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CONTENTS

Features:

Research Reports:

Academy Affairs:

The Journal

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The First Trans-Atlantic Cable

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ABSTRACT

The first trans-Atlantic cable was successfully laid in 1866. The cable itself and virtually all the equipment was designed from scratch, and a great deal of pioneering was done in many technical fields. Much of the development was a learn-by-doing process, but sound scientific principles were observed throughout. The article describes the progress of the project from beginning to completion. It includes as analysis of the conditions that led to the project and the developments that made it succeed after many attempts. The completed cable not only bound Britain and America in instant communication—it furnished an indispensable foundation for the scientific development of modern deep-sea cable construction and design.

Modern submarine telephone cables today connect important countries throughout the world under wide oceans and seas and enable persons to talk with each other as easily as if they were in the same town. One cable can carry as many as 1,840 two-way talking circuits, and a new cable now planned will increase this to 4000.

The wonders of today's submarine cable accomplishments have been built upon a long background of scientific development dating back many years. Many of the cable-laying and design techniques go back to the early telegraph cables of over a century ago. One of those that probably contributed more than any other was the first Atlantic cable, finally successfully laid in 1866.

Favorable Conditions of the Times

The idea of spanning the Atlantic first developed into a practical application in 1854. Cyrus Field, a successful American business man, was attracted to the idea through his chance acquaintance with a venturesome but unsuccessful engineer, Fredrick Gisborne. Gisborne had started, but because of financial difficulties, failed to complete a telegraph line through Newfoundland which would connect with existing lines to New York. Field was looking for new ventures on which to use his time and money, and it occurred to him that the telegraph line should not stop at Newfoundland but should continue across the Atlantic to Ireland, the closest part of the British Isles.

Telegraph land lines had already been built in great numbers on both sides of the Atlantic, and connected most of the large cities in Europe, Britain, and the United States. Short submarine cables had also been laid between England and Ireland, across the English Channel, the Mediterranean, and the Black Sea. However in each of these cases the waters were relatively shallow and distances were short. Largely unexplored were such basic considerations for a trans-atlantic cable as the character of the ocean bottom, the time delay, and reduction of signal strength in long distance cable transmission, and the techniques of laying cables at great ocean depths.

Field had been to England a few years before and could see the need for better communication between America and Europe or England. He was impressed with how little America knew about what went on in the other two areas. There were American reporters on the scene, but their reports lost their vitality in transmittal by boat. Business between the areas was slow and handicapped for the same reason.

Everywhere Field went he found a spirit of optimism, progress, and innovation. The railroads, telegraph, mills, and foundries seemed far more advanced than in America. Such geniuses as Farady and Thomson were introducing Britain to the Age of Electricity. New principles of electricity, magnetism, and physics were being discovered. New products such as gutta percha were also being developed. This material could be moulded into various shapes and sizes such as plastic dolls, caps for cabmen, handles for surgical appliances, and tubes for hearing devices.

Farady had found gutta percha to be an effective insulation for telegraph wires in cables, and it was starting to be used for several short submarine cables in England and Europe. It was water resistant, durable, and pliable, and it could be molded around the conductors in liquid state. After cooling it became hard but not brittle, and its insulation qualities improved in the ocean depths.

Field returned to America with a firm conviction of the need for improved communication with England and Europe. He could also see that England, with its progress in manufacturing and business management, would be the land to turn to for help in any great project.

Exploring the Possibilities

After his meeting with Gisborne, Field lost no time in exploring the feasibility of an Atlantic cable. Lieut. Maury, head of the U. S. National Observatory and a leading authority on oceanography, advised Field that recent soundings indicated that the ocean bottom of the route between Newfoundland and Ireland was primarily a plateau, deep enough to clear iceburgs and ships, but shallow enough to make a submarine cable feasible. Samples from the ocean floor indicated that it was composed of soft microscopic shells, with no sand or gravel to damage a cable.

Professor Morse, a noted American telegraph scientist and inventor, advised Field that telegraph transmission through a long cable such as the trans-Atlantic was entirely feasible, and that commercial service could be provided. Two years later Morse proved this, in cooperation with some English scientists, by sending telegraph signals at commercial speeds as fast as 270 per minute through a looped cable network of over 2000 nautical miles in length.

Financing the Project

With the encouraging reports from Lieut. Maury and Prof. Morse, Field secured the financial assistance of a venturesome group of business associates, that was needed to complete the project started by Gisborne. A company was organized and financed to construct the telegraph line in Newfoundland, and thus have a complete telegraph system from New York to the American end of the proposed Atlantic cable. This would cut almost in half the boat time, and thus materially improve communication until the cable was finished.

The Newfoundland project included 500 miles of land line on poles, and 90 miles of submarine cable. Because of the rugged terrain and bad weather, it took two years to complete the extension (in 1856). The first submarine cable was lost in a storm due primarily to using a sailing vessel to lay it. These experiences proved that only a steamship should be used in cable laying, and that much improvement was needed in cable laying methods and machinery.

The company that completed the Newfoundland project was also organized to construct the Atlantic cable. However upon completion of the former, it was clear that the company did not have sufficient money to construct the latter. Since the Atlantic cable would terminate in Britain, it was decided to try to raise the needed money in that country. A new company (Atlantic Telegraph) was therefore organized in England, and the initial capital of £350,000 (about $1,750,000) was subscribed in that country. There were a number of prominent English scientists and business men who were active or interested in telegraphy, and most of this capital was furnished by them. Several of these became officers in the new company and took an active part in the Atlantic cable project. Financial assistance was also obtained from the British and United States govenments on the basis that they would have prior rights to the use of the cable. The two governments also agreed to provide the necessary ships to lay the cable.

During the ten years that were required to bring the project to a successful conclusion (1856–1866) the Atlantic Telegraph Company (or its successors) raised an additional £700,000 (about $3,500,000) to finance a total of five major cable laying expeditions. In spite of the apparent failures of the early expeditions, the optimistic faith of the company's officers always led them to approve the continuation of the project, and even to furnish their own money to help in the financing. In the final stages of the project the newly formed Telegraph and Maintenance Company, responsible for manufacturing and laying the cable, showed such faith in the project that it agreed to accept no payment unless the cable operated satisfactorily.

Developments Leading to Success

The same optimistic faith displayed by the officers of the company was also shown throughout the project by those in charge of the cable construction. To them the unsuccessful termination of each expedition was not a failure but only a temporary setback that would ultimately lead to success. Something was learned from each failure, and they could see the progress that was being made each time. They were confident that they could overcome all difficulties, and they were able to instill this same confidence into those associated with the project.

There were many developments and improvements during the period of ten years construction. Different cables were manufactured and laid, setbacks were experienced, and changes were made to correct troubles. During this period only 335 miles of cable were laid in 1857, and 341 miles were laid in the first expedition of 1858 (fig. 9). Cable-laying was suspended in each case because of cable breakage, and because no equipment was available to recover the end of the cable from the ocean bottom.

In preparation for the second expedition of 1858, the cable payout machinery was completely redesigned by William E. Everett, Chief Engineer of the U. S. Navy. This greatly reduced its size and weight and simplified its construction. Self-releasing brakes were provided, which automatically released when the cable tension reached an unsafe value. Electrical testing and signal transmission was also greatly improved by the invention of Prof. Thomson's "marine" galvanometer of extreme sensitivity. The second expedition was an apparent success as the entire cable of 2050 miles was laid with only minor difficulties due to several mysterious but temporary electrical interruptions in the cable continuity. However, success was short lived. Signals over the cable gradually weakened, and they failed completely a month after the cable had been completed.

Group Scientific Research

After the cable failure in 1858 there was an extensive study made of the entire cable project by a committee of experts called the "Joint Scientific Committee." The committee analyzed all the difficulties that had been experienced and made recommendations for correcting them.

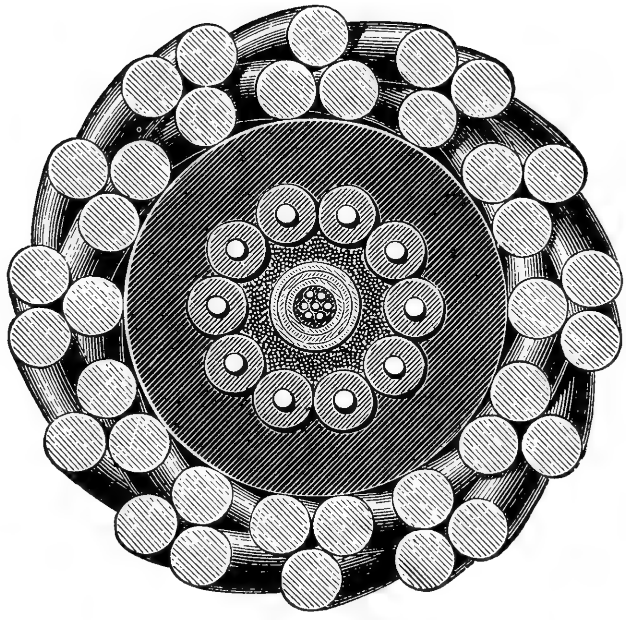

Fig. 1. Improved cable (cross section) used in 1865 and 1866 expeditions. Heavy shore end.

These included cable specifications, cable manufacturing and laying, and telegraph transmission arrangements. A summary of its report, published in 1863, stated that the 1858 cable failure was due to a number of causes which could and should be corrected before another attempt was made. These included the following:

1. During storage the cable had not been properly protected from the heat of air and sun, and this had softened and weakened the gutta percha insulation. The committee recommended that the cable be stored in water at all times during manufacture, laying, and intermediate operations.

2. In the early expeditions inadequate stowage on ship allowed the cable to shift during severe storms, so the cable was badly tangled and twisted. This undoubtedly weakened the insulation and may have caused some of the temporary interruptions. These failures were mainly due to the use of ships not constructed for cable laying. Such ships should be of large capacity, very steady in rough seas, and should have sufficient power to maintain constant speeds over the range of 4 to 6 knots in all kinds of weather.

3. A careful survey of the ocean bottom along the cable route should be made before laying the cable. Irregularities in ocean bottom levels are more important than actual depths in placing the cable so as to provide proper slack. Complete records of the survey would also facilitate any future cable repairs.

4. The conductivity and insulation of the cable conductors should be improved by increasing the size of each strand from No. 22 to No. 18 BWG, and the copper purity should be maintained at no less than 85%. Insulation should be of the latest improved gutta percha, and should be tested under the highest hydraulic pressure attainable. Joints should be tested separately, and should not show a greater leakage than twice that of a corresponding length of core.

The committee concluded its report by stating that a well insulated cable, properly protected, of suitable specific gravity, made with care, properly tested under water throughout the project, and laid with the best machinery, could not only be successfully installed, but should give satisfactory service for many years.

The report was signed by the following prominent telegraph engineers and scientists: Douglas Galton, Cromwell F. Varley, Charles Wheatstone, George Saward, Latimer Clark, William Fairbairn, Edwin Clark, and George P. Bidder.

The committee's findings were rather broad and required more specific development and design. This work was carried out under the direction of Charles T. Bright, a prominent British telegraph engineer, in collaboration with the committee. The result was a cable with three times the copper cross section, tensile strength, and weight. However because of the increased diameter, its weight in water was practically the same as the previous cable.

Preparation for laying the improved cable (figs. 1, 2) proceeded more carefully than in earlier expeditions, and it was 1865 before all was ready. This time the *Great Eastern* (figs. 3–5) a huge steam ship, five times the size of any other ship afloat, was used to lay the entire cable.

The ship had the needed cable capacity and power, and needed only the required stowage and payout equipment. The cable-laying operation worked perfectly, and over 1200 miles of cable were laid. However, two serious cable defects were experienced from bits of metal between the conductor and the metal sheath. In each case it was necessary to recover several miles of cable (fig. 6) to find the trouble, and the recovery operation was slow and cumbersome. In the second case the cable broke and sank (fig. 7), and the grappling equipment was not strong enough to raise the cable.

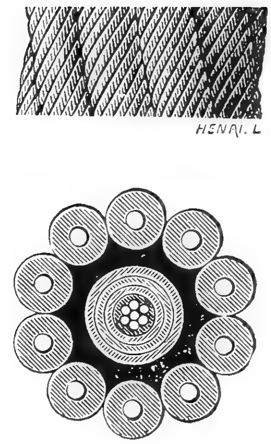

Fig. 2. Improved cable used in 1865 and 1866 expeditions. The seven-strand copper core was covered by four layers of gutta percha, wrapped in tarred hemp, and protected by ten steel wires, each wrapped in impregnated hemp.

Final Success

In spite of another failure and the apparent loss of 1200 miles of cable, it was felt that the 1865 expedition contained all of the elements of success. The cable laying operations had worked perfectly, and it was only in the recovery operations where improvement was needed. To correct this condition, both fore and aft recovery gear was provided with more powerful steam engines. This would avoid moving the cable from stern to bow when the recovery operation was started. Improved grappling equipment was also provided that was stronger and more flexible.

Sufficient cable was manufactured at Greenwich, England, and the *Great Eastern* was fitted out for an 1866 expedition. With the improved equipment provided, one cable was laid the entire distance between Ireland and Newfoundland

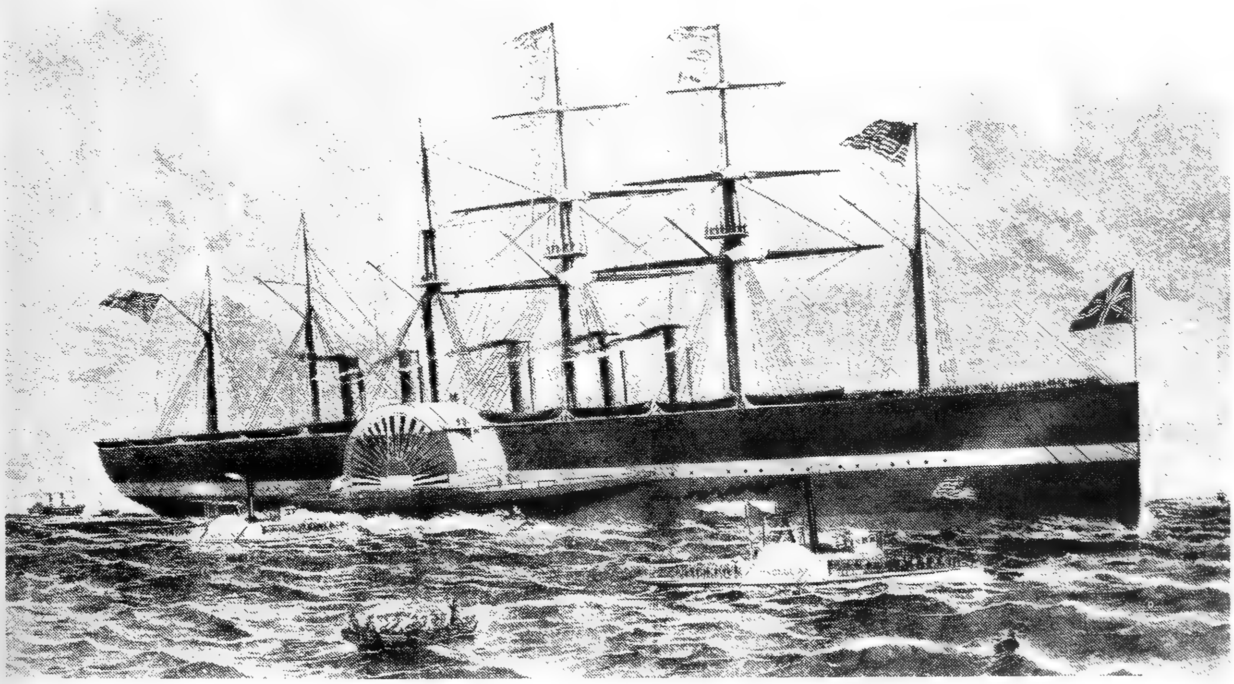

Fig. 3. The *Great Eastern*, 1860 (courtesy Burndy Library).

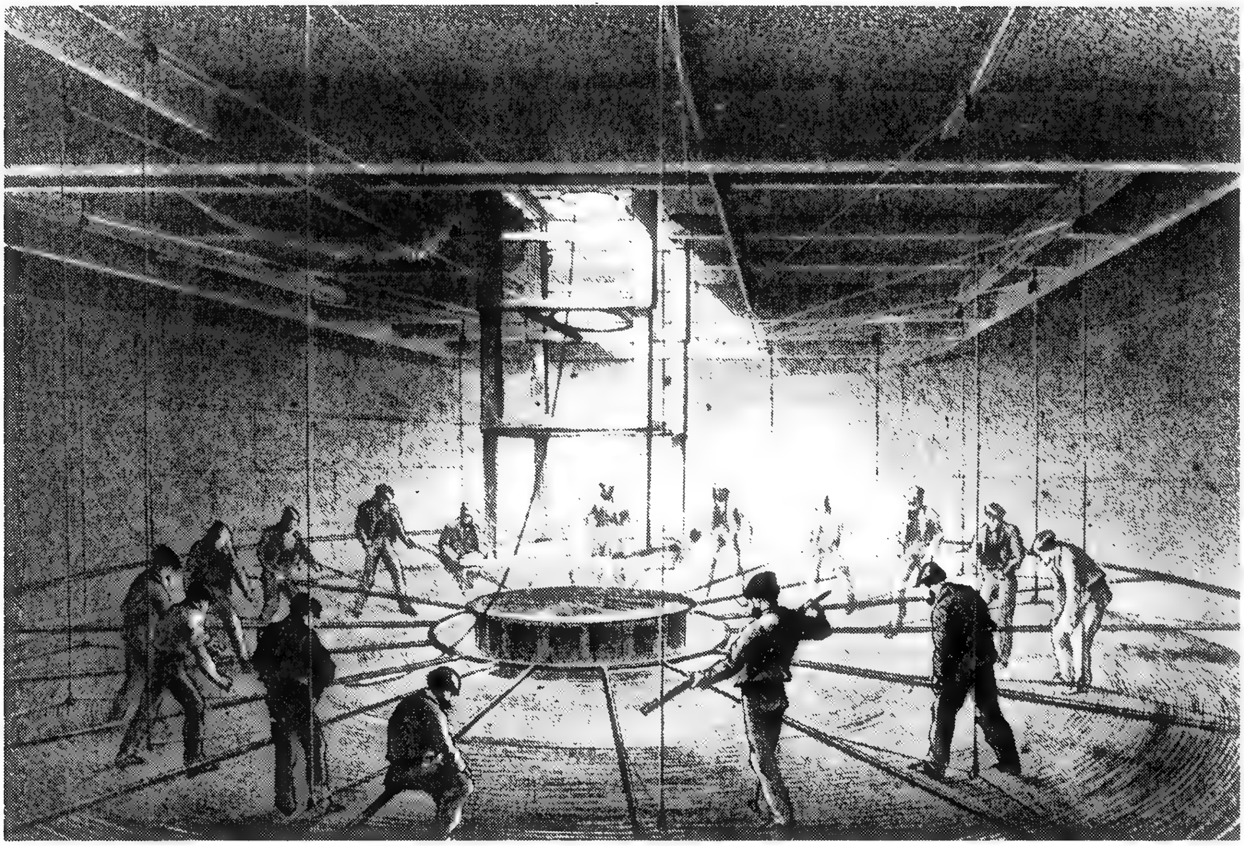

Fig. 4. Cable stowage tanks on board the *Great Eastern* (courtesy Burndy Library).

