended for assistants (agents) who were employed to visit areas of insect outbreaks at various locations in the Nation, and their observations and recommendations contributed greatly to solving the problems. A few, but by no means all, of the appointees who also distinguished themselves throughout their careers in entomology at other institutions or in permanent Federal positions were J.H. Comstock, who was employed as an agent in Alabama, Herbert Osborn in Iowa, Francis M. Webster in Indiana, and Henry C. Hubbard and William H. Ashmead in Florida; in each case the agent investigated and reported on insect problems in his area. A working association may have existed between special agents, field agents, and field stations, all of which were discontinued in 1894 by Secretary of Agriculture Julius Sterling Morton (Osborn 1937). The reason for discontinuing the program remains unknown, but was most likely due to lack of funding, though program redirection or reduction may have also been considerations. In retrospect, the decision was poorly advised. Only a few of many outstanding entomologists that participated in the program are mentioned above, but they provide outstanding testimony to its contributions.

Riley became involved in practical aspects of controlling injurious insects to prevent crop damage. From Glover's earliest work, which included agricultural statistics, collections of insects and seed, and early identifications and life histories of pest insects and their natural enemies, Federal entomology has been charged with problem-solving focused on improvement of food and fiber crops and animal production by increasing yields and quality and improving animal health.

Riley recognized a need to control damaging insect infestations and the potential of insecticides for the purpose. Available materials were not very effective (Howard 1930). As an editorial comment in the first issue of *Practical Entomologist,* Cresson et al. (1865) stated, "Quack remedies were exploited and most entomologists frowned on the idea of insecticides. Agricultural journals have from year to year presented through their columns various recipes as preventive of the attacks or destructive to the life of curculio, apple-moth, squash-bug, or other pests. The majority of the proposed decoctions and washes were considered useless." The authors further suggested that if the destruction of insects is to be accomplished satisfactorily, it will have to be the result not of chemical preparations, but of simple means directed by a knowledge of the history and habits of the depredators.

In general, methods of controlling vegetable insects in the early 20th century stressed identification of the insect, characterization of the injury, natural control (abiotic and biotic), production inputs, and host-plant resistance as potential methods for controlling pest infestations (Waite et al. 1926). The chemical component of insect control methodology was used cautiously. Insect pest populations were known to be held in check by natural agents and could be reduced by cultural means. When it became necessary to combat them with chemicals in the form of dusts, sprays, baits, or fumigants, such methods were acknowledged as expensive and not always satisfactory, but valuable because they were the only means of relief once the crop or product became infested. This approach, with little modification, would do credit to the most discerning of current-day integrated pest management specialists.

The standard insecticides in the 1870s and 1880s were paris green and london purple for gnawing insects, kerosene-soap emulsion for sucking insects, and pyrethrum for household insects. These remained for many years the chemical tools of the economic entomologist (Howard 1930). Waite et al. (1926) referred to lime-sulfur concentrate, nicotine sulfate, kerosene emulsion, lubricating oil emulsion, lead and calcium arsenate. and paris green as the more important insecticides available at the time. Klassen and Schwartz (1985), Klassen (1989), and Kenaga (1989) suggest that little new occurred in insecticide chemistry until carbon tetrachloride, chloropicrin, and paradichlorobenzene fumigants were discovered between 1908 and 1911.

The more notable insecticide discoveries had their beginning about 1942. The public reaction of near-panic proportions to the devastations of Colorado potato beetle in the 1860s, gypsy moth [*Lymantria dispar* (L.)] beginning in 1892, and boll weevil in the 1890s provided near-perfect perceptions of disasters in the making that encouraged insecticide use. Concern for safety of insecticides and resources, particularly on edible commodities, began with the increase in insecticide use. Busbey (1962) reported that the search for more effective, safer insecticides began in Federal laboratories in the late 1920s and continued through the mid-1950s, when redirections to fund nonchemical control methods took higher priority.

Even with the concerns for the safe use of insecticides, the public's fear of insect losses resulted in—and often continues to result in—acceptance of the widespread use of arsenicals in the 1800s and other insecticides at later dates. The evolution throughout the era of increasing insecticide resistance, harmful effects of residues on nontarget organisms, and other environmental assaults is well documented. These problems developed despite warnings from the few scientists who predicted resistance and other adverse effects (Smith 1989). The euphoria associated with the "quick fix" insecticide approach was shared by most of the entomological community, not only that of the agriculturally oriented economic entomologists.

Misuse, overuse, and plain error in implementation of scientific technology for chemical control of pests were real. However, the entomological community's total assumption of the stigma associated with chemical control and its adverse environmental impacts has been abundantly overextended and must be ameliorated by extensive recent evidence of changes in the focus of entomology, education, research, and extension that has resulted in significant progress and intensified development of ecologically oriented integrated pest management (IPM) for some major pests. An active, highly competent group of entomologists and other scientists are making significant progress in refining and developing new pest-management systems. New, more selective chemistries, resistance management, sampling, action thresholds, and other technologies are being employed to develop safe, efficient, effective use of chemical control in IPM. The current-day entomological community is keenly aware of social, environmental, and economic considerations in pest management.

Returning to Riley, perhaps the most notable of his achievements was his support of exploration and introduction of natural enemies for biological control of insect pests. He was responsible for initiation of classical biological control in Federal entomology. During 1883 and 1884 Riley encouraged importation of the natural enemy *Cotesia glomerata* (L.) into the United States for control of imported cabbageworm [*Pieris rapae* (L.)] (Coulson et al. 2000). This was the first insect parasite of foreign origin imported for establishment in the United States. The most famous example of his biocontrol initiatives is Koebele's importation of vedalia beetle [*Rhodalia cardinalis* (Mulsant)] from Australia into California in 1888 for control of cottony-cushion scale [*Icerya purchasi* Maskall]. Doutt (1964) commented that though the biological control method antedated the introduction of vedalia beetle, it is everywhere agreed that this project against cottony-cushion scale established the procedure as a valid method of pest control.

The value of biological control has been so widely acclaimed that since 1919 foreign parasite introduction laboratories have been located in 19 or more different countries and Puerto Rico to work on biological control of numerous insect pests (Vail et al. 2001). Quarantine facilities are currently located in six States to handle and clear imported beneficial insects for use in the United States.

Though the potential of biological control was clearly recognized, until 1934 all USDA foreign explorations, introductions, and releases of natural enemies were handled independently by commodity-oriented units of the entomology sections, branches, investigations, and Bureaus (Coulson et al. 2000).

Riley also recognized natural resistance to insect attack in some plants. He recommended grafting European grapes susceptible to grape phylloxera [*Daktulosphaira vitifoliae* (Fitch)] onto resistant American rootstock (Hooker 1929, Summers 1925). His role in saving the French wine industry was rewarded with the French Order of Merit in Agriculture. In spite of this success and a report of wheat varieties resistant to Hessian fly (Havens 1792) and later a wheat selected for leaf rust resistance that also provided resistance to Hessian fly, opportunities for developing resistant plants by selective breeding were not pursued extensively until Painter published his book, *Insect Resistance in Crop Plants*.

Throughout his career, Riley also played a role in publication and documentation of entomological study. The first journal in the United States that addressed applied entomology was *Practical Entomologist,* published from 1865 to 1867 by the Entomological Society of Philadelphia (later named the American Entomological Society). With its demise, Riley and Benjamin D. Walsh initiated *American Entomologist* in 1868 (*American Entomologist and Botanist* after 1869). *American Entomologist and Botanist* was discontinued in 1879. Riley revived it in 1880 as *American Entomologist: An Illustrated Magazine of Popular and Practical Entomology*.

Smith (1989) wrote that Riley was a strong proponent of the 1887 Hatch Act, which provided Federal financing for State experiment stations. Following passage of the Act, Riley was quick to advocate formation of an organization to establish entomological professionalism in agriculture. He instructed his assistant L.O. Howard, with the help of James Fletcher, to develop documents and convene a conference to be held in conjunction with the American Association for the Advancement of Science (AAAS) meeting in 1889 to consider such an organization. Fletcher was President of the Entomological Club, a special interest group formed in 1872 in association with AAAS, which was formed in 1847. At the meeting Riley was elected president of the Association of Official Economic Entomologists (AOEE), S.A. Forbes and Albert J. Cook were elected vice-presidents, and John B. Smith became secretary. AOEE was later named the Association of Economic Entomologists and finally the American Association of Economic Entomologists (AAEE)

Riley also became the first editor of *Insect Life,* which published the proceedings of the AOEE. *Insect Life* was published by USDA beginning in 1888 and continuing to 1895 (Smith 1989).

The congressional mandate for USDA to collect, analyze, and publish statistical and other useful agricultural information has been closely followed throughout its history. For entomology, when *Insect Life* was discontinued, it was promised that in its place USDA would publish two series of bulletins, one technical in nature and the other of more general interest (Howard 1897a). AAEE proceedings were published in USDA Bulletins from 1895 until 1907 (7th to 19th annual meetings). It is small wonder that biographers account Riley as more than an entomologist, describing him with the talents of an artist, poet, writer, journalist, linguist, naturalist, and philosopher (Wood 2005).

Throughout their history, Federal entomology programs have interacted with, supported, and complemented State programs. These relationships were facilitated by enactment of the Hatch Act on March 2, 1887. Riley's early involvement in establishing a professional entomological organization and working closely with State entomologists provided for lasting and productive cooperation. Entomological activities were established within the Department of Agriculture's Office of Experiment Stations in 1888. The name was changed to Office of Extension Service on May 8, 1914, and to State Experiment Stations Division, Agricultural Research Service, in 1953. In 1961, the organization became known as the Cooperative State Research Service and is currently the Cooperative State Research, Education, and Extension Service (CSREES).

The mission of CSREES is to advance knowledge about agriculture, the environment, human health and well-being, and communities (Rockey 2004). To accomplish this, CSREES provides program leadership to identify, develop, and manage programs that support university-based or other organizationally based agricultural research, education, and extension and provides Federal assistance for such activities though grants and agreements.

CSREES and preceding organizations have played important roles in development of American, as well as worldwide, agricultural entomology research and technology transfer through education and through cooperative extramural research efforts and other activities with State and other agencies. The book *State Agricultural Experiment Stations: A History of Research Policy and Procedure* by Knoblauch et al. (1962) is a source of information on policy and legislation enabling and implementing growth of the agricultural experiment station concept as part of the land grant college system. Throughout their histories, Federal and State research organizations have engaged in dialogue to establish the roles of their scientists in the agricultural community, their responsibilities and priorities, and the limits of each organization's involvement at local levels.

In 1894, Howard succeeded Riley as chief of the Division of Entomology. Spilman (1989) considered Howard one of the giants in the history of entomology and a man of wit, a raconteur, a diplomat, an accomplished administrator, and a great economic entomologist. Howard expanded Federal interests into economic aspects of insect problems that affect agricultural production as well as other entomological areas. Charles L. Marlatt from Kansas State Agriculture College had been employed in the Division of Entomology since 1888. He became the first assistant and subsequently associate entomologist of the division.

In 1897, the entomological work of the Federal government was conducted in a single laboratory in the District of Columbia. Early research consisted of species identifications, life history studies, and development of control methods. Four events in the last decade of the nineteenth century had a profound effect on the perception of the importance and direction of Federal entomology (Howard 1930):

- Discovery of gypsy moth in Massachusetts
- Discovery of San Jose scale [*Quadraspidiotus perniciosus* (Comstock)] in the eastern United States
- Discovery of Mexican boll weevil in Texas,
- Discovery that malaria was carried and transmitted by mosquitoes

San Jose scale, more than any insect pest of the past, stimulated worldwide development of insect control interests and eradication efforts (Marlatt 1940). Its presence stimulated "quarantine consciousness." The first quarantine regulation in the United States was enacted in California in 1881. The Federal Plant Quarantine Act was not established until 1912.

The diversified areas of insect involvement identified by Howard and their potential for damaging food and fiber production and human health fueled a desire to increase the quality and quantity of research towards solving these threats. Howard's enthusiasm for entomology and his writings highlighted public awareness of entomological problems (Sollers 1952).

While Riley pioneered the area of natural and biological control of insects, Howard expanded and developed these areas as well as uncovering the role of insects in relation to human disease. He was among the first scientists to document the dangers of insect-borne diseases to humans (Howard 1909). His discovery that kerosene could be used in mosquito control captured the attention of the Army and public health officials battling yellow fever (Moore 1947). Howard (1902) also initiated some of the first efforts in Federal entomology to consider microbial control of insect pests. His introductions of fungal cultures for grasshopper control were among the first of many attempts to use exotic organisms in insect control. The early recognition of honeybee and silkworm diseases and USDA's investigations of milky disease for control of Japanese beetle [*Popillia japonica* Newman (White and Dutky 1940)] were credited for drawing attention to the potential of micro-organisms in biological control (Steinhaus 1964).

Howard's support for applied economic entomology is well illustrated in his writings in 1897 and 1898 concerning gypsy moth and San Jose scale. Gypsy moth was brought into the United States from Europe and accidentally released in 1869 at Medford, MA, but for various reasons it did not become of concern until 1889. All of the gypsy moth work was done under State authority and with Commonwealth of Massachusetts funds. Federal funds were requested (1894–1895), but Congress did not respond until 1896–1897 when appropriations were made for USDA to document the ravages of gypsy moth and evaluate the research approaches that were undertaken to solve the problem (Howard 1897b). After a detailed study, Howard concluded that the efforts of Massachusetts would rank as one of the great experiments in economic entomology. Howard further concluded that the State's appropriation for extermination in lieu of management was justified and extermination was possible and within sight with continued appropriations. Unfortunately, State funding was terminated in 1901, and the gypsy moth infestation expanded to include 400 square miles of Massachusetts forests within a short time and a much greater area in later years.

Howard (1898) wrote that San Jose scale was the first pest in economic entomology to excite so much public interest in the United States; and in view of that it aroused the fruit-growing population of the country to a sense of the value of entomological investigations, it brought about legislation against injurious insects in a number of States, and it alone was responsible for an appeal for national legislation, not only by the horticulturalists of the country but also by dealers in nursery stock. To Howard the advent of the pest had been far from an unmixed evil.

The Division of Entomology consisted of a few assistants and field agents when Howard assumed leadership in 1894 (Osborn 1937). During Howard's 33 years, the division became the Bureau of Entomology employing several hundred people in various States. Howard's broad interest in public health and safety and his international relationships resulted in the Bureau's increasing influence and improved service to include a higher level and scope of the scientific community.

Budget appropriations to accomplish the ever-expanding Federal entomological goals, as well as to address other agricultural concerns, were increased in most cases each year from 1879 to 1930. Funding for the Division of Entomology in 1879 was $10,000. Annual amounts varied thereafter through 1900, and increased fairly regularly through 1930. The growth of all USDA programs with more diverse responsibilities resulted in recognition of the need for reorganization to facilitate communication and efficiency. The organization of USDA at the end of the 19th century with only two Bureaus—Animal Industry and Weather—was viewed as inadequate to serve the Nation's agricultural needs. The Bureau of Animal Industry was established in 1884 and the Weather Bureau in 1891 (Baker et al. 1963). There were other independent Federal scientific organizations that were considered by many in executive and congressional positions as unwieldy, difficult to organize, and operationally autonomous. Because of congressional concern for the need to intensify and expand research, divisions with similar goals and objectives were combined in 1901 to form four Bureaus: Plant Industry, Soils, Chemistry, and Forestry. Additionally, some divisions were consolidated into the Bureau of Animal Industry. The Bureau of Statistics was established in 1903, and the Bureau of Biological Survey in 1905.

The Division of Entomology was also targeted for restructuring, but remained an independent entity because Howard stressed his view of the division's importance and the need for a visible Federal entomology community (Howard 1930). In 1902, as a result of the expanding role of Federal entomology and apparently increasing political pressure, Associate Division Chief Charles L. Marlatt prepared, at Howard's request, an organizational structure to accommodate the subject areas of the existing entomology. The organizational structure maintained entomology's visibility. The suggested organizational structure was included in the 1902 annual Division of Entomology report to the Secretary of Agriculture with the recommendation for its adoption by the 1904 Congressional Appropriation Committee.

Apparently, the work of the Division was organized and assigned as described in Marlatt's 1902 report before Congress not only accepted the organizational structure but elevated it to Bureau status on July 1, 1904. Congressional recognition of the importance of entomology in the early part of the 20th century was a major accomplishment. House and Senate debates, as previously discussed, denied a need to elevate USDA to Cabinet level status until 1889. The organizational entities of the new Bureau were divisions (Osborn 1937).

Bureau of Entomology

The entomological research organization and program areas as submitted to the Secretary of Agriculture by Marlatt in 1902 were as follows (Howard 1930):

Program Area	**Program Leader**
Field crop insect investigations:	
(a) Southern section—cotton, tobacco, sugarcane	W.D. Hunter
(b) Northern section—cereals and forage plants	F.M. Webster
Fruit insect investigations:	A.L. Quaintance
(a) Southern section—citrus and other tropical fruits	
(b) Northern section—orchard fruits, deciduous	
Small fruit and truck crop insect investigations	F.H. Chittenden
Forest and forest product insect investigations	A.D. Hopkins
Insecticide and insecticide machinery investigations:	C. Marlatt
(a) Section of field operations and experiments	
(b) Section of chemical analyses and tests	
Investigations of insects affecting stored products	F.H. Chittenden, followed by E.A. Back after 1904
Investigations of insects in relation to disease of humans and animals and as animal parasites	W.D. Hunter after 1904
Insect laboratory, collections, and experimental garden apicultural investigations	E.F. Phillips
Special insect investigations—miscellaneous work:	L.O. Howard (Division/Bureau Chief)
(a) Section for investigation and introduction of beneficial insects, and quarantine	
(b) Section for fungal and other diseases of insects	
(c) Section for special insect investigations—emergency unclassified work	
Sericultural investigations	
Librarian and bibliographer	

Entomology Research Leadership and Program Direction

Walter D. Hunter was hired from Iowa State College in 1901 and placed in charge of the Field Crop Insect Investigations Southern Section in the new Bureau. Because of his interests, Hunter was also assigned responsibility for insects affecting humans and animals. According to Osborn (1937), this remained in effect until man-and-animal insect work was removed from the Southern Section of the Field Crop Insect Investigations in 1926 and cotton insect work was removed in 1930; in each case, the section was established as an independent division. Frank C. Bishopp provided leadership for research on Insects Affecting Man and Animals, and Roby W. Harned was named Chief of the Cotton Insects Investigations Division.

