At the end of year 2012, the School of Environmental and Biological Sciences of Rutgers University arranged a major symposium to celebrate the 60th anniversary of Professor Selman A. Waksman’s receipt of the Nobel Prize for Physiology or Medicine in 1952. Dr. Waksman’s studies had led to discovery of streptomycin, a new antibiotic. Streptomycin was the first effective cure for tuberculosis. Its history, however, is a rather complicated story. It persistently presented problems for Dr. Waksman up to his death in 1973.

As an early research participant at Rutgers, in 1939 I studied under Dr. Waksman toward a PhD degree. (Fig.1.) Afterwards, I became employed at Merck & Co., Inc., where I conducted further microbial research with Dr. Waksman while he served as a consultant. Eventually, I received an assignment to record the history of Dr. Waksman’s activities and this is that document.

The history was orally presented at the opening the year 2012 symposium. It also served to introduce several research specialists, who planned to discuss various approaches to overcome the gradual loss of effectiveness of streptomycin over a period of 60 years. Streptomycin often required a six month treatment period to achieve a permanent cure of tuberculosis. That long time period resulted in the appearance of
streptomycin resistant *M. tuberculosis* cells, released by mutation. Then, especially in developing countries, due to cost and inconvenience, many treatments were being shortened, resulting in the requirement for repeated treatment and the release of even more streptomycin resistant cells, the end results being that tuberculosis still remains a serious disease today, even though several additional drugs have been added to supplement the treatments. In Africa, recent mass treatments have resulted in less than 50% success. Fortunately, in the USA and other countries, where TB infected patients have been carefully managed, the problem is not yet as severe. Regardless, a solution must be found. Therefore, we were pleased to learn that the experts at the symposium would discuss approaches to overcome the problem.

**ANTIBIOTIC TIME PERIODS**

Streptomycin’s history actually involves three separate time periods. The first goes back into the 1920s. During that far away period, the Rutgers Agriculture School’s long-time soil microbiology professor, Robert Starkey, was serving as Dr. Waksman’s PhD student. Dr. Waksman and student Starkey together very actively studied microbes of the soil, with Robert Starkey first being a student, then later a companion teacher. Dr. Waksman, with the aid of numerous PhD students, continued to establish Soil Microbiology as a discipline over the next 15 years, before his primary interest changed to antibiotics. Back in 1923, Waksman and Starkey, as professor and student, discovered that rather complex soil bacteria, the actinomycetes, when multiplying in numbers in soil, were killing many common bacteria also growing there. They stated “Certain actinomycetes produce substances toxic to bacteria – Around an actinomycete colony, upon a plate, a zone is found free from bacterial growth”.(1)
These findings were published and were available to all scientists, so one might expect the first discovery of an antibiotic, such as streptomycin, would have been reported shortly thereafter, that is 90 years ago. The information obtained was clear in their published record. It seems that active researchers at that time reading the data should have realized that the bacteria being killed in soils by soil actinomycetes could easily have been human pathogens growing there, being killed by an antibiotic, for our benefit. However, the idea that an active antibiotic might be present among the soil actinomycetes seems to have escaped the microbiologists of that time, as well as Dr. Waksman, so that the first pre-antibiotic period lasted less than one year.

In 1937 Dr. Waksman suddenly realized that the actinomycete-bacterial fight to death, observed much earlier with student Starkey, needed to be investigated in further detail, but he wanted it done scientifically. He selected two of his best PhD students to aid him. The first student, Jackson Foster, studied the battles taking place when mixtures of microbes were placed together on a laboratory bench. The second student, Imri Hutchings, covered the interactions that were occurring between various microbes while they were destroying plant residues. Their works, plus Dr. Waksman’s historical report, were published in 1937. (2)