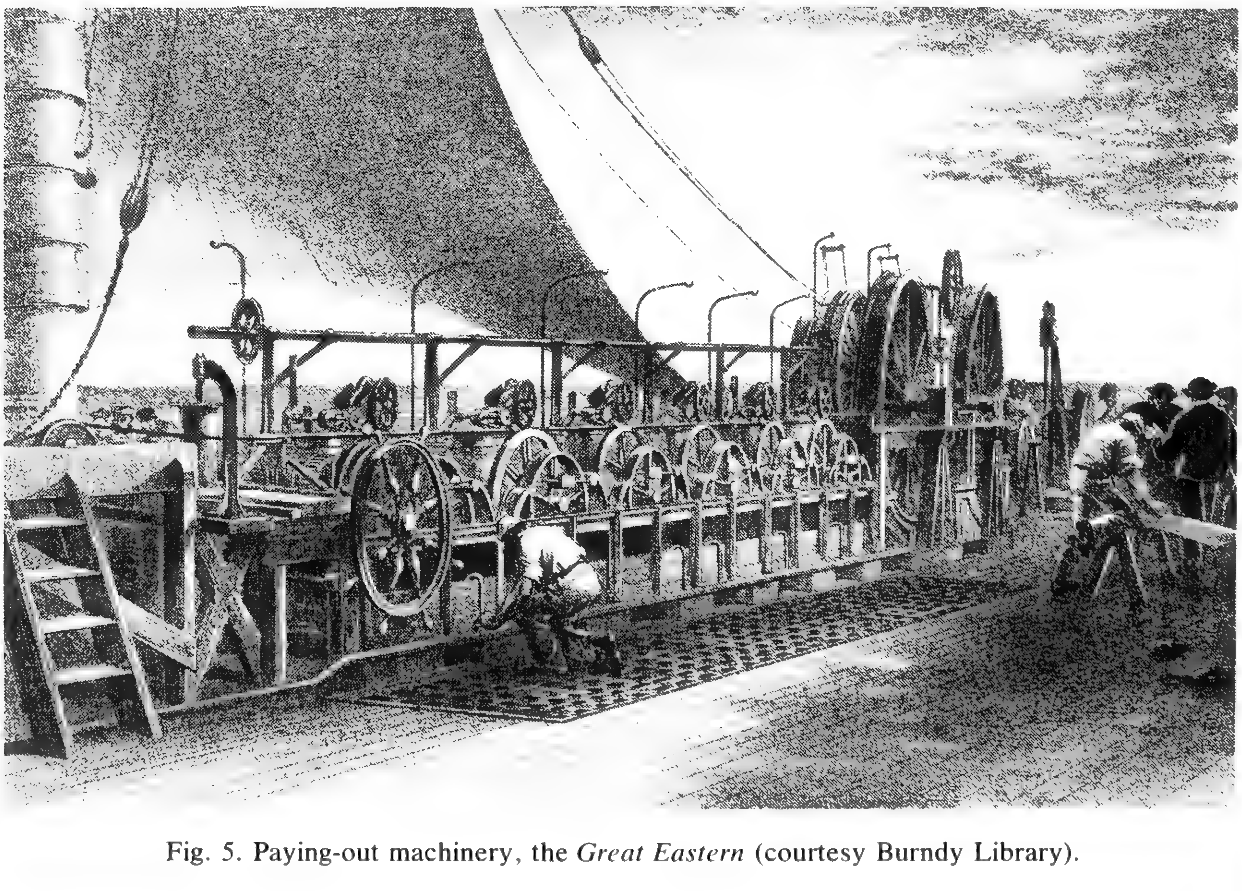

Fig. 5. Paying-out machinery, the *Great Eastern* (courtesy Burndy Library).

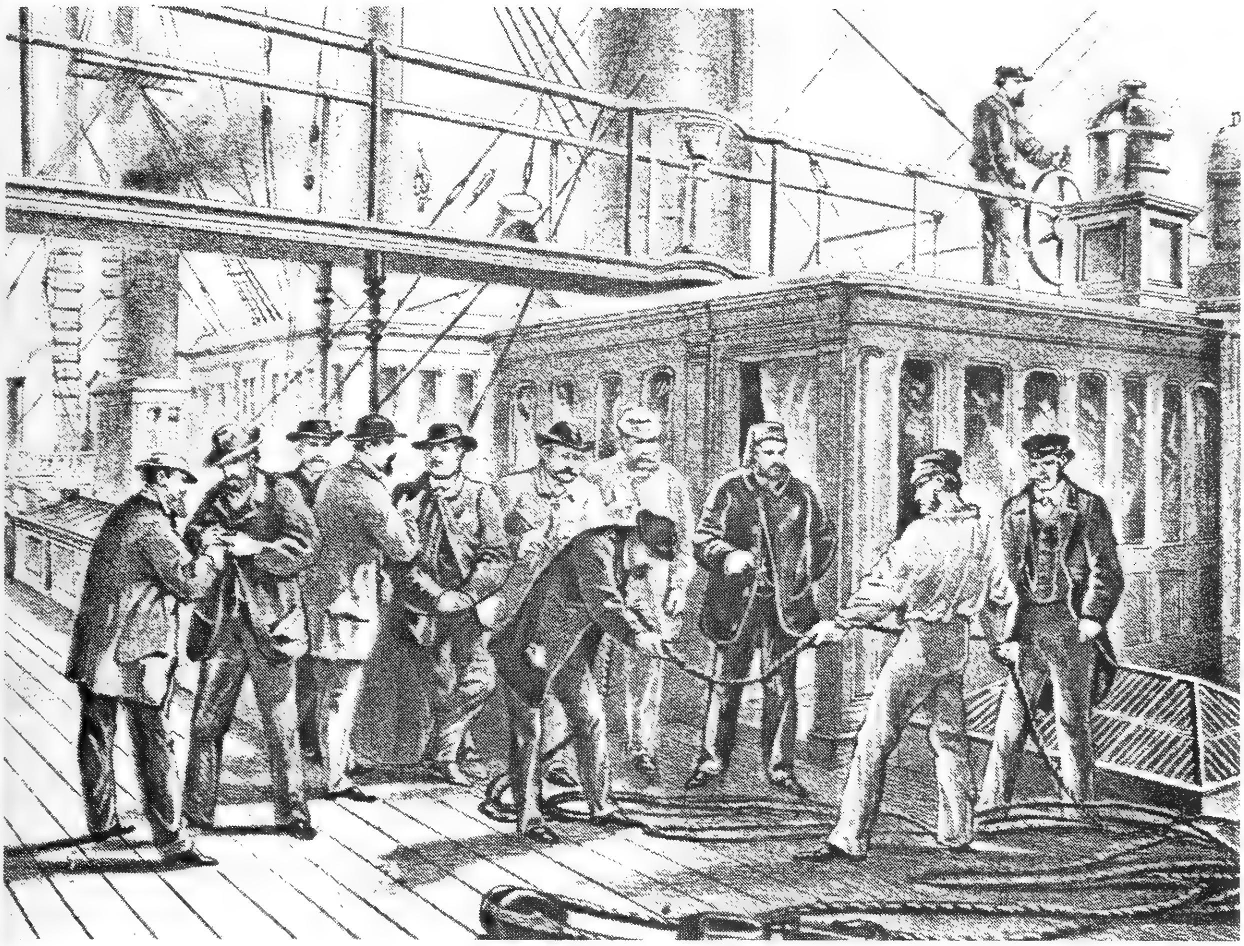

Fig. 6. Searching for fault after recovery of cable from bed of the Atlantic, July 31, 1865 (courtesy Burndy Library).

without difficulty. The end of the 1200-mile cable laid in 1865 was then recovered, after considerable difficulty due to bad weather, and was extended the remaining distance. Thus two working cables were provided between Ireland and Newfoundland.

After suitable testing the first cable was placed in service, to be followed six weeks later by the second cable. Both cables carried increasing message loads, and the benefits to trade and international relations were soon apparent. Business and government problems were solved faster, and people were kept better informed of what was happening in the different countries. Trading was based on sound information, and much of the business instability between Europe and America was corrected. The cable was also of great help in settling the differences between the United States and Britain arising from the latter's help given to the South during the Civil War.

Important Technological Problems Solved

A great deal of basic experimentation and scientific planning went into preparation for the first cable expedition in 1857, and was continued during the life of the project. This included experiments in the fundamental laws of telegraph transmission in long cables, determining the electrical and mechanical requirements of the cable and terminal equipment, electrical tests in manufacture and laying of the cable, and cable laying methods and equipment. Laboratory facilities were elementary and inadequate, and it was frequently a learn-by-doing process. In spite of these handicaps a remarkable amount of progress was made.

The experiments in telegraph trans-

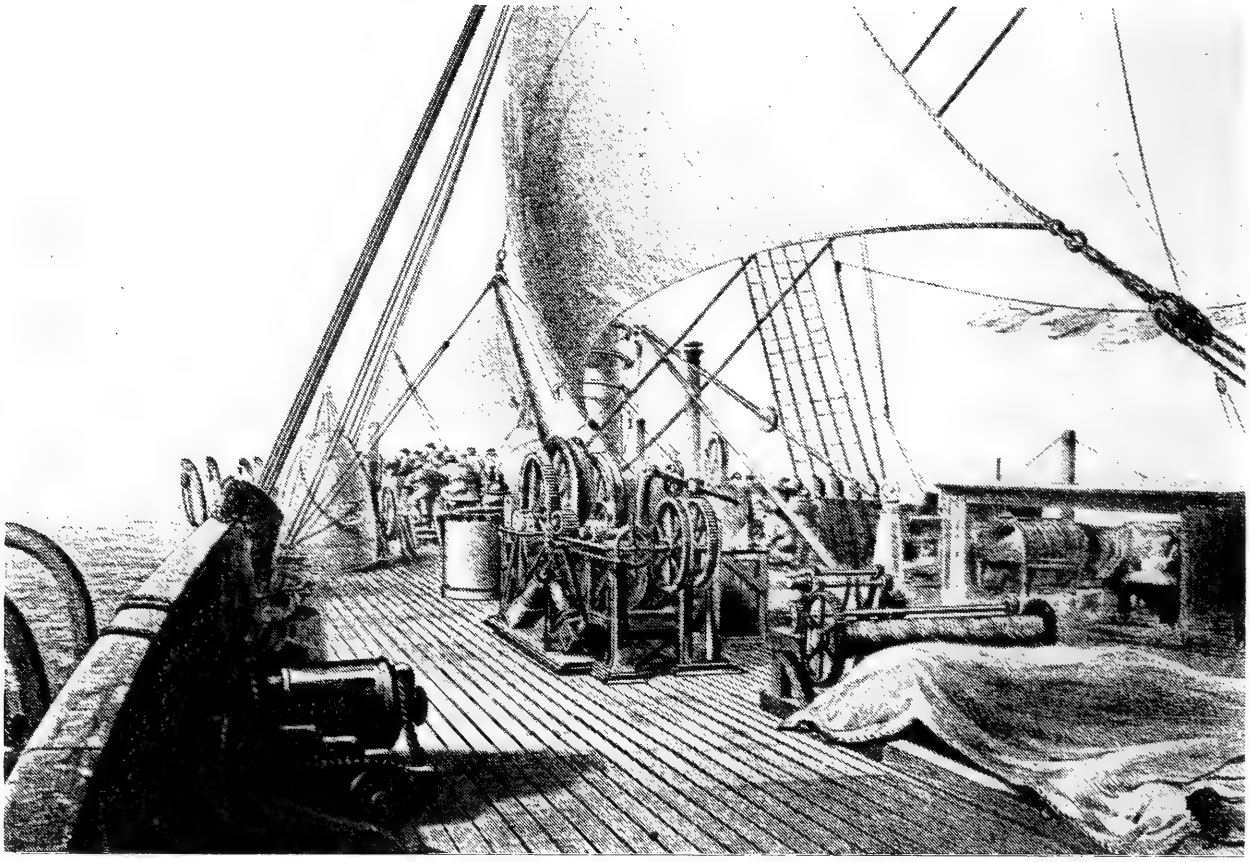

Fig. 7. Forward deck cleared for final attempt at grappling, Aug. 11, 1865.

mission conducted by Dr. E. O. W. Whitehouse, British scientist, indicated that the telegraph signals would be considerably retarded through a long cable such as the Atlantic. The time lag between signals would thus seriously impair the readability of the dots and dashes of the Morse code. Although not completely understood, it was realized that this retardation was related to the capacity and inductance of the cable and was proportional to the cable length. The tests indicated that this reduction in transmission speed and received signal current was much closer to a direct proportion to the cable length, rather than to the square of their ratios as was first believed (Table 1). The use of reversed polarity signals reduced this retardation, because they were opposite to the charge and discharge currents. It was also first thought that sending potentials equivalent to about 2000 volts were needed for satisfactory transmission. However, after the failure of the 1858 cable, further tests indicated that this may have weakened the cable insulation and that satisfactory transmission was possible with much lower potentials.

As a result of this fundamental research, the terminal equipment was considerably improved during the life of the project. The polarized receiving relay, responding to sending voltages of reversed polarity, was later replaced by the more sensitive "marine" galvanometer, invented by Prof. Thomson (later Lord Kelvin). This greatly increased the speed of telegraph reception and permitted reduced transmitting voltages. The "marine" galvanometer (fig. 8) used a beam of light to magnify the tiny movements of a mirror suspended in the magnetic field of the received signal current. The beam of light was reflected on to a graduated screen where the amplitude of the coded signals could be read. Kelvin later improved his galvanometer with the so-called "siphon recorder." This automatically recorded the coded signals as an undulating line on paper tape and thus eliminated

Table 1.—Transmission Loss in Long 16-Gauge Gutta Percha-Insulated Cable Conductors.

1. *Transmission Time of the Signal*

Test No. 1.—Direct Battery Supply

Miles of Conductor	Ratio of Cum. Dist.	Transmit Time in Sec.	Ratio of Cum. Time
83	—	.08	—
166	2	.14	1.75
249	3	.36	4.5
498	6	.79	9.87
1,020	12	1.42	17.5

Test No. 2—Magneto Electric Supply

Miles of Conductor	Ratio of Cum. Dist.	Transmit Time in Sec.	Ratio of Cum. Time
300	1	.06–.08	—
600	2	.11–.16	1.83–2.00
900	3	.2–.25	3.12–3.33

(Note No. 1—Magneto-electric supply provided through induction coils and alternate reversals of supply polarity.)

Test No. 3—Effect of Increased Size of Conductors

Miles of Each Conductor	No. of Wires in Parallel	Transmission Time (Sec.)	
		Battery	Mag. Elec.
166	1	.16	.08
166	2	.21	.09
166	3	.28	.095
250	1	.29	.145
250	2	.406	.185

2. *Reduction of Received Signal Current*

Miles of Conductor	Ratio of Cum. Dist.	Strength of Current (grains)	Ratio of Rec'd Current
0	—	25,000	—
200	—	10,650	2.3
400	2.0	3,250	3.3
600	1.5	1,400	2.3

(Note No. 2—Measurements made with a so-called magneto electrometer, designed to measure the mechanical force of the signal exerted through an electromagnet.)

the need to read the signals as they were sent. Equipment was also later provided for duplexing the telegraph circuit, whereby two messages could be sent at the same time. By use of the Wheatstone bridge principle, the receiving relay was made insensitive to transmitted signals but sensitive to received signals.

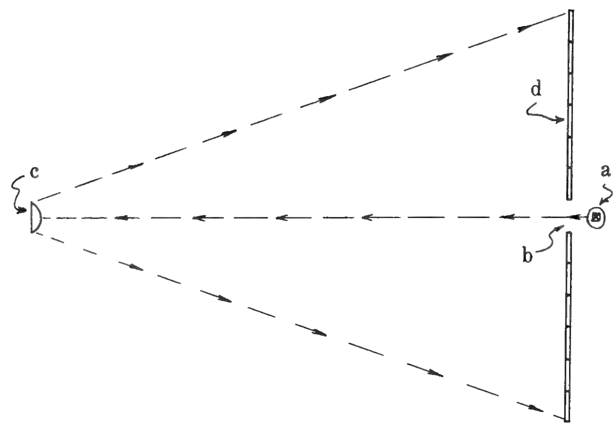

Fig. 8. Prof. Thomson's marine galvanometer, consisting of a very small magnet to which was fastened a mirror. The magnet was suspended by a silk filament within a coil through which the signal current was passed. A light source from lamp (a) passed through slot (b) and was reflected from mirror (c) upon the scale (d).

As the project developed, complete manufacturing specifications were needed to make sure the cable was as perfect as possible. Based on the research done by the Joint Committee, the manufacturer, under the direction of Mr. Bright, prepared specifications covering the important electrical and mechanical requirements of the cable. Seven strands of No. 18 BWG conductors were specified with a carefully controlled copper content of at least 85%. Machines for stranding the conductors and the application of gutta percha by an extrusion process had been developed earlier in the project. During cable manufacture and placing, electrical continuity, insulation, and resistance were measured with the cable immersed in water under pressure. Mechanical breaking tests were also made periodically to insure the proper strength of the cable. An artificial line, invented by C. F. Varley, was used in preliminary cable design. The line was composed of variable resistances, inductances, and condensers, and by its use the transmission characteristics of various cable designs could be predicted.