Francis M. Webster retired from Ohio State University with extensive experience in field crop entomology and was hired in 1903–1904 to head up the Field Crop Insect Investigations Northern Section on cereal and forage plants. One of his first field laboratories was established in 1905 in Richmond, IN, to work on hessian fly (Luginbill 1955). The laboratory was moved in 1909 to the Purdue University Experiment Station and for many years did important research on corn insects, wheat jointworm [*Tetramesa tritici* (Fitch)], white grub, aphids, Hessian fly, and chinch bug. Altus L. Quaintance, with experience in tree fruit insects in Alabama, Florida, and Georgia, was hired in 1904 to head the Division of Fruit Insects Investigations. Some early work on deciduous fruit insects was established at Vincennes, IN, in 1923 on San Jose scale, and the program was expanded over the years to include peachtree borer, tarnished plant bug [*Lygus lineolaris* (Palisot de Beauvois)], oriental fruit moth [*Grapholita molesta* (Busck)], and codling moth. Tobacco insects work was also transferred from Field Crop Insect Investigations Southern Section to Small Fruit and Truck Crop and Garden Insects Investigations, and sugar cane insect work was transferred to Field Crops Insect Investigations Northern Section, Cereal and Forage Crops Investigations.

Later program changes within the Bureau were also made. For example, in addition to his other duties on small fruit and truck crop insects, Frank H. Chittenden was charged with investigations concerning insects attacking flower gardens, ornamental greenhouse plants, and shade trees; and later investigations concerning insects affecting sugar beets, strawberries, brambleberries, and mushrooms. He was also assigned studies of stored-products insects.

Ernest A. Back was Chief of Investigations of Insects Affecting Stored Products from 1917 to 1935 (Howard 1930, Osborn 1937). However, research on insects infesting stored products had been initiated much earlier in the Division of Entomology. In the late 19th century, for example, Chittenden (1897) found that 150 to 200 insect species more or less frequently infested stored materials. About half of the recognized species he listed and their parasites had been reared by his staff at the Washington, DC, location. His report included studies on the biologies, life cycles, and parasites of insects affecting stored vegetables, grains, cowpeas, beans, and coffee.

Andrew D. Hopkins had distinguished himself with his work on southern pine beetle [*Dendroctonus frontalis* Zimmerman] in West Virginia (Furniss 1997). He was in charge of work on forest insects in the Division of Entomology from 1902 (Furniss and Wickman 1998). Hopkins was originally hired in USDA's Bureau of Forestry in 1901 by Gifford Pinchot (Furniss 1997). His first assignment was to investigate bark beetle problems in South Dakota forests. With his background and experience, he apparently was the obvious choice to be in charge of forest insects research in the Bureau of Entomology. Hopkins remained as Chief of Forest and Forest Product Insect Investigations until 1923, when Frank C. Craighead became Chief of Forest Insects Investigations (Wickman et al. 2002, Furniss 2003).

The Bureau of Entomology conducted forest insect research in 1935 in California, Colorado, Idaho, and Oregon on western bark beetle and in Connecticut, Louisiana, Michigan, New Jersey, North Carolina, Ohio, and Wisconsin—and Oxford, England—on forest tree insects. The work in England was probably associated with natural enemy exploration and introduction.

Work on bee culture was begun in 1885 by special agent Nelson W. McClain. Honeybees were introduced into the country by early colonists (Montgomery 1955). However, the first Italian honeybees were imported in 1859, apparently by the Patent Office. Until 1853, beekeeping methods did not differ materially from what had been used in the Old World for centuries. In 1853, L.L. Langstroth, "Father of American (or Modern)

Beekeeping," published his *Hive and the Honeybee* and Moses Quinby, "Father of Commercial Beekeeping," published *The Mysteries of Beekeeping Explained* entirely independently of each other (Montgomery 1955). The principles set forth in these two books provided impetus for expansion of beekeeping in the United States and probably stimulated research interest at the Federal level. Everett F. Phillips became Chief of the Apicultural Investigations Division in 1907.

Insect identification was not designated as a separate division until 1928, when Harold Morrison became chief of the newly established Division of Insect Identification. Additional changes in leadership from 1904 to 1935 were described by Osborn (1937). Parencia (1978) traced Federal cotton insect work from the cotton leafworm studies of Riley and Comstock through expansion of research in Texas, Louisiana, Mississippi, South Carolina, Oklahoma, Georgia, Arizona, Mexico, and Hawaii. Federal entomologists contributed significantly to our knowledge and control of boll weevil, bollworm, tobacco budworm [*Heliothis virescens* (Fabricius)], cotton aphid [*Aphis gossypii* Glover], cotton fleahopper [*Pseudatomoscelis seriatus* (Reuter)], cotton leafperforator [*Bucculatrix thurberiella* Busck], pink bollworm [*Pectinophora gossypiella* (Saunders)], *Lygus* bugs, and many miscellaneous pest insects, mites, beneficial insects, and insect pathogens.

By 1913, 35 entomological field laboratories had been established in various States. Entomological research had expanded into the pursuit of knowledge and control measures for boll weevil, gypsy and browntail moths, San Jose scale, and some insect vectors of plant diseases. Identification of mosquito-borne agents causing malaria, yellow and dengue fevers, and filariasis, as well as tick-borne agents of tick fever of cattle, were major events of the late 1800s and early 1900s, highlighting need for expanded research in medical entomology (Howard 1930, Matheson 1950). The Bureau of Entomology would also, at later dates, develop separate sections for research on gypsy moth, browntail moth [*Euproctis chrysorrhoea* (Linnaeus)], and Japanese beetle. Some of the early work on fighting gypsy moths with aerial applications would be classified as "methods development specific activity." Methods development expanded small-scale studies in the laboratory to demonstrate sucessful use of the technology under field conditions. This success led to formation of a Methods Development Branch in ARS in 1969 (Kauffman and Kingsley 2000).

During World War I, the Bureau of Entomology received special funds for control and eradication of certain insects (Baker et al. 1963), none of which appear directly related to the war effort. The sudden interest and increased appropriations remain unexplained; however, the unusual interest may simply relate to an increased concern for protection of food and fiber sources during the war years. European corn borer [*Ostrinia nubilalis* (Hübner)], Japanese beetle, and pink bollworm were three of the insect species that the Bureau helped to combat as a result of increased financial support from Congress.

European corn borer is believed to have entered the country about 1909 or 1910 and was discovered first in 1917 near Boston, MA. In 1918, the Bureau began a study of the species. Through the years, the work expanded; major research locations were established Indiana, Iowa, and Ohio (Luginbill 1955).

Japanese beetle was found in 1916 near Riverton, NJ, in a shipment of iris roots from Japan. The Bureau began active work on the pest in 1917, and in 1919 imposed a domestic quarantine financed by a special appropriation.

Pink bollworm was discovered in Texas in 1917, and the Department assisted in its control by pulling and burning plants, cotton, and seed in infested areas.

Metcalf (1940) called attention to the fact that the emergencies of World War I revealed to the public the importance of insects and established entomology as a great science. Essig (1940) concurred, attributing the phenomenal development of crop production to the need forced on the United States to feed itself and its allies as part of the war effort.

Federal Horticultural Board

While Federal attention to entomology research increased, the important area of invasive pests, though recognized as early as 1865 by Glover (Howard 1930), was not addressed at the Federal level until the early 1900s. Sasscer (1940) was at a loss to explain the apparent indifference of legislators toward developing measures to exclude new pests from the United States. He recalled a song of the time that appeared to fit the existing state of mind in the late 1800s to the early 1900s regarding insect pests and plant diseases: "Let earth withhold her goodly root, Let mildew blight the rye, Give the worm the orchard fruit, The wheat field to the fly."

The United States suffered heavy losses as a result of pests imported from other countries through commerce. This is not surprising, since until 1912 most agricultural products entered the country without any plant quarantine restrictions (Sasscer 1940). Opportunity for introduction of exotic insects apparently began soon after the discovery of America. A Puerto Rican historian suggested that the only reason Columbus landed in Puerto Rico on his second voyage in 1493 was to obtain water to keep alive plants he was bringing to the new continent.

It became apparent in the late 1800s that plant pests and insects were being brought into the country in imported commodities as well as in association with exploration efforts to bring in new seed and plant materials from abroad. Marlatt (1940) would describe the 1890s as an era of developing consciousness concerning quarantine and eradication of invasive pest species. Thirty exotic pest species were identified during the 1800s, with 12 more recognized during the first 40 years of the 1900s (Sasscer 1940). Sasscer also suggested there were probably many additional exotic species not yet observed. Another 40 years later, Sailer (1983) identified 1,683 introduced arthropod species that have become established in the United States.

In spite of concern for introduced pests, the United States was one of the last countries to adopt effective quarantine to reduce introduction of new entomological problems from outside sources (Howard 1930). Though a number of States enacted quarantine legislation, beginning with California in 1881, repeated attempts to obtain Federal quarantine restrictions were not successful until much later. Congress did pass the Insect Pest Act in 1905, which provided Federal authority to regulate entry and interstate movement of living, injurious insects. Because of concern for exotic pest introduction on imported fruit tree and nursery stock, the Bureau of Entomology on its own authority further expanded its area of responsibility and began inspecting some of these plant materials in 1906 (Baker et al. 1963). Howard and Marlatt championed Federal regulatory and quarantine efforts.

Increasing concern and expansion of pest infestation areas as well as discoveries of insect infestations in interstate commerce by State inspections resulted in congressional passage of the Plant Quarantine Act on August 20, 1912. The Act provided formally for regulation of importation and interstate shipment of plants and other commodities and appointment of a Federal Horticulture Board to administer the duties of the Act. Representatives of the Bureaus of Entomology, Plant Industry, and Forest Service were board members. Marlatt, Assistant Chief of the Bureau of Entomology, served as board chairman from 1912 to 1928, Marlatt resigned as Chairman of the Board to become Chief of the Bureau of Entomology from 1929 to 1933. Port inspections at various points of entry resulted in interception of numerous potential pests. These activities set the stage for a long association of Federal entomological research with plant and animal inspection, quarantine, and regulatory agencies.

Beginning of the End of an Era: Establishment of the Plant Quarantine and Control Administration

Howard retired as Chief of the Bureau of Entomology in 1927 and was replaced by Marlatt from 1927–28* to 1933. A series of important events affected entomology research and regulatory activity in monitoring movement of plants and insects within and between agriculture communities and internationally that had been handled by the Federal Horticultural Board within the Bureau of Entomology from 1912 to 1928.

The Federal Horticultural Board filled an important gap in Federal entomology activities, but it was evident that several different agencies were involved, with overlapping areas of responsibility. Closer coordination of Federal quarantine activities was the objective when the Plant Quarantine and Control Administration was established on July 1, 1928. Marlatt was in charge from 1928 to 1929, followed by Lee A. Strong from 1929 to 1932. The Federal Horticultural Board was abolished, and the regulatory responsibilities of the Board, the Bureau of Entomology, and the Bureau of Plant Industry were absorbed by the new administration. Entomology research and regulatory functions were separated. After only 4 years, the Plant Quarantine and Control Administration was abolished, and the Bureau of Plant Quarantine was established in 1932 to succeed it.

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* Marlatt was Acting-in-Charge during 1927–1928 pending formal appointment in 1929, or his initial acting-official appointment spanned the 1927 fiscal year.

Marlatt retired in 1933 after serving for 3 years as Chief of the Bureau of Entomology. Baker et al. (1963) recalled the event as having left a serious gap in USDA.

Bureau of Plant Quarantine

The new Bureau included all of the functions of the Plant Quarantine and Control Administration. These were the Divisions of Pink Bollworm and Thurberia Weevil Control, Date Scale Control, European Corn Borer Control, Japanese Beetle Control, and Mexican Fruitfly Control. Strong remained in charge of the new organization. On December 1, 1933, the plant disease eradication and control functions of the Bureau of Plant Industry were assigned to the Chief of the Bureau of Entomology, who established the Plant Disease Eradication Division which included projects on barberry eradication, blister rust control, citrus canker eradication, dutch elm disease control, and phony peach disease eradication (Baker et al. 1963).

Bureau of Entomology and Plant Quarantine

Henry A. Wallace became Secretary of Agriculture on March 4, 1933. Faced with the threat of drastic budget reductions, he made a number of shifts in Bureau responsibilities that profoundly affected entomology. The Bureau of Entomology, the Bureau of Plant Quarantine, and the plant disease control and eradication work of the Bureau of Plant Industry were combined to form the Bureau of Entomology and Plant Quarantine (BEPQ) on July 1, 1934. BEPQ consolidation was implemented to provide more economical and effective administration of insect research and regulatory programs.

BEPQ's responsibilities included research on insecticides from plants, synthetic organic insecticides, spray residues, inorganic insecticides, fumigants, oil emulsions, analytical work, toxicology, and accessories for insecticides. The Bureau also had a Division of Foreign Plant Quarantine with inspection or regulatory activities in 18 States, Hawaii, Puerto Rico, and Washington, DC, and a Division of Domestic Plant Quarantine with many locations in the United States.

Strong, who had been chief of the Bureau of Plant Quarantine, provided continuing leadership of the consolidated Bureau from 1934 to 1941.

The Bureau of Entomology consisted of the Divisions of—

- Fruit and Shade Tree Insect Investigations.
- Japanese Beetle and Asiatic Garden Beetle Investigations
- Forest Insects
- Truck Crop and Garden Insects
- Cereal and Forage Insects
- Cotton Insects
- Bee Culture
- Insects Affecting Man and Animals
- Insect Identification, Foreign Parasite Introduction, and Control Investigations
- Plant Disease Eradication

The Insecticide Division of the Bureau of Chemistry and Soils (established in 1933) was transferred to the Bureau of Entomology in September 1935. In 1954 it became the Pesticide Chemical Research Section of the Entomology Research Branch (Luginbill 1955).

In 1935, the Division of Japanese and Asiatic Garden Beetle Investigations was made part of the Division of Fruit Insect Investigations.

The Bureau of Plant Quarantine consisted of the Divisions of—

- Foreign Plant Quarantines
- Domestic Quarantines
- Japanese Beetle and European Corn Borer Control
- Gypsy and Brown-Tail Moths
- Mexican Fruit Fly
- Date Scale Eradication
- Pink Bollworm
- Thurberia Weevil

Quarantine stations were located at Hoboken, NJ; San Francisco, CA; Seattle, WA; Miami, FL; Laredo, TX; San Juan, PR; and Honolulu, HI.

Within BEPQ, a Division of Foreign Parasite Introduction (DFPI) was formed, which was charged with responsibility for exploration and importation of insect parasites and predators, and later of natural enemies of weeds and plants and insect pathogens (Vail et al. 2001). This division was the first USDA organization to provide centralized direction of natural enemy introductions (Coulson et al. 2000). It would remain operational under various names until 1972.

The Division of Control Investigations was formed in 1934 at the same time that BEPQ was established (Latta 1951). A technical unit transferred from the Bureau of Plant Quarantine that was developing commodity treatment methods for mediterranean fruit fly [*Ceratitis capitata* (Wiedemann)] and a physiology and toxicology unit from the Bureau of Entomology were the major components of the new division. Mediterranean fruit fly commodity treatment had previously been transferred to the Bureau of Plant Quarantine from the Bureau of Plant Industry when the Plant Quarantine and Control Administration was formed.

Insect physiology and toxicology work began between 1915 and 1919, when physiological studies were initiated to find a substitute for nicotine. The physiology and toxicology research was subsequently housed in 1930 in a new laboratory at Takoma Park, MD, and later moved to Beltsville, MD, during 1934 and 1935. Research on insect physiology and toxicology and development of new control methods remained centered at Beltsville. Insecticide testing expanded to locations at Orlando and Sanford, FL, in 1937; to Anaheim, CA, in 1945; and to Yakima, WA, in 1946 and 1947. Commodity treatment work was done at El Paso and Alpine, TX; Moorestown, Hoboken, and White Horse, NJ; Sunset, New Orleans, and Lafayette, LA; St. Louis, MO; Gulfport, MS; Burgan, NC; Ft. Valley, GA; Washington, DC; and Arlington Farms, VA, from 1934 to 1951. In 1951–1952, the Division of Control Investigations was abolished and all programs transferred to Stored Products Investigations.

Frank Campbell (1935, personal communication), considered development of insect physiology-toxicology research as one of the most progressive steps ever taken by the Bureau. Need for fundamental entomology studies was recognized, and authority was given to scientists to proceed without the restrictions of focusing on a specific pest or commodity. This concept would prevail.

Though many USDA laboratories became established to address specific problems, pioneering research was supported by administrators as research not aimed at specific practical problems or objectives but rather at the advancement of science. The research was to be undertaken to discover the underlying principles and develop theory that would facilitate research on specific problems as needs arose. It was expected to build a foundation for the quick, effective, and economic solution of research problems. The first research laboratory was established at Beltsville on August 21, 1957, with the assignment of investigations on mineral nutrition of plants. Sixteen pioneering research laboratories were established by 1961. Some of the pioneering entomology research areas addressed were insect physiology, behavior, biological control, and insect pathology.

Agricultural Research Administration

Though World War II provided immediate stimulus and awareness of the need to rally agricultural research in support of the war effort, the issues of Bureau dysfunctions and overlapping program responsibilities again became an issue to Congressional leadership. These problems had existed for a long time. Several attempts were made to improve communication and efficiency:

March 23, 1897, to September 30, 1897	Appointment of an Assistant Secretary of Agriculture to supervise some scientific divisions and a Foreign Market Section
October 1, 1921, to June 30, 1934	Appointment of a Director of Scientific Work to advise the Secretary and Bureau chiefs
From March 16, 1936	Assignment of the Chief of the Office of Experiment Stations as Director of Research

Apparently, none of these actions were completely satisfactory. For example, during the 16-year secretaryship of James Wilson beginning in 1897, a new era of scientific interest was born. From 1901 to 1904, eight additional research Bureaus were established with increasing numbers of personnel and increasing budgets (Baker et al. 1963). In 1913, at the end of Wilson's tenure, incoming Secretary of Agriculture David Houston viewed the Department as a number of autonomous Bureaus with diverse functions. This situation persisted for many years thereafter, and Secretary William Jardine in 1925 and later Secretaries of Agriculture addressed the same issues. Irving et al. (1981) commented on some of these issues that lead to the perception of a need to establish a unified research organization. Issues of jurisdiction and lack of cooperation among the Bureaus were said to be common and of paramount concern.