The second antibiotic research period occurred thereafter, covering a 5 year period from 1939 to late 1943. Dr. Waksman, with his re-awakened interest in antibiotics, had gathered eight researchers together to specialize in antibacterial studies and as a new PhD student in 1939 I was included. We eight were engaged in various research efforts dealing with antibiotics. We quickly discovered a few new ones, actinomycin, streptothricin, fumigacin and clavacin. Unfortunately, all four were toxic to
animals. In the final portion of that five year period, Albert Schatz, the most recent PhD student joining our group to search for antibiotics, arrived and started his research under Dr. Waksman. (Figure 2) Then, he was drafted into the army. After a few months, he was released and was able to return to actively search for a useful antibiotic, again directed by Dr. Waksman. In his eleventh consecutive soil plating, each of which required less than a week’s time in organization, including the checking for the presence of an antibiotic, he isolated a *Streptomyces griseus* culture, obtained from the farm soil of the Rutgers Agricultural School. His *Streptomyces griseus* produced an antibiotic. (3) The culture differed little from Dr. Waksman’s many prior *Actinomycetes griseus* isolations, made over his many years of research, but the presence of an antibiotic was new. Dr. Waksman and student Schatz named it streptomycin. A sample was given by Dr. Waksman to the Mayo Clinic’s expert researchers Drs. William Feldman and Corwin Hinshaw, who were specialists in tuberculosis studies, and they, after testing, reported it to be not toxic for various animals. It was the first Rutgers antibiotic obtained that was not toxic to animals. Therefore, Schatz’s culture was a very significant discovery.

The third study period started almost immediately. In an unbelievably short period of time, there were many accomplishments. Dr. Waksman asked the specialists at the Mayo Clinic to use streptomycin in a new tuberculosis screening technique they had developed using guinea pigs. The guinea pigs responded typically when infected with tuberculosis cell inoculum. It was assumed that would eventually be the case when humans were tested, but guinea pigs were responding first, very quickly. Streptomycin proved to be curative for infected guinea pigs, the first drug to do so. (4) Dr. Waksman
was asked to release larger amounts of streptomycin to them so they could treat humans. He agreed to do so, with student Schatz preparing the material given. At Mayo, the experts eventually found that streptomycin could overcome tuberculosis in humans.

INDUSTRIAL NEEDS

Merck and Co., Inc., a Rahway, NJ, pharmaceutical company, for whom Dr. Waksman was serving as a consultant, then entered the scene. Their own scientists, combined with the Rutgers PhD students with Dr. Waksman as their leader, quickly obtained the standard information required by the FDA and as a result the FDA approved the marketing of streptomycin as a cure for tuberculosis. The Merck Company built a factory in Virginia to produce streptomycin and it became marketed world-wide. All of this was accomplished in less than 10 years and it led to Dr. Waksman being awarded the Nobel Prize in 1952 for Physiology or Medicine. (5) This is a brief history leading to Dr. Waksman receiving the Nobel Prize. However, it becomes more interesting when research details are examined.

EXPANDED HISTORY

Dr. Douglas Eveleigh, of the School of Environmental and Biological Sciences at Rutgers, asked me to present the history story in detail. As a member of Waksman’s team of eight, assigned to find a new useful antibiotic, it seemed appropriate that I do so. We also discussed the opportunity to fulfill a secondary objective, to gather details of Dr. Waksman’s past research activities that would provide additional evidence justifying his sole receipt of the Nobel Prize. My initial feeling, however, was to decline that request. My age is 95 years and we would have discussed activities ranging over
many years. Then, I realized that I was the only known survivor of the eight PhD candidates who had worked actively together with success under Dr. Waksman’s leadership. I decided I had an obligation, so agreed to do so.

During Dr. Wallgren’s Nobel Prize presentation speech in 1952, he stated, “Selman Waksman, the Caroline Medical Institute has awarded you this year’s Nobel Prize for Physiology or Medicine for your ingenious, systematic and successful studies of soil microbes that led to the discovery of streptomycin.” Based on my understanding of this statement, in Selman Waksman’s case it meant his Nobel Prize was based on two activities. First was his important background. He had completed 24 years of detailed early research on soil microorganisms, something new that others had only minimally tackled. Then, after that period, Dr. Waksman’s research interests had moved to antibiotics produced by actinomycetes. Student Albert Schatz, acting under his direction, found the culture that produced the new antibiotic streptomycin and it was quickly established as the prime treatment of tuberculosis world-wide, as well as many other gram negative diseases not previously treatable. They, plus TB, provided the basis for Dr. Waksman receiving the 1952 Nobel Prize.