Electrical insulation and continuity tests for use during cable laying were developed by Latimer Clark, noted Brit-

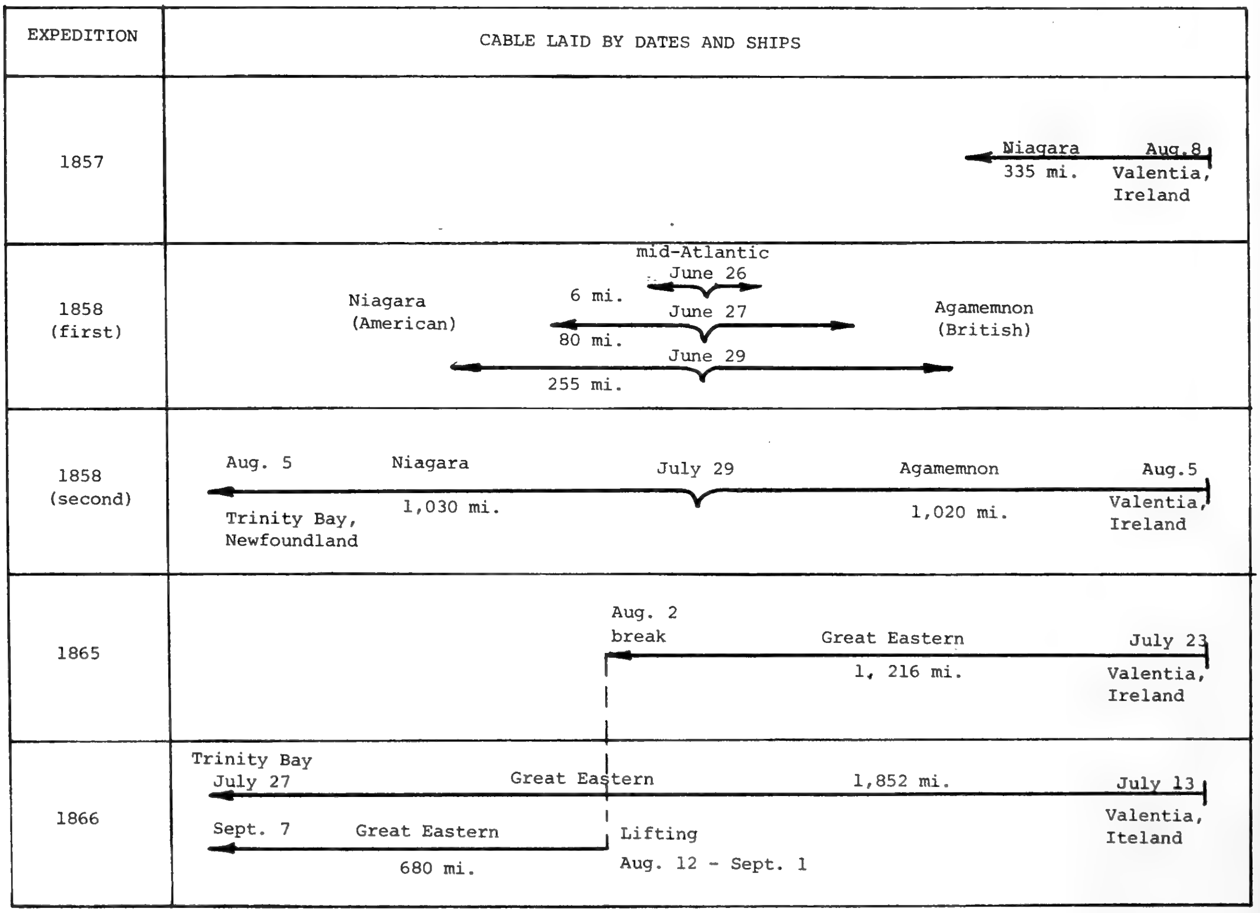

Fig. 9. Summary of five Atlantic cable expeditions, 1857–1866.

ish telegraph engineer. These insured that conductor troubles were detected as soon as they developed. Charles Wheatstone invented a resistance bridge for measuring the conductor resistance, and Varley devised a method of using the bridge to locate conductor troubles. This avoided the effect of fault resistance, thus improving the accuracy of trouble location.

It was realized that improvement was badly needed in cable laying and recovery methods to avoid costly cable damage that had been experienced. Therefore Lord Kelvin made a scientific analysis of the mechanical forces involved in these operations and their application to the method of operations. The analysis was so complete and accurate that it is still the standard mathematical treatise on the subject. Kelvin showed that when a cable is laid in deep water, at uniform speed, on a level bottom, and without tension at the bottom, it moves on an inclined straight line from the water's edge to the ocean floor. Under these conditions the cable tension at the ship during cable laying is essentially equal to the weight in water per unit length of cable multiplied by the depth of the water. The cable should therefore be laid with just enough slack to conform to the contour of the ocean floor, so as to avoid residual bottom tension during and after laying. In cable recovery, a method of lifting the cable from the ocean floor was described using three ships. Each ship would raise the cable only part way, and the tension would always be less than the breaking strength of the cable.

Kelvin's methods were successfully used in laying the 1865 and 1866 cables, and recovery of the partially laid 1865 cable in 1866. Cable-laying and recovery machinery was also developed, and many improvements were made during the project. These included the use of self-releasing brakes, recovery machinery at the same location as the payout machinery, and an electric log for automatically recording the speed of the ship. The machinery for cable laying and recovery was so satisfactory that the design was used for many years on other cable-laying projects.

Compared to modern day standards, the methods and equipment used in the first Atlantic cable seem rather elementary. However, the scientific knowledge of submarine cable manufacture and installation that was developed provided a very important foundation for modern day methods and equipment. Although the knowledge was not as complete nor were the phenomena as well understood as they are today, what was available was used in the scientific way. Development was accelerated under the pressure to complete the project, and failures did occur. However it was recognized that these were a part of the development process, and were to be expected as steps leading to ultimate success.

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The General Linear, First-Order Ordinary Differential Equation

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ABSTRACT

A tersely annotated collection of references on types of approaches used in currently available methods to solve the general linear, first-order ordinary differential equation is presented, and another variant on a standard technique is described for obtaining the general solution of this type of equation.

In applied mathematics, the most important and frequently occurring differential equations are linear differential equations (51). This class of equations supplies some of the most frequently used models in all branches of science. Additionally, because any differential equation is linear to a first-order approximation, knowledge of the linear theory (already satisfactorily developed) often suggests how one should study a nonlinear problem (11). The present paper is concerned with a special type of linear equation, namely, the general linear, first-order ordinary differential equation. This equation is written in standard (normal) form as

$$\frac{dy}{dx} + Py = Q, \qquad (1)$$

where P and Q are continuous functions of x over the intervals for which solutions are sought. Although this is one of the simplest types of differential equations, its practical importance stems from its applicability to a wide variety of problems (see, for example Betz, Burcham and Ewing (6); Buck and Buck (11); Spiegel (65); and Tenenbaum and Pollard (67)). A number of standard techniques and many variations thereof is already available to solve the above type of equation. The objectives of the present paper are to (a) provide a tersely annotated collection of references on types of approaches used in currently available methods to solve equation (1), and (b) describe another variant on a standard technique for obtaining the general solution of equation (1). The substance of the present paper should be of particular interest to the undergraduate student encountering for the first time the rudiments of elementary differential equations in general and equation (1) in particular.

Approaches to Existing Methods of Solution

Approaches used in existing techniques to obtain the general solution of equation (1) range from the very simplistic to the more mathematically elegant and include:

I. Simply stating the general solution as a formula (17, 37)—a trivial case indeed,

II. Direct application of a known positive integrating factor (2, 21, 23, 33, 38, 43, 50, 59, 65, 67), or a minor variation thereof (5, 52, 54, 63, 66, 69),

III. Determination of an integrating factor by considering the homogeneous equation (also referred to as the reduced, abridged, associated homogeneous, corresponding homogeneous, or related homogeneous equation) and its solution (7, 8, 16, 19, 30, 34, 35, 46, 47),

IV. Introduction of an unknown integrating factor followed by the application of the necessary and sufficient condition for exactness which enables the determination of this factor (14, 26, 28, 32, 35, 41, 53, 60, 67),

V. A variation of IV which considers equation (1) as a special case of a category of equations having an integrating factor which is a function of one variable only (6, 8, 26, 39, 40, 46, 65),

VI. Another variation of IV which is based on the identification (by the perspicacious observer) of a potentially integrable combination consisting of the derivative of a product of the dependent variable and an unknown but determinable function of the independent variable (an integrating factor) (3, 4, 9, 10, 11, 13, 24, 29, 31, 42, 55, 56, 64, 68, 70),

VII. An interesting variation of VI in which the simultaneous consideration of equation (1) and its adjoint equation leads to a directly integrable differential equation which readily yields the desired general solution (25),

VIII. The method of Lagrange (generally called the method of variation of parameters or variation of constants) in which the general solution of equation (1) is obtained from the general solution of the corresponding homogeneous equation by allowing the integration constant to vary with the independent variable (that is, by replacing the integration constant in the solution of the homogeneous equation with an unknown but determinable function of the independent variable) (10, 12; 14, 15, 20, 26, 32, 40, 43, 44, 49, 57, 59), and

IX. A change in variable approach which assumes the dependent variable to be a product of 2 functions of the independent variable (an assumption possessing the advantage that one of these 2 functions can be made to satisfy any convenient condition (58)) (22, 29, 44, 48, 50, 51, 57, 58, 61, 62). For a rather unique change in variable approach (i.e., $z = Q/P - y$) leading to a non-conventional, but correct, expression for the general solution of equation (1), see page 2 of the second entry in reference (20).

Another Variant On A Standard Technique

With the above information as a backdrop, we are now ready to proceed with the second objective of the present paper. In order to perform certain operations in the technique to be described, let us assume that the quotient $Q(x)/y(x)$ is continuous on the interval of integration and $y \neq 0$. Equation (1) can now be rewritten in the form

$$\frac{dy}{y} + \left(P - \frac{Q}{y}\right)dx = 0, \qquad (2)$$

then integrated, and the result expressed as

$$ye^{\int Pdx}e^{-\int(Q/y)dx} = K, \qquad (3)$$

where K is an integration constant. Obviously, equation (3) does not yet constitute a satisfactory solution because it contains a factor having the dependent variable, y, under an integral sign. Taking into consideration properties of exponentials suggests a way to complete the solution.

Equation (3) is differentiated, yielding

$$e^{-\int(Q/y)dx}\frac{d}{dx}(ye^{\int Pdx}) + ye^{\int Pdx}\frac{d}{dx}(e^{-\int(Q/y)dx}) = 0. \qquad (4)$$

Rearranging terms and simplifying, we obtain

$$\frac{d}{dx}(ye^{\int Pdx}) = ye^{\int Pdx}\frac{d}{dx}\int\frac{Q}{y}dx. \qquad (5)$$

With the conditions imposed above on $Q(x)/y(x)$ and $y(x)$,

$$\frac{d}{dx}\int^{x}\frac{Q(t)}{y(t)}dt = \frac{Q(x)}{y(x)}, \qquad (6)$$

and equation (5) becomes

$$\frac{d}{dx}(ye^{\int Pdx}) = Qe^{\int Pdx}. \qquad (7)$$

Direct integration of equation (7) gives the general solution

$$y = e^{-\int Pdx}[C + \int Qe^{\int Pdx}dx], \qquad (8)$$

where C is an integration constant. The restriction $y \neq 0$, which we had imposed in a previous section of this paper, can now be removed since equation (8) is valid for all y, C, P(x) and Q(x).

Concluding Remarks

Although the above derivation is a variant on a standard technique, it has the desirable feature of dealing with equation (1) in its entirety without resorting to homogeneous equations, unknown integration factors, or changes in variables. It is always instructive to examine the solution process of fundamental equations from various perspectives (as exemplified by the hundreds of proofs of the well known Pythagorean proposition (theorem) (36)) since this allows one to obtain a greater insight and understanding of fundamental concepts.

APPENDIX

(Consideration of a Nonlinear Differential Equation)

Phillips (page 64, reference (50)) discusses a problem in mathematical biology which gives rise to the differential equation

$$\frac{dx}{dt} + mx = Rx^2, \tag{9}$$

with initial condition $x = a$ at $t = 0$, where x is the number of inhabitants in a country who at the end of t years have no ancestors in a specified group (of inhabitants);

$$m = \frac{1}{100}; \quad \text{and} \quad R = \frac{e^{-t/100}}{50(a + b)},$$

where a and b are positive constants (for additional details, see Phillips (50)).

Equation (9) is a nonlinear differential equation (a special case of the so-called Bernoulli equation). This type of equation is ordinarily solved by first reducing it to a linear differential equation by a change of variable (see, for example, Rainville and Bedient (53)). We shall, however, solve equation (9) by applying the technique used in the present paper for the solution of equation (1). Equation (9) is rewritten in the form

$$\frac{dx}{x} + (m - Rx)dt = 0, \tag{10}$$

then integrated, and the result expressed as

$$xe^{mt}e^{-\int Rxdt} = M, \tag{11}$$

where M is an integration constant. As in the case of equation (3), equation (11) does not yet constitute a satisfactory solution because it contains the dependent variable (x in the present case) under an integral sign. Equation (11) is differentiated, yielding

$$e^{-\int Rxdt}\frac{d}{dt}(xe^{mt}) + xe^{mt}\frac{d}{dt}(e^{-\int Rxdt}) = 0. \tag{12}$$

Rearranging terms and simplifying, we obtain

$$\frac{d}{dt}(xe^{mt}) = xe^{mt}\frac{d}{dt}\int Rxdt. \tag{13}$$

Since

$$\frac{d}{dt}\int^{t} R(z)x(z)dz = R(t)x(t), \tag{14}$$

equation (13) becomes

$$\frac{d}{dt}(xe^{mt}) = Rx^2e^{mt} = Re^{-mt}(xe^{mt})^2. \tag{15}$$

Replacing m and R with the values given, equation (15) may be written in the directly integrable form

$$\frac{d(xe^{t/100})}{(xe^{t/100})^2} = \frac{-d(e^{-t/50})}{(a + b)}. \tag{16}$$

Integration of equation (16) followed by evaluation of the integration constant (using the given initial condition x = a at t = 0) gives the desired solution

$$x = \frac{a(a + b)}{ae^{-t/100} + be^{t/100}} . \qquad (17)$$

Additional cases of nonlinear differential equations will be investigated to determine conditions under which the technique used in the present paper can be extended to other differential equations of the nonlinear-type.

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Design of Detention Structures for Controlling Runoff from Highway Surfaces

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ABSTRACT

Storm water runoff from highways and parking lots causes frequent localized flooding in urban areas. Storm water detention provides a means of minimizing the hydrologic impact of increased highway development and simultaneously reducing the total cost of the drainage system. A hydrologic model was formulated to determine the volume of storage that would be required to limit the peak rate of runoff from highways and parking lots to the discharge that occurred prior to development. A design curve that relates the area under development to the required volume of detention storage is presented for use specifically with highways and parking lots.

In most metropolitan areas, streets and parking lots may account for as much as 20% of the total area. Wallace (*9*) indicated that in 1968, highways and parking areas represented 17.22% of a 134-square-mile (347 km^2) watershed, which includes part of Atlanta, Georgia; the corresponding figure for 1949 was 8.62%. An extensive land-use sampling analysis of a 132-square-mile (342 km^2) watershed in suburban Washington, D. C., showed that, in 1971, 12.83% of the watershed was paved in either streets or parking areas (*6*). And for smaller subwatersheds in urban areas the percentage may be significantly greater. Furthermore, the area paved in streets and parking lots may represent over 50% of the total impervious area.

In many urban areas the peak rate of runoff may be 5 times greater than the peak discharge on a natural nonurbanized watershed having similar physiographic characteristics (e.g., slope). To cope with such increases in runoff rates, the size and capacity of a storm drainage system must be increased significantly. In many areas a portion of the runoff from rooftops, both residential and commercial, is not connected directly to the storm drainage system. Since streets and parking lots account for a major portion of the impervious area and are usually connected directly to the drainage system, they may be a primary source of increases in peak rates of runoff. Stormwater runoff from highways and parking areas entering directly into small streams may be responsible for increased erosion and degradation of the quality of the water.

Many stormwater management practices have been suggested as alternatives for minimizing the hydrologic impact of continued urbanization. Various forms of stormwater detention and/or retention have proven to be both a practical and economically efficient means of reducing peak runoff rates, especially the frequent storms of small volume and small return periods. The objective of on-site stormwater detention is to redistribute the runoff with respect to time such that the peak rates of runoff are below some prescribed standard. The use of temporary ponding in the Fort Campbell (Ky.) storm drainage system reduced the total project cost from an estimated $5,500,000 to $2,000,000 (*3*). In addition to the cost of the storm drainage system, stormwater detention can reduce downstream flooding and channel erosion, which may be a primary cause of stream pollution.

Design of Detention Structures

The maximum allowable discharge rate and the required volume of storage are the primary variables considered in the design of a detention structure. The maximum allowable discharge rate is usually set equal to the discharge rate that would occur on the site prior to development; a return period is usually selected for the design storm. However, in some instances, the maximum allowable discharge rate may depend on the discharge capacity of downstream sewer systems or the bankfull flow rate of receiving streams.

The time distribution of inflow and the maximum allowable discharge rate is necessary but not sufficient to determine the required storage. The required storage will also depend on the configuration of the detention structure. The required volume of storage will be equivalent to the maximum difference between the cumulative distribution of inflow and the cumulative distribution of outflow when the maximum allowable discharge is not exceeded. The inflow to a detention structure may be simulated by routing a design hyetograph over the highway surface or parking lot and through the gutter/culvert system that connects the paved surface to the detention structure. The depth-discharge (or volume-discharge) relationship of the detention structure must be specified in order to route the inflow distribution through the detention structure.

Different design criteria exist for designing detention structures. Design curves may differ because of different hydrologic criteria or because of differences in the models used in their derivation. A model used in the derivation of detention structure design curves should include the following components: (1) a design hyetograph of some preselected frequency and duration, (2) a routing procedure to represent the effect of overland runoff and gutter flow on the design storm, and (3) a stage-discharge relationship, which is controlled by certain detention facility design parameters, for the detention structure. The third component is especially important if the required volume of storage, and thus project cost, is to be minimized. But many models do not include this important component. In some cases the maximum allowable discharge may be determined from an empirical prediction equation, such as the rational method or the Burkli-Ziegler formula.

In the past, design criteria have been established for use in residential and commercial areas. Such criteria assume that the area under development is composed of a variety of land uses, including buildings, streets, and non-impervious surfaces. As such the design criteria may be inadequate for use with land uses that are predominantly transportation oriented. For areas that include only small parcels of pervious surface, such as a major highway and the adjoining right-of-way, the time of concentration will be much shorter than that of a residential development that includes large quantities of pervious surfaces. Thus, the peak discharge from a highway or parking lot after development will be greater than that for a residential area, and thus, a larger volume of detention storage may be required.

The design of detention structures requires the determination of the required volume of storage and the maximum allowable release rate. The maximum allowable release rate was assumed herein to be the peak discharge on a natural watershed prior to development. The rational method is used herein to estimate the design peak discharge Q_p. An estimate of the time of concentration of the watershed is required for estimation of Q_p with the rational formula. Estimates of the time of concentration T_c were computed using a method outlined by Kent (*2*). A runoff coefficient of 0.2 was used for determining the peak discharge for the natural watershed. The area was varied over the range shown in Fig. 1. Fig. 1 shows the resulting peak discharge for an undeveloped drainage area.