The frequent cases of overlapping responsibilities and duplications of effort became a continuing aggravation to Congress and the executive branch (Shaw 1950). Thus, following the Japanese attack on Pearl Harbor on December 7, 1941, Secretary Claude R. Wickard, who was aware of the Bureau's controversies, realigned USDA in an attempt to improve the situation and optimize agricultural support for the war effort; this realignment became effective on February 23, 1942. He created the Agricultural Research Administration (ARA) as an administrative layer to provide overall cooperation and coordination among the research Bureaus. The duties of the Director of Research in the Office of Experiment Stations were assumed by ARA.

ARA consisted of—

- Bureau of Plant Industry
- Bureau of Agricultural Chemistry and Engineering
- Bureau of Animal Industry
- Bureau of Dairy Industry
- Bureau of Entomology and Plant Quarantine
- Bureau of Home Economics

The Office of Experiment Stations and the Beltsville Agriculture Research Center were also included.

Individually the Bureaus were highly competent and productive. The Federal agricultural research community made huge strides during the war and brought agricultural sciences and technology to new levels of excellence. Following the death of Strong in 1941, Percy Annand provided able leadership of BEPQ during the war years and into 1950, when he died. During World War II, insect control research in Federal agencies was a vital part of the war effort (Baker et al. 1963). Plant protection from insect ravages and increased production of food and fiber to support the Nation and its fighting forces and to provide assistance to our allies were high priorities. Control of lice, fleas, mosquitoes, and flies was vital to the health and operational efficiency of military forces (Knipling and Linquist 1962). Better methods and improved materials for delousing personnel and facilities were credited with reducing typhus in the European theater of war.

The much-sought-after but elusive development of aerosol insecticide application achieved a major breakthrough in 1941 with the concept of liquefied gas (freon) as an insecticide solvent and propellant (Fulton and Sullivan 1962). The technology was immediately adopted and implemented in the war effort. Aerosol technology reaches into the lives of people throughout the world in its many applications in medicine, cosmetics, lubricants, household use, and numerous other applications. The effects of this achievement remain grossly understated.

The discovery of hydrocarbon insecticides, insect repellants, and the role of DDT in World War II are well known. The discovery of DDT and aerosol bombs and their use in the southwestern Pacific were acknowledged by some as responsible for shortening the war against Japan, perhaps by many years (Davis 1955). On the home front, BEPQ in cooperation with the War Production Board and later the War Food Administration* certified weekly the amounts and types of insecticides needed for crop production. As a result, no pesticide rationing was instituted, and there were no serious insect outbreaks in commercial agricultural crops. Entomologists continue to play an important role in military organizations with medical entomology expertise in the United States Army, Navy, and Air Force that support U.S. forces worldwide (Berté 2005).

BEPQ Organizational Changes and Other Events

The years 1942 to 1953 saw a number of events of interest and additional changes in the organizational structure of BEPQ:

Year	Action
1942	Division of Grasshopper Control established by transferring activities relating to grasshopper, chinch bug, and Mormon cricket [*Anabrus simplex* (Haldeman)] control from Division of Domestic Quarantine.
1949	Golden Nematode [*Heterodera rostochiensis*] Division established.

* The War Production Board was established in 1942 and the War Food Administration in 1943. Both were terminated in 1945.

1950 Avery S. Hoyt becomes Chief of BEPQ and served in that capacity until 1953.

1951 Golden Nematode Division, Japanese Beetle Control Division, and Gypsy and Brown-Tail Moth Control Division redesignated as projects.

Division of Insect Pest Survey and Information renamed Division of Insect Survey and Identification. Four Assistant Bureau Chiefs—Regulatory, Research, Control, and Insecticides and Chemistry—assigned to specific divisions.

Four regional offices established for administrative and regulatory work.

Division of Stored-Product Insect Investigations established. This unit superceded the Division of Control Investigations and included functions of the Divisions of Cereal and Forage Insects, Fruit Insects, Truck Crop and Garden Insects, and Insects Affecting Man and Animals.

1952 Division of Fruit Fly Investigations established, and included research on Japanese beetle, European chafer [*Rhizotrogus* (*Amphimallon*) *majalis* (Razoumowsky)], Hall scale [*Nilotaspis Halli* (Green)], and oriental fruit fly [*Bactrocera dorsalis* Hendel].

Division of Insect Identification and Detection created and additional duties assigned to it.

Division of Bee Culture and Biological Control established by combining Bee Culture and some functions of Foreign Parasite Investigations and Fruit Insects and Forest Insects Division.

Division of Foreign Plant Quarantine redesignated Division of Plant Quarantine.

Division of Insecticide Investigations established to accommodate research functions not transferred from Division of Control Investigations to Stored-Products Insects Investigations.

Insects—The Yearbook of Agriculture published by USDA in 1952. From the editor's preface we begin to appreciate an amazing success story that began with a single entomologist in 1854: "Into this yearbook have gone the results of nearly 100 years of the study of insects. The Bureau of Entomology and Plant Quarantine, which was responsible in large measure for the book, traces its origins that far back. The century has seen great changes in farming methods, the intensiveness and extent of agriculture, transportation and crops. All have affected profoundly our relationships with insects" (Stefferud 1952).

Insects revealed the diversity of Federal involvement in entomology—from identification, need for knowledge of insects, role of beneficial insect species, status on depredations of pest species, problems associated with chemical control, and alternatives to chemical control to the damaging roles of the major insect pests of home, people, animals, and various commodities. The authors were an outstanding collection of leaders of the first half of the 20th century in university, experiment station, State and Federal establishments, and industry, all with long-term records of accomplishment and contributions to agriculture and the scientific community.

1953 Division of Insects Affecting Cotton and Other Fiber Plants established, and Division of Cotton Insect Investigations abolished.

The Bureaus remained, but the perception of a need for a mechanism to deal with issues of jurisdiction and cooperation among Bureaus, as previously mentioned, did not subside. USDA had attempted to correct its internal problems in 1941 by creating ARA as an administrative layer between the Bureaus and the Secretary. ARA was designed to ride herd on the Bureaus, define research roles, coordinate programs, and attempt to guide USDA programs through the budgetary process in accord with what it determined to be priorities. This effort was not wholly effective because of strong opposition and foot-dragging by the then-powerful Bureau chiefs, all of whom had strong supporters in certain parts of Congress and in many

States (Klassen 1990). Thus, continued Congressional dissatisfaction with a loose confederation of independent and autonomous Bureaus and agencies, as reported in 1952 by a Commission headed by former President Herbert Hoover, finally led to their dissolution. Secretary of Agriculture Ezra Taft Benson announced on October 13, 1953, that the effective date for reorganization was November 2, 1953.

Before reorganization the Bureau comprised the following divisions: Bee Culture and Biological Control, Cereal and Forage Insect Investigations, Insects Affecting Cotton and Other Fiber Plants, Forest Insect Investigations, Fruit Insect Investigations, Insect Detection and Identification, Insect Investigations, Insects Affecting Man and Animals, Plant Quarantine, Stored Product Insect Investigations, and Truck Crop and Garden Insect Investigations.

Agricultural Research Service

Abolishing the scientific Bureaus as organizational entities was particularly controversial, but the action prevailed. Functions of the research Bureaus of ARA, the Bureau of Agricultural Economics, and the Production and Marketing Administration were transferred to new or reorganized services. The Agricultural Research Service (ARS) was designated the principal in-house research agency of USDA and retains that responsibility (Agricultural Research Service 1982, 1991, 1999, 2003).

ARS's units were Farm Research, Nutrition Consumer and Industrial Use, Marketing, Regulatory and Control, and Administrative Management. Entomology activity was performed in ARS research, regulatory, and control units. Functions of BEPQ were transferred to ARS and later assigned to the Director of Crops Research or the Director of Crops Regulatory Programs as appropriate for their missions and objectives. As a result of the reorganization, former Bureaus were designated "branches," and former divisions were designated "sections" (Anonymous 1954, Coulson et al. 2000). The Crops Regulatory Program Division consisted of Plant Pest Control Branch and Plant Quarantine Branch. The Division of Forest Insects was transferred to the Forest Service (established 1905). The Division of Stored-Products Insects Investigations became the Stored Products Insects Section of the newly established (November 2, 1953) Agricultural Marketing Service, Marketing Research Biological Science Branch.

Excellent overviews of forest entomology research from 1953 to 1993, with emphasis on biological control, have been published (Dix 2000, Dix et al. 2000). The catalyst for ecological awareness in forests was Rachel Carson's *Silent Spring* (1962). Steen (2005) wrote that other writers had repeatedly failed to capture public attention, but Carson, a scientist talented in literary expression, electrified a slowly growing science-dominated environmental movement.

The Division of Stored-Product Insect Investigations of BEPQ, which was formed in 1951, superseded the Division of Control Investigations and included some functions from the Divisions of Cereal and Forage Insects, Fruit Insects, Truck Crop and Garden Insects, and Insects Affecting Man and Animals (Baker et al. 1963). The Division of Control Investigations included most of the Bureau's research on commodity treatment. Lyman S. Henderson was named as chief of the new division. Stored-Products Division's research outline in 1953 showed work on insects attacking processed foods that included studies on insect-resistant packaging materials, treatments to prevent insect damage to building materials, and treatments to prevent insect damage to cured meats. Work on insects inhabiting households and industrial establishments also included research on protecting military equipment such as fabric, rope, and similar materials.

The Agricultural Marketing Service was created in 1953 as a result of yet another reorganization of USDA; insect problems involved in the marketing of agricultural products became a specific area of research responsibility in the new agency. The stored-products insect program transferred from BEPQ was broadened and strengthened in the new agency. The work was reassigned back to ARS, Market Quality Research Division, Stored-Products Insects Branch, in 1963.

Entomology Research Branch—Beginning of a New Era

Following transfer of forest insect and stored-products insect work to other agencies and abolishment of BEPQ, the sections within ARS's Entomology Research Branch were—

- Fruit Insects Investigations
- Insects Affecting Cotton and Other Fiber Plants
- Cereal and Forage Insect Investigations
- Truck Crop and Garden Insect Investigations
- Insects Affecting Man and Animals

Insecticide Investigations
Bee Culture and Biological Control
Insect Identification and Detection

In 1957, branches were redesignated as divisions (Baker et al. 1963) and the sections as research branches. Within branches, investigation units were located throughout the United States and in some foreign countries.

Edward F. Knipling served as Director of the Entomology Research Branch from 1953 to 1957. Few entomologists influenced insect pest management as profoundly as Edward F. Knipling (Klassen 2003). During World War II, Knipling and his colleagues developed highly effective measures to protect both military personnel and civilian populations from major arthropod-borne diseases. The sterile insect technique was Knipling's conception, and he successfully guided its development and use against screwworm and various other pests. He inspired and guided development of a wide range of ecologically selective methods of insect detection and suppression. Knipling became a leading proponent and theoretician of areawide pest management and design of systems of pest population suppression to achieve synergy between control methods efficient at high pest population densities and those efficient at low densities. Knipling was convinced that many pest problems could be met without harm to the environment by areawide application of systems including augmentation of natural enemies.

Knipling's address at the National Agricultural Chemicals Association meeting in 1958, during the heyday of unilateral chemical control enthusiasm, illustrates his remarkable foresight of the need for change (Knipling 1958). He recommended research to learn more about various enzyme systems and growth-regulating mechanisms; nutritional requirements; factors involved in diapause; influences on behavior, reproduction, and migration; the mode of action of insecticides; and other fundamentals. Development of a proper balance between basic and applied research is essential, and once achieved it must be maintained. He recommended that more attention be given to methods of insect control that do not require use of chemicals or that require only minimal use.

Entomology Research Division

The Entomology Research Division and its branches existed with minor internal changes for approximately 18 years. Knipling's leadership as Director of the Entomology Research Division continued through 1971 when he was appointed as Science Advisor to the Administrator of ARS. Knipling served in that capacity from 1971 to 1973 (Klassen 2003). Clarence H. Hoffman succeeded E.F. Knipling as Acting Director until H.C. Cox was appointed Director. Cox served as the Entomology Research Division Director in parts of 1971 and 1972.

The 1950s to the 1970s saw far-reaching and lasting changes in Federal entomological research communities. Insect pest control using synthetic chemicals began during World War II. The benefits attributed to these chemicals have been and continue to be of monumental importance. However, problems did develop and have become more evident with increasing research. Effects on nontarget organisms, chemical residues, arthropod resistance to chemicals, high cost, and the temporary nature of treatments became of increasing concern beginning in the late 1940s.

DDT, perceived to be one of the most notorious of the offending chemistries, came into use in the early 1940s. The first case of an insect species resistant to the material—the housefly [*Musca domestica* Linnaeus]—was reported in 1946. Twelve insect species were reported resistant to synthetic insecticides in 1948. This number increased to 157 species in 1963 and 165 species in 1966. Tabashnik (1994) reported that more than 500 pest species have resistance to conventional insecticides. Statistics continue to show increases in the number of resistant species as of 1999 (Castle et al. 1999).

Resistance and numerous other adverse effects of insecticides stimulated entomological efforts to develop effective, efficient alternative insect controls that are compatible with and have minimum effect on the complex components of agroecosystems. Carson's (1962) revelations on pesticides stimulated public concern for the environment that triggered a turning point in the entomological community's approach to pest insect control. Concern from the public sector reinforced the decisions made under Knipling's leadership to focus research on development of more ecologically oriented insect-control methods in lieu of unilateral reliance on chemical control.

Under Knipling's leadership, the Entomology Research Division began to reorient its research program in 1953 from emphasis on conventional insecticides to development of more selective chemical and nonchemical methods to control major insect pests (Hoffman 1970). Within 15 years, 84 percent of the division's resources was devoted to research to develop alternatives to conventional insecticides and conventional application technology for insect control compared to 16 percent to insecticide technology (table 1). Foresight into future needs of the entomological community were further reflected in establishment of pioneering research laboratories in insect physiology and insect pathology at Beltsville, MD; the Biological Control of Insects Laboratory at Columbia, MO: the Bioenvironmental Control Laboratory at Stoneville, MS; the Insect Attractants Laboratory at Gainesville, FL; and the Metabolism and Radiation Research Laboratory at Fargo, ND. The names of these laboratories have been modified over time but continue to be on the forefront of entomological research. During the 1960s and 1970s, ARS had more insect pathology and microbial control specialists that any other institution in the world (Vail et al. 2001). Numerous other changes were made at local laboratory and other levels that encouraged development of ecologically oriented insect pest management.

Though Knipling published extensively, some of his best motivational influence on the research direction of human and financial resources of the Entomology Research Division was the numerous unpublished papers he wrote and circulated to agency and other scientists. The subject matter in the papers illustrates Knipling's open-minded, innovative approach to entomological research of the era. Knipling was quick to call his efforts in these writings, by intent, as theoretical and thought provoking. The writings were meant to invite comments, criticisms both positive and negative, and open communications that stimulated and encouraged novel approaches to suppressing pest insect populations. Analysis of the communications leaves one with a profound appreciation for the scope of Knipling's contributions to the development of new genetic, behavioral, and biological control approaches to solving entomological pest problems.

During the first 10 years following the abolishment of USDA Bureaus, there were some minor changes in organizational names. In 1963 the Entomology Research Division had laboratories at 99 locations in 32 States and in France, Argentina, Mexico, Italy, Puerto Rico, and Guam (tables 2 and 3).

Table 1. Distribution of Entomology Research Division resources in 1968 according to major research program areas

	Percentage of resources	
Major lines of work	**By program**	**Subtotal**
Conventional insecticides	16	16
Other control methods		51
Biological control	14	
Insect sterility	12	
Plant resistance	7	
Cultural and mechanical methods	4	
Attractants, hormones, etc.	14	
Fundamental entomology		33
Basic insect biology	19	
Metabolism	2	
Taxonomy	6	
Insect transmission of plant and animal diseases	2	
Agriculture	4	

Source: Hoffman 1970.

Table 2. Entomology Research Division headquarters, research branches, and laboratory locations in 1963

[Developed from division records and the author's personal files]

All research branch headquarters were located at Beltsville, MD.

Branch	Locations
Office of Entomology Research Division	Beltsville, MD
Apiculture Research Branch	Baton Rouge, LA
	Beltsville, MD
	Laramie, WY
	Logan, UT
	Madison, WI
	Tucson, AZ
Cotton Insects Research Branch	Baton Rouge, LA
	Beltsville, LA
	Brownsville, TX
	College Station, TX
	Florence, SC
	State College, MS
	Stoneville, MS
	Tallulah, LA
	Tempe, AZ
	Tucson, AZ
	Waco, TX
Fruit and Vegetable Insects Research Branch	Agana, Guam
	Albany, GA
	Beltsville, MD
	Charleston, SC
	Corvallis, OR
	Farmingdale, NY
	Florence, SC
	Forest Grove, OR
	Fort Valley, GA
	Geneva, NY
	Hilo, HI
	Hoboken, NJ
	Honolulu, HI
	Kahului, HI
	Kearneysville, WV
	Lake Alfred, FL
	Logan, UT
	Mesa, AZ

Table 2. Entomology Research Division headquarters, research branches, and laboratory locations in 1963—cont'd.

Branch	Locations
Fruit and Vegetable Insects Research Branch (cont'd.)	Mexico City, Mexico Moorestown, NJ Orlando, FL Orono-Presque Isle, ME Oxford, NC Quincy, FL Riverside, CA Shreveport, LA Sumner, WA Twin Falls, ID Vincennes, IN Wenatchee, WA Weslaco, TX Wooster, OH Yakima, WA
Grain and Forage Insects Research Branch	Ankeny, IA Baton Rouge, LA Beltsville, MD Bozeman, MT Brookings, SD Canal Point, FL Columbia, MO Florala, AL Forest Grove, OR Houma, LA Lincoln, NE Manhattan, KS Mayaguez, PR Mesa, AZ Minot, ND State College, MS Stillwater, OK Tifton, FA Tucson, AZ University Park, PA West Lafayette, IN Wooster, OH

Table 2. Entomology Research Division headquarters, research branches, and laboratory locations in 1963—cont'd.