BACKGROUND MATERIAL

There is much background material available. For example, in 1910, Selman Waksman immigrated to family living in Metuchen, New Jersey, from the Russian Ukraine. The next year, that is 1911, he enrolled as an undergraduate student at the close-by Rutgers College. His professor, Dr. Jacob G. Lipman, soon discovered that he was a skillful researcher. As a student, Waksman completed the school’s Bachelor of Science degree requirements during his first three years, so Dr. Lipman proposed that
during his senior year he should spend his full time growing and researching a wide list of soil microbes. For student Waksman, it proved to be an interesting year, with Dr. Lipman presenting his student’s results in abstract form at the 17th Annual Meeting of the Society of American Bacteriologists, under the title “Bacteria, Actinomycetes and Fungi in Soil” printed in the first year of the Journal of Bacteriology. (6)

Next, Dr. Lipman recommended that student Selman Waksman should achieve a Master’s degree, but this time it should be based on actinomycetes only. Actinomycetes are rather slow growing, filamentous soil bacteria and at that time they were seldom studied. Student Selman Waksman spent his whole time during his Master’s year studying them. In fact, they became his favorite organisms for future studies, especially *Actinomyces griseus*. He took several actinomycetes with him for studies in biochemistry at the University of California and he received a PhD degree there. Then, he returned to the Rutgers’ Agricultural School as an employee.

As mentioned in my condensed version, one of Dr. Waksman’s favorite cultures was *Actinomyces griseus*. He had spent much time studying it. Then, 28 years later, under a more modern name, *Streptomyces griseus*, student Albert Schatz had re-isolated it. Interestingly, the new genus name, *Streptomyces*, which was applied to student Schatz’s isolate, actually had been created by Dr. Waksman himself when working together with Dr. Henrici during a former realignment of the official names of the actinomycetes.

Dr. WAKSMAN’S SHIFT TO ANTIBIOTICS
Four years before the discovery of streptomycin, that is in 1939, I arrived at Dr. Waksman’s office in the Rutgers Ag School as a new PhD student. About a month after my arrival, Dr. Waksman excitedly came rushing to my lab and he cried out “Woodruff, Woodruff, drop everything. My former student René Dubos has discovered a way to find antibacterial agents produced by soil microorganisms. And he found an antibiotic, I am impressed. We must discover a better one.” (7)

His past student Dubos had added living pathogenic bacteria repeatedly to soil. He hoped that some minor microbe in the soil would be capable of killing the pathogen and would use the dead cells as a nutrient and start to multiply, to the point that he, Dubos, could isolate it. He was successful. He isolated a microbe that produced an antibiotic. He named it tyrothricin. It cured localized staphylococcal infections in humans when applied to the infected site. Dr. Dubos had just published these data and Dr. Waksman was fascinated by them.

Dr. Waksman rather excitedly directed me to repeat the Dubos procedure, but stated I must make significant changes. First, I must use a gram negative pathogen as the target to be destroyed in my soil pot, not the gram positive microbe that Dr. Dubos had used. Waksman knew that gram negative organisms were not being killed by the newly developed penicillin, whereas Dr. Dubos’s gram positive organism was, so finding drugs to treat gram negative pathogens had to receive top priority. E. coli was chosen to be our gram negative target cell, based on undergraduate studies showing that E. coli cultures easily can be counted based on a metallic sheen they develop when they are grown in a special culture medium. (8) With it, the number of E. coli cells still surviving in soil pots could be counted, after millions of E. coli had been added a week previously.
In fact, the number of living *E. coli* cells in the soil pots did decrease, slowly at first, then faster and faster, and finally after two months of weekly *E. coli* additions, a week after that last addition was made, no living *E. coli* cells could be found in the soil pot. All seemed to have been killed, probably by an antibiotic. So, that remaining soil was plated and, surprisingly, about half of the cultures obtained were able to inhibit growth of *E. coli*. This type of organism had increased in number in the soil pot. One such culture, whose antibiotic could be extracted by a solvent, was selected. Dr. Waksman gave some extract to Dr. Max Tishler, leader of chemistry at the Merck Company, and within a week Dr. Tishler had obtained red crystals. Dr. Waksman decided to name them actinomycin (9, 10). We believed our actinomycin was the most active antibiotic ever discovered, but it soon proved to be one of the most toxic ones.