A design hyetograph having a duration of 24 hours and a 10-year return period was formulated. The total volume, in inches, was determined from Weather Bureau Technical Paper No. 40 (*7*). The method by Kent (*2*), which was described above, was also used to determine the time of concentration for the developed drainage area. The 10-year rainfall volume for a storm of duration equal to the time of concentration was then obtained from Technical Paper No. 40 (*7*); this volume was uniformly distributed at the center of the design hyetograph over a period of time equal to the time of concentration. The volumetric difference between the 24-hour storm and the storm of duration equal to the time of concentration was distributed over the remainder of the 24-hour period using a cumulative distribution graph.

A unit hydrograph approach was used in the model to represent the effect of overland flow routing. A unit hydrograph was determined for the developed drainage area using a method outlined by Viessman (*8*). The inflow hydrograph to the detention structure was determined using the convolution integral, which is given in a generalized form by:

$$\int_0^t X(\tau)h(t - \tau)d\tau \qquad (1)$$

where $X(\tau)$ is the design hyetograph, $h(t - \tau)$ is the 1-minute unit hydrograph, and τ is the variable of integration. The discrete form of the above integral was used with the computer program to determine the inflow hydrograph.

A mathematical model of a stormwater detention facility (*1*) was used to determine the required storage. The model requires values representing the length, width, and side slope of the detention basin, the diameter of the riser pipe, the height of the top of the riser and bottom of the spillway above the bottom of the detention basin, and the cross sectional properties of the emergency spillway. The model also includes an option to simulate the effect of holes in the riser; if this option is selected, input variables are required that describe the number of holes, their diameter and the height of each hole above the bottom of the detention structure.

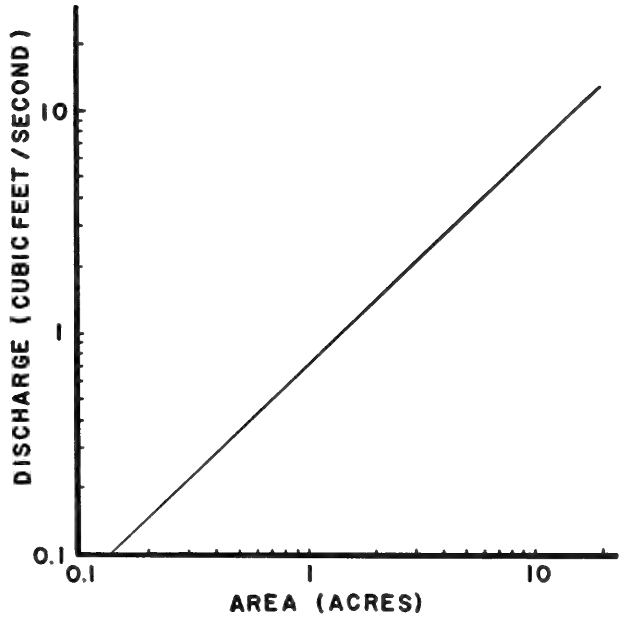

Fig. 1. Allowable release rate.

The stage-discharge relationship of the detention structure is represented by an algorithm that describes flow through the performations in the riser, flow through the top of the riser, and flow through the emergency spillway. If the option for flow through holes in the riser is selected, the flow rate through the holes is computed by

$$Q_i = 0.0436C_iN_iD_i^2H_i^{0.5} \qquad (2)$$

where Q_i (cfs) is the flow through the i^{th} set of holes, C is a discharge coefficient for orifice flow, N_i is the number of holes in the i^{th} set, D_i is the diameter (inches) of the holes and H_i is the effective head (feet) of the holes.

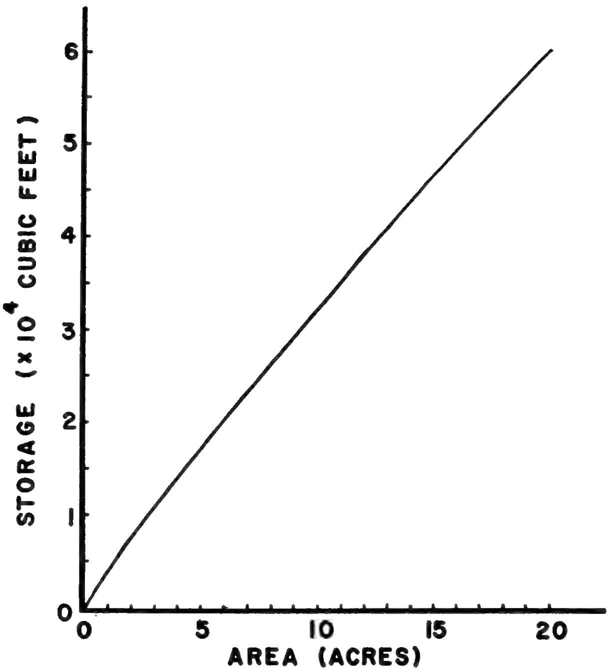

Fig. 2. Required storage.

Flow over the top of the riser was treated as flow over a sharpcrested weir having a length equal to the circumference of the riser pipe. The outflow can be computed by

$$Q = \pi C_r D_r H_r^{1.5} \qquad (3)$$

where Q is the flow, cfs, C_r is a discharge coefficient, D_r is the diameter of the riser, in inches, and H_r is the effective head, in feet. If flow in the riser is controlled by the pipe, the discharge from the pipe is given by

$$Q = 0.44\, D_r^2 H_r^{0.5} / (1.5 + 3.8\, L_p / D_r^{1.33})^{0.5} \qquad (4)$$

where L_p is the length of the pipe in feet.

Flow through the emergency spillway is treated as flow over a broadcrested weir:

$$Q = 3bH^{1.5} \qquad (5)$$

where Q is the flow in cfs, b is the width, in feet, of the spillway and H is the effective head, in feet. Thus, the total flow is the sum of the orifice flow, flow over the crest of the riser, and flow through the emergency spillway.

The above procedure, which involved the determination of an inflow hydrograph and routing the hydrograph through a detention structure, was used to determine the detention storage required to maintain a flow that did not exceed the flow prior to development. The resulting storage requirements for different areas of development are given in Fig. 2. The relationships shown in Figs. 1 and 2 are designed especially for use with highways and parking lots. Because highways and parking lots do not usually include significant portions of pervious surfaces, the required storage indicated by Fig. 2 will be greater than the storage required for other patterns of land use that include significant amounts of pervious surfaces.

Discussion and Conclusions

A mathematical model that includes components representing overland runoff from an impervious surface, such as a parking lot or highway, and a detention structure was used in formulating design curves for determining the storage required to minimize the hydrologic impact of highway development. In addition to the reduction in flooding, detention structures will also have a positive effect on water quality. If properly designed, a detention basin can serve as a settling basin and thus serve to remove dust and particulate matter that is suspended in the runoff from the highway surface or sediment and/or decayed leaves that are in the runoff originating from right-of-way areas. In many areas the poor quality of runoff from highways and parking lots is responsible for a reduction in the efficiency of waste water treatment facilities and degradation of water quality in receiving streams.

In addition to reducing the problem of localized flooding, the use of stormwater detention as part of a drainage system for highways should result in significant reductions in the cost of drainage systems. Leach and Kittle (*3*) and Poertner (*10*) demonstrated that detention storage can result in significant reductions in the cost of a storm drainage system. Rawls and McCuen (*11*) provided an equation for estimating the cost of detention storage facilities.

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Field Observations on the Cliff Swallow, Petrochelidon pyrrhonota *(Vieillot), and the Swallow Bug,* Oeciacus vicarius *Horváth*

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ABSTRACT

Observations are presented on the longevity of swallow bugs, *Oeciacus vicarius* Horváth, in the prolonged absence of their normal hosts and on the parasites and predators of these bugs. The use of the cliff swallow nests by other birds and mammals is discussed.

Studies on known and suspected vectors and pathogens were initiated by Vector-Borne Diseases Division personnel in the Colorado Counties of Morgan and Logan in 1972 in connection with a proposed impoundment of the South Platte River. Of special interest has been the report by Hayes *et al.* (1977) of the recovery in 1973 of an alphavirus strain serologically related to western encephalitis (WE). The virus was isolated from a pool of the swallow bug (*Oeciacus vicarius*) from an inactive house sparrow (*Passer domesticus*) nest built inside a cliff swallow (*Petrochelidon pyrrhonota*) nest under Bijou Bridge, just outside Fort Morgan, Morgan County, Colorado. Hayes *et al.* (1977) recovered virus from

O. vicarius from several swallow nesting sites around Fort Morgan each month from May 1974 through February 1975, and from nestling house sparrows and cliff swallows during the summer months of 1974. These findings suggested the swallow bug as a possible overwintering mechanism for WE virus.

Later studies have indicated that the virus strains from the bugs, house sparrow nestlings and cliff swallow nestlings represent 2 viruses, 1 serologically related to WE (tentatively named Fort Morgan virus), and the other related to Venezuelan equine encephalitis (VEE) (referred to as Bijou Bridge virus).

Investigations designed to clarify the taxonomic status and natural history of these viruses are continuing. Viral isolations have been made more frequently from nestling house sparrows than from nestling cliff swallows, and antibodies to the viruses are more prevalent in adult house sparrows than in adult cliff swallows. This presents a rather anomalous situation. *O. vicarius* normally parasitizes cliff swallows, although we have on occasion found the species in considerable numbers in barn swallow (*Hirundo rustica*) and bank swallow (*Riparia riparia*) nests. We know of no record of this bug being recovered from house sparrow nests unassociated with cliff swallow nests. If these are normal house sparrow viruses, vectors other than cimicids would have to be involved when the sparrows are not nesting within or in the vicinity of swallow nests.

O. vicarius seems to be restricted to only a portion of the extensive range of the cliff swallow. It is widely distributed in the United States, although to our knowledge it has not been previously reported from the southeastern region. We have the species from cliff swallow nests from the face of Hartwell Dam located on the Savannah River in northern Georgia, July 12, 1975, coll. T. Monath. In spite of intensive efforts, Usinger (1966) was unable to find *O. vicarius* in the Southern Hemisphere where the cliff swallows spend the winter.

In Colorado, cliff swallows commonly use cliff faces, bridges, and culverts for nesting, with buildings less frequently selected as nesting sites. During our cimicid bug collecting in Colorado, we have found house sparrows nesting in cliff swallow nests only under bridges and culverts. There are records, however, in the literature of house sparrows rearing their young in cliff swallow nests on buildings (Grinnell 1937, Herman 1935). It would appear that cliff swallow nests on cliff faces are not especially attractive nesting sites for house sparrows, although on one occasion one of us (GS) found house sparrow nests in such a situation in Bon Homme County, South Dakota on June 21, 1977.

The life cycle of *O. vicarius* is adjusted to long periods of fasting. In northern Colorado, cliff swallows begin returning in late April and early May and depart in September. Thus, the swallows are only in the area 5 months and considerably less than half of this time is spent in the nesting cycle, when adult and young birds are in the nests for appreciable periods of time. In this connection, cliff swallows probably produce single annual broods, with only an occasional second brood. In contrast, the house sparrow rears multibroods. The cliff swallows begin nesting activities at widely spaced intervals, with the consequence that in early July the nests may contain all stages—from eggs to almost fully feathered fledglings.

Swallow bugs have been observed to survive in the nest for 2 years in the absence of the swallows. A colony of cliff swallows consisting of some 300 nests under a concrete culvert in Lory State Park, some 10 km west of Fort Collins, Larimer County, Colorado, has been under observation for several years. These nests were occupied by cliff swallows during the summer of 1975. The nests were heavily infested with both nymphal and adult bugs during the winter of 1975–76. Winter-collected bugs fed readily in the laboratory on adult pigeons, wet chicks, mice and people, but laid negligible numbers of eggs, even when cold-treated in an attempt to break the apparent diapause.

In the spring of 1976, the bugs were observed massed just inside the nest entrances, awaiting the return of the swallows. Bugs collected at this time were fed in the laboratory on wet chicks, nestling house sparrows and adult cliff sparrows. All *O. vicarius* females laid numerous eggs, although more were produced from bugs fed on cliff swallows.

Swallows did not use the nests in the Lory Park culvert during the summer of 1976. There have been reports of swallows alternating the use of nesting sites (Grinnell *et al.* 1930, Mayhew 1958). Our observations, however, have been that cliff swallows continue to use an established nesting site each year, except for some specific reason. In this case, the small stream that usually provides water through the culvert was dry, and mud for nest repair and building was not available.

Several collections made during the winter of 1976–77 demonstrated the continuing presence of live bugs in the nests. In late April of 1977, bugs were not present in sufficient numbers to mass at the nest entrances as they had done the previous spring. However, 25 live nymphal and adult bugs were taken from 2 nests. A third swallow nest in which a well-formed grass nest had been built contained several hundred cimicids in all stages of development. It was evident that a pair of birds other than swallows had used the nest the previous summer, providing an opportunity for the cimicids to feed.

The swallows also passed up the Lory Park nesting site during the summer of 1977, even though water ran through the culvert in April and the first 2 weeks in May. Thus, the cliff swallow bugs in this colony sustained themselves in large numbers through the winter of 1975–76 and the summer of 1976 and in fair numbers during the winter of 1976–77 and the summer of 1977, in the absence of their regular hosts.

This is not to say that the bugs might not have had an opportunity to take blood meals. No house sparrows have been observed in this nesting site during summer or winter. However, on May 12, 1977, we found a pair of western bluebirds, *Sialia mexicana*, rearing a brood of young within one of the swallow nests; 2 other swallow nests containing well formed grass nests of the type constructed by bluebirds were seen, but they contained no eggs or young birds.

Considerable activity of other bird species in cliff swallow nesting sites in all seasons has been documented, especially in natural nesting sites on cliff faces. Sooter *et al.* (1954) reported use of cliff swallow nests as winter shelter in Larimer County, Colorado, on cliff faces by the black rosy finch (*Leucosticte atrata*), the gray-crowned rosy finch (*L. tephrocotis*) and the canyon wren (*Catherpes mexicanus*), and for summer nesting by a pair of Say's phoebe (*Sayornis saya*). Bailey and Niedrach (1965) indicate that both gray-crowned and brown-capped rosy finches (*L. australis*) were seen in numbers in and about cliff swallow nests near Ault, Weld County, Colorado, February 13, 1960.

We have observed 3 species of birds nesting in association with 2 large cliff swallow colonies on cliff faces in Eden Valley, some 16 km west of Fort Collins, Larimer County, Colorado. The swallows did not return to nest repair and building until the middle of May in 1977. For several weeks prior to this, rock doves (*Columba livia*) were nesting on ledges in the immediate vicinity of the swallow nests; starlings (*Sturnus vulgaris*) were nesting in cracks and crevasses in the rocks and 2 pair of canyon wrens built grass nests within swallow nests for rearing their young.

Of interest has been the comparatively harmonious relationships which seem to exist between cliff swallows and other species of birds utilizing their nests. Winter usage of the nests as shelter would present no problems as the swallows are not there. However, in the Fort Morgan study area, house sparrows may occupy one-half or more of the nests in a swallow nesting site. This is a year-round occupancy, with the nests also used for winter shelter. The house sparrows have a brood of young about ready to fly by the time the swallows return from the south. When the swallows reappear, they simply repair old nests not being used by the sparrows and build new ones sufficient for their needs. The sparrows have not been observed to interfere with the brooding activities of the swallows. However, it is entirely possible that they do evict the swallows, because sparrow nestlings in newly constructed nests have been commonly observed.

The use of cliff swallow nests by other animal species is not confined to birds. In August of 1975, 2 juvenile deer mice, *Peromyscus maniculatus*, were discovered in a grass nest within a cliff swallow nest on a cliff face at the Weaver ranch near Fort Collins, Colorado.

The mud nests are finite, being subject to action of the elements when on exposed cliff faces. Nests under bridges frequently are loosened and fall as a result of continuing traffic vibrations. Without annual repair of old nests and the construction of new ones by returning swallows, the crumbling nests would, in a few years, be unsuitable for use by other species of birds either in the summer or winter. Consequently, the long-term maintenance of large populations of bugs depends on the regular return of cliff swallows.

High population densities of the swallow bugs commonly encountered attest to the fact that natural enemies exercise little control of the species. Spiders are commonly observed in and around the nests, evidently preying on the bugs. No systematic effort has been made as yet to collect spiders from the nests for identification. The following have been taken from cliff swallow nests in Larimer County, Colorado, in 1976–77: *Steatoda borealis*, family Theridiidae; *Herpyllus propinquus*, family Gnaphosidae; *Nuctenea* sp. (juveniles), family Araneidae; Dictyna sp. (females and juveniles), family Dictynidae; and *Mallos niveus*, family Dictynidae.

Four specimens of the masked bed bug hunter (*Reduvius personatus*), 2 early and 2 late instar nymphs, were discovered in a cliff swallow nest September 27, 1976, in the Lory State Park nesting site (Larimer County, Colorado). Two additional nymphs were taken from cliff swallow nests under a bridge June 6, 1977, in Weld County, Colorado.

It seems unlikely that parasitic wasps would overlook the concentrated mass of swallow bugs. However, the only species we have taken from the swallow nests has been *Nasonia vitripennis*, a parasite of the blow fly, *Protocalliphora hirundo*, which attacks the nestling swallows.

Acknowledgments

We thank Norman I. Platnick, American Museum of Natural History, for determining the spiders; Jon L. Herring, Systematic Entomology Laboratory, U. S. Department of Agriculture, for identifying the *Reduvius*; C. W. Sabrosky of the same Laboratory for the blow fly determination; and H. Evans, Colorado State University Zoology and Entomology Department, for specifically naming the wasp.

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New Genera and Species of Neotropical Tephritidae (Diptera)

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ABSTRACT

The following Neotropical taxa in the dipterous family Tephritidae are described: *Lezca*, n. gen., type-species *L. tau*, n. sp.; *Laksyetsa*, n. gen., type-species *L. trinotata*, n. sp.; *Caenoriata*, n. gen., type-species *Acrotaenia pertinax* Bates; and *Neotaracia*, n. gen., type-species *Acrotaenia imox* Bates. Comments on the relationships of these taxa to others are presented.

The following taxa of Mexican and Neotropical Tephritidae are described to make the names available for inclusion in a forthcoming key to the genera of Tephritidae occurring south of Texas and Florida.

Genus **Lezca,** new genus

Type-species.—*Lezca tau* Foote, new species.