Branch	Locations
Insect Identification and Parasite Introduction Research Branch	Beltsville, MD
	Berkeley, CA
	Moorestown, NJ
	Riverside, CA
	Washington, DC
	Buenos Aires, Argentina
	Paris, France
	Rome, Italy
Insects Affecting Man and Animals Research Branch	Beltsville, MD
	Corvallis, OR
	Denver, CO
	Fresno, CA
	Kerrville, TX
	Lincoln, NE
	Mission, TX
	Orlando, FL
	Stoneville, MS
Pesticide Chemicals Research Branch	Beltsville, MD
	Brownsville, TX
	Kerrville, TX
	Orlando, FA
	State College, MS
	Tifton, GA
	Vincennes, IN
	Yakima, WA

Table 3. Research locations and program areas in the Entomology Research Division, 1963

[Developed from division records and author's personal files]

Location	Branch	Unit	Investigating
Alabama			
Florala	Grain and Forage Insects Research Branch	White-Fringed Beetle Investigations	Biology, ecology, and control of white-fringed beetles
Argentina			
Buenos Aires	Insect Identification and Parasite Introduction Research Branch	Biological Control of Weeds Investigations (Satellite of Berkeley, CA, laboratory)	Exploration for insect enemies of alligator weed
Arizona			
Mesa	Fruit and Vegetable Insects Research Branch	Vegetable and Sugar Beet Disease Vector Investigations (Satellite laboratories at Twin Falls, ID, and Logan, UT)	Biology, ecology, and control of insects that attack vegetables and sugar beets
	Grain and Forage Insects Research Branch	Alfalfa and Cloverseed Insects Investigations (Satellite of Tucson, AZ, laboratory)	Resistance of alfalfa varieties to injurious insects, biological control of spotted alfalfa aphid
		Grasshopper Investigations (Satellite of Bozeman, MT, laboratory)	Biology and ecology of grasshoppers
Tempe	Cotton Insects Research Branch	Western Cotton Insects Investigations (Satellite of Tucson, AZ, laboratory)	Biology and control of insects and spider mites that affect cotton and other fiber plants
Tucson	Apiculture Research Branch	Honey Bee Pollination Investigations	Insect pollination of agricultural crops, effect of insecticides on insect pollinators
	Cotton Insects Research Branch	Western Cotton Insects Investigations (Satellite laboratory at Tempe, AZ)	Biology and control of insects and spider mites that affect cotton and other fiber plants

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
	Grain and Forage Insects Research Branch	Alfalfa and Cloverseed Insects Investigations (Satellite laboratories at Mesa, AZ, and Forest Grove, OR)	Control of alfalfa, clover, and other legume insects in the West
California			
Berkeley	Insect Identification and Parasite Introduction Research Branch	Biological Control of Weeds Investigations (Satellite laboratories at Rome, Italy, and Buenos Aires, Argentina)	Biological control of weeds
Fresno	Insects Affecting Man and Animals Research Branch	Western Insects Affecting Man and Animals Investigations (Satellite of Corvallis, OR, laboratory)	Insects that affect humans and animals, especially mosquitoes
Riverside	Fruit and Vegetable Insects Research Branch	Arid Areas Citrus and Vegetable Insects Investigations	Biology and control of insects and mites on citrus and other subtropical fruits and vegetables
		Bean, Berry and Leafy Vegetable Insects Investigations	Biology and control of insects that affect vegetables, strawberries, and bramble berries, and methods of applying insecticides with ground equipment
		Deciduous Fruit Disease Vector Investigations (Satellite laboratories at Corvallis, OR)	Insect transmission of tree fruit virus diseases
	Insect Identification and Parasite Introduction Research Branch	Foreign Parasite & Predator Investigations (Satellite of Paris, France, laboratory)	Exploration and research on beneficial insects
Colorado			
Denver	Insects Affecting Man and Animals Research Branch	Livestock Insects Investigations (Satellite of Kerrville, TX, laboratory)	Insect transmission of bluetongue disease in sheep

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
District of Columbia			
Washington	Insect Identification and Parasite Introduction Research Branch	Taxonomic Investigations of Acarina	Taxonomy of mites and ticks
		Taxonomic Investigations of Coleoptera	Taxonomy of beetles
		Taxonomic Investigations of Diptera	Taxonomy of two-winged flies
		Taxonomic Investigations of Hemiptera and Thysanoptera	Taxonomy of aphids, true bugs, thrips, etc.
		Taxonomic Investigations of Hymenoptera	Taxonomy of bees, wasps, etc.
		Taxonomic Investigations of Lepidoptera	Taxonomy of moths and butterflies
		Taxonomic Investigations of Orthoptera	Taxonomy of grasshoppers, crickets, etc.
Florida			
Canal Point	Grain and Forage Insects Research Branch	Sugarcane Insects Investigations (Satellite of Houma, LA, laboratory)	Biology, ecology, and control of sugarcane insects
Lake Alfred	Fruit and Vegetable Insects Research Branch	Biological Control of Citrus Insects Investigations	Biological control of citrus insects and mites
Orlando	Fruit and Vegetable Insects Research Branch	Humid Areas Citrus Insects Investigations	Biology and control of insects and mites that affect citrus and other subtropical fruits
	Insects Affecting Man and Animals Research Branch	Insects Affecting Man Investigations	Biology and control of insects of medical importance to the military services and of household insect pests
	Pesticide Chemicals Research Branch	Synthesis Investigations (Satellite of Beltsville, MD, laboratory)	Development of synthetic organic insecticides
Quincy	Fruit and Vegetable Insects Research Branch	Tobacco Insects Investigations (Satellite of Oxford, NC, laboratory)	Biology and control of insects that affect tobacco in the field

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
France			
Paris	Insect Identification and Parasite Introduction Research Branch	Foreign Parasite and Predator Investigations (Satellite laboratories at Riverside, CA, Beltsville, MD, and Moorestown, NJ)	Explorations in Western Europe for insect enemies of agricultural pests
Georgia			
Albany	Fruit and Vegetable Insects Research Branch	Pecan Insects Investigations (Satellite laboratory at Shreveport, LA)	Biology and control of insects and mites that affect pecans
Fort Valley	Fruit and Vegetable Insects Research Branch	Peach Insects Investigations	Biology and control of insects that affect peaches
Tifton	Grain and Forage Insects Research Branch	Forage Insecticide Residue Investigations	Insects that attack legume and grass crops in the southeastern plains, insecticide residues on forage crops
		Southern Grain Insects Investigations (Satellite laboratories at Vincennes and West Lafayette, IN, Stillwater, OK, and State College, MS)	Biology and control of corn earworm and other insects that attack grain
	Pesticide Chemicals Research Branch	Analytical Investigations (Satellite of Beltsville, MD, laboratory)	Analysis of pesticides, pesticide residues, and accessory materials
Guam			
Agana	Fruit and Vegetable Insects Research Branch	Hawaii Fruit Investigations (Satellite of Honolulu, HI, laboratory)	Biology, ecology, and control of oriental fruitfly, Mediterranean fruitfly, and melonfly
Hawaii			
Honolulu	Fruit and Vegetable Insects Research Branch	Hawaii Fruit Fly Investigations (Satellite laboratories at Hilo and Kahului, HI, and Agana, Guam)	Biology, ecology, and control of oriental fruitfly, Mediterranean fruitfly, and melonfly; development of quarantine treatments for commodities infested with fruitflies and mango seed weevils

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
Hilo	Fruit and Vegetable Insects Research Branch	Hawaii Fruit Fly Investigations (Satellite of Honolulu, HI, laboratory)	Biology, ecology, and control of oriental fruitfly, Mediterranean fruitfly, and melonfly
Kahului	Fruit and Vegetable Insects Research Branch	Hawaii Fruit Fly Investigations (Satellite of Honolulu, HI, laboratory)	Biology and ecology of subtropical fruitflies
Idaho			
Twin Falls	Fruit and Vegetable Insects Research Branch	Vegetable & Sugar Beet Disease Vector Investigations (Satellite of Mesa, AZ, laboratory)	Biology, ecology, and control of insects that affect sugar beets, beans, and other vegetables
Indiana			
Vincennes	Fruit and Vegetable Insects Research Branch	Humid Areas Deciduous Fruit Insects Investigations (Satellite laboratories at Wooster, OH, and Kearneysville, WV)	Biology and control of insects and mites that affect deciduous tree fruits
	Pesticide Chemicals Research Branch	Analytical Investigations (Satellite of Beltsville, MD, laboratory)	Analysis of pesticides, pesticide residues, and accessory materials
	Grain and Forage Insects Research Branch	Southern Grain Insects Investigations (Satellite of Tifton, GA, laboratory, with laboratory at Stillwater, OK)	Resistance of wheat varieties to Hessian fly attack; plant resistance to corn earworm in sweet corn
Ankeny	Grain and Forage Insects Research Branch	European Corn Borer Research Laboratory Corn Borer Investigations (Satellite laboratory at Wooster, OH)	Biology, ecology, and chemical control of European corn borer, varietal resistance, and biological control
West Lafayette	Grain and Forage Insects Research Branch	Chemical Analysis Investigations	Pesticide research
		Southern Grain Insects Investigations (Satellite of Tifton, GA, laboratory)	Plant resistance to corn earworm in sweet corn

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
Italy			
Rome	Insect Identification and Parasite Introduction Research Branch	Biological Control of Weeds Investigations (Satellite of Berkeley, CA, laboratory)	Exploration in Mediterranean region for insect enemies of range weeds
Kansas			
Manhattan	Grain and Forage Insects Research Branch	Small Grain Insects Investigations	Resistance of wheat strains to attack by Hessian fly and wheat jointworm, research on insect vectors of wheat diseases
Louisiana			
Baton Rouge	Apiculture Research Branch	Bee Breeding Investigations	Methods of queen and package bee production, genetics of bees, insect pollination
	Grain and Forage Insects Research Branch	Sweetclover and Other Legume Insects Investigations (Satellite of Lincoln, NE, laboratory)	Biological control of armyworms and cutworms
		Rice Insects Investigations	Insect vectors of rice diseases
	Cotton Insects Research Branch	Cotton Insects Insecticide Resistance Investigations	Resistance of cotton insects to insecticides
Houma	Grain and Forage Insects Research Branch	Sugarcane Insects Investigations (Satellite laboratories at Canal Point, FL, and Mayaguez, PR)	Chemical and biological control of sugarcane borer, insect vectors of sugarcane diseases
Shreveport	Fruit and Vegetable Insects Research Branch	Pecan Insects Investigations (Satellite of Albany, GA, laboratory)	Biology and control of insects and mites that affect pecans
	Cotton Insects Research Branch	Boll Weevil Investigations	Biology and control of insects and spider mites that affect cotton, including boll weevil
Tallulah	Cotton Insects Research Branch	Boll Weevil Investigations (Satellite of State College, MS, laboratory)	Biology, ecology, and control of boll weevil

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
Maine			
Orono and Presque Isle	Fruit and Vegetable Insects Branch	Potato Aphids Investigations	Biology, ecology, and control of aphids that affect seed and culinary potatoes
Maryland			
Beltsville	Office of the Director Administrative Office		
	Agricultural Research Center	Insect Pathology Pioneering Research Laboratory	Insect pathogens and conditions under which they cause disease in insect populations
			Physiological and biochemical processes of insects, action of insecticidal compounds on these processes
	Apiculture Research Branch	Headquarters Bee Disease Investigations (Satellite laboratory at Laramie, WY)	Diseases of honeybee and other insect pollinators, bee management, and insect pollination
	Cotton Insect Research Branch	Headquarters	
	Fruit and Vegetable Insects Research Branch	Headquarters	
	Fruit and Vegetable Insects Research Branch	Vegetable and Ornamental Plant Insects Investigations (Satellite laboratory at Farmingdale, NY)	Biology and control of insects and mites that affect vegetables and methods for preventing insect contamination of processed fruits and vegetables; research on biology and control of insects that affect flowering bulbs, annual and perennial flowers, ornamental and flowering shrubs, and greenhouse crops

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
	Grain and Forage Insects Research Branch	Headquarters	
		Alfalfa Weevil Investigations (Satellite laboratory at University Park, PA)	Biology, ecology, and control of alfalfa weevil and other insects that attack legumes in the eastern United States
	Insects Affecting Man and Animals Research Branch	Headquarters	
		Anaplasmosis Vector Investigations (in cooperation with ADP)	Research on ticks and mites as vectors of animal diseases
	Insect Identification and Parasite Introduction Research Branch	Headquarters	
		Sorting and Assignment	
		Foreign Parasite and Predator Investigations (Satellite of Paris, France, laboratory)	Exploration and research on beneficial insects
	Pesticide Chemicals Research Branch	Headquarters	
		Aerosol Investigations	Development of testing of improved insecticide formulations for application in aerosol form and further research on propellants, improvements of equipment
		Analytical investigations (Satellite laboratories at Tifton, GA, Vincennes, IN, Kerrville, TX, and Yakima, WA)	Development and application of chemical and bioassay methods for analysis of insecticidal chemicals and their residues in agricultural crops, animal tissues, mil, and soils
		Biological Investigations (Satellite laboratory at Brownsville, TX)	Screening and evaluation of new compounds for insect control; development of improved methods of disinfecting aircraft

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
		Natural Products Investigations	Search for naturally occurring substances that can be used in insect control, determination of the chemical structure of such substances, preparation of identical chemical compounds
		Synthesis Investigations (Satellite laboratories at Orlando, FL, and State College, MS)	Synthesis of compounds for evaluation in insect control, development of improved formulations and methods of application for insect control
Mexico			
Mexico City	Fruit and Vegetable Insects Research Branch	Mexican Fruit Fly Investigations	Biology, ecology, and control of fruitflies and other insect and mite pests that threaten United States subtropical horticulture and development of quarantine treatments for insect-infested tropical fruits
Mississippi			
State College	Grain and Forage Insect Research Branch	Southern Grain Insects Investigations (Satellite of Tifton, GA, laboratory)	Biology, ecology, and control of corn earworm, plant resistance to earworm attack, research on other corn insects
	Cotton Insect Research Branch	Boll Weevil Investigations (Satellite Laboratories at Tallulah, LA, and Stoneville, MS)	Fundamental and applied research on all phases of boll weevil program
	Pesticide Chemicals Research Branch	Synthesis Investigations (Satellite of Beltsville, MD, laboratory)	Biochemical investigation of boll weevil
Stoneville	Cotton Insects Research Branch	Boll Weevil Investigations (Satellite of State College, MS, laboratory)	Biology and control of insects and spider mites that affect cotton

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
	Insects Affecting Man and Animals Research Branch	Livestock Insects Investigations (Satellite of Kerrville, TX, laboratory)	Biology and control of insects that affect livestock, especially deerflies and houseflies
Missouri Columbia	Grain and Forage Insects Research Branch	Sweetclover and Other Legume Insects Investigations (Satellite of Lincoln, NE, laboratory)	Biology, ecology, and control of insects that attack forage crops and seeds, including soybeans, in the southern United States
Montana Bozeman	Grain and Forage Insects Research Branch	Grasshopper Investigations (Satellite laboratory at Mesa, AZ) Northern Grain Insects Investigations (Satellite of Brookings, SD, laboratory)	Biology, ecology, and control of grasshoppers Biological and chemical control of wheatstem sawfly and plant resistance to sawfly attack
Nebraska Lincoln	Grain and Forage Insects Research Branch	Sweetclover and Other Legume Insects Investigations (Satellite laboratories at Baton Rouge, LA, and Columbia, MO)	Resistance of alfalfa to spotted alfalfa aphid, pea aphid, and potato leafhopper; resistance of sweetclover varieties to sweetclover weevil and sweetclover aphid
	Insects Affecting Man and Animals Research Branch	Livestock Insects Investigations (Satellite of Kerrville, TX, laboratory)	Biology and control of insects that affect livestock, especially stable flies and cattle grubs
New Jersey Hoboken	Fruit and Vegetable Insects Research Branch	Plant Quarantine Commodity Treatment Investigations	Treatments for plants and commodities regulated by plant quarantine
Moorestown	Fruit and Vegetable Insects Research Branch	Japanese Beetle and European Chafer Investigations (Satellite laboratory at Geneva, NY)	Biology and control of japanese beetle and other soil-infecting insects
	Insect Identification and Parasite Introduction Research Branch	Counterpests Quarantine, Propagation, and Shipping Investigations	Receipt and distribution of foreign parasites and predators for biological control of harmful insects

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
		Foreign Parasite and Predator Investigations (Satellite of Paris, France, laboratory)	Exploration and research of beneficial insects
New York			
Farmingdale	Fruit and Vegetable Insects Research Branch	Vegetable and Ornamental Plant Insects Investigations (Satellite laboratory of Beltsville, MD)	Biology and control of insect and mites of greenhouse and ornamental plants
Geneva	Fruit and Vegetable Insects Research Branch	Japanese Beetle and European Chafer Investigations (Satellite of Moorestown, NJ, laboratory)	Biology, control, and methods of detection of European chafer and methods of treatment of infested nursery stock
North Carolina			
Oxford	Fruit and Vegetable Insects Research Branch	Tobacco Insects Investigations (Satellite laboratories at Quincy, FL, and Florence, SC)	Biology, ecology, and control of insects that affect flue-cured tobacco in the field
North Dakota			
Minot	Grain and Forage Insects Research Branch	Northern Grain Insects Investigations (Satellite of Brookings, SD, laboratory)	Biology, ecology, and control of wheatstem sawfly and plant resistance to sawfly
Ohio			
Wooster	Fruit and Vegetable Insects Research Branch	Humid Areas Deciduous Fruit Insects Investigations (Satellite of Vincennes, IN, laboratory)	Biology and control of insects and mites that affect grapes and deciduous tree fruits
	Grain and Forage Insects Research Branch	Corn Borer Investigations (Satellite of Ankeny, IN, laboratory)	Plant resistance of corn strains to European corn borer
Oklahoma			
Stillwater	Grain and Forage Insects Research Branch	Small Grain Insects Investigations (Satellite of Tifton, GA, laboratory, with laboratories at West Lafayette and Vincennes, IN)	Biology, ecology, and control of greenbug and mites that attack small grains, chemical control of armyworms and cutworms of small grains