NEW ANTIBIOTICS

Dr. Waksman was greatly excited by the discovery of actinomycin. He started rearranging his department to specialize solely on antibiotics. He added a new program, headed by my companion PhD student, Elizabeth Horning, to search for antibiotics produced by molds. Elizabeth was a very efficient student. She had been previously employed and had requested half time release to pursue a PhD. She attended classes at Rutgers but most experimental work was continued at her commercial lab a few miles away. Amazingly, without the benefit of student discussions, she made rapid progress. She modified the screening approach to direct soil plating, with subsequent analysis of the copious isolates for their antagonistic activity. Two new mold antibiotics were found, one was named fumigacin, the other clavacin. (11) But these two, like our actinomycin, proved to be highly toxic. She also isolated 244 actinomycetes, 31 of
which she showed had antagonistic activity, though fuller screening was not accomplished. At that time, with Dr. Waksman's aid, I had purified a newly obtained and different actinomycete antibiotic. We named it streptothricin. (12) It was less toxic, proving it is possible for one to discover less toxic antibiotics, but even streptothricin was not sufficiently suitable for wide scale human use, as proved by a brief trial with humans as targets, so the search for safer ones had to be continued.

DR. WAKSMAN AS A RESEARCH LEADER

Immediately it was learned why Dr. Waksman had been so effective as a past leader in science. As he had done several times with other students, he joined me, working at our laboratory bench. So, for a year, I became his lab assistant, serving him about half time each day. It turned out to be a wonderful learning period for me, and it lasted about a year. Then, after two more years of personal research, when nearing the end of my PhD studies, Dr. Waksman sent me to Merck & Co., six months before my graduation date, with the assignment to aid the Merck microbiologists in establishing, on an industrial scale, a new type of submerged culture, to produce commercial amounts of penicillin. The new submerged culture procedure had been strongly recommended to the Merck workers by Dr. Waksman, because he had used it successfully. It would be my responsibility to make certain it was adopted at Merck for penicillin production.

Submerged culture was a new technique. It involved very large aerated tanks, able to produce a desired product from top to the bottom of the large tank, great volumes achieved, in contrast to the usual surface cultures of actinomycetes, where hundreds up to thousands of trays were needed to achieve a relatively small volume. The new leader of Merck's Microbiology Department was Dr. Waksman's prior student Jackson.
Foster, who had studied the fighting microbes successfully. Dr. Foster immediately adopted the new industrial submerged culture procedure to produce penicillin. The new procedure had been brought home by Dr. Starkey, who had spent a sabbatical with Dr. Kluyver in Delft, the Netherlands, and Dr. Waksman adopted it immediately, using shaking machines as a means of producing citric acid in large quantities, working with another PhD student, Edward Karow.

NATIONAL ACADEMY OF SCIENCES

During the time that I was still his student, Dr. Waksman received the honor of being elected to membership in the National Academy of Sciences. His election was based largely on his early basic research on soil microbes, that is the same portion of his work that later influenced the Nobel Prize Committee, plus his entry into antibiotics. Those who voted him into membership of the National Academy were the leading scientists of the world, so I felt the honor he had received was truly very great.