Diagnosis.—In lateral view, head higher than long, frons and face meeting at an angle of about 135°; frons haired; 3 pairs lower fronto-orbitals; 2 pairs upper fronto-orbitals, ocellars poorly developed; face shining, spotted, with deep antennal grooves and broadly rounded carina; antenna distinctly longer than face, 3rd segment quite narrow, arista bare; 1 pair dorsocentrals, situated between transverse lines through the anterior supra-alars and postalars; acrostichals present; 1 pair anepisternals; 2 pair scutellars; wing hyaline with a prominent transverse two-toned brown band and other dark marks; vein r-m closer to vein dm-cu than length of former; vein R2 + 3 slightly sinuate; vein R4 + 5 haired; posterior extension of basal cubital cell long.

Discussion.—The genus *Lezca* rather closely resembles 3 other trypetine genera—*Cryptodacus* Hendel (Hendel 1914a, b), *Cryptoplagia* Aczél (Aczél 1951), and *Haywardina* Aczél (Aczél 1951). These 4 distinctive Neotropical genera feature a distally narrowed 2nd cell C, at least 1 prominent dark transverse band from the costa at or near the stigma to the posterior wing margin that may or may not cover both crossveins, a dark area covering the basal cubital cell and a region anterior to it, and usually an apical infuscation. From closely related genera, *Lezca* can be distinguished by the features shown in Table 1. The wing venation and pattern also afford distinguishing characters: veins r-m and dm-cu in *Cryptodacus* and *Cryptoplagia* are far removed from each other and are covered by separate transverse brown bands, while those of *Lezca* and *Haywardina* are situated very close together and are covered by a single brown band. The latter 2 genera differ from each other in that the transverse band of *Haywardina* is very narrow, and a 2nd partial transverse band is completely lacking. All 4 of these genera belong to the tribe Trypetini of the subfamily Trypetinae.

The name *Lezca*, gender hereby designated feminine, is an anagram of the name Aczél. Martin L. Aczél labored effectively to bring order out of chaos among the Neotropical genera of the subfamily Trypetinae.

Lezca tau, new species
(Figs. 1, 2, 4)

Head (fig. 1).—About 1.3 times as high as long; frons yellow, rather narrow, proportion of greatest width to length from ptilinal fissure to anterior corner of ocellar triangle 1.0:1.8, frontal setulae very slender, short, sparse; ocellar triangle black, ocellars only about as long as, but more slender than, posterior upper fronto-orbitals; 3rd antennal segment 4.5–5.0 times as long as greatest width,

Table I.—Comparison of taxonomic characters of trypetine genera.

	Lezca	*Haywardina*	*Cryptodacus*	*Cryptoplagia*
Face and frons mmeting in	angle of 135°	angle of 135°	curve	curve
Face surface	shining	matte	matte	matte
Facial spots	present	absent	absent	absent
Facial carina	present	present	absent	absent
Apex 3rd antennal segment	rounded	pointed	rounded	pointed
Antenna longer than face	yes	no	no	no
Ocellar bristles	short	long	long	long
Gena ⅓ eye height	yes	shorter	shorter	shorter
Location of dorso-centrals	between asa and pa	at asa	at pa	at asa
Vein r-m	beyond mid discal cell	beyond mid discal cell	beyond mid discal cell	at mid discal cell
Vein R2 + 3	straight	sinuate	straight	straight
Vein R4 + 5	haired	haired	haired	bare

slightly wider near apex than at base, base of arista yellow, remainder black; face in profile slightly swollen at middle, 1 pair large, rounded dark spots near anterior oral margin, antennal grooves deep along each side of rounded facial carina; gena with elongated black spot immediately ventrad of eye, postgenal setulae black; palpi expanded.

Thorax.—Scutum orange with a large black inverted triangle between and touching humeri, its apex extending posteriorly along ¼ to ⅓ length of scutum, or a longitudinal line in this position; a rounded black spot at base of prescutellar bristle and 2 narrower dark parallel postsutural fasciae, the supra-alar bristle in the ectal fascia and the postalar between them; a distinct median whitish triangle occupying posterior half of scutum; scuto-scutellar suture with a rather wide black band lying partly on the scutum, partly along anterior margin of scutellum, otherwise scutellum entirely light yellow; postscutellum black to yellow with longitudinal dark median line; humerus yellow; pleuron black but for contrasting yellow markings as follows: a wide band along dorsal margin of katepisternum; a diamond-shaped area along pleural suture, including wing base posteriorly, the top half of the diamond extending dorsally to cover visible portion of transverse suture; a small area surrounding base of halter. *Legs* with basal ⅓ of fore femur markedly expanded, setae in posteroventral row slender, shorter than width of femur at insertions, dorsal femoral setae scattered; basal half of mid femur infuscated posteriorly and ventrally; mid tibia yellow, lacking a row of outstanding setae; basal ⅔ of hind femur darkly infuscated around entire circumference; hind tibia less darkly but more extensively infuscated, with a row of heavy antero-dorsal setae, each about ¾ as long as diameter of tibia, extending full length of tibia. Wing (fig. 4) rather narrow, about 7 mm long, proportion of width to length 1.0:2.5; disk hyaline, with the following dark areas: a triangular area in posterior ½ of cell M extending posteriorly into basal part of CulA and ending about ½ the distance between base and apex of vein A; a wide brown fascia with narrow darker borders extending from cell 1st C through cell 2nd C, subcostal cell, bases of cells R1 and R3, apical ⅓ of cell R and extreme base of cell R5, through apical ⅓ of discal cell to hind margin; a much lighter brown area at apices of cells R3 and R5, and a faint dark area between the latter and the broad 2-toned brown band; vein r-m at a definite angle to vein dm-cu, these 2 veins much closer together along vein M than length of vein r-m, both crossveins covered by the dark brown margin of the wide transverse band; posterior extension of basal cubital cell about 4 times as long as its width at base.

Abdomen (fig. 2).—Yellow, a broad brown band covering all but extreme anterior and posterior borders and a narrow central area of tergite III, and 2 narrower mesal bands separated by a yellow area as wide as one of the bands, on each of the following tergites; in addition, dark spots at the extreme lateral margins of tergites IV and V and large paired dark spots laterally on tergite VI and sternite VI in the female; ovipositor sheath orange yellow, about as long dorsally as tergite VI. Epandrium rounded dorsally with rather long, thickly set setae; surstyli long, slender, only very slightly curved; glans nearly rectangular in outline, the basiphallus relatively short.

Type-series.—Holotype female, Cuernavaca, Mexico, 13-III-57, trampa cebo, O. Hernandez, coll. (USNM Type No. 75865); allotype male, same data; paratype (head and abdomen missing), same data, wing slide No. 15 (USNM).

The species is named for the unusual dark "T"-shaped mark on the abdominal dorsum.

Genus **Laksyetsa**, new genus

Type-species.—*Laksyetsa trinotata* Foote, new species.

Diagnosis.—In profile, head higher than long, frons and face meeting at an angle of about 120°; face shining, rather deep grooves beneath antennae but in no sense is a distinct carina present, spotted; frons haired, wider than long; 3 pairs lower fronto-orbitals, the anterior pair white; 2–3 pairs upper fronto-orbitals, all white; postoculars mixed black and white; parafrontal spot present; antenna as long as face, 3rd segment triangular but not distinctly pointed apically, arista bare; 1 pair dorsocentrals, situated in a transverse line through supra-alars; 3 pairs anepisternals; 1 pair katepisternals; 2 pairs anepimerals; 2 pairs scutellars, equal in length; wing essentially dark with numerous light spots; bulla present, vein R2 + 3 bent forward around it; vein r-m apicad of middle of discal cell; vein R4 + 5 bare or haired only at base; posterior extension of basal cubital cell nearly 2 times as long as its width at base.

Discussion.—This genus comes out in a key to Neotropical genera now in preparation with *Paracantha* Coquillett and *Neorhabdochaeta* Malloch in a unique group of genera within the tribe Ditrichini having a number of characteristics in common. The heads of species of all 3 genera are quite similar in having a wide frons, large lunule, antennae widely separated at their bases, notably projecting oral margin, the face with a spotted, shining surface, mixed black and white postoculars, the anterior lower fronto-orbital light colored in contrast to the 2 dark posterior pairs, the upper fronto-orbitals all light colored or whitish, the scutum beset with setulae such that 6–8 rounded bare spots remain on the surface in barely distinguishable patterns, and the fore femora with mixed dark and light bristles dorsally and ventrally.

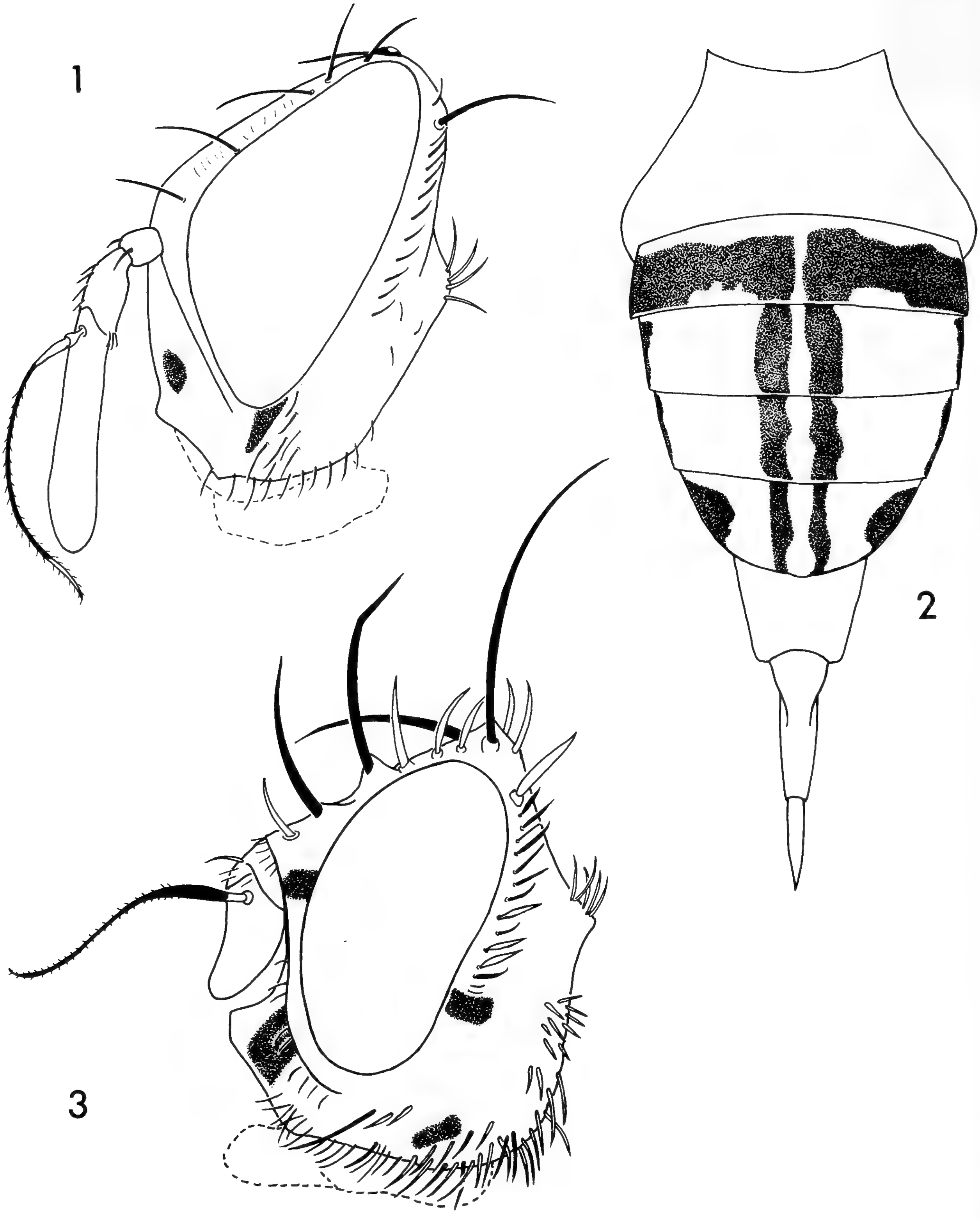
From *Paracantha* and *Neorhabdochaeta, Laksyetsa* may be distinguished by the wing pattern, which does not possess the characteristic dark rays from the center of the disk to the anterior, apical, and posterior margins, but is mainly dark with numerous light spots. In addition, the dorsocentrals of *Laksyetsa* are closer to a transverse line through the supra-alars than to the suture, and the anterior upper fronto-orbitals are located distinctly behind a transverse line through the posterior lower fronto-orbitals.

The name *Laksyetsa*, gender hereby designated feminine, is an anagram of the name Steyskal. George C. Steyskal originally pointed out that this genus had never been described or named.

Laksyetsa trinotata Foote, new species
(Figs. 3, 5)

Head (fig. 3).—In profile, about 2.5 times as high as long; frons about 2.4 times as wide as length from anterior tip of ocellar triangle to ptilinal fissure; setulae on surface extremely fine, lacking pigment; upper fronto-orbitals well mesad of line through lower fronto-orbitals, anterior upper fronto-orbital distinctly posterior to a transverse line through posterior lower fronto-orbitals; anterior pair of lower fronto-orbitals white, about 0.5 times as long as middle pair; ocellar triangle black; lunule with an "M"-shaped dark mark; face with 1 median black spot at level of posterior margin of 3rd antennal segment, another median spot at oral margin, and larger paired spots immediately anterior to anterior-most genal setulae; parafacial spot small but distinctly bordered; postocular row with 2–4 light colored setae among the black; genal bristle and 2–4 bristles close to it all about equal in size.

Thorax.—Brown, matte, with golden setulae which are absent directly behind head between humeri, in vicinity of visible parts of transverse suture, and directly posterior to bases of acrostichals on each side; 1 pair semicircular dark spots at extreme posterior end of scutum, continuing across scutoscutellar suture to cover basal corners of scutellum; 1 pair large rounded dark spots at bases of postalars; pleurae concolorous with scutum except for an indistinctly bordered dark brown stripe involving humerus and proceeding posteriorly between notopleurals below and presutural and postalar above, and a somewhat narrower dark stripe along upper margin of katepisternum; center of anepisternum and most of katespisternum suffused with darker brown; postscutellum entirely dark but with a pair of lateral, black bands when viewed in incident light from behind. *Legs* yellowish brown with darker brown markings in the following areas: most of posterior margin of fore femur but darker ventrally subapically and subbasally, fore tibia suffused with brown subapically and subbasally, femora and tibiae of mid and hind legs each with distinct black subbasal and subapical black spots, especially ventrally on the femora; posteroventral row of setae of fore femur mixed black and white; 5–6 setae in a posterior row on hind tibia, rather slender, shorter than diameter of tibia. *Wing* (fig. 5) 2.3 times as long as wide, field dark brown to base but slightly lighter along costa and in cell A, beset with numerous small rounded light brown (rather than hyaline) spots except in proximal posterior ¼ of disk, where these small spots lighten and coalesce to form a rather broad, nearly hyaline area; vein dm-cu distinctly bowed apically at middle.



Figs. 1–3. *Lezca tau*: 1, side view of head, female; 2, abdominal tergum, ovipositor sheath, ovipositor, female. *Laksyetsa trinotata*: 3, side view of head, female.

Abdomen.—Abdominal terga entirely matte, in female with paired median spots on tergites IV and V, dark area about 2 times as large on tergite IV as on tergite V; tergite VI entirely unspotted; in male, tergite V mostly black, those spots on tergite IV larger than in female. Ovipositor sheath as long as tergites V and VI together, suffused with brown, especially toward apex: epandrium with long setae dorsally, surstyli short, truncated, the prensisetae distinctly separated; glans with the appearance of a transverse plate subapically.

Type-series.—Holotype, female, Llano de las Flores, Oaxaca, Mexico, 24 November 1969, R. L. Hodgdon, flower head of *Dahlia tenuicaulis*. Intercepted Laredo, Tex. No. 000548, 69-24957 (USNM Type No. 75866) Allotype, male, same data. Paratypes: 1 male, 2 (without abdomens), same data, 1 female, 10 mi. W. El Salto, Durango, Mexico, 9000′, 30 June 1964, W. R. M. Mason (Canadian National Collection, Agriculture Canada). The specimens from Oaxaca were found in the flowers of *Dahlia tenuicaulis* being sent to the United States for propagation.

The species is named for the 3 dark spots on the anterior oral margin.

Genus **Caenoriata,** new genus

Type-species.—*Acrotaenia pertinax* Bates 1934: 12, fig. 3 (wing).

Diagnosis.—Frons bare; 3 pairs lower fronto-orbitals; 2 pairs upper fronto-orbitals, both pairs light-colored; all setae in postocular row concolorous light; face with broad, rounded carina; 2 pairs dorsocentrals, 1 pair anterior to transverse suture; both pairs notopleurals unicolorous; 2 pairs scutellars, posterior pair longer than 0.5 times anterior; basal 0.6 of wing (fig. 6) almost entirely dark with narrow dark rays radiating to anterior, apical, and posterior margins from center of cell R5; vein r-m apicad of middle of discal cell; vein R2 + 3 rather sinuate; posterior extension of basal cubital cell rather long; bulla absent.

Discussion.—The type-species, known only from Brazil, is the only known representative of the genus. For comments on relationships with other genera, see discussion section under the following genus.

The name *Caenoriata*, hereby designated feminine in gender, is an anagram of the generic name *Acrotaenia*.

Genus **Neotaracia,** new genus

Type-species.—*Acrotaenia imox* Bates 1934: 11, fig. 2 (wing).

Diagnosis.—Frons bare, 3 pairs lower fronto-orbitals; 2 pairs upper fronto-orbitals, only the posterior pair light colored; all setae in postocular row light colored; broad, rounded facial carina present; 1 pair dorsocentrals, situated almost directly in transverse suture; both pairs notopleurals the same color; 2 pairs scutellars, posterior pair less than 0.5 times length of anterior pair; wing (fig. 7) mostly dark, cell R1 almost completely and evenly dark save for a hyaline incision immediately apicad of subcostal cell and one at extreme apex descending into cell R2 + 3; vein r-m at or very close to middle of discal cell; vein R2 + 3 nearly straight; posterior extension of basal cubital cell quite short; bulla absent.

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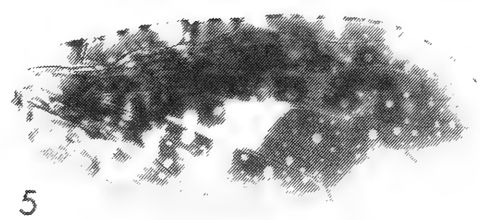

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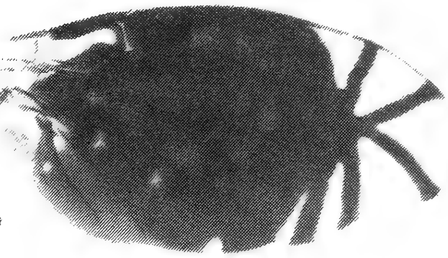

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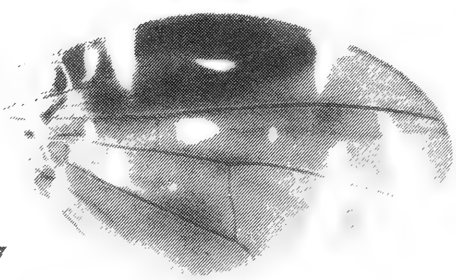

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Figs. 4–7, right wings. 4, *Lezca tau*; 5, *Laksyetsa trinotata*; 6, *Caenoriata pertinax* (Bates); 7, *Neotaracia imox* (Bates).