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
Oregon			
Corvallis	Fruit and Vegetable Insects Research Branch	Deciduous Fruit Disease Vector Investigations (Satellite of Riverside, CA, laboratory)	Biology and control of insect vectors of stone fruit virus diseases
	Insects Affecting Man and Animals Research Branch	Western Insects Affecting Man and Animals Investigations (Satellite laboratory at Fresno, CA)	Biology and control of insects that affect humans and animals, such as mosquitoes, biting flies, ticks, cattle grubs, and lice, in the western United States
Forest Grove	Fruit and Vegetable Insects Research Branch	Insecticide Application Methods Investigations	Methods of applying insecticides to truck crops with aircraft and ground equipment
	Grain and Forage Insects Research Branch	Alfalfa and Clover Seed Insects Investigations (Satellite of Tucson, AZ, laboratory)	Biology, ecology, and control of clover insects
Pennsylvania			
University Park	Grain and Forage Insects Research Branch	Alfalfa Weevil Investigations (Satellite of Beltsville, MD, laboratory)	Biology and ecology of forage insects, insect vectors of forage crop diseases, varietal resistance of alfalfa to potato leafhopper
Puerto Rico			
Mayaguez	Grain and Forage Insects Research Branch	Sugarcane Insects Investigations (Satellite of Houma, LA, laboratory)	Research on sugarcane insects
South Carolina			
Charleston	Fruit and Vegetable Insects Research Branch	Winter Vegetable Insects Investigations	Biology, ecology, and control of insects and mites that affect vegetables and berries
Florence	Cotton Insects Research Branch	Southeastern Cotton Insects Investigations	Biology and control of insects and spider mites that affect cotton

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
	Fruit and Vegetable Insects Research Branch	Tobacco Insects Investigations (Satellite of Oxford, NC, laboratory)	Biology, ecology, and control of insects that affect flue-cured tobacco in the field
South Dakota Brookings	Grain and Forage Insects Research Branch	Northern Grain Insects Investigations (Satellite laboratories at Bozeman, MT, and Minot, ND)	Biology, ecology, and control of insects that affect corn and other grains
Texas Brownsville	Cotton Insects Research Branch	Pink Bollworm Investigations	Chemical, biological, cultural, and mechanical control; plant resistance; ecological, physiological, biochemical, and morphological studies of pink bollworm
		Bioclimatic group	Relationship of climate and climatic factors to development, abundance, and distribution of insect and mites
	Pesticide Chemicals Research Branch	Biological Investigations (Satellite of Beltsville, MD, laboratory)	Laboratory tests on effectiveness of insecticidal materials
College Station	Cotton Insects Research Branch	Southwestern Cotton Insects Investigations (Satellite laboratory at Waco, TX)	Biology and control of insects and spider mites that affect cotton and other fiber plants
Kerrville	Insects Affecting Man and Animals Research Branch	Livestock Insects Investigations (Satellite laboratories at Denver, CO, Stoneville, MS, Lincoln, NE, and Mission, TX)	Research on cattle grubs, hornflies, ticks, lice, fleas, screwworms, and other insects that attack livestock or poultry
	Pesticide Chemicals Research Branch	Analytical Investigations (Satellite of Beltsville, MD, laboratory)	Analysis of pesticides, pesticide residues, and accessory materials
Mission	Insects Affecting Man and Animals Research Branch	Livestock Insects Investigations (Satellite of Kerrville, TX, laboratory)	Research on screwworms that attack livestock or poultry

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
Waco	Cotton Insect Research Branch	Southwestern Cotton Insects Investigations (Satellite of College Station, TX, laboratory)	Biology and control of insects and spider mites that affect cotton
Weslaco	Fruit and Vegetable Insects Research Branch	Brown Soft Scale Investigations.	Studies of brown soft scale of citrus
Utah			
Logan	Apiculture Research Branch	Wild Bee Pollination Investigations	Effect of pesticides on honeybees, biology of bee diseases, breeding and management for improvement of productivity, behavior, utilization of honeybees in pollination
	Fruit and Vegetable Insects Research Branch	Vegetable and Sugar Beet Disease Vector Insects Investigations (Satellite of Mesa, AZ, laboratory)	Biology and control of insects that affect sugar beets and vegetables
Washington			
Sumner	Fruit and Vegetable Insects Research Branch	Bulb Insects Investigations	Biology and control of insects that affect flowers, bulbs, and greenhouse plants
Wenatchee	Fruit and Vegetable Insects Research Branch	Arid Areas Deciduous Fruit Insects Investigations (Satellite of Yakima, WA, laboratory)	Biology, ecology, and control of insects and mites that affect deciduous fruits
Yakima	Fruit and Vegetable Insects Research Branch	Arid Areas Deciduous Fruit Insects Investigations (Satellite laboratory at Wenatchee, WA)	Biology and control of insects and mites that affect deciduous fruits
		Potato, Pea, and Sugar Beet Insects Investigations	Biology, ecology, and control of insects and mites that affect potatoes
	Pesticide Chemicals Research Branch	Analytical Investigations (Satellite of Beltsville, MD, laboratory)	Analysis of pesticides, pesticide residues, and accessory materials

Table 3. Research locations and program areas in the Entomology Research Division, 1963—cont'd.

Location	Branch	Unit	Investigating
West Virginia			
Kearneysville	Fruit and Vegetable Insects Research Branch	Humid Areas Deciduous Fruit Insects Investigations (Satellite of Vincennes, IN, laboratory)	Biology and control of insects and mites that affect deciduous tree fruits
Wisconsin			
Madison	Apiculture Research Branch	Bee Management Investigations	Research on honeybee colony management
Wyoming			
Laramie	Apiculture Research Branch	Bee Disease Investigations (Satellite of Beltsville, MD, laboratory)	Research on honeybee diseases

Research Accomplishment Highlights

The forward-looking, progressive leadership fostered by Knipling has persisted in the Federal entomology research community over five decades at this writing. The literature is replete with reports of the outstanding progress made in developing nonchemical insect pest control at Federal, university, and private-sector levels. Only a few examples of Federal entomological achievements during this period will be presented here to give the reader an appreciation for the effects of the redirected research effort toward ecologically oriented insect control in the Entomology Research Division.

In 1954, the Insect Identification and Parasite Introduction Research Branch was established within the Entomology Research Division (Vail et al. 2001). Biological control increased from 5 scientific years (SY) in 1954 to a peak of 53 SY in 1965 (Coulson et al. 2000). (An SY is the work of one scientist employed full-time or the equivalent in part-time employees.) This decreased to 45 SY in 1972 because of budgetary restrictions. Successful biological control programs were developed for cereal leaf beetle [*Oulema melanopus* (Linnaeus)], alfalfa weevil [*Hypera postica* (Gyllenhal)], and Rhodesgrass mealybug [*Antonina graminis* (Maskell)], as well as other introduced pests. Coulson et al. (2000) conservatively estimated that benefits resulting from selected ARS classical biological control programs equaled or exceeded $150 million annually. Other successful programs involved beneficial insect augmentation and conservation, microbial control, and use of entomopathogenic nematodes. More complete and specific histories of the progress of Federal entomologists in biological control are presented in Coulson et al. (2000) and Vail et al. (2001).

Another outstanding achievement was development of wheat varieties resistant to Hessian fly and wheat stem sawfly [*Cephus cinctus* Norton], alfalfa varieties to spotted alfalfa aphid [*Therioaphis maculata* (Buckton)], and corn varieties to European corn borer (Luginbill 1969). Hessian fly infestations at one time resulted in greater than 50 percent yield loss in the United States; losses are minimal today largely due to development of resistant wheat varieties. Similarly, the discovery of a solid stem-wheat variety that was resistant to wheat stem sawfly resulted in more than $4 million annual saving to wheat farmers. Spotted alfalfa aphid was discovered in New Mexico in 1954. After only 3 years of Federal and State cooperative efforts, a resistant variety was developed and released. Farmer savings in control costs were estimated at $35 to $70 million annually. The European corn borer was estimated to cause $350 million dollars in damage in 1949 alone. A continuing program of developing corn borer resistance in hybrid corn reduced these losses 60 percent.

Methods of using induced insect sterility to control or eradicate insect populations (Knipling 1960) were among the most significant contributions to entomology during the 1950s and 1960s. The best known method, sterile insect release, involves sustained overflooding of native insect populations with sterile insects of the same species at densities that are high enough that few fertile native matings take place. The method was hypothesized about 1937 by Knipling (Gall 1968). After many years of research, it became scientific reality when screwworm flies sterilized by irradiation with cobalt-60 were released at the rate of 800 per square mile on Curaçao in the Netherlands Antilles in 1954. Eradication was complete about 3 months after the first release (Baumhover et al. 1955).

Screwworm sterile release programs in the Southwest were similarly successful (Baumhover 1966, Knipling 1960). The southwestern screwworm sterile release program resulted in estimated savings of $400 million or more during the research phases. Accumulated savings over the last 30–40 years far exceed that amount. Far more important was demonstration of the concept of areawide population suppression (Knipling 1979).

The program's success had far-reaching and persistent positive effects on the direction of entomological research. The concept is clearly recognized as one of the most outstanding contributions in entomology. Knipling's understanding of ecology, insect population dynamics, and dispersal gave him the vision to be the first entomologist to fully appreciate and employ the advantages of areawide pest population suppression compared to local focus of pest control on a farm-by-farm basis. His areawide concept profoundly affected approaches to applied entomological control and research worldwide. The sterile-insect release program, as one of the first areawide programs, is an outstanding achievement in its own right; but more importantly, its successful implementation led to a new era of basic research on biology, ecology, physiology, and genetics as foundations for sound, efficient, effective insect pest management.

Insect responses to chemical, biological, and physical stimuli had long been seen as a potential way to manipulate behavior to achieve economic control through trapping and killing, luring and sterilizing, or disrupting mating behavior. Expanded efforts beginning in the mid-1950s resulted in identification of potent and specific insect sex pheromones. Jacobson (1965) compiled a list showing that sex pheromones were demonstrated in more than 200 insect species. Numerous additional sex pheromones and other behavior-modifying chemicals have been identified since then. Leonhardt and Moreno (1982) reported that sex pheromones were known for more than 250 insect species. Identification of sex pheromones set the stage for development of successful behavioral control using mating disruption technology for highly damaging insect pests such as pink bollworm in cotton and codling moth in tree fruits.

The potential of attractants combined with a toxicant ("attract and kill") to provide low-cost control of pests over large areas was demonstrated in 1965 when the oriental fruit fly was eradicated using this method on the island of Rota (Steiner et al. 1965). Methyleugenol, a powerful male attractant, was combined with an insecticide and impregnated in cane-fiber squares. The squares were dropped along aircraft flight lines about 5 miles apart. Daily monitoring with traps showed an immediate 93 percent reduction in the fly population. After 10 aerial drops, no flies were captured and none were found during 24 subsequent months of trapping and inspecting host fruits. Only 3.5 grams of toxicant per acre was required for the entire program. Numerous research projects throughout the United States have since focused on some modification of the attract-and-kill approach.

During the 1960s scientists of the Entomology Research Division initiated extensive research on insect hormones and hormonelike materials that disrupt insect development rather than cause immediate death. Sterility in adult insects was observed after treatment with molting hormones or their analogs, whereas juvenile hormones interrupted insect development (Williams and Robbins 1968). Some of these hormonal materials had little effect on nontarget organisms but were effective against test insects at rates as low as one-billionth of a gram. New "hybrid" synthetic ethers, which are juvenile-hormone-like materials, have been found to block normal insect growth and development. Some of these components showed greater potency than the insects' own hormones (Bowers 1969). These accomplishments were the forerunners of current, highly effective new insecticide chemistries with modes of action similar to those of insect growth and molting hormones.

Cultural controls have been a fundamental tool in the entomologist's arsenal for many years. New applications or modification of host-free periods were implemented in the 1960s. For example in the Pacific Northwest, the green peach aphid [*Myzus persicae* (Sulzer)] vectors beet western yellows and beet yellows viruses, diseases that resulted in annual losses of as much as 25 to 30 percent of sugar beet yields (Wallis 1967a,c). Beet western yellows, the most prevalent of the yellows diseases in the area, has 30 or more hosts other than beets that serve as virus reservoirs (Wallis 1967b). Green peach aphids overwintered primarily in the egg stage on peach trees in the general area. Small numbers of the summer forms overwinter and feed on plants growing year-round in protected places. Many of the overwintering hosts of the summer aphid forms are also reservoirs for beet western yellows virus (Wallis 1967b). Removal (by burning) of weeds growing in warm-spring water drain ditches in spring, before sugar beets began growing and aphids began migrating, resulted in 91 percent fewer aphids and 76 percent fewer diseased plants than in unburned check areas (Wallis 1965). The increased yield in the burned test area was estimated at more than 2 tons per acre.

Host elimination or replacement was also developed to reduce beet leafhopper [*Circulifera tennellus* (Baker)] populations in Idaho. Beet leafhopper is the vector of curly top virus. In large desert and range area studies in southern Idaho, Russian thistle [*Salsola iberica* Senn and Pace] was found to be the most important beet leafhopper summer host. Scientists recognized that the breeding area might be the vulnerable link in the host-plant cycle and postulated that if it were broken, the insect could be effectively controlled. Reseeding more than 200,000 acres of beet leafhopper breeding areas with crested wheatgrass [*Agropyron cristatum* (L.) Gaertn] reduced curly top disease to a minor problem (Douglas and Cook 1954, Gibson and Fallini 1963). Establishment of crested wheatgrass also increased range carrying capacity for grazing ten-fold, increased dependability of available range forage, and reduced grass fire and wind erosion hazards (Gibson and Fallini 1963).

These examples are only a few of the many outstanding achievements of scientists and staff of the Entomology

Research Division and its predecessor organizations. The examples were selected to illustrate the diversity of research approaches and efforts directed to ecologically based insect pest management.

With this record of success, it is understandable that some concern should arise when, in 1972, ARS underwent a major reorganization characterized by decentralization and abolishment of all subject-matter divisions (Coulson et al. 2000). The discipline-commodity-oriented research branches that had been headed by branch chiefs and their staffs provided overall administrative and research program directions that were national in scope, but were centrally headquartered in Beltsville, MD. Though renamed and reorganized on several occasions (table 4), entomology as an organizational entity in USDA existed from 1863 to 1972. (This does not include the single Federal Entomologist position established in 1854 in the Patent Office.) The broad subject areas of entomology research programs and commodities that were identified when the Bureau of Entomology was created in 1904 remained similar through 1972.

A brief history of medical and veterinary entomology (Schmidt and Fluno 1973) and an overall entomological leadership review in USDA from 1853 to 1972 (Rainwater and Parencia 1981) have been published. Other historical accounts of entomology in USDA include the reviews of Geong (2001) on the establishment of medical entomology in the Bureau of Entomology, Coulson et al. (2000) and Vail et al. (2001) on the history of biological control, the unpublished report of Nolan (1939) on accomplishments in bee culture in the Bureau of Entomology and Quarantine, the review of the role of insect pollination of cultivated crop plants in agriculture by McGregor (1976), and the review by Parencia (1978) of 120 years of research on cotton insects in the United States.

Also worthy of mention is the particularly active role Federal scientists have played in coordinating national programs (Parencia and Hardee 1996). This function is exemplified by the Cotton Insect Research and Control Conference, held annually since 1947. The Federal entomology role was recognized by the cotton industry and the National Cotton Council of America with publication of "Cotton Insects and Mites: Characterization and Management" (King et al. 1996) by the Cotton Foundation. The conference has been a major factor in bringing States, ARS, consultants, and the cotton industry together in their research, extension, and control efforts. The conference is part of what evolved into the Beltwide Cotton Research and Production Conferences sponsored by the National Cotton Council of America and others.

A Study of Discipline-Commodity-Oriented Entomology Research

Changes in the entomology research branches and other discipline-oriented programs that related to new research, closures, redirections, and organizational structure are typified by the Insect Pests of Vegetables, Ornamentals and Specialty Crops Research Branch, which was dissolved in the 1972 ARS reorganization.

Work on truck crop (vegetables, berries, etc.—(table 5) insects began in 1854 with establishment of the Agriculture Division in the Patent Office. Work was carried on in USDA beginning in 1862 and formalized in the newly created Division of Truck Crop and Special Insect Investigations in 1904 in the new Bureau of Entomology. The early Federal entomology philosophy was to attack problems at the site. Small staffs at numerous locations where specific insect problems were developing were the order of the day.

One of the earliest records of Federal vegetable insect research is that on Colorado potato beetle, which began soon after the insect was found invading potato fields in some western States in 1860. The effective use of paris green in 1867 against the Colorado potato beetle was one of the first recorded demonstrations of effective chemical control of a vegetable insect pest (Busbey 1962). Paris green thereafter found additional use in controlling other pests and for many years remained the standard treatment for control of chewing insects.

In 1891, Chittenden was appointed to the Division of Entomology Staff to develop information on truck crop insects. When the Bureau of Entomology was established in 1904, Chittenden was designated in charge of the Division of Small Fruit and Truck Crop Insect Investigations. The division investigated insect pests of vegetables and berries, greenhouse and ornamental plants, tobacco, sugar beet, and some specialty crops. Stored products and shade tree insects were also assigned, but were later transferred to other divisions. Some of the first work on truck crop insects in the division was conducted in the early 1900s at one of the Bureau of Entomology locations in Plymouth,

Table 4. Federal entomological organizations and leadership from 1854 to 1972

Organization	Years	In charge
Department of the Interior, U.S. Patent Office	1854-1859	Townend Glover
Department of Agriculture:		
Division of Entomology	1863-1878	Townend Glover
	1878-1879	Charles V. Riley
	1879-1881	John H. Comstock
	1881-1894	Charles V. Riley
	1894-1904	Leland O. Howard
Bureau of Entomology	1904-1927[1]	Leland O. Howard
	1927-1933[2]	Charles L. Marlatt
	1933-1934[2]	Lee A. Strong
Bureau of Entomology and Plant Quarantine[3]	1934-1941	Lee A. Strong
	1941-1950	Percy N. Annand
	1950-1953	Avery S. Hoyt
Entomology Research Branch	1953-1955	Edward F. Knipling
Entomology Research Division[4]	1956-1971	Edward F. Knipling
	1971-1972	HC Cox

Source: Baker et al. 1963.

[1] The Plant Quarantine Act was passed in 1912, and a Federal Horticultural Board was appointed to administer the act. This was the first official Federal entomology involvement in quarantine procedures.
[2] The Plant Quarantine and Control Administration was established in 1928 assuming responsibility for Bureau of Entomology and Bureau of Plant Industry regulatory work. The Bureau of Plant Quarantine followed in 1932, and in 1934 the Bureaus of Plant Quarantine and of Entomology were combined.
[3] The unit became Crop Regulatory Programs in the 1953 abolishment of the bureaus, and subsequent reorganization of the unit had Plant Pest Control and Plant Quarantine Branches.
[4] Abolished June 30, 1972. Since 1972 entomological research has been conducted in various laboratories under the administrative supervision of the ARS Area Directors. Clarence H. Hoffman served as acting division director until H.C. Cox's appointment was formalized.