EXPANDED ANTIBIOTIC STUDIES

PhD student Albert Schatz was placed in my prior student position, Dr. Waksman’s sole university-financed PhD program. All others were financed by outside interests. He was deeply interested in discovering antibiotics produced by actinomycetes. Dr. Waksman asked him to continue the E. coli gram negative approach. However, as previously stated, Schatz’s student days were interfered with by being drafted into the military, but only briefly. Then, after returning to Rutgers, he felt he needed to increase the number of antibiotics studied. Non-toxic ones seemed to be very rare, so he felt he must change to an easy screening approach from the previous slow two month scientific approach. Elizabeth Horning had done so successfully with molds. So, he changed to a
well-known simple plating technique to isolate many new soil actinomycete cultures. Platings were made on washed *E. coli*, *M. tuberculosis* (*hominis*) and *Sarcina lutea*. The indicator cells were rarely completely clear, so cells were taken from all growth levels for further study, so many checks were made for presence of antibiotics. Thus, student Schatz increased the number of cultures evaluated many times over the prior two month tests used, when *E. coli* had disappeared completely and that soil had been tested, with actinomycin discovered. His simple approach proved successful. (13).

Based on Mayo Clinic’s evaluation, he had obtained streptomycin, a new antibiotic which was safe for animal treatments and it proved effective in curing tuberculosis. (Figures 3, 4)

PATENTS

With respect to a patent for streptomycin, Dr. Waksman was worried that student Schatz’s screening approach, because it was routine, would lead to failure to receive a patent. Natural products by then had been banned from receiving American patents, so he feared streptomycin would fail. The Merck lawyers felt they would be successful. They had succeeded in patenting Dr. Waksman’s actinomycin and streptothricin antibiotics. However, to accomplish that, Dr. Waksman’s aid had been needed. He studied and then reported his results to the patent specialists. He made it evident that crystalline antibiotics and other high potency preparations are very different from the natural products that exist in soils, so he argued that purified antibiotics were no longer natural products, therefore they should be patentable, and they eventually were judged to be so. The Merck lawyers planned to again use Waksman’s arguments in obtaining a streptomycin patent, and they were successful.
Years later, Dr. Waksman was fully retired. He still had an office in the newly built Microbiology Building on Rutgers’ Busch campus. Its construction, at Dr. Waksman’s request, had been funded by streptomycin patent royalties. He called me often on the phone at Merck, always saying approximately the same, “Come visit me, right away, I have several new ideas and I would like to discuss them with you.” So, I would drive down, but I often found him forgetful, due to his advanced age, often failing to recall the reason for asking me to come. But we almost always ended up discussing various aspects of his past scientific activities. On one occasion, he told me he had enjoyed working at a lab bench with me for a year because our target, the killing of gram negative \textit{E. coli} cells, was research based. However, after student Schatz had replaced that approach with his routine soil platings, Dr. Waksman said he felt it was no longer a true research project, just screening, so he could not bring himself to work with student Schatz at his basement lab bench to help broaden his studies. But, in fact, Waksman had become greatly concerned. He felt his failure to work with student Schatz in his basement lab several years in the past had led to some complications that had developed between him and Dr. Al Schatz.

\textbf{COMPLICATIONS}

The complications between Dr. Waksman and Dr. Schatz, after he had graduated, became truly serious. The distribution of royalties on sale of streptomycin had not been clearly defined and became altered as time went by. Eighty percent of the funds were set aside for construction of a new microbiological research program at the Busch Campus, which had become the center for the university’s scientific programs. Dr. Waksman accepted rights for the 20\% royalty remainder, primarily to expand
research on streptomycin beyond the scope of Rutgers University. He felt strongly that
was necessary to do so for any patented discovery made in a university. He spent the
funds on purchases of streptomycin and he supported studies on it by other universities
and other established research programs. Later, a change in royalty distribution was
introduced, that Dr. Waksman should receive some royalty funds as a salary to add to
his university income, because it was taking so much of his working time.

Dr. Waksman was absolutely shocked when a legal suit was filed by Dr. Schatz
against him and the University, especially after Dr. Schatz as a post-doctorate scientist
had obtained several research positions based on Dr. Waksman’s recommendations.
The University management had adopted a procedure by a vote, accepted by Dr.
Waksman, that the royalty funds should be directed to the university laboratory where
the discovery had been achieved, that is the Soil Microbiology Department of the
Agricultural College. The legal suit thereafter became a severe concern for Dr.