Discussion.—The type-species has been recorded to date only from Trinidad, Costa Rica, and Panama. The name *Neotaracia*, gender hereby designated feminine, is an anagram of the generic name *Acrotaenia*.

Caenoriata and *Neotaracia* are closely allied to *Acrotaenia* Loew and belong, with several other genera, to the tribe Platensinini of the subfamily Tephritinae. Table 2 sets forth the principal characters

Table II.—Comparison of taxonomic characters of tephritine genera.

	Acrotaenia	*Caenoriata*	*Neotaracia*
Color of postoculars	mixed dark and light	all light	all light
Frons	bare or haired	bare	bare
Upper fronto-orbitals	unicolorous	unicolorous	posterior pair light
Facial carina	absent	present	present
Dorsocentrals	1 pair	2 pairs	1 pair
Posterior pair scutellars	equal to anterior	longer than 0.5 anterior	shorter than 0.5 anterior
Vein r-m	beyond mid discal cell	beyond mid discal cell	at mid discal cell
Vein R2 + 3	sinuate	straight	straight
Posterior extension of basal cubital cell	very short	moderately long	very short

distinguishing the 3 genera being considered here. Although the wings of all 3 are rather similar structurally, their wing patterns differ markedly as shown in figs. 6 and 7. The wing of neither of the new genera possesses a) strongly emphasized bullae in the anterior basal quarter of the wing disk, b) the numerous small rounded hyaline spots in the basal half, nor c) the transverse brown bands in the apical third of the wing disk, all of which are so characteristic of *testudinea* (Loew), the type-species of *Acrotaenia*, and its true congeners. Species of *Acrotaenia* have been recorded from southern United States, Mexico, Central America, Bahamas, West Indies, Trinidad, and Brazil (Foote 1967), and I have seen additional specimens more recently from Colombia and Surinam.

Acknowledgments

The assistance of George C. Steyskal, my colleague in the Systematic Entomology Laboratory, in making preliminary studies of some of the new taxa described herein, is deeply appreciated. He and F. L. Blanc, Sacramento, California, critically and very effectively reviewed the manuscript.

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THE AWARDS PROGRAM OF THE ACADEMY

Kelso B. Morris, General Chairman

The Annual Awards Dinner meeting of the Academy was held on Thursday, March 16, 1978 at the Indian Spring Country Club. The general chairman, Dr. Kelso B. Morris of the faculty at Howard University, announced that four research scientists and three science teachers were recipients of the Academy's awards for outstanding scientific achievement.

In the area of research, the persons honored were the following: Dr. Robert Hogan (for the Behavioral Sciences) of the Johns Hopkins University; Dr. John Kebabian (for Biological Sciences) of National Institutes of Health; Dr. Tse-Fou Zien (for Engineering Sciences) of the Naval Surface Weapons Center; and Dr. Sandra C. Greer (for Physical Sciences) of the National Bureau of Standards. For the Teaching of Science, a joint award was presented to Dr. David S. Falk and Dr. Marjorie H. Gardner, both at the University of Maryland in the Physics and Chemistry Departments, respectively. The honoree for the Berenice G. Lamberton Award for teaching of High School Science was Mr. John Liebermann, Jr., of the T. C. Williams High School in Alexandria, Virginia.

Robert Hogan

Behavioral Sciences

Dr. Robert Hogan, Professor of Psychology at the Johns Hopkins University, was cited for "theoretical and empirical work in the developmental process of socialization." He was born in Los Angeles, California. In 1960, he received the A.B. degree from the University of California at Los Angeles. His Ph.D. degree was earned at the University of California at Berkeley in 1967. After completing all work for the Ph.D. degree, he was appointed Assistant Professor of Psychology at the Johns Hopkins University and held that position for four years (1967–71). He next advanced to the rank of Associate Professor and held that position until he was promoted in 1976 to his present rank, Professor of Psychology. He has more than forty publications at the present time.

He holds memberships in the following organizations: Eastern Psychological Association; American Psychological Association, and American Association for the Advancement of Science. Honors received by him are Summa Cum Laude when the A.B. was conferred; Phi Beta Kappa; and Fellow, Division 8, American Psychological Association.

John Kebabian

Biological Sciences

Dr. John Kebabian, Experimental Therapeutics Branch of the National Institute of Neurological and Communicative Disorders and Stroke, National Institutes of Health, Bethesda, Maryland, was cited for "outstanding demonstration of dopamine-sensitive adenylyl cyclase in mammalians." Dr. Kebabian was born in New York City. His B.S. degree was received from Yale College in 1968. At the graduate level, his M. Phil. (1970) and Ph.D. (1973) degrees were both earned at Yale University.

The honoree is a world recognized authority on the mechanism by which dopamine initiates its physiological effects. Our present knowledge of the biochemical events associated with dopamine receptor activity in the striatum is largely due to Dr. Kebabian's efforts.

Engineering Sciences

Dr. Tse-Fou Zien, Research Aerospace Engineer of the Mathematics and Engineering Branch (NSWC) was cited for "Significant contributions to the field of fluid mechanics and heat transfer through research and teaching that have gained him national recognition." He was born in Shanghai, China. His B.S. degree was received in June 1958 from National Taiwan University. His M.S. and Ph.D. degrees, respectively, were earned at Brown University and California Institute of Technology.

Organizations in which he holds membership are American Institute of Aeronautics and Astronautics (Associate Fellow); American Physical Society, and Society of the Sigma Xi.

The current issue of "Oak Leaf," a publication of the Naval Surface Weapons Center at White Oak, Maryland, contains a very enlightening article about Dr. Zien and his researches. In the article, Dr. Zien states that "heat transfer is closely tied to fluid mechanics. It is important to understand the heat transfer phenomena in the optimal design of vehicles." In addition to his being a

Tse-Fou Zien

Biographee in the current issue of "Who's Who in the East" (Marquis), he received an outstanding performance award with quality salary increase in 1974.

Physical Sciences

Dr. Sandra Greer, the honoree this year in the Physical Sciences, is a researcher in the Institute for Basic Standards at National Bureau of Standards, Washington, D. C. She was cited for "her outstanding achievement as a research scientist in devising a carrying out experiments and applying new theories so as to help produce a better understanding of the behavior of systems near critical points."

Dr. Greer is a native of Greenville, South Carolina. Her undergraduate degree, B.S. (magna cum laude) was received at Furman University in 1966. Both her M.S. (1968) and Ph.D. (1969) degrees, respectively, were earned at the University of Chicago.

Organizations in which she holds membership are the following: AAAS; American Physical Society, and American Chemical Society.

Sandra Greer

In her researches, she and her associates recognize that critical points are points of inherent instability. Such points occur in diverse systems such as, for example, pure fluids; fluid mixtures, magnetic solids, and binary alloys. The instabilities are sufficiently strong to produce anomalous behavior over a moderately large region around the critical point for each kind of system. This and the fact that critical points are end points of loci of phase transitions makes understanding the behavior of systems near their critical points important both scientifically and technologically.

Teaching of Science
A Joint Award

The two recipients of this Award are Dr. David S. Falk and Dr. Marjorie H. Gardner, both at the University of Maryland. Dr. Falk was cited for being an innovative teacher and an able administrator of Physics Education." For Dr. Gardner, the citation was "for her great local, national, and international impact on chemistry teaching."

Dr. Marjorie H. Gardner was born in Logan, Utah. Her B.S. in Political Science/Chemistry was received from Utah State University in 1946. Her M.A. and Ph.D. degrees, both in Science Education and Chemistry, were earned at Ohio State University in 1958 and 1960, respectively.

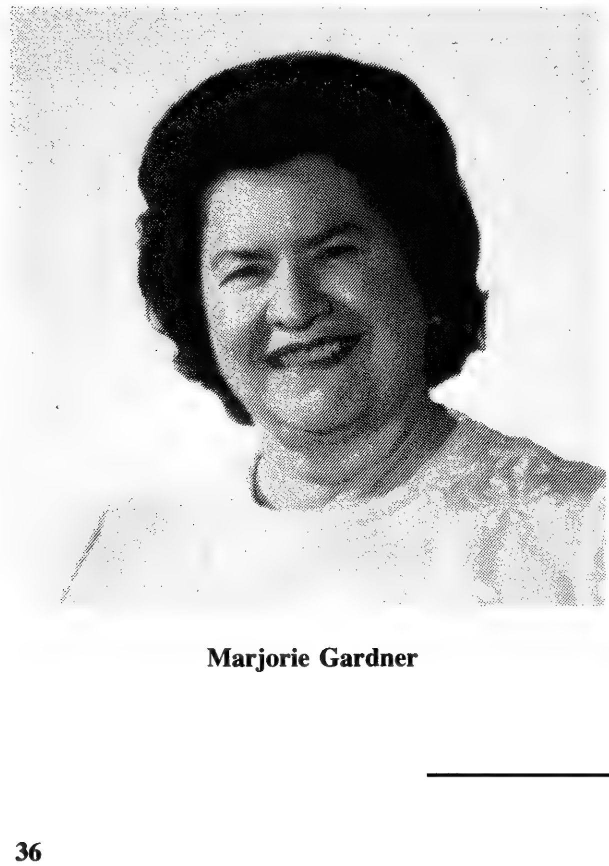
Her experience in higher education is rather noteworthy. She joined the University of Maryland as an Assistant Professor (Chemistry and Secondary Education) in 1964. Today she is an Associate Dean in the College of Education and a Professor of Chemistry and Secondary Education. Part of her experience involves participation in national and international meetings.

Memberships in scientific organizations include the following: American Association for the Advancement of

David Falk

Science; American Chemical Society; American Educational Research Association; American Institute of Chemists; and others.

The other co-winner of the Award, Dr. David S. Falk, was born in New York City. His B.S. degree was earned at Cornell University in 1954. The M.A. and Ph.D. degrees were both earned at Harvard University in 1955 and 1959, respectively.



Marjorie Gardner

He has been associated with the University of Maryland since 1961. Today, he is Professor and Associate Chairman of the Department of Physics and Astronomy at the University of Maryland.

Professional and honorary memberships include Tau Beta Pi, Sigma Xi, and the American Physical Society.

He is described by associates as an able administrator of science teaching. As the Department Associate Chairman for Educational Affairs, he is responsible for the total physics teaching program.

The Berenice G. Lamberton Award
Teaching of High School Science

Mr. John Liebermann, Jr. is a resident of Fairfax, Virginia. As the recipient of the Berenice G. Lamberton Award for Teaching of High School Science, he was cited for "inspiring students to excell in science through effort and application by the example he set for them in his teaching and research."

He was born in Washington, D. C. His B.S. degree in Chemistry was received from George Mason University in 1969. He is currently studying toward the Ph.D. degree at American University. Organizations in which he holds membership are: NEA, VEA, EAA, and American Chemical Society.

At the end of the presentation of the Awardees, the General Chairman stated that personal efforts were made by him a few years ago to make certain that the President, Deans and Department Heads in science-related fields at the Johns Hopkins University developed a greater awareness of the Awards Program of the Washington Academy of Sciences. It is significant, therefore, that the awardee this year in the Behavioral Sciences is the first one from that institution.—*Kelso B. Morris.*

SCIENTISTS IN THE NEWS

Contributions in this section of your Journal are earnestly solicited. They should be typed double-spaced and sent to the Editor by the 10th of the month preceding the issue for which they are intended.

National Institutes of Health

Dr. Robert H. Purcell, head of the Viral Hepatitis Section of the Laboratory of Infectious Diseases, National Institute of Allergy and Infectious Diseases, was recently awarded the Gorgas Medal for 1977 by the American Association of Military Surgeons.

This medal is presented annually for "distinguished work in preventive medicine" and Dr. Purcell was given the honor for his outstanding contributions to the development of methods for detecting and preventing viral hepatitis.

Dr. Purcell has made many contributions to the study of viral hepatitis and his accomplishments have made him an internationally recognized authority.

His leadership of research teams attacking the various aspects of this major public health problem has led to the development of prototype vaccines for hepatitis B, and to visualization of the virus causing hepatitis A—a first step toward prevention.

Recently, Dr. Purcell and his colleagues have presented evidence that in addition to hepatitis B virus at least one other hepatitis viral agent (non-A non-B) can be transmitted by blood transfusions.

A graduate of Oklahoma State University in 1957, Dr. Purcell received his M.S. degree in biochemistry from Baylor University in 1960 and received his M.D. degree in 1962 from Duke University.

Dr. Purcell came to NIAID in 1963. Since 1967 he has headed the Institute's intramural hepatitis research program.

Dr. Robert J. Huebner has retired after 35 years with the U. S. Public Health Service. He came to NIH in 1944 and studied infectious diseases until 1968, when he became chief of the National Cancer Institute Laboratory of RNA Tumor Viruses.

Dr. Huebner will continue doing research at NCI as an expert consultant on RNA tumor viruses and on immune protection against cancer.

He entered the PHS in 1942 after receiving his M.D. degree from the St. Louis University School of Medicine. "I wanted to go into endocrinology," he says, "but infectious disease was the only field that was open."

While working for the National Institute of Allergy and Infectious Diseases, Dr. Huebner's experience ranged from catching rats in Harlem to checking household milk supplies in Los Angeles to investigating Coxsackie virus in Texas.

Dr. Wallace Rowe, a co-worker at NIAID, said that Dr. Huebner first received distinction by investigating a rickettsial outbreak in New York City.

"In record time, Dr. Huebner had identified the organism and the vector," says Dr. Rowe. "He had solved the whole problem in 2 months—and he was basically a kid just starting out."

Then Dr. Huebner was off to California to investigate a Q-fever epidemic which was being spread in milk. Q-fever is a respiratory infection caused by another rickettsial microorganism.

He set up his lab in a garage and hired young people living in the neighborhood to take care of his experimental animals.

In 1950, after 3 years and between 3,000 and 4,000 household visits, his report that the disease was carried in milk was released by the American Medical Association.

"When that hit the papers, there were weeks that no milk could be sold. The dairy industry didn't even want me in the state," he recalls.

Dr. Huebner did extensive work with Coxsackie A virus in Maryland, swabbing the throats of hundreds of school children in the process. He also discovered several viruses responsible for herpangina.

Dr. Huebner also worked in Texas with a disease called devil's grip, distinguished by chest pain and fever. He demonstrated that devil's grip is caused by the Coxsackie B3 virus.

In the late 1950's, Dr. Huebner began to work with polyoma viruses and other tumor viruses in animals, and he developed a special procedure that enables research to be done with tumor viruses just as it is with other viruses.

He later discovered that adenoviruses produced tumors in mice. Further study showed that these tumors contained viral proteins, which are the telltale signs of virus infection in the cell.

However, subsequent studies he has conducted have shown that there is no relationship between adenoviruses and human cancer.

In 1969, Dr. Huebner and Dr. George Todaro of NCI introduced the viral oncogene theory.

This theory incorporated the idea that cancer viruses were genetically inherited and yet could be dealt with as an infectious disease, plus the idea that the key determinant of cancer is in the genes.

It states that there are transforming genes, or oncogenes, that exist in DNA and viruses. These can transform the cell from a normal state to a cancerous state when a cellular mechanism is not in control.

"Dr. Huebner has a tremendous breadth of interest and the ability to see things that others just don't see," Dr. Todaro says. "His contribution to tumor virology goes far beyond the oncogene theory.

"Some of his observations in the early 1960's were key to the molecular biology now being done; things that are now being taken for granted."

Dr. Huebner is now trying to identify a tumor antigen associated with many types of cancer in man. Such an antigen might lead to the development of tumor vaccines in humans.

"There are a lot of things still left to do," he says. "One of these days I've got to write a book. . . . It's all kind of an adventure."

NAVAL SHIP R&D CENTER

Dr. Elizabeth H. Cuthill, the Numerical Analysis Coordinator for the Computation, Mathematics, and Logistics Department of the David W. Taylor Naval Ship R&D Center (DTNSRDC), Bethesda, Maryland, recently received the David W. Taylor Award for Scientific Achievement for the calendar year 1976.

Dr. Cuthill was recognized for her valuable contributions in the development and exploitation of mathematical and computational techniques for significant Navy applications. Her achievements date back to when she first joined DTNSRDC in 1953 and include technical leadership in the development of the Navy's nuclear reactor codes, a field in which she and her colleagues were preeminent and internationally recognized for their many accomplishments. Upon completion of this effort, Dr. Cuthill led the successful development of the widely used General Bending Response Codes which have received

Dr. Elizabeth H. Cuthill

wide acceptance and are in general use throughout the nation. She was also the leader within the Navy in promoting the use of general purpose finite element codes for structural analysis.

Dr. Cuthill's personal technical contributions include the development of band width reduction techniques which reduced by half the time and cost of structural analysis calculations. A leader in exploiting the use of computers for symbolic mathematics, she is presently engaged in making this capability available to the entire Navy laboratory community.

Captain Myron V. Ricketts, USN, DTNSRDC Commander, presented the Award to Dr. Cuthill, citing her "outstanding personal contributions and technical leadership." Reviewing her accomplishments Captain Ricketts praised her "technical excellence and expertise of the highest order, scientific productivity addressed to Navy applications of major significance, and an ability to motivate and lead colleagues and subordinates."

The Award is named after Rear Admiral David Watson Taylor, a naval constructor with a brilliant reputation in the field of naval engineering who was the driving force behind the development and adoption of modern experimental techniques in ship and aircraft research. Originally established by the Navy in 1961, this Award has been presented annually since that time to the individual scientist whose contributions were considered truly outstanding in the field of research and development.

Dr. Cuthill is the author of many papers on mathematical and computational techniques and is a member of the following societies and associations: Phi Beta Kappa, Sigma Xi, the American Mathematical Society, the Mathematical Association of America, the Society for Industrial and Applied Mathematics, the Association for Computing Machinery, the American Association for the Advancement of Science, and the Washington Philosophical Society.

RICE UNIVERSITY

Dr. Frederick D. Rossini, professor emeritus of chemistry at Rice University and an internationally recognized authority on petroleum chemistry, received the National Medal of Science from President Carter at ceremonies in Washington, D. C., Tuesday, Nov. 22, 1977. Dr. Rossini, 78, was honored for his "contributions to basic reference knowledge in chemical thermodynamics."