Table 5. Vegetable and berry insects research in the Entomology Research Division and its predecessor organizations through 1972

Location		Original research assignment	Additional assignment	Status
Whittier, CA	1913	Potato insects (potato tuberworm)	–	Transferred 1916 to Alhambra, CA
Baton Rouge, LA	1914	Vegetable insect investigations (turnip aphid); berry insects (strawberries)	1932, cole crop investigations (cabbage caterpillars) 1944, sweetpotato investigations (by transfer from Opelousas, LA) 1920, tomato fruitworm 1925, cucumber beetles	Discontinued 1951
Madison, WI	1916	Onion investigations (onion maggot)	1917, melon investigations (cucumber beetle) 1923, pea insects investigations (pea aphid)	Discontinued 1952
Alhambra, CA	1916	Potato tuberworm, pea aphid	1917, celery insect investigations (celery leaftier) 1924, wireworms 1925, vegetable insect investigations (pepper weevil) 1932, cole crop investigations 1936, tomato insect investigations 1945, onion insect investigations (onion thrips) 1949, vegetable insects investigations (serpentine leaf miner) 1949, seed corn maggot	Transferred 1951 to Whittier, CA
Biloxi, MS	1917	Sweetpotato insects (sweetpotato weevil)	1935, vegetable weevil (transferred from Gulfport, MS) 1927, wireworms	Transferred 1937 to Sunset, LA

Table 5. Vegetable and berry insects research in the Entomology Research Division and its predecessor organizations through 1972—cont'd.

Location		Original research assignment	Additional assignment	Status
Bay St. Louis, MS	1917	Sweetpotato insects (sweetpotato weevil)		Transferred 1937
Grand Bay, AL	1917	Sweetpotato insects (sweetpotato weevil)		Transferred 1937
MacClenny, FL	1918?	Sweetpotato insects (sweetpotato weevil)		
Plant City, FL	1918?	Sweetpotato insects (sweetpotato weevil)		
Waveland, MS	1918?	Sweetpotato insects (sweetpotato weevil)		
Chadburn, NC	1919	Seed corn maggot	1921, mole crickets 1922, strawberry weevil 1932, cole crop investigations (melonworms, pickleworm)	Transferred 1939
Tampa, FL	1918	Sweetpotato weevil	–	Transferred 1928
Cash Corner, NC	1923	Temporary substation of Chadburn; seed corn maggot	–	
Estancia, NM	1923	Bean insects (Mexican bean beetle)	–	Transferred 1935 to Grand Junction, CO
Gulfport, MS	1924	Vegetable weevil quarantine treatment	1946, sweetpotato weevil	Transferred 1935 to Biloxi, MS

Table 5. Vegetable and berry insects research in the Entomology Research Division and its predecessor organizations through 1972—cont'd.

Location		Original research assignment	Additional assignment	Status
Charleston, SC	1925	Seed corn maggot	1932, cole crop investigations (cabbage, caterpillars) 1934, wireworms (transferred from Fairfax, SC) 1949, melon investigations (melonworm, pickleworm)	Active
Thomasville, AL	1925	Mexican bean beetle, temporary substation	–	Discontinued, date unknown
Philadelphia, PA	1926	Physiology and toxicology investigations	–	Discontinued, date unknown
Riverton, NJ	1926?	Physiology and toxicology investigations	–	Discontinued, date unknown
Twin Falls, ID	1925	Sugar beet insects	1949, beans and curlytop	Discontinued after 1972
Geneva, NY	1924	Bean insects (Mexican bean beetle)	1932, cole crop insects 1926, strawberry insects	Discontinued 1932
Toppenish, WA	1924	Wireworms	–	
Columbus, OH	1925	Bean insects (bean leafhopper, Mexican bean beetle)	1932, cole crop insects	Discontinued 1953
Birmingham, AL	1921	Mexican bean beetle, tomato fruitworm	–	Transferred 1929 to Norfolk, VA

Table 5. Vegetable and berry insects research in the Entomology Research Division and its predecessor organizations through 1972—cont'd.

Location		Original research assignment	Additional assignment	Status
Sanford, FL	1926	Celery insects (celery leaftier) Sweetpotato weevil	1931, vegetable insecticide investigations (Puerto Rican mole cricket)	Discontinued 1939
Picayune, MS	1926	Sweetpotato insects (sweetpotato weevil)	–	Discontinued 1937
Walla Walla, WA	1928	Wireworms	1933, sugar beet insects (transferred from Toppenish, WA)	Transferred 1961 to Yakima, WA
Sligo, MD	1926	Berry Insects Research Station	Insect transmission of bramble diseases	Transferred 1935 to Beltsville, MD
Puyallup, WA	1928	Berry insects, European earwig	–	Transferred 1941 to Union Gap, WA
Arlington Farm, Rosslyn, VA	1930	Berry Insects Research Station	Berry insects	Transferred 1935 to Beltsville, MD
San Jose, CA	1928	Vegetable weevil	–	Discontinued, date unknown
Norfolk, VA	1929	Bean insects	–	Discontinued 1958
Santa Ana, CA	1924	Pepper weevil	–	Transferred 1931 to Alhambra, CA
Parma, ID	1927	Wireworms	–	Transferred 1941 to Twin Falls, ID
Corvallis, OR	1930	Pea insects (pea weevil)	–	Transferred 1939 to Forest Grove, OR
Fairfax, SC	1930	Wireworms	–	Transferred 1934 to Sanford, FL

Table 5. Vegetable and berry insects research in the Entomology Research Division and its predecessor organizations through 1972—cont'd.

Location		Original research assignment	Additional assignment	Status
Moscow, ID	1931	Pea investigations (pea weevil)	–	Transferred 1935 to Walla Walla, WA
Ventura, CA	1931	Bean insects (lima bean pod borer)	1939, wireworms	Transferred 1951 to Whittier, CA
Phoenix, AZ	1932	Lettuce insects	1935, sugar beet insects (beet leafhopper, transferred from Grand Junction, CO) 1948, beet leafhopper (melons) 1949, vegetable insects investigations (serpentine leafminer)	Transferred 1959 to Mesa, AZ
Dayton, WA	1935	Pea weevil	–	Transferred 1935 to Walla Walla, WA
Logan, UT	1936	Sugar beet insects	1947, celery insects investigations (celery leaftier)	Discontinued 1964
Sunset, LA	1937	Relocation of Biloxi, MS, work; sweetpotato weevil, vegetable weevil, wireworms	–	Transferred 1943 to Opelousas, LA
Forest Grove, OR	1939	Pea insects (pea weevil)	1948, insecticide application methods	Discontinued 1948
Scottsbluff, NE	1939	Potato insects (potato psyllid)	–	Discontinued 1956
Union Gap, WA	1941	Potato insects (tuber flea beetle)	–	Transferred 1961 to Yakima, WA
Presque Isle, ME	1942	Potato insects (aphids)	–	Discontinued after 1972

Table 5. Vegetable and berry insects research in the Entomology Research Division and its predecessor organizations through 1972—cont'd.

Location		Original research assignment	Additional assignment	Status
Plant City, FL	1943	Celery insects (puerto rican mole cricket)	–	Discontinued 1943
Opelousas, LA	1943	Sweetpotato insects (transferred from Sunset, LA) (sweetpotato weevil)	–	Transferred 1944 to Baton Rouge, LA
Orono, ME	1945	Potato insects (aphids)	–	Discontinued after 1972
Whittier, CA	1951	Relocation of Alhambra and Ventura work	1951, wireworm (transferred from Ventura, CA)	Transferred 1961 to Riverside, CA
Mesa, AZ	1959	Relocation of Phoenix work	–	Discontinued 1977
Yakima, WA	1961	Relocation and consolidation of Union Gap and Walla Walla work	–	Active

IN (Luginbill 1955). Research was initiated on specific commodities or insect problems with funding by Congress in response to requests by constituents, by relocations and redirections of existing work, or by recognition of problems by the headquarters research program staff.

Early vegetable insect work was conducted on pests of celery, potatoes, cole crops, onions, sweetpotatoes, beans, peas, lettuce, tomatoes, and melons. Insects studied were the potato tuberworm [*Phthorimaea operculella* (Zeller)], celery leaftier [*Udea rubigalis* (Guenée)], crickets, onion thrips [*Thrips tabaci* Lindeman], caterpillars, cucumber beetles, melon worm [*Diaphania hyalinata* (Linnaeus)], pickleworm [*Diaphania nitidalis* (Stoll)], pea weevil [*Bruchus pisorum* (Linnaeus)], pea aphid [*Acyrthosiphon pisum* (Harris)], sweetpotato weevil [*Cylas formicarius elegantulus* (Summers)], Mexican bean beetle [*Epilachna varivestis* Mulsant], tomato pinworm [*Keiferia lycopersicella* (Walsingham)], and tomato fruitworm [*Helicoverpa zea* (Boddie)]. Studies were initiated on strawberry insects at Baton Rouge, LA, as early as 1914 and at Geneva, NY, in 1926. Strawberry root weevil [*Otiorhynchus ovatus* (Linnaeus)] was studied at Chadbourn, NC, from 1922. Research on berry insects began at Puyallup, WA, in 1928 and at Arlington Farm in 1930. Studies were initiated on insect transmission of bramble diseases at Sligo, MD, in 1926; this project was later (1930) transferred to Arlington Farm and thence to Beltsville in 1935. Work on berry insects was apparently discontinued at Puyallup in 1930.

Investigations on greenhouse and ornamental insect problems were sporadic and were originally accomplished under funds appropriated for tropical insects research (table 6). The first systematic study was initiated in 1918 with establishment of a laboratory and greenhouse facility in Washington, Washington, DC. In 1935, the buildings and greenhouses were completed at the Agricultural Research Center, Beltsville, MD, and greenhouse insect work was transferred to the new location. In 1925, research on narcissus bulb fly [*Merodon equestris* (Fabricius)] started in Santa Cruz, CA; then it was transferred to Puyallup, WA, and finally to Sumner, WA, in 1929; the work ended in 1969. Research on insects affecting bulb crops was initiated in 1929 at Babylon, NY, and ended in 1944. In 1948, a laboratory to investigate greenhouse and ornamental insect problems in cooperation with Cornell University was established at Farmingdale, NY; this work was discontinued in 1973. At present, work on greenhouse and ornamental insect pests is conducted at Beltsville and at the United States National Arboretum, DC, under administrative guidance of the Plant Science Institute at Beltsville.

From 1904 to 1929, tobacco insects research was conducted by the Southern Field Crops Insects Investigations groups but thereafter was transferred to the Truck Crop and Garden Insect Investigations. The first laboratory was established in 1907 at Clarksville, TN, to develop methods to control tobacco hornworms [*Manduca sexta* (Linnaeus)] and flea beetles [*Epitrix hirtipennis* (Melsheimer)]. In 1915, a substation of the Clarksville laboratory was established at Quincy, FL, to investigate insects affecting shade-grown tobacco. In 1928, an entomologist was sent to Tempe, AZ, to investigate potential tobacco insect problems pending commercial tobacco production in Arizona. Research on insect pests of stored tobacco started at Richmond, VA, in 1930 and in 1936 at Windsor, CT, and on flue-cured tobacco at Oxford, NC, and Florence, SC, the same year.

Laboratories at Clarksville, Tempe, and Windsor were closed between 1932 and 1951. Also, in August 1951 the functions of the Richmond laboratory were transferred to the Division of Stored Product Insect Investigations. In 1966, a substation of the Oxford laboratory was established on St. Croix, VI, to investigate nonchemical methods of suppressing insect populations.

In 1929, a project was established at the request of the mushroom industry to develop methods of insect and mite control to end the producers' excessive losses (table 6). Office and laboratory space was provided in Takoma Park, MD, with experimental mushroom houses and storage facilities at Arlington Farm. The entire project was transferred to Beltsville in 1935. Research continued there until 1953, at which time the project was terminated.

Federal appropriations were made as early as 1899 to promote the sugar beet industry in the United States. Research dealt mainly with culture and seed production and subsequently with breeding disease-resistant varieties. Until 1905, the relationship between curly top disease and beet leafhopper was unknown. The first laboratory to investigate and develop methods of controlling beet leafhopper was established in 1909 at Compton, CA (table 7); however, the first Federal

Table 6. History of greenhouse and ornamental, tobacco, and mushroom insects research in the Entomology Research Division and its predecessor organizations through 1978

Location	Est.	Investigations	Status
Greenhouse and Ornamentals			
Washington, D.C.	1918	Greenhouse insects, gladiolus bugs	Transferred 1935 to Beltsville, MD
Santa Cruz, CA	1925	Bulb insects	Transferred 1927 to Puyallup, WA
Puyallup, WA	1927	Bulb insects	Transferred 1929 to Sumner, WA
Babylon, NY	1929	Narcissus bulb insects	Discontinued 1944
Sumner, WA	1929	Narcissus bulb insects	Discontinued 1969
Beltsville, MD	1935	Greenhouse insects	Active
Farmingdale, NY	1948	Greenhouse, ornamental insects	Discontinued 1973
Tobacco			
Clarksville, TN	1907	Hornworm, flea beetles	Discontinued 1951
Florence, SC	1936	Insect pests of flue-cured tobacco	Discontinued, date unknown
Tempe, AZ	1928	Tobacco insects, tobacco stalkborer	Discontinued 1932[1]
Oxford, NC	1935	Insects of flue-cured tobacco	Discontinued, date unknown
Quincy, FL (substation of Clarksville)	1915	Shade tobacco insects	Discontinued 1974
Richmond, VA	1930	Stored tobacco insect problems	Transferred 1951 to Stored Product Insects
Windsor, CT	1936	Shade tobacco insects	Discontinued 1942
St. Croix, VI	1966	Tobacco hornworm	Discontinued, date unknown
Chadbourne, NC	1925	Wireworms	
Mushroom			
Takoma Park, MD	1929[2]	Mites and mushroom flies	Transferred 1935 to Beltsville, MD
Arlington Farm, Rosslyn, VA	1929[3]	Mites, mushroom flies, and chemical residues	Transferred 1935 to Beltsville, MD
Beltsville, MD	1935	Mushroom flies	Discontinued 1953, Reestablished 1978

[1] Reassignment of research to investigating lettuce and vegetable insect problems in 1932, which was transferred 1934 to Phoenix, AZ; see Vegetable Insects Research, table 5.
[2] Laboratory and office space.
[3] Mushroom houses and storage.

Table 7. Locations of sugar beet insects[1] research in the Entomology Research Division and its predecessor organizations in USDA through 1977

Location		Status
Compton, CA	1909	Transferred 1917 to Alhambra, CA[2]
Jerome, ID	1910	Discontinued 1914
Alhambra, CA	1917	Transferred 1939 to Ventura, CA[3]
Riverside, CA	1919	Discontinued 1924
Twin Falls, ID	1925	Discontinued after 1972
Toppenish, WA	1925	Transferred 1933 to Walla Walla, WA
Richfield, CT	1927	Transferred 1930 to Salt Lake City, UT
Walla Walla, WA	1928	Transferred 1961 to Yakima, WA
Davis, CA	1929	Transferred 1933 to Modesto, CA
Grand Junction, CO	1929	Discontinued 1939
Hermiston, OR	1929	Transferred 1933 to Grand Junction, CO
Las Cruces, NM	1929	Discontinued, date unknown
Salt Lake City, UT	1930	Transferred 1936 to St. George, UT
Modesto, CA	1933	Discontinued 1943
Phoenix, AZ	1935	Transferred 1959 to Mesa, AZ
Logan, UT	1936	Discontinued 1964
St. George, UT	1936	Transferred 1938 to Modesto, CA
Fort Collins, CO	1957	Discontinued 1962
Mesa, AZ	1959	Discontinued 1977
Yakima, WA	1961	Discontinued, date unknown

[1] Except for the sugar beet wireworm project in Compton, CA, all sugar beet insect research concerned beet leafhopper.
[2] Scope expanded to include all irrigated-land wireworms.
[3] Wireworm only.

appropriation for sugar beet entomology did not come until 1913. Research was conducted on sugar beet insects by Federal entomologists at 20 locations in the United States.

Commodity treatment work began in 1929 in Florida to develop methods of treating citrus for Mediterranean fruit fly infestations. The research continued in the Division of Control Investigations in BEPQ beginning in 1934 (table 8). In 1935, work on baled cotton fumigation was conducted at Alpine, TX. The Truck Crop and Garden Insects Section became associated with commodity treatment programs in 1937 when a laboratory was set up in the District of Columbia to develop treatments for plant material, such as rose stock and evergreens, imported under special permits. The project was transferred first to Arlington Farm in 1940, then to St. Louis, MO, in 1941, and finally in 1942 to El Paso, TX. The Hoboken, NJ, station was established in 1940 to investigate quarantine commodity treatment, closed in 1943, and reopened in 1946. A substation on golden nematode fumigation at Hicksville, NY, was also maintained for a period. In 1953, when BEPQ was abolished, the Hoboken station (including the Hicksville substation) was assigned to the Truck Crops and Garden Insects Section of the Entomology Research Division.

The events described in this case study are similar to the evolution of other research branches of the Entomology Research Division. Initiations and relocations of research as needs arose is good evidence of the responsiveness of the organization to consumer needs and the ability to establish priorities for existing research resources. Additionally, the flexibility and ability to respond quickly afforded the opportunity for continuity and long-term programs irrespective of personnel changes.

More on Entomology Regulatory Programs

Quarantine, inspection, and regulation of within-State, interstate, and international commerce have been a major part of Federal entomology's history.

Research and regulatory programs have been separated and recombined on several occasions. The first separation was abolishment of the Federal Horticultural Board in the Bureau of Entomology and establishment of the Plant Quarantine and Control Administration (1928), which later became the Bureau of Plant Quarantine (1933). As part of the 1953 reorganization some functions—either research or regulatory responsibilities—of the Bureaus of Plant Protection, Animal Industry, Entomology, and Plant Quarantine were transferred to ARS. The entomology regulatory units were designated Plant Pest Control Branch and Plant Quarantine Branch.