The case, however, was actually settled before going to court. Dr. Schatz
accepted a proposal put forward by Dr. Waksman. Although not pre-approved officially
by the legal staff, Dr. Waksman decided that if he were to receive royalty as salary,
similar gifts should be passed to students and laboratory employees who had been
involved with streptomycin. He proposed that 10% of the royalties should be passed to
them, 26 persons in all, the majority as lump sums, other portions as percentages for
the remaining royalty period, with Dr. Schatz, as discoverer of the streptomycin-
producing culture receiving the largest fraction. Dr. Schatz accepted the proposal. This
settlement restored somewhat the relationship between Dr. Schatz and Rutgers
University. Several important awards, including the Rutgers Medal, were given to him by Rutgers University’s top management. Also, some lectures by Dr. Schatz were presented in the Rutgers facilities during the 50th anniversary of the discovery of streptomycin. Later, Rutgers Agriculture School students insisted that a plaque showing that student Schatz was truly a co-discoverer of streptomycin must be placed in the building where streptomycin had been discovered and it was done.

GENERAL SCIENTIFIC ACTIVITIES

At the beginning of this document, referring to streptomycin, I stated “Its history is a rather complicated story. It persistently presented problems for Dr. Waksman”. I believe the primary reason for that is now clear. However, I do believe we should have a paragraph or two to demonstrate that Dr. Waksman’s general scientific activities were important and were widespread. I had attended his undergraduate Soil Microbiology course. Dr. Robert Starkey, the regular professor, was on sabbatical leave in Holland, so Dr. Waksman that year was teaching both the graduate students and the undergraduate seniors. He had selected a graduate level lecture to open the undergraduate class. It had a major effect on me. I was amazed at the possibilities offered by soil microbiology and I immediately decided I would be a soil microbiologist. Teacher Waksman reported how his tiny microorganisms achieved major breakthroughs, certainly far more frequently than discoveries I had observed in chemistry, my prior interest. Secondly, Dr. Waksman was creative as a teacher. As an immigrant, he was so sold on the USA form of government, in contrast to his experiences in Russia, that he insisted all his graduate students, foreign and local, must visit Philadelphia with him, to evaluate a new country’s formation and its constitution.
Each summer, he also insisted that a day must be spent by his PhD students and friends at the New Jersey seashore, or, in autumn, at parks in the nearby Pocono Mountains. He insisted on preparing the hot dogs on those occasions.

Dr. Waksman had great interest in the Society of American Bacteriologists (now the American Society for Microbiology). He was elected President of SAB during a complex period. It was the beginning of World War II, when for the first time an SAB Annual Meeting was cancelled. However he was tremendously busy, along with his general research responsibilities. He was greatly concerned that the SAB was at the stage of breaking apart. Because practical studies were only occasionally accepted by its Journal, the concern became greater and greater as time went by. Eventually, the Journal of Bacteriology publisher Williams and Wilkins agreed to finance an applied journal. Committees were established, the new journal Applied Microbiology was established, initially published bimonthly. By the end of the first ten years, during which I was Editor in Chief, it had proven to be a profitable journal. New editors transferred it to a monthly publication, then semimonthly, the name eventually being changed to Applied and Environmental Microbiology. Applied and Environmental Microbiology eventually became one of the most successful journals published by ASM, demonstrating that a very large number of individuals had become interested in applied and environmental microbiological problems.
CONCLUDING COMMENTS

Again, let us return to the Nobel Prize and my assigned responsibilities. I was asked to edit a new book covering Dr. Waksman’s full scientific life-time activities. (14) During his scientific life period, Dr. Waksman had published 447 articles, a very large number. His new book of 391 pages was divided into eleven topics. Ten were for ten different areas he had studied during the first half of his research years on soil microbes, thereby fulfilling initial support for his receiving the Nobel Prize. The eleventh topic was antibiotics, which covered the latter half of his productive life. Many of the first 10 topics clearly fit the ingenious, systematic and successful studies of soil microbes, the Nobel objectives mentioned by Dr. Wallgren. I calculated that 127 of his early published papers met those requirements. The eleventh topic, the discovery of antibiotics, had 198 additional Waksman publications, including the discovery of streptomycin, the total being judged all to be of value as part of the Nobel award’s basic efforts, thus leading to more than 300 publications supporting his having received the Nobel Prize.