The award—one of 15 made by President Carter—came to Dr. Rossini some 13 months after receiving the coveted Carl Engler Medal from the German Society for Petroleum and Coal Chemistry, Germany's equivalent of the American Petroleum Institute. It recognized the Rice professor's outstanding contributions to Petroleum research over the past several decades. Dr. Rossini is one of the very few non-Germans to win the Carl Engler Medal.

The National Medal of Science Dr. Rossini received Tuesday from President Carter was established in 1959 by the 86th Congress. It is awarded to individuals "deserving special recognition by reason of their outstanding contributions to knowledge in the physical, biological, mathematical, or engineering sciences."

Dr. Rossini, a native of Monongahela, Pennsylvania, is a member of the National Academy of Sciences and past presidents of the London-based World Petroleum Congress and of the Washington Academy of Sciences. He is the author of some 250 scientific articles and 11 books dealing mainly with thermodynamics, thermochemistry, numerical data for science and technology, and the physical chemistry of petroleum and hydrocarbons.

Dr. Rossini joined the Rice faculty in 1971 after a distinguished academic and governmental career that began in 1923 as a laboratory assistant in physics at the Carnegie Institute of Technology (now Carnegie-Mellon University) and included 22 years (1928–1950) with the National Bureau of Standards in Washington, D. C.

NEW AFFILIATE

The Potomac Chapter of the American Fisheries Society, organized as a local chapter of the parent national society in 1976, is a new affiliate of the Academy.

Objectives: a.) To promote the conservation and effective management of fish, other aquatic environment for the optimum benefit of the people of this continent. b.) To advance the science, technology, education, and practice of all branches and disciplines related to the conservation of aquatic resources. c.) To encourage and recognize effective performance in all aspects of the fisheries profession. d.) To encourage and promote effective communications among professional aquatic scientists, and between the profession and the public.

Members: The membership of the Chapter shall be composed of those American Fisheries Society members in good standing residing in Maryland, Virginia, District of Columbia, and Jefferson, Berkeley, and Morgan Counties of West Va. who are listed on the Chapter membership roll by virtue of having paid established Chapter dues.

Meetings: The chapter shall hold at least one (1) meeting annually at a time and place designated by the Executive Committee or its officially delegated alternate committee. The program and presentation of papers shall be the responsibility of the Program Committee.

OBITUARY

Louis S. Jaffe, 63, professor of epidemiology and environmental health at George Washington University's medical school, died July 24, 1977 after a heart attack while vacationing in Israel. He lived on Highland Drive in Silver Spring.

Jaffe was a pioneer in the development of air quality criteria—the technical documents which delineate the various effects of specific air pollutants on man, animals, vegetation and materials and serve as the cornerstones of the national air quality standards.

He joined the medical school staff in 1970 upon his retirement from the U. S. Public Health Service. His last assignment during his 31 years of government service was as physical science administrator and special assistant to the director of the air quality criteria and standards development program.

A native of Newark, N. J., and a graduate of Brooklyn College and Columbia University, Jaffe was elected a fellow in the Washington Academy of Sciences in 1974 in recognition of his contributions to environmental medicine.

Jaffe was active in civic affairs and at the time of his death was a vice president of the National Capital Area of B'nai B'rith Lodges. He was a past president of the Cardoza and Montgomery Lodges.

He also served a two-year term as president of the Woodside Park Civic Association in Silver Spring and was a former chairman of the Montgomery County Civic Federation's planning and zoning committee.

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CONTENTS

Features:

Research Reports:

Academy Affairs:

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Biological Society of Washington	William R. Heyer
Chemical Society of Washington	David H. Freeman
Entomological Society of Washington	D. W. S. Sutherland
National Geographic Society	T. Dale Stewart
Geological Society of Washington	Marian M. Schnepfe
Medical Society of the District of Columbia	Inactive
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Electrochemical Society	Delegate not appointed
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American Association of Physics Teachers	To be appointed
Optical Society of America	Lucy B. Hagan
American Society of Plant Physiologists	Walter Shropshire
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Human Factors Society	H. McIlvaine Parsons
American Fisheries Society	No delegate

Delegates continue in office until new selections are made by the representative societies.

On the Humanism of Science[1]

Raymond J. Seeger

National Science Foundation (Retired).

John Donne, the poetic Dean of St. Paul's Cathedral (London), wrote in his "Devotions" (1624), "No man is an island entire of itself." We live in one world; we all live in the same world. There isn't an old world and a new world, a white world and a black world, a man's world and a woman's world, a starry world above and a moral world within, a natural world and a supernatural world, an objective world and an existential world, a world of science and a world of humanities. We all live in one world, the same world.

Our experience, too, is one: we the subject, the world the object. Years ago when I was teaching a physics course, on "Our Physical Heritage" for non-science students, I invited a professor of history to lecture on the reciprocal influences of history and science. "What," he began, "is history?" "History," he proclaimed, "is the study of man and his environment!" I made a note of this; although I had studied history all my life, no one had ever bothered to define it for me. Later I asked a professor of philosophy to discuss philosophical implications of science. "What is philosophy?" he asked rhetorically. "The study of man and his environment!" he explained. For the moment I was nonplussed. The next year, however, I introduced the course with a query, "What is physics?" "The study of man and his environment!" I joyfully announced. I, too, had realized that we are all studying the same thing, namely, the universe with man at its focus—but different aspects of it.

The English Augustan poet Alexander Pope argued in his "Essay on Man" (1737), "The proper study of mankind is man"—usually understood to advocate a separation of man from his environment. This poem, however, which deals primarily with the justification of God's ways to man, connotes a quite different discrimination as shown in the preceding line: "Know then thyself, presume not God to scan." Ralph Waldo Emerson, the American transcendentalist essayist, also invoked the Delphic oracle in his famous Phi Beta Kappa address (1837) on "The American Scholar;" "The ancient precept, 'Know thyself,' and the modern precept, 'Study nature,' become at last one maxim." Man is thus part and partner in his changing environment—what might properly be called human ecology. The Greeks never separated man from his environment. They looked at nature and discovered it to be real and interesting and comprehensible. Greece itself contained both scientific Ionia and humanistic Attica in continuous communication. The word interesting, by the way, comes from the Latin inter esse, meaning to be among, viz., man and his environment. One cannot conceive of a man without an environment, and even the women's lib is loath to have an environment without a man.

[1] Given at colleges and universities under the NSF-funded Sigma Xi Bicentennial Lecture Program (1974–1977) on "Science and Society."

Nevertheless, we are wont to view our experience in differently colored lights, whether we look at a planet or a plant or a person. We can distinguish three primary cultural colors. There is sky blue signifying our aesthetic enjoyment—"how brief the beauty of the moon!" Grass green symbolizes the nourishment of scientific relatedness—how "the moon may draw the sea!" Earth red represents technological use—how "He appointed the moon for certain seasons!" Possibly a fourth light! an invisible aura—within the red, beyond the violet—that intimates mystically the unity of the universe! This many colored rainbow shines upon our everyday life. We need its integrated light to insure the integrity of our personal experience.

Our outlook, however, is colored by our daily lookout through the tinted education spectacles furnished each one of us upon scholarly matriculation. Everyone nowadays is familiar with the two academic cultures publicized (1959, 1963) by Charles Percy Snow, the British novelist. He himself is always careful to indicate that these two cultures—so-called humanities and science—are strictly academic fields. He deplores the gap between them and urges that it be bridged (modern education is spuriously measured at times by their very distance apart). It is, indeed, remarkable that both the "Civilisation" (1969) by the English art connoisseur Kenneth McKenzie Clark and the "Ascent of Man" (1971) by the English humanist mathematician Jacob Bronowski exhibit so little overlap, although they are presumably describing the same world. They reveal little evidence of the underlap of their common experience—a natural bridge. I must confess, however, my own deeper anxiety about the need to bridge a far greater gap, namely, that between these very academic cultures and the nonacademic—not our concern here.

Victor Cousin, the French eclectic philosopher, sounded a tocsin in his 1818 Sorbonne lectures: "L'art pour l'art" ("art for art's sake"). Some modern scientists would counter with the slogan, "Science for the sake of science." More basic, I believe, is, "Art and science together for man!" We must comprehend them. I am personally dissatisfied with the academic compartmentalization of ideas resulting so often from an administrative departmentalization of fields of interest.

Like the pilgrim (1638) of the English non-conformist preacher John Bunyan, we are eager to set out on a quest for ultimate truths. But like Alighieri Dante, the Italian philosophic poet, "Midway upon the journey of our life I found myself in a dark wood where the right way was lost" (c. 1307). It was the Roman epic poet Vergil who guided him through Hell, where he accosted the Greek empirically oriented philosopher Aristotle as "the master of those who know." Aristotle, indeed, had begun his "metaphysics," All men by their very nature feel the urge to know"—owing to an innate curiosity about their awful environment. Wondering Ionians sought eternal answers to their perennial questions: where am I? who am I? what will I be? This perpetual quest is a unique human activity. In his pursuit of it man has become enchanted with his mysterious universe; he zealously searches for a unifying pattern—not a crazy quilt of his own making. I do not fathom a recent pronouncement of Harvey Cox, that apparently godless Harvard theologian: "Life is not an unfathomable mystery. . . . We know there is no ordered universe awaiting the discovery of it by man. . . . The universe is a human invention." Who would be so egotistical as to believe the universe to be man-made?

I pity the modern Macbeths who regard life as "a tale told by an idiot, full of sound and fury, signifying nothing." I pity modern dramatists—the Czech Karl Capek who would try to solve human problems with dehumanized robots (R. U. R. 1921); the German Friedrich Dürrenmatt who would have physicists seek security in an insane asylum (1962). I pity modern novelists: the English George Orwell with his 1984 madmen seemingly united in a meaningless brother-hood (1949); the English Aldous Huxley seeking solace in his caricature of scientists as cringing creatures crawling blindlessly to escape his so-called "Brave New World" (1932), only to become later (1958) Buddhist addicts to painless nihilism.

In his perpetual quest for knowledge, on the contrary, man has found some comfort in science's liberation from cultural bondage of some of his attitudes and thoughts. We shall now focus our attention on this humanistic science.

Confusion is rampant with respect to humanism in general and the humanities in particular. One speaks thoughtlessly of literary humanists, scientific humanists, Christian humanists, et al. The term humanities, in turn, varies from college to college (in their catalogues); it is actually defined in the final report (1964) of the U. S. Commission of Humanities, viz., "The humanities are the study of that which is most human. . . . The body is usually taken to include the study of history, the arts, religion, and philosophy." No science? Jacques Maritain, the French religious philosopher, whom no one can accuse of being partial to natural science, advocated in the Terry lectures (1943) on "Education at the Crossroads," "Physics should be taught and revered as a liberal art of the first rank, like poetry." We are liable to forget that one of the nine muses was Urania (astronomy). The Roman statesman Cassiadorus' seven liberal arts comprised the trivium (grammar, logic, rhetoric) and the quadrivium (astronomy, arithmetic, geometry, music (then largely applied mathematics)). What happened over the ages? Nevertheless, the liberal arts, in principle, have always been for free men, to set men free, free to drink hemlock or to die on a cross for the general welfare. In historical perspective we can see the omnipresent role of science in the spread of humanism.

What is humanism? We might seek its origin in the Greek philosopher Socrates' ethical concerns in the golden age of antiquity or in the Renaissance's emphasis upon the dignity of an individual. It is amazing how often a representative humanist is popularly selected to be a non-scientist. My own preference would be a person like the Italian genius Leonardo da Vinci who doodled with art alongside his engineering notes and with engineering alongside the ones on art. Another versatile person was the Italian natural philosopher Galileo Galilei. In later life he reminisced about his youthful dream of becoming an artist (the American art critic Erwin Panofsky concluded that he probably would have been successful in this capacity). In the tradition of his family (his father was a composer) he himself played several musical instruments. He boasted, when young, of knowing by heart the entire "Orlando Furioso" (1516) by the Italian poet Lodovico Ariosto. His own writings in the vernacular was an expression of his overwhelming desire to impress his own convictions on the common reader of his day. That led to his celebrated social controversy with the ruling Church; the people understood him.

The popular formulation of humanism is credited to the Roman dramatist Publius Terentius Afer; in his comedy "Heauton Timoramenos" (168 B.C., "The Self-Tormentor") a retired farmer justifies his own interest in the activities of a neighbor's son by the remark, "Homo sum: humani nihil a alienum puto" ("I am a man: I consider nothing of man alien to me"). There are, however, different levels of human interest, from the star light of idealistic youth to the earth dung of realistic babes. The intelligent (Latin *inter legere*—to choose between) person chooses between possible courses of action; he discriminates rather than behaving promiscuously at random. The Greeks, for example, chose the potential excellence of the individual; for them humanism meant man at his best.

In this spirit, we, too, might regard humanistic science from purely classical viewpoints: "the glory that was Greece and the grandeur that was Rome," the grace that was Galilee. We must, however, be careful not to become mere antiquarians; we must look also from a modern point of view. For example, it is not enough that we share Dante's feeling as he regarded the Ptolemaic universe of his day; we must consider how he might have felt in the Copernican universe of today. Regardless of our esteem for the classical vision (I myself began college as a classics major) or of our indebtedness to its later renascence (I still admire Galileo) we must be sensitive to the distinctive feature of our current culture, its new dimension of science and technology. To be sure, this itself is actually an extension of man's propensities and interests and capabilities. It is, therefore, surprising to find so little regard for science in "Democratic Experience" (1975) by the Pulitzer prize winning Librarian of Congress, Daniel Joseph Boorstin.

There is, moreover, understandably widespread popular confusion between these two technical terms, science and technology. They can be regarded actually as the extremes of a whole spectrum; scientific understanding per se and technological utilizing per se. The former leads to intellectual abstractions, the latter to social (including moral) applications. One cannot fix any artificial line of demarcation which, at best, would shift with dominant interest from time to time. The picture is further complicated by their continuous interactions. For example, the amusing electric phenomena of the early nineteenth century gave rise to the engulfing electrical age at its close, while the contemporary powerful steam engine led inevitably to the fascinating field of thermophysics.

It is helpful to distinguish three different types of revolutions in this cultural melée. First of all, there have been a number of technological revolutions, all of which have been concerned primarily with sources of energy and power. (As someone remarked, "The greatest invention in the nineteenth century was the invention of invention.") One begins naturally with man's use of mechanical energy, the energy of the wind and of the wave, with manpower and horsepower. Then came his employment of electrical energy, which was succeeded by chemical energy, and now by so-called atomic energy. As each new form of energy has come into prominence, new social (and moral) problems have been encountered.

Strictly scientific revolutions, on the contrary, have revolved about central ideas. For example, in the time of Galileo one might have properly inquired, "How does a stone fall?" "Let us consult Aristotle," would volunteer a classical scholar. "Why not Thomas Aquinas?" would urge a Christian thinker. Galileo, however, would probably ask, "Why not observe it directly as it falls?" Such a suggestion that one might obtain some answers directly from nature itself was truly revolutionary. In the nineteenth century some speculators were emboldened to seek answers to all man's questions in this manner (but not I). Today there are some who claim that man can obtain such answers solely by the method of the physical sciences (but not I). Even though we may be able pragmatically to describe behavior sufficiently for everyday use, we cannot necessarily explain it to our complete satisfaction; for example, the origin of matter and life, of mind and spirit. With each scientific revolution there are disclosed new intellectual problems of a decidedly personal concern because of their philosophical and religious implications.

The twentieth century ushered in a third type of revolution, what might be called scientific-technological. Certain (not all) fields of science and of technology apparently converge with beneficial interactions. Because one can describe certain phenomena scientifically, one then finds that one can make technological predictions. Accordingly, organized research, jointly basic and applied, has become sponsored by industry and by government and even by academia. In such common ventures, however, there is always a danger that one component will completely overshadow the other. In his "Grand Academy of Lagado in Laputa" (1726) the Irish satirist Jonathan Swift noted that while the dedicated projectors were trying to understand phenomena (e.g., the extraction of sunbeams out of cucumbers), "the whole country lies miserably waste, the houses in ruins and the people without food or clothes." Here was an extreme prevalence of personal scientific interests with dire social consequences. Nowadays the opposite is increasingly true: an anxious overemphasis upon harvesting technological fruits is leading to a careless neglect of sowing scientific seeds, a short-sighted search for social applications to the neglect of long-range basic science (new wars are not won now with old weapons). In life one must always allow a margin for the unexpected, in science for technology and in technology for science.

Evidently a primary democratic need today is understanding of science by the public. We shall not be concerned here with reasons for the widespread current misunderstanding; to what extent it may be due to the spreading habit of technical jargon in all fields of human endeavor, to what extent it is a consequence of ever vacillating fashions of professional educationalists. Mommy consoles Johnny, "You are having trouble with the new mathematics? Don't worry; Mommy had trouble with the old mathematics. And look how she turned out!" (When Johnny did, he really became worried.) One time when I passed out problems to my sophomore Physics students, one of them exclaimed, "Do you expect me to do these? Who do you think I am? Einstein?" I looked at him quizzically and replied, "No! Einstein wouldn't be taking this course the fourth time." A Congressman once illustrated the scientific method as follows: Pluck the legs off a grasshopper, one by one. In each case tell the grasshopper then to hop; he will do so until all the legs have been removed. "Proving," said the Congressman, "by the scientific method that when a grasshopper has lost all its legs it has lost also its sense of hearing!" Our modern culture is permeated with such everyday misunderstandings of science.

Evidently the public needs to improve its understanding of natural phenomena, and, even more, the very understanding of that understanding, viz., the development of scientific thinking, including its interactions with politics and economics, with sociology and ethics, its philosophical and religious implications. Science, I am convinced, can and must be taught humanistically. After all, scientists are people, human beings. They are not the youthful (21) Mary Godwin Shelley's Frankenstein creating fantastic monsters; they are not the fanciful creatures lurking in the horror nightmares of science-fiction writers. On the other hand, one is well aware that even the so-called humanities are not necessarily taught humanistically.

What is science? Essentially it is not such academic misrepresentations as the following: "Information, please!" Organized common sense. Black magic ("Beyond me!") Black-box gadgetry. Mysterious mathematics (with the imprimatur Q.E.D.). Technically, it is not primarily induction as popularized by the English lawyer statesman Francis Bacon (1620), or deduction as argued by the French mathematical philosopher René Descartes (1637), or puzzle solving as advocated by the American historian of science Thomas Samuel Kuhn (1962). Each of these, to be sure, may be involved in scientific reasoning, but none of these is the fundamental criterion which was characteristic of the experiential work of Galileo.

What, then, is science? Obviously the result of the so-called scientific method! And this? Something used by a scientist! It would appear that we are merely begging the question. On the contrary, we are emphasizing that the "what" of science is dependent on "how" this is reached, which is meaningless except in terms of "who" does it. This point of view can be illustrated with four essential elements that are inherent in any accepted scientific method.

First of all, I—and you (the scientific method is necessarily communal)—experience something, with nature as a source (possibly indirect). (One should preferably study nature—not science. Note that mathematics per se is excluded in this definition.) Out of our intellectual curiosity we frame questions, selected, but not necessarily answerable at the time. In religious studies, for example, typical questions were the following: Why cannot an omnipotent God make a triangular circle? How many angels can be placed on the point of a needle? In mathematics, why can't I try to square a circle if I wish to do so? Which is larger $\sqrt{1}$ or $\sqrt{-1}$? In physics, what is the color of that beautiful atom? Where is the elusive electron inside it? Selective questions allow for even fewer possible answers, obtained sometimes by penetrating insight, at other times through mystifying intuition. What is truly embarrassing is to have irrelevant questions reveal relevant answers, to find impertinent questions lead to pertinent relations. One's experience, to be sure, depends upon the questioner "who."

Secondly, I—and you—review these findings somehow, with imagination as inspiration—in the sense of the English romantic poet Samuel Taylor Coleridge, i.e., definitely not imaginary or fanciful, like a mermaid. An old lady once accosted the English romantic painter Joseph M. W. Turner, "I've never seen a sunset look like that!" He replied "Don't you wish you could?" The French Fauvist Georges Rouault was asked how he was able to portray so brilliantly the glistening white birches of spring. "By observing the snow-clad fields of winter" was the reply. As the English natural philosopher Isaac Newton sat under an old apple tree, an apple fell on his head. "What a lucky day!" he probably mused, "Suppose it had been the moon!" What a revolutionary comparison, a moonlike apple and an applelike moon! This was the first time man conceived of a physical universe, where the gravity of the earth acts on both moons and apples. Up to that time, man had actually inhabited a duoverse with the celestial heaven perfect and unchanging while in the terrestrial region below it there was a perfect mess ever changing. What a comprehensive imagination—made possible by the intellectual and emotional freedom of a scientist "who."

The third element is your ability—and mine—to deduce something else, with reason as a guide. We insist upon logical consistency with respect to man's mind. In this connection we note the role of mathematics which may insure sufficiency, but not necessity. Suppose, for example, the price x of an apple is given by the equation $x^2 = 25$. Is 5¢ the correct answer? No! there are two answers; the one we choose is determined by the marketplace. Mathematics, you see, may tell us about all possible worlds that fit our stipulations. The actual world, however, can be determined only by some experiential boundary condition.

The fourth element is that very criterion: I—and you—check our conclusions, with nature as a re-source. Our speculations must be bound by our experience. You may recall the antics which the Greek giant Antaeus exhibited when he was strangled mid-air by that work-force of the Greek gods, Heracles. The unforgettable trick was to keep Antaeus' feet from touching his mother earth where his strength would always be nourished upon contact. To me this is a parable of science—not to mention art and religion; one's vital strength is continually renewed so long as there is direct contact with experience, otherwise one merely goes through antics, regardless of how clever or complex.

The sequence of these four elements is not significant, being dependent largely upon the skill of the explorer. The success is a consequence mainly of the properties of the materials themselves. The whole process, however, is cumulative—not so much like the smooth ascent of a pyramid as the rough climbing a mountain with its unexpected ups and downs, going arounds, and occasional lost direction amid engulfing fog.

In this concise review of what I call the scientific method (in preference to various incomplete statements which are often popularly dubbed scientific methods) we have ignored certain important tacit assumptions. The most familiar one is the seeming experiential unity of nature. Nowadays we have become accustomed to the apparent uniformity of matter whether it exists on the earth or on the moon, whether on the planet Mars or on evolving stars. More significant is the assumption of human comprehensibility. The German theoretical physicist Albert Einstein is said to have remarked that the one fact about the universe incomprehensible to him is its evident comprehensibility by man. Recently we have become more and more aware of the importance of a third requirement, viz. social acceptability. This assumption takes two prominent forms, viz., special professional dominances and the general cultural matrix.

Max Planck, the German theoretical physicist, who conceived the quantum theory, notes in his posthumous (1948) "Scientific Autobiography": "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it." In this connection one recalls the first presentation of the conservation of energy to professional scientists. When James Prescott Joule, the English experimental physicist, presented a paper at the 1847 Oxford meeting of the British Association for the Advancement of Science, the chairman of the session insisted that the Manchester brewer's son be brief, and allowed no time for any discussion. Fortunately a young Scotch-Irish professor of natural philosophy at the University of Glasgow, William Thomson (later Baron Kelvin), academically acceptable, rose to call attention to this epoch-making work that was about to be by-passed. Almost a century later (1937) the English experimental physicist Ernest Rutherford (Baron of Nelson) predicted the impracticability of atomic energy—only eight years prior to awesome Hiroshima. Senior scientists are wont to re-view current developments in the perspective of their own pioneering work—a reactionary procedure.

This retarding social behavior is even more widespread with respect to the current cultural matrix. If there had been a Vatican Digest in 1616, it would undoubtedly have presented Galileo's dilemma with respect to the Ptolemy-Copernicus issue in the form of a do-it-yourself analysis. Which is true: the hypothesis of the Alexandrian Claudius Ptolemy that all planets revolve about the earth, or that of the Polish Nicholaus Copernicus with the earth itself joining the planets all moving about the sun? What factors are critical in making such a decision? First of all, I suppose, is the requirement of agreement with observational data. In this case both hypotheses could be regarded as satisfactory, although the data themselves were wanting in precision (the Ptolemaic theory however, had been useful for more than 1400 years). The Copernican theory, to be sure, was more mathematically elegant than the Ptolemaic in the disuse of any large epicycles (there were still 34 circles in the Copernican theory in constrast with more than 80 in the Ptolemaic). Ptolemy's view, however, was enshrined in Dante's "Divine Comedy," an epitome of the culture of the day, whereas Copernicus' radical conception would have to be regarded as philosophically wanting. What about usually reliable common sense? Francis Bacon believed that any "fool" could see the sun moving across the sky. On the basis of these considerations one would reasonably favor overall the Ptolemaic hypothesis. Such as the concensus of intellectual opinion in Galileo's day. Science is evidently culture-bound; hence the increasingly important new field, the sociology of science.

We digress to discuss briefly several fruitful by-products of the scientific method that are noteworthy. First of all, there are the observed facts. Despite the German historian Leopold von Ranke's dictum to let facts speak for themselves ("wie es eigentlich gewesen"—"how it really was"), they don't! It is rather the scientist who selects, questions, observes, describes, and infers with respect to what, where, when, how, and how much (measures always approximate). These observed facts, in short, reveal man's fingerprints, like the soil that clings to a plucked root.

Science, moreover, is never merely a loose-leaf notebook of recorded facts; it at least has them classified. But the scientist again plays the chief role; he himself identifies associates, idealizes, and conceives. He transforms percepts into concepts, both empirical and theoretical. For example, it is truly amazing that there was not even a thermoscope to detect temperature changes until the advent of Galileo. Up to that time a thing was regarded as having either heat or cold. It was Galileo who viewed these two conditions as being different states on a single scale—thus leading to the invention of a thermometer.

Even more significant is the first theoretical concept ever formulated by man. The story is a familiar one. Hieron II, king of Syracuse (3rd century B.C.), ordered his goldsmith to make a new crown out of the royal gold. He was, however, suspicious of the goldsmith; he wondered if the gold was in the completed crown or under the goldsmith's gown. He called upon his chief scientist Archimedes (the first great mathematical physicist) for advice. Archimedes' celebrated bath in this connection was not an uneventful occasion. In his life of Marcellus the first-century Greek biographer Plutarch notes that this action was community inspired every now and then. In his Roman bath Archimedes was certainly not striving to be the best bathed Syracusan. He was anxiously waiting for the ordeal to be over. Meanwhile he paddled playfully in the water and suddenly noted that just as much water would overflow as he himself became immersed. Rushing out down the street, he shouted, "Eureka!" ("I have found it"). The townspeople were amazed—not because he was naked (Greek runners always ran naked), but because there was no race. Out of this simple experience Archimedes formulated the first theoretical concept in the history of mankind, viz., specific gravity, which relates two important factors, the weight of a body and that of an equal volume of water. The concept is just as valid and useful today as when it was proposed more than 2000 years ago.

In addition to observed facts and related factors, there is a third important by-product, namely, a factitious theory. The word theory itself comes from the same Greek root as theatre; it signifies a view. The scientist attempts finally to relate all his findings in a single view, to comprehend all the facts and factors. A scientist is thus a creative artist and science a human artifact. To change the metaphor, he is like an involved coach with a game plan—not a neutral referee judging the legality of each play. Max Born, the German theoretical physicist, concludes the Appendix of his Wayneflete Lectures (1949) on "Natural Philosophy of Cause and Chance" with his conviction that "faith, imagination, and intuition are decisive factors in the progress of science as in any other human activity." Science in the making is adventure-some (one can always expect the unexpected), wonder-full, and joy-full.

What are the chief factors that determine the progress of science? Why does it flourish here and now, but not there and then? Why, for example, in colonial England and France, but not in colonial Spain? What are the essential developmental conditions? We would all like to optimize them. We will just mention two important factors.

The progress of science depends in the first place on the definability of phenomena, which, in turn, is a function of their complexity and of the inevitable involvement of the observer. (Pure objectivity does not exist, although the object aspect may be distinguishable.) The second major factor is the reproducibility of the phenomena, which is dependent upon the multiplicity and interrelatedness of their constituents, e.g., the proverbial unpredictability of weather is a notable illustration. The rapid development of the physical sciences in comparison with that of the life sciences and of the social sciences is owing largely to their relative simplicity —more so than to the interest of private investigators or to the funds available from social agencies (usually in proportion to the practicability expectation).

The progress of science is civilly LTD. There are definite limitations to any man's dream that the scientific method will achieve success at all times and all places under all conditions. Blaise Pascal, the French philosophical physicist, noted in his fragmentary "Pensées" that man is seemingly suspended between the infinite and infinitesimal. Today man is floundering between ignorance of the very large (e.g., nebulae receding with almost the speed of light away from us) and ignorance of the very small (e.g., the German theoretical physicist Werner Heisenberg's uncertainty principle with respect to precise knowledge simultaneously of the position and speed for an elementary particle). A fog shrouds our scientific venture as it moves forward. Complete liberation seems more and more doubtful as we find ourselves bound not only by our mental processes, but also by our man-made instruments. As an expanding ball of light spreads its illumination, at the same time it reveals proportionately more the immensity of the surrounding darkness. This phenomenon has become increasingly evident in the well-developed physical sciences; one wonders how long it will take the life sciences, basking currently in the glow of success through utilizing fruits of the physical sciences, to reach a similar apparent impasse.

Let us now touch lightly upon some philosophical limitations—at least from my own point of view. There are four primary scientific approaches to the basic problem of man and his environment, viz., the avenue of the physical sciences, that of the biological sciences, that of psychology, and that of the social sciences. Each of these avenues is attendant with certain common questions: Pilate's, "What is truth?" Macbeth's, "Is this a dagger?" Hamlet's, "To be or not to be!" The attempt to answer these three questions on truth, reality, and value is the philosophy of science. Physics, for instance, presupposes some metaphysics—not that metaphysics is essentially a part of physics, but rather it is part of the scaffolding used in building the physics edifice. In the twentieth century, accordingly, science has become more philosophical and philosophy, in turn, more science based.

What is true? This formulation of the first question, more akin to Hebraic verbal action than to the Greek nounal abstraction of Pilate, is typical of a behavioral approach. (The legal demand to "tell the truth, the whole truth, and nothing but the truth" belongs to the "theater of the absurd." Who would claim to know all the truth?) In science, accordingly, one is content to insist only that a statement be true to observation and logic, and to hope that it may lead to a greater comprehension of the known and possibly to the unification of science itself. A scientist never pretends to know everything; on the other hand, he cannot deny knowing something. An illustration or two may serve to clarify how scientific thinking has influenced philosophical ideas.

Imagine a trailer with two newlywed coeds inside. As she lights a candle in the very middle of the trailer, she muses, "Have you ever had physics?" Chagrined by the very thought—particularly on his honeymoon—he grunts, "Yes." She then asks, "When I light this candle, will the light reach the forward end first, or the rear?" His countenance beams; he knows the answer, "It reaches both at the same time." You and I, however, standing outside, see that the trailer is moving. Obviously, the light will reach the approaching rear end before it gets to the receding front end. Which answer is correct? Both! The theory of restricted relativity is based on the experimental fact that the speed of light is the same for all observers, independent of any relative motion of the observed and the observer. If we are not positive about the simultaneity of such phenomena, how can we be certain about basic concepts like space and time? Our notion of these, indeed, has had to be revised. The essence of relativity, indeed, is not that phenomena may be relative to the observer; rather, that some (e.g., the speed of light) are invariant to all observers. It is unfortunate, therefore, that a popularizer like Joseph Fletcher, the Cambridge (MA) secular theologian, has made relativity per se the corner stone of his so-called new mortality with respect to old situation ethics. What is requisite for relative mores are ethical invariances—what used to be called absolutes.

Another familiar misunderstanding seems to be inherent in the popular notion of atomic energy. (cf. Jacob Bronowski's comment (1973), "We should never have turned mass into energy.") By the end of the nineteenth century it had become customary to regard the world as containing electromagnetic radiation (light, x-rays, et al.) coexistent with material things. But how does radiation differ essentially from matter? Both have energy (E) and momentum. In addition, however, matter has mass (M); does radiation have mass also? Albert Einstein concluded from basic physical laws that radiation, as well as matter, has mass given by the universal formula $E = Mc^2$, where c is the speed of light. Its misinterpretation consists in thinking of mass transforming into energy, or vice versa. Actually neither is true. Mass is always conserved, and so is energy. The difficulty, I believe, stems from our shorthand way of speaking. We characteristically associate inert matter with its characteristic property mass and penetrating radiation with its dominant characteristic energy. Hence when matter is transformed into radiation, we carelessly think of their associated characteristics as being transformed.

Ever since the Ionian philosophers, the nature of matter itself has intrigued thinking man. Immanuel Kant, the German transcendental philosopher, first pointed out the antimony lurking in matter; one cannot conceive of its infinite division or of its limited divisibility (cf. the Greek radical concept of an atom). There was a time when the story of the universe could presumably be written with an alphabet of 92 letters, which could be formed with a single p e n (*p*roton, *e*lectron, *n*eutron). Then a number of new elementary particles were discovered: the positron, neutron, meson, and so on. Each year the situation became more and more puzzling as the number of so-called elementary particles increased to more than 200. In view of their approximate similarity of mass and electric charge, Werner Heisenberg proposed the possibility of these particles being merely different states of a single dynamical system—like the various energy levels of a single atom.

The second philosophical question is concerned with the reality of scientific theory. One would certainly prefer a behavioral approach here, too; largely because of the linguistic confusion inherent in the multiple usage of the word real. (The American experimental physicist Percy Williams Bridgman refused ever to use the word real.) For example, how does realism in art differ from that in philosophy? Or existence in religion from that in mathematics? Scientists, therefore, are wont to content themselves with a pragmatic use of the term. The gravitational force field, for instance, is generally accepted as real because of its usefulness as a concept. May there not be other logics? Say, some kind of Aristotelian potential reality, where a Newtonian material force and a Maxwellian force field may be regarded as different manifestations of the same reality? Suffice it for the moment to comment that reality appears as a tantalizing multifaced creature facing many different points of view. We shall not discuss it further here except to remind you of the confusion that arose in physics itself as to the basicity of particles and waves, both of which were unwarranted speculations with respect to experiential phenomena.

The question of value presents an immediacy of practical concern. Here, too, a behavioral approach is desirable; for scientists do behave like human beings. Noting their failures they make value judgements—in terms not always of scientific goals, but rather of pragmatic successes. They have generally been successful when they themselves have been truth-full and hope-full, as well as cooperative, regardless of color or creed, class or country. In so doing man has found himself to be a partner in a creative coordination like snowflakes that crystallize out of chaotic vapor motion. Out of the complexity emerges order, out of uncertainty an apparent sense of direction. Not that a scientist ever attains ultimate truth—or even strives for it. Great scientists like the English natural philosophers Isaac Newton and Michael Faraday have been sincerely humble.

Extrinsic values, however, are of greater concern nowadays than these intrinsic ones. For example, is science possibly evil? Some years ago I was invited to participate in a symposium on "Poetry and Science" sponsored by the American Society of Aesthetics. Another speaker was a poet-in-residence at a well known college, the third was a philosopher at a major university. The poet began by addressing me, "I do not know you. I have nothing against you personally. Science, however, is essentially evil!" I was dumfounded by this novel introduction to an academic discussion. I had to lay aside my notes, which argued that science, dealing with the whole universe, is probably more imaginative than poetry, restricted narrowly to man's own feelings. I was forced, however, to tackle the problem at hand. "Take a knife," I said, "Is it good or bad?" In the hands of a benevolent physician it can cut out a bad appendix; in the hands of a predatory man it can stab a good heart. The knife itself is neither good nor bad, but it can be used by its holder for either good or bad. Science, to be sure, in times of war can and must help to produce longer spears, sharper swords, and bigger bombs, but that same science can enable the partially blind to see better, the partially deaf to hear more, the very lame to get about from place to place. Science of itself is neither good nor bad; it is neutral. It can, however, be used by technological man for good or for bad. The heart of the war problem, for instance, has been, is now, and ever will be the heart of man himself.

Scientists, however, are people; their personality has many aspects. As citizens, for example, they cannot remain morally neutral. Recently I had occasion to note the Greeks whom Dante had assigned to the first circle of Hell; among the chatting throng was the mathematician Euclid, the astronomer Ptolemy, and the physician Galen. I was surprised, moreover, to find the famous adventurer, wise Ulysses, being tormented in the eighth circle for his abandonment of his old father Laertes, of his faithful wife Penelope, and of his infant son discreet Telemachus; he was pictured by the English poet Alfred Tennyson as still setting out in his last years "to follow knowledge like a sinking star." Each individual, scientist or not, must personally solve his own social problems. He may appear vacillating like Albert Einstein who, as a nationalist, recommended the making of an atomic bomb (potentially for war), and later, (as a pacifist, deplored its actual use. Each one of us has to decide for himself; and no one knows just what he will do under stringent circumstances. Each scientist, however, should strive to tell just what he truly knows and the limitations of that very knowledge, beyond which he must act on faith. It is impossible to quarantine a scientist from the contagious ills of society.

Intimately related to philosophical beliefs are religious implications of science. Man, of course, is intellectually curious about his spatial environment and is awfully inspired by its challenging mystery