Apparently, these periodic organizational adjustments were a continuing effort to consolidate and improve efficiency of the animal and plant protection activities that began with establishment of the Agricultural Research Administration in 1941 and were among the earlier concerns of Secretaries of Agriculture Houston, Jardine, and others (Baker et al. 1963). The major responsibilities of USDA for regulatory and quarantine entomology have therefore undergone major changes since the first formal authorities for inspections and regulatory duties affecting interstate commodity movement and importations into the United States were established. As previously discussed, these authorities stem from the Plant Quarantine Act of 1912 establishing a Federal Horticultural Board. The work of the board was accomplished within the Bureau of Entomology until 1928, when the Plant Quarantine and Control Administration was established. The Bureau of Plant Quarantine succeeded the Plant Quarantine and Control Administration in 1933, and the Bureau of Plant Quarantine was combined with the Bureau of Entomology in 1934.

Following the 1953 USDA reorganization, quarantine and plant pest control work that was formally assigned as described above became the Plant Pest Control and Plant Quarantine Branches in the Regulatory and Control Organizational Unit of ARS. This included Federal and State cooperative pest surveys, regulation (quarantine), and control activities. Crop regulatory programs assumed responsibility for preventing introduction of foreign pests into the United States, eradicating or containing infestations of newly introduced pests before they could become established, and controlling spread of some native pests that were more effectively managed through coordinated areawide action (Spears and Upholt 1979).

Control activities range from commodity fumigation and cold treatment to areawide control programs for insects such as boll weevil, gypsy moth, cereal leaf beetle, imported fire ant [*Solenopsis geminata* (Fabricius)], pink bollworm, and other pests. Control

Table 8. Bureau of Entomology Plant Quarantine Commodity Treatment Research Stations in the Entomology Research Division and its predecessor organizations through 1968

Location	Est.	Investigations	Status
Doylstown and Willowbrook, PA	1921	Rosebeetle fumigation	Discontinued 1929
Washington, DC	1937[1]	Quarantine commodity treatment (roses, beans, evergreens)	Transferred 1940 to Arlington Farm, Rosslyn, VA
Arlington Farm, Rosslyn, VA	1940	Quarantine commodity treatment	Discontinued 1941
Hoboken, NJ	1940	Quarantine commodity treatment	Discontinued 1943
St. Louis, Mo	1941	Fumigation treatment of evergreens and other plants	Transferred 1942 to El Paso, TX
El Paso, TX	1942	Fumigation treatment of Mexican fruitfly, pink bollworm	Transferred 1949 to Hoboken, NJ
Beltsville, MD	1945	Fumigation problems of evergreens, rose stock	Transferred 1968 to Plant Quarantine Division
Hoboken, NJ	1946	Quarantine commodity treatment	Transferred 1968 to Plant Quarantine Division
Lafayette, LA	1946	Sweetpotato weevil quarantine	Transferred 1968 to Plant Quarantine Division
Hicksville, NY	1951	Golden nematode	Transferred 1968 to Plant Quarantine Division

work was cooperative with State departments of agriculture, State experiment stations, extension services, and the public sector.

Another aspect of Federal entomological activity involved regulation of chemicals for insect control (Spears and Upholt 1979). The Food and Drugs Act of 1906 was concerned for the most part with safety of foods, drugs, medicines, and legumes. It was administered by the Bureau of Chemistry (established 1901). The need for the same overview on insecticides and fungicides resulted in the Insecticide and Fungicide Act of 1910. An Insecticide and Fungicide Board was formed to enforce the 1910 Act. The Chief of the Bureau of Entomology was a member of the board. In 1927, all functions of the Insecticide and Fungicide Board were transferred to the newly established Food, Drug and Insecticide Administration, which was redesignated the Food and Drug Administration (FDA) in 1930. The Food and Drug Administration was transferred to the Federal Security Agency and is now part of the U.S. Department of Health and Human Services.

Later, Congress enacted the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) in 1947 to replace the 1910 Act. The new Act was introduced soon after discovery of organic insecticides. The Act was modified at various times and totally revised in 1972. Residue tolerances were set by the FDA. In December 1970 the Environmental Protection Agency was established and inherited administration of FIFRA for registration of pesticides (formerly in USDA) and establishment of pesticide residue tolerances (formerly set by FDA).

Separation of Regulatory Activities From ARS

One of the objectives of the 1953 reorganization of the Bureaus, to provide research to support regulatory activities in ARS, was never achieved because of competing demands of research and regulation. ARS was oriented toward basic scientific research, while plant protection and quarantine regulation and control required practical pest and disease management tools. A new agency was created in 1971 and called the Animal and Plant Health Service (APHS). In 1972, the meat and poultry inspection divisions of the Consumer and Marketing Service (later known as the Agricultural Marketing Service) were added to APHS, resulting in the name changing to Animal and Plant Health Inspection Service (APHIS). A recent book edited by Hallman and Schwalbe (2002) describes the current role of APHIS in agriculture, the challenges of preventing and coping with invasive pest species, and the history of the organization.

Dowdy (2004) wrote that, "As a regulatory organization, APHIS provides leadership in protecting and improving the health and care of animal and plant resources, improving agricultural productivity and competitiveness and contributing to the national economy and public health. The agency consists of six main program delivery areas: Animal Care, International Services, Biotechnology Regulatory Services, Plant Protection and Quarantine (PPQ), Veterinary Services, and Wildlife Services. The primary mission of the agency is regulatory, but APHIS also conducts research projects in conjunction with specific regulatory needs. These research activities are primarily within PPQ, Veterinary Services, and Wildlife Services. Thus, APHIS employees are involved in the operational aspects of program delivery, as well as other aspects that provide scientific support of agency operations."

Reorganization of ARS

In 1972, a departmental reorganization established the position of Assistant Secretary of Agriculture for Science and Education with responsibility for several agencies, each with an administrator and associate and assistant administrators (Toba 1998):

- Agricultural Research Service
- Cooperative State Research Service
- Extension Service
- National Agricultural Library
- Forest Service
- Soil Conservation Service

The reorganization of ARS conformed to President Richard Nixon's doctrine of government decentralization. In 1972 all divisions and branches were abolished. National Program and Program Analysis and Coordination Staffs were established to provide centralized leadership, planning, and coordination for commodity and discipline research areas. Deputy administrators were appointed to 4 geographical regions, which were divided into 29 areas. Additionally, an International Programs Division was established at Headquarters in the Beltsville and District of Columbia area. The National Program

Staff was headed by assistant deputy administrators with national program leaders responsible for specific scientific areas:

Livestock and Veterinary Sciences*
- Animal Diseases**
- Beef Cattle**
- Dairy Cattle**
- Poultry**
- Sheep and Other Animals**
- Swine**

Marketing, Nutrition and Engineering Sciences*
- Agricultural Structures and Electrification**
- Farm Machinery**
- Food Safety and Health**
- Human Nutrition and Family Living**
- Market Quality**
- Marketing Specialist**
- Processing Technology—Foods**
- Processing Technology—Fibers**
- Processing Technology—Industrial**
- Transportation and Facilities**

Plant and Entomological Sciences*
- Bees**
- Cotton**
- Grain and Forage Insects**
- Forage-and-Range**
- Fruit and Vegetable Insects**
- Fruits**
- Genetics and Plant Breeding**
- Man, Animal and Stored Products Insects; and Household Pests**
- Narcotics**
- Oilseeds**
- Pest Management**
- Plant Introduction**
- Plant Pathology and Nematology**
- Sugar Crops**
- Tobacco**
- Vegetables**
- Weeds**

Soil, Water and Air Sciences*
- Environmental Quality**
- Erosion and Sedimentation**
- Remote Sensing**
- Soil Fertility and Plant Nutrition**
- Soil-Plant-Atmosphere**
- Waste Management and Microbiology**
- Water Management**
- Watershed Hydrology**

* Assistant deputy administrator level.
** National program leader responsibility area.

Also, regional staffs consisted of assistant deputy administrators, assistants to deputy administrators for program planning and research, regional information officers, and regional administrative officers. Each region was divided into areas, each with an area director and assistant area director. The regions, areas, and office locations were—

Northeast Region, Beltsville, MD
- Beltsville Agricultural Research Center, Beltsville, MD
- Chesapeake-Potomac Area, Hyattsville, MD
- Eastern Regional Center, Wyndmoor, PA
- North Atlantic Area, Ithaca, NY
- Plum Island Animal Disease Center, Orient Point, NY

North Central Region, Peoria, IL
- Dakotas-Alaska Area, Fargo ND
- Illinois-Indiana-Ohio Area, Lafayette, IN
- Kansas-Nebraska Area, Clay Center, NE
- Michigan-Minnesota-Wisconsin Area, St. Paul, MN
- Missouri-Iowa Area, Columbia, MO
- National Animal Disease Center, Ames, IA
- Northern Regional Research Center, Peoria, IL

Western Region, Berkeley, CA
- Northern Arizona Area, Phoenix, AZ
- Colorado-Wyoming Area, Fort Collins, CO
- Idaho-Montana-Utah Area, Logan, UT
- Southern Arizona-New Mexico Area, Tucson, AZ
- Northern California-Nevada Area, Fresno, CA
- Oregon-Washington Area, Pullman, WA
- Southern California-Hawaii Area, Riverside, CA
- Western Regional Research Center, Albany, CA

Southern Region, New Orleans, LA
- Alabama-North Mississippi Area, Mississippi State, MS
- Athens, Georgia Area, Athens, GA
- Florida-Antilles Area, Gainesville, FL
- Georgia-South Carolina Area, Tifton, GA
- Mid-Atlantic Area, Raleigh, NC
- Mississippi Valley Area, Stoneville, MS

Oklahoma-Texas Area, College Station, TX
Southern Regional Research Center, New Orleans, LA
Subtropical Texas Area, Weslaco, TX

Division and research branch entomology resources were incorporated into the region/area organization in 1972. Designated ARS areas have been progressively consolidated, so that by 2006 only eight remained. Toba (1998) catalogued a brief chronology of events affecting ARS following the 1972 reorganization:

1974 In the Western Region, the area office in Riverside, CA, was closed and consolidated into the California-Hawaii-Nevada Area. The area office in Phoenix, AZ, was closed and consolidated into the Arizona-New Mexico Area.

1977 In the Northcentral Region, the area offices in St. Paul, MN, and Columbia, MO, were closed and combined, forming a new area called Mid-Great Plains Area headquartered at Ames, IA.

1978 Conservation, research, and education in USDA was reorganized by consolidating ARS, Extension Service, CSRS, and NAL into the new Science and Education Administration (SEA). Under this administration were Research, Education and Teaching Staff, ARS, and the Cooperative Research and Education Service. Additionally, the Office of International Cooperative Development (OICD) was established and absorbed much of the responsibility of ARS's International Program Division.

With further reduction in the number of area offices in SEA-ARS, the number of areas in Western Region was reduced from 5 to 4:

- California-Hawaii Area, Fresno, CA
  - California, Hawaii
- Arid Southwest Area, Logan, UT
  - Arizona, New Mexico, Nevada,Utah
- Rocky Mountain Area, Fort Collins, CO
  - Colorado, Montana, Wyoming
- Pacific Northwest Area, Pullman, WA
  - Idaho, Oregon, Washington

1981 An International Activities Office was established in ARS and the International Program Division abolished. The International Activities Office had responsibility for ARS overseas laboratories and thus influenced entomology and biological control programs.

1982 SEA abolished. To reduce administrative costs, the number of positions on the National Program Staff was reduced from 57 to 35. Under the new structure, the Deputy Administrator for National Programs had two associate deputy administrators (ADA), each with three national program directors (NPD) and several national program leaders (NPL).

ADA for Plant & Natural Resource Sciences Staff was assisted by NPDs for Natural Resources, Crop Production, and Crop Protection and by NPLs for—

- Water Management/Salinity
- Soil Productivity/Environmental Quality
- Hydrology
- Systems, Remote Sensing
- Grain crops
- Fiber, Oil, Tobacco
- Horticultural, Sugar
- Forage, Pasture, Range
- Engineering/Energy
- Plant Health
- Weeds
- Entomology
- Tillage/Erosion/Soil-Plant-Air, Plant Physiology/Biotechnology, and Pest Management were covered by ADAs and NPDs

ADA for Animal, Human Nutrition, & Postharvest Sciences Staff was assisted by NPDs for Animal Production, Animal Protection, and Product Use, and by NPLs for—

- Bioregulation
- Product Losses
- Product Quality
- Animal Health
- Insects, Man & Animals
- Food Safety
- Dairy
- Textiles & Fibers
- Beef & Sheep, Poultry, and Swine were covered byADAs and NPDs

1984 To further reduce administrative costs, the number of areas was reduced from 26 to 11:

- Northeast Region, Beltsville, MD
  - Beltsville Area, Beltsville, MD
    - Beltsville Area Research Center
    - Beltsville Human Nutrition Center
    - National Arboretum
    - Family Economic Research Group
  - North Atlantic Area, Philadelphia, PA
    - Connecticut
    - Delaware
    - Massachusetts
    - Maine
    - Maryland
    - New Jersey
    - New Hampshire
    - New York
    - Pennsylvania
    - Rhode Island
    - Vermont
    - West Virginia
    - Eastern Regional Research Center
    - Plum Island Animal Disease Center
    - North Atlantic Human Nutrition Center
- North Central Region, Peoria, IL
  - Central Plains Area, Ames, IA
    - Iowa
    - Kansas
    - Missouri
    - Nebraska
    - National Animal Disease Center
  - Mid-West Area, Peoria, IL
    - Illinois
    - Indiana
    - Ohio
    - Northern Regional Research Center
  - Northern States Area, St. Paul, MN
    - Michigan
    - Minnesota
    - North Dakota
    - South Dakota
    - Wisconsin
    - Northern States Human Nutrition Center
- Western Region, Oakland, CA
  - Pacific Basin Area, Albany, CA
    - California
    - Hawaii
    - Western Regional Research Center
    - Pacific Basin Human Nutrition Research Center
  - Mountain States Area, Ft. Collins, CO
    - Arizona
    - Colorado
    - Nevada
    - New Mexico
    - Utah
    - Wyoming
  - Northwest Area, Portland, OR
    - Alaska
    - Idaho
    - Oregon
    - Montana
    - Washington
- Southern Region, New Orleans, LA
  - South Atlantic Area, Athens, GA
    - Florida
    - Georgia
    - Puerto Rico
    - North Carolina
    - South Carolina
    - Virginia
  - Southern Plains Area, College Station, TX
    - Arkansas
    - Oklahoma
    - Texas
    - Southern Plains Human Nutrition Research Center
  - Mid-South Area, Stoneville, MS
    - Alabama
    - Kentucky
    - Louisiana
    - Mississippi
    - Tennessee
    - Southern Regional Research Center

1985 Regional headquarters were abolished, but area offices remained the same as in 1984. However, areas were realigned:

- Beltsville Area, Beltsville, MD
  - Beltsville Agricultural Research Center
- Midwest Area, Peoria, IL
  - Iowa
  - Illinois
  - Indiana
  - Michigan
  - Missouri
  - Minnesota
  - Ohio
  - Wisconsin

Mid South Area, Stoneville, MS
- Alabama
- Kentucky
- Louisiana
- Mississippi
- Tennessee

North Atlantic Area, Philadelphia, PA
- Connecticut
- Delaware
- Massachusetts
- Maine
- Maryland
- New Jersey
- New Hampshire
- New York
- Pennsylvania
- Rhode Island
- Vermont
- West Virginia

Northern Plains Area, Ft. Collins, CO
- Colorado
- Kansas
- Montana
- North Dakota
- Nebraska
- South Dakota
- Utah
- Wyoming

Pacific West Area, Albany, CA
- Alaska
- Arizona
- California
- Hawaii
- Idaho
- Nevada
- Oregon
- Washington

South Atlantic Area, Athens, GA
- Florida
- Georgia
- Puerto Rico
- North Carolina
- South Carolina
- Virginia
- Virgin Islands

Southern Plains Area, College Station, TX
- Arkansas
- Oklahoma
- Texas
- New Mexico

The organization of ARS remains essentially the same at this writing (2006). Recruitments, retirements, changes in assignment, and other internal changes continue, normal activities of any organization.

ARS Entomology Research 1972 to 2007

Rapid advances in entomological, genetic, biological, chemical, and physical sciences, data processing, and other scientific technologies during the past 30 years have provided new information and tools that facilitate development and implementation of ecologically oriented insect pest management systems. Integrated control (or integrated pest management—IPM) became the buzzwords of the entomological world during the 1960s and 1970s (Bottrel 1979, Bartlett 1956, Stern et al. 1959, Geier and Clark 1961, Smith and Reynolds 1965). The term became of such importance to entomologists that it was defined by an independent FAO (U.N. Food and Agriculture Organization) panel of experts in 1967 and adopted by the Entomological Society of America (Glass et al. 1975): "A pest management system that in the context of the associated environment and the population dynamics of the pest species utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economic injury." Though rarely cited, this definition remains a good description of the concept.

As an interesting sideline that provides fuel to support the saying that "history repeats itself" and the common assertion that very little is really new, a century and a half ago Curtis (1860) wrote that man is not allowed to extirpate insect pests, though he is permitted to reduce and restrain these pests within narrowed limits. Perkins (1982) likened this philosophically to modern IPM.

The scope of Federal entomology research broadened with implementation of areawide IPM systems in cooperation with other agencies, growers, and agricultural industries. Areawide application of suppression technologies against key insect pests evolved with our increasing awareness of the limitations of attacking local infestations that represent only a small part of the total pest population. The concept developed and pioneered by Knipling (1979) suggests that moderate and consistent pressure applied to the total pest population is more effective than intensive pressure applied to small segments.

This approach contrasts with the focus of individual farmers treating local infestations on a farm-by-farm basis. Their efforts are generally asynchronous and have little effect on the total pest population. Areawide pest suppression involves the efforts of the entire agricultural community. Coordinated efforts and input from many scientific disciplines, agricultural experiment station and extension staff, industry, and producers, as well as State and Federal agencies, provide synergy and commonality of interest and objectives.

There are numerous successful examples of IPM implementation in pilot tests conducted on large areas. The first areawide program, which served as a model for those to follow, was the sterile insect release system for suppressing screwworm. Many biological and ecological principles were implemented.

In the southeastern U.S. cotton growing areas and in Arizona, areawide boll weevil management using combinations of population monitoring, cultural control, insecticide treatment thresholds, and crop management reduced pesticide use 50 to 90 percent and lowered producer costs, resulting in increased profits (Hardee and Henneberry 2004). The long-term intensive Federal effort in boll weevil research ultimately provided evidence that elimination of the boll weevil from the United States was technologically and operationally feasible (Parencia 1978).