Secondly, the Soil Science Department at Rutgers, after Dr. Waksman’s death, requested an official obituary, to be published in a major encyclopedia. The following is a small quotation taken from the rather long obituary. “Selman Waksman was a prolific writer, publishing papers in a wide range of scientific journals, in several languages. He was author or co-author of 28 books. His “Principles of Soil Microbiology”, an 897 page volume, the first edition published in 1927, for years became the standard text book of his field. He guided 78 students to graduate degrees. He was an inspiring lecturer. His presentations included stories of his relationships with leaders of his field and were avidly followed by his students and audiences. He was beloved by his students, recent...
ones spoke of him as the “The Old Maestro.” Waksman’s name is generally included with Winogradsky, Omeliansky, Beijerinck and the Americans Lipman and Thom in lists of the pioneers of soil microbiology”.

Let me summarize the new points which I believe added to the Nobel Prize significance. They are four-fold and have been referred to already. First, from Holland, Dr. Waksman passed the new submerged culture approach to Merck for use in producing penicillin and streptomycin, and for himself to produce citric acid. Second, he was responsible for the Merck lawyers successfully obtaining patents for Waksman’s antibiotics, actinomycin, streptothricin and later, streptomycin, by showing that crystalline and high concentrate products differed appreciably from the natural soil products, thereby opening for patenting hundreds of new discoveries by others. Third, he had created the new genus name *Streptomyces* and with friend Arthur T. Henrici realigned the actinomycete’s taxonomy, and finally he had led his department into finding various new drugs, with methods used later copied by dozens of commercial organizations. These supplemental items justified him being the sole awardee for the 1952 Nobel award.

I believe my assignment today, to describe the reasons leading to Dr. Waksman’s success in achieving a Nobel Prize 60 years ago, has been fulfilled. I now come to the end of my history. (Figure 5) It was intensely interesting to have been a participant in these life-long happenings, leading to medical discoveries, and for that I am greatly indebted to 40 years association with Dr. Waksman.

After my oral history was presented in December, 2012, the remainder of the 60th Anniversary Lectures were presented, related in part to finding new streptomycin
equivalents as replacements for streptomycin itself, or discussing alternate approaches to overcome the disease. The fact that experts are still actively searching for a new useful drug to be used to control tuberculosis is consoling, but the slow progress is worrisome. Indeed, as reported, only about 50 percent success in TB control is being found in developing countries at present, even with the addition of new drugs. Also, there is concern regarding the possible rapid spreading of streptomycin resistant TB disease occurring in the immediate future, with no remaining drug replacements available.

Addendum. An item was published in The New York Times Business Section on January 1, 2013, shortly after the holding of our 2012 Celebration. It was headed “F.D.A. Approves Drug for Resistant Tuberculosis.” Therefore, the situation may not be as difficult as I have feared. (15)

Acknowledgments. The author has greatly appreciated the aid of Dr. Douglas E. Eveleigh, Fenton Professor of Applied Microbiology, School of Environmental and Biological Sciences, Rutgers University, in converting an oral lecture into a printed commentary. He has confirmed the validity of statements made, aided in article condensation and, especially important, obtained acceptance for publication in Applied and Environmental Sciences, my special honor, having served ten years as its organizing editor. Dr. Eveleigh was especially helpful in organizing the publication, being skilled in historical observations, well trained by contact with widespread historical institutions, including the Natural History Museum and the Science Museum,
London. His special fascination has been with microbial abnormalities occurring in New Jersey, dating back into Rutgers University’s pre-USA years.

REFERENCE CITATIONS


8 Wikipedia 2013, “If E. coli cells are grown on eosin methylene blue agar, it will give them a distinctive metallic green sheen.” Many references exist, back to 1939 when Dr. Waksman decided to search for antibiotics.


**FIGURE LEGENDS**

Figure 1. Professor Selman Waksman with graduate student H. Boyd Woodruff. Laboratory photo during the studies of the discovery of actinomycin (1940). Administration Building, School of Environmental and Biological Sciences (SEBS), Rutgers University. (Special Collections and University Archives, Rutgers University Libraries. With permission.)

Figure 2. Professor Selman Waksman with graduate student Albert Schatz. Laboratory photo during the studies of the discovery of streptomycin (1944). Administration Building, SEBS, Rutgers University. (Special Collections and University Archives, Rutgers University Libraries. With permission.)

Figure 3. The Waksman Antibiotic Team. Department Reunion, Society of American Bacteriology Annual Meeting, Philadelphia, 1947. Standing (left to right): David Hendlin (fosfomycin at Merck), Albert Schatz (streptomycin), H. Boyd Woodruff (actinomycin, streptothricin), Elizabeth Horning (clavacin and fumigacin), Ed Karow (development of submerged fermentation); seated (left to right): Christine Reilly (streptomycin development), Mrs. Deborah Waksman, Dr. Wayne Umbreit (visiting researcher), Professor Selman Waksman, Professor Robert Starkey; front row (left to right): D. Montgomery Reynolds (grisein), Harry Katzenelson (rhizosphere studies). (Department of Microbiology Collections, Rutgers University. With permission.)

Figure 4. (Left to right) Professor Waksman with Randolph Major (Research Director, Merck and Co.) and Alexander Fleming (Nobel Laureate, penicillin) discussing the cross-streak antibiotic screening technique. [Waksman laboratory, Administration Building, SEBS, Rutgers University, 1940s.] (Special Collections and University Archives, Rutgers University Libraries. With permission.)
Figure 5. (Left to right) H. Boyd Woodruff in discussion with Joachim Messing (Director, The Waksman Institute) and Robert Goodman (Dean, SEBS) at the opening of the Selman Waksman Room, Library of Science and Medicine, Rutgers University, and celebration of H. B. Woodruff’s 90th birthday, August 2007. (Photo courtesy of Douglas E. Eveleigh.)
Figure 1. Professor Selman Waksman with graduate student H. Boyd Woodruff. Laboratory photo during the studies of the discovery of actinomycin (1940). Administration Building, School of Environmental and Biological Sciences (SEBS), Rutgers. (Special Collections and University Archives, Rutgers University Libraries).

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Figure 3. The Waksman Antibiotic Team. Departmental Reunion, Society of American Bacteriology Annual Meeting, Philadelphia, 1947. Standing - left to right – David Hendlin (fosfomycin at Merck), Albert Schatz (streptomycin), H. Boyd Woodruff (actinomycin, streptothricin), Elizabeth Horning (clavacin and fumigacin), Ed Karow (development of submerged fermentation); Seated - left to right: Christine Reilly (streptomycin development), Mrs. Deborah Waksman, Dr. Wayne Umbreit (visiting researcher), Professor Selman Waksman, Professor Robert Starkey. (Front row) D. Montgomery Reynolds (grisein), Harry Katznelson (rhizosphere studies) (Department of Microbiology Collections, Rutgers University).

Figure 4. (left to right): Professor Waksman with Randolph Major (Research Director, Merck and Co.) and Alexander Fleming (Nobel Laureate penicillin) discussing the cross streak antibiotic screening technique. (Waksman laboratory, Administration Building, SEBS, Rutgers,1940s). (Special Collections and University Archives, Rutgers University Libraries).
Figure 5. (left to right): H. Boyd Woodruff in discussion with Joachim Messing (Director, The Waksman Institute) and Robert Goodman (Dean, SEBS) at the opening of the Selman Waksman Room, Library of Science and Medicine, Rutgers, and celebration of H. B. Woodruff's 90th birthday, August, 2007. (Eveleigh photo).