The boll weevil has occupied a prominent role in Federal entomology circles since it first crossed the Rio Grande River, apparently near Brownsville, TX, in 1892. Its epidemiology, devastations, and effect on the history and culture of the southern United States have been written many times and reviewed most recently by Hardee and Harris (2003). The turning point from defensive to offensive tactics for boll weevil control apparently was realized when Congress established a Boll Weevil Research Laboratory (BWRL) on the Mississippi State University campus at Starkville. Knipling's remarks at the laboratory's dedication encouraged the goal of eradication.

Research results at BWRL and other laboratories supported the rationale for the Pilot Boll Weevil Eradication Experiment conducted from July 1971 to August 1973 in parts of Mississippi, Alabama, and Louisiana. In spite of a highly vocal antieradication effort, a second Boll Weevil Eradication Trial was initiated in North Carolina and Virginia in 1978. In the same year a companion, optimum pest management trial was conducted in Mississippi to answer objections of the antieradication coalition. The successes of the incremental segments of boll weevil eradication effort are a monument to the efforts of Federal entomologists E.F. Knipling, Theodore B. Davich, and James R. Brazzel (Hardee and Harris 2003).

In Arkansas, areawide management of bollworm and tobacco budworm increased farmer income by more that $18 per acre (Hardee and Henneberry 2004). In Arizona, pink bollworm, sweetpotato whitefly [*Bemisia tabaci* (Gennadius)], and other cotton insects were opposed by areawide management using population monitoring, chemical treatment thresholds, resistance management, cultural control, and insect-resistant cottons. Insecticide use went from 6.6 to 1.1 applications, achieving savings of more than $110 per acre (Frisvold et al. 2000, Ellsworth and Martinez-Castillo 2001, Henneberry and Nichols 2002). In addition to economic benefits for farmers, areawide pest management is environmentally acceptable.

Areawide programs have been successes in other agricultural ecosystems. Such evidence of the superiority of areawide insect pest management over farm-by-farm local efforts and the resulting reductions in financial, environmental, and social costs are too evident to ignore. Continuing research on ecological relationships and interactions of pests, beneficial insects, their hosts, and host-plant resistance have improved areawide programs and identified additional technologies for expanded program options.

ARS Leadership in Areawide Pest Management

The successful results of IPM research by State, Federal, and industry scientists during the 1970s and 1980s gave stimulus to development of a USDA initiative in 1993 to launch a program of operational areawide pest management (AWPM) trials (R.M. Faust, 2003, personal communication). A USDA areawide working group consisting of representatives from APHIS, CSREES, ARS, and State Agricultural Experiment Stations (SAES) from the four experiment station geographic regions identified key pests.

The first 5-year program, initiated in 1995, was for management of codling moth in apple and pear orchards in the Pacific Northwest. An 11,000-acre apple and pear orchard trial using codling moth sex pheromone mating disruption as the key IPM component grew to 125,000 acres in Washington, Oregon, and California by the year 2000. Orchard sanitation, natural enemies, and early season Bt sprays were additional IPM components. Conventional insecticide use declined by 70 to 90 percent. Orchard growers realized savings estimated at $400 per acre. ARS's partners included Washington State University, Oregon State University, and the University of California (Calkins et al. 2000, Stelljes 2001a, Calkins and Faust 2003).

Corn rootworm (*Diabrotica* spp.) was the target of another AWPM program developed in South Dakota, Indiana, Illinois, Kansas, Iowa, and Texas. An "attract and kill" technology reduced populations 70 to 90 percent at sample sites after 4 years of application. The insecticide-attractant combination was the main IPM component. Baits contain less than ounce of insecticide per acre and pose no problem to beneficial insect such as bees and ladybugs. The trial, initiated in 1996, partnered with seven universities: Illinois, Purdue, Iowa State, South Dakota State, Kansas State, Nebraska, and Texas A&M (Chandler et al. 2000).

A 4-year areawide IPM program in cooperation with grain elevator managers was initiated in Kansas and Oklahoma in 1997 (McGraw 2001, Flinn et al. 2005). ARS, Kansas State University, and Oklahoma State University used two elevator networks (one in each State) that stored wheat harvested from about 800,000 acres. Insect-sampling, decision-making, and risk-analysis databases were developed. Frequency of elevator fumigation was reduced by at least 50 percent. A commercial pest-management company was developed using results of the study. The company currently has over 30 commercial grain elevators on contract.

Fire ants [*Solenopsis geminata* (Fabricius) and *S. richteri* Forel] have invaded over 350 million acres of the United States and Puerto Rico. Natural enemies (more than 22 parasitic fly species), microbial pesticides, and attracticides were combined in an effective AWPM for fire ants. Fire ant populations have been reduced 85 to 99 percent in demonstration sites. USDA and APHIS, with cooperators from Texas A&M, Oklahoma State, Clemson, South Carolina, and University of Florida, have developed an outstanding team effort (Vander Meer et al. 2005).

Cultural control, resistant cultivars, crop diversification, and biological control were combined into a coordinated AWPM of wheat aphid pests. Wheat production in six States involving about 400,000 acres in dryland production are included. Producers in these areas are receiving benefits of new technology and management approaches (Faust 2001).

Another program involved male annihilation, sterile releases, attract and kill baits, and biological control of fruit flies. The fruit fly areawide IPM program targets four key species: oriental fruit fly, melon fly, Mediterranean fruit fly, and solenaceous or Malaysian fruit fly (Wood 2001). Dozens of crops are at risk. The program focuses on five control tactics: sanitation, male annihilation, bait sprays, sterile fly releases, and biological control. The University of Hawaii, State of Hawaii, and ARS are cooperating in the program.

Tarnished plant bug [*Lygus lineolaris* (Palisot de Beauvois)] areawide management in Mississippi was approached based on the ecological knowledge that marginal hosts of the insect exist in about 2.4 percent of the total land area. Destruction of early-season hosts resulted in 45 to 47 percent reduction of populations in cotton. Every dollar spent for control of the *L. lineolaris* weed host reduced insecticide costs by $8.50 (Snodgrass et al. 2003, Able et al. 2005).

The AWPM approach has also been successfully applied to pests from other realms of nature, such as the plant pests witchweed [*Striga asiatica* (L.) Kuntze], leafy spurge [*Euphorbia esula* L.], and melaleuca [*Melaleuca quinquenervia* (Cav.) Blake].

Federal-State-private-sector AWPM efforts have resulted in numerous awards and outstanding recognition. Four programs won the top technology transfer awards from ARS: the codling moth project in 1998, the corn rootworm project in 1999, and the Hilo fruit fly project in 2004, in addition to TEAM Leafy Spurge in 2003. Three projects have won USDA's Group Honor Awards for successfully implemented programs against fruit fly, codling moth, and leafy spurge. Also, the United States Pacific Basin Agricultural Research Center in Hilo, HI, in 2004 won a Federal Consortium Award for Excellence in Technology Transfer for fruit fly IPM work, and the Yakima (Washington) Agricultural Research Laboratory in 1999 won the same award for codling moth.

The ARS areawide pest management effort is a continuing, long-term program to implement cooperation across disciplines, institutions, and geographic boundaries. Much experience and knowledge has been gained during each program operation and put to use in planning and improving new programs. The areawide concept has been accepted around the world. New horizons of accomplishment can be predicted.

Current ARS and Federal Entomology Research Organization

In 2007, ARS entomology research is conducted at 40 or more laboratories across the country and at several laboratories abroad (table 9). Most entomologists entering ARS during the last 30 years appeared to have little or no concern for the lack of discipline visibility in the ARS organizational structure. Their self-generated research needs, research direction with national overview as described below, and accomplishments appear to be as satisfactory and acceptable to the agency and stakeholders as under the centralized, discipline-oriented organization prior to 1972.

Outstanding leadership for Federal entomological and other discipline-oriented research in ARS continues, and, on a decentralized basis, it continues to be recognized for its contributions that improve quality and quantity of national and international agricultural production and marketing systems. After 30 years of a multidisciplinary, decentralized organization, ARS entomological efforts appear functional and productive.

Part of the rationale for developing a decentralized regional and area organization in 1972 was to enhance and increase multidisciplinary research, to bring management of research programs closer to area and regional problems, to increase cooperation between ARS and State experiment station scientists and other regional and local groups, and to eliminate a number of research administrative and support positions with a corresponding return of resources to hands-on research. Multidisciplinary cooperative research has been fostered with synergistic effects on depth and scope of research investigations and improvements in quantity and quality of the research product. Location of administrative research program managers in the field (table 10) achieves closer cooperative working relationships with State agricultural experiment stations.

Leadership and continued focus on national aspects of ARS programs and coordination of research by commodity, discipline, and program areas are being accomplished by the National Program Staff and other planning and coordinating bodies (table 11). Also, within ARS a continuing program of long-term, high-risk, fundamental research provides a solid base for ensuring continued improvement in agricultural systems technology. Customer and stakeholder satisfaction remains high, as shown by the continuing level of support for entomology programs.

Future of Federal Entomology Research

Need for expansion of entomological and all agricultural research appears obvious. Worldwide, current farm values of crop and animal production are estimated at more than $1.3 trillion. Various authors have suggested that farm production losses to insects and mites appear to be in the range of 10 to 15 percent, with additional losses of 10 to 40 percent during postharvest handling (Schwartz and Klassen 1981). Cost of insecticides in the United States in 1995 was $2.1 billion, and worldwide is currently estimated to exceed $120 billion.

Efforts to save these yield losses and insect control costs has been a driving force in scientific communities. Over the past two decades, world food production outpaced population growth in most countries. However, a continuation of this trend is not assured. Measurable increases in numbers of undesirable pests moving across regional and international boundaries have accompanied rapid expansion and improvements of transportation systems. Invasive species cost well over $100 billion annually just in the United States.

The Invasive Species Council was established in 1999 by Presidential Executive Order 13112. Invasive species were defined as any plant, animal, or organism that is not native to the ecosystem and is likely to cause harm to human health or the environment, or to cause economic losses (Faust 2001). Research to develop methods to reduce the rate of introduction of invasive species; to develop detection, identification, and eradication technology for newly introduced pests; and to manage established invasive species have become high priorities.

The world's human population exceeds 6 billion people. If the population growth rate is 1–2 percent, an additional 160,000 to 320,000 people are added to

Table 9. Agricultural Research Service entomology research programs in 2003

Area/city and State	Organizational entity
Beltsville	
National Arboretum (Washington, DC)	Floral and Nursery Plants Research Unit
Henry M. Wallace Beltsville Agricultural Research Center	Plant Science Institute
	Bee Research Laboratory
	Chemicals Affecting Insect Behavior
	Insect Biocontrol Laboratory
	Systematic Entomology Laboratory
Mid South	
Baton Rouge, LA	Honeybee Breeding, Genetics, and Physiology Research
Starkville, MS	Crop Science Research Laboratory
	Corn Host Plant Resistance Research
New Orleans, LA	Southern Regional Research Center
	Crop Protection Chemical Research
Stoneville, MS	Southern Insect Management Research
	Application and Production Technology Research
	Biological Control and Mass Rearing Research
Midwest	
Ames, IA	Corn Insects and Crop Genetics Research
Columbia, MO	Biological Control of Insects Research
Peoria, IL	National Center for Agricultural Utilization Research
West Lafayette, IN	Crop Production and Pest Control Research
Wooster, OH	Application Technology Research
	Crop Bioprotection Research
North Atlantic	
Ithaca, NY	Plant Protection Research
Kearneysville, WV	Appalachian Fruit Research Laboratory
	Innovative Fruit Production Improvements and Production Research Unit
Newark, DE	Beneficial Insects Introduction Research
Northern Plains	
Brookings, SD	Crop and Entomology Research
Fargo, ND	Red River Valley Agricultural Research Center
	Insect Genetics and Biochemistry Research
	Sunflower Research
	Sugar Beet Research Unit
Laramie, WY	Arthropod-Borne Animal Diseases Research
Lincoln, NE	Midwest Livestock Insects Research
Logan, UT	Pollinating Insect-Biology, Management and Systematics Research
Manhattan, KS	Grain Marketing and Production Research Center
	Plant Science and Entomology Research
	Biological Research Unit
Sidney, MT	Pest Management Research Unit
	Agricultural Systems Research Unit

Table 9. Agricultural Research Service entomology research programs in 2003—cont'd.

Area/city and State	Organizational entity
Pacific West	
Albany, CA	Western Regional Research Center
Corvallis, OR	Horticultural Crop Research
Fairbanks, AK	Subarctic Agricultural Research Unit
Hilo, HI	U.S. Pacific Basin Agricultural Research Center
	Postharvest Tropical Commodities
	Tropical Plant Pest Research
	Plant Protection Research
	Exotic and Invasive Weeds Research
Parlier, CA	San Joaquin Valley Agricultural Center
	Commodity Protection and Quarantine Research
	Exotic and Invasive Diseases and Pests
Phoenix, AZ	Western Cotton Research Laboratory
Shafter, CA	Western Integrated Cropping Systems Research
Tucson, AZ	Honeybee Research Unit
	Cotton Insect Pest Management, Biological Control and Biocontrol Genetics Research Unit
	Cotton Physiology, Genetics, and Host Plant Resistance Research
Yakima (Wapato), WA	Fruit and Vegetable Insect Research
South Atlantic	
Byron, GA	Fruit and Nut Research
Charleston, SC	Vegetable Research
Fort Pierce, FL	U.S. Horticultural Research Laboratory
	Subtropical Insects Research
Gainesville, FL	Center for Medical, Agricultural and Veterinary Entomology
	Insect Behavior and Biocontrol Research Unit
	Imported Fire Ant and Household Insects Research
	Mosquito and Fly Research
	Post-Harvest and Bioregulation Research
	Chemistry Research
Miami, FL	Subtropical Exotic Pest Insect Research
Tifton, GA	Crop Genetics and Biology Research Unit
	Crop Protection and Management
Southern Plains	
Beaumont, TX	Rice Research
College Station, TX	Southern Plains Agricultural Research Center
	Areawide Pest Management Research
Southern Plains	
Kerrville, TX	Knipling-Bushland U.S. Livestock Insects Research Laboratory
Lane, OK	South Central Agricultural Research Laboratory
	Genetics and Production Research
Panama City, Panama	Screwworm Research
Stillwater, OK	Wheat, Peanut and Other Field Crop Research
Temple, TX	Grassland Protection Research
Weslaco, TX	Crop Quality and Fruit Insects Research
	Beneficial Insects Research
International	
Buenos Aires, Argentina	South American Biological Control Laboratory
Montpellier, France	European Biological Research

Table 10. ARS Areas, 2007

Area	States
Beltsville Area 10300 Baltimore Blvd Bldg 003 BARC-West Beltsville, MD, 20705	
Mid South Area Experiment Station and Lee Roads P.O. Box 225 Stoneville, MS 38776	Alabama, Kentucky, Mississippi, Louisiana, Tennessee
Midwest Area 1815 North University Street Peoria, IL 61604	Iowa, Illinois, Indiana, Michigan, Minnesota, Missouri, Ohio, Wisconsin
North Atlantic Area 600 East Mermaid Lane Philadelphia, PA 19118	Connecticut, Delaware Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia
Northern Plains Area 2150 Centre Avenue, Building D, Suite 300 Fort Collins, CO 80526	Colorado, Kansas, Montana, North Dakota Nebraska, South Dakota, Utah, Wyoming
Pacific West Area 800 Buchanan Street Albany, CA 94710	Arizona, Alaska, California, Hawaii, Idaho, Nevada, Oregon, Washington
South Atlantic Area College Station Road P.O. Box 5677 Athens, GA 30604	Florida, Georgia, North Carolina, Puerto Rico, South Carolina, Virginia, Virgin Islands
Southern Plains Area 1001 Holleman Drive East College Station, TX 77845	Arkansas, New Mexico, Oklahoma, Texas; Panama
National Agricultural Library 10301 Baltimore Ave Beltsville, MD, 20705	

Table 11. ARS Administrator's Council, 2007

Position	Location
Administrator	Washington, DC
Associate Administrator Research Programs	
Associate Administrator Research Operations	
Program Planning and Coordination (National Program Staff)	Beltsville, MD
Deputy Administrator, Animal Production and Protection	
Deputy Administrator, Natural Resources and Sustainable Agricultural Systems	
Deputy Administrator, Crop Production and Protection	
Deputy Administrator, Nutrition, Food Safety and Quality	
Director, Office of International Research Programs	
Area and National Agricultural Library Directors	
Northern Plains Area	Ft. Collins, CO
South Atlantic Area	Athens, GA
Midwest Area	Peoria, IL
Beltsville Area	Beltsville, MD
Mid South Area	Stoneville, MS
North Atlantic Area	Wyndmoor, PA
Southern Plains Area	College Station, TX
Pacific West Area	Albany, CA
National Agricultural Library	Beltsville, MD
Program Support and Operations (Headquarters)	
Deputy Administrator, Administrative and Financial Management	Beltsville, MD
Special Assistant to the Administrator	Washington, DC
Director, Budget and Program Management Staff	Washington, DC
Director, Information Staff	Beltsville, MD
Chief Information Officer	Beltsville, MD
Director, Office of Outreach, Diversity, and Equal Opportunity	Washington, DC
Director, ARS Homeland Security	Wadhington, DC
Assistant Administrator, Office of Technology Transfer	Beltsville, MD
Senior Legislative Advisor, Office of the Administrator	Washington, DC

the world daily. These and similar demographics have intrigued and challenged scientists to develop new food and fiber production technology to provide for the needs of the escalating population. Since the 1960s, worldwide agricultural production has increased 80 percent.

The competitive struggles between mankind and arthropod pests for the products of mankind's agricultural labors have existed since the beginning of time. The revolutionary discovery of DDT and, subsequently, thousands of other synthetic organic chemicals for insect control placed insecticides in the forefront of insect control. The bright future of the insecticide era became clouded with issues of heavy reliance, misuse, and in some instances overuse. Threats to human health, development of insect resistance, environmental contamination, harm to nontarget organisms, and proliferation of secondary pests have been reported.

Maintaining or increasing crop and animal production but providing alternatives to chemical control is a formidable challenge. Foremost among the advanced concepts to provide economically, environmentally, and socially acceptable insect control continues to be integrated pest management (IPM). The concept originally addressed insect management, but was broadened to include diseases, weeds, and other pests. Successful IPM programs provide economic benefits to farmers and more environmentally acceptable crop protection practices. The exciting evidence of practical application of IPM provides a glimpse of the future of Federal entomology.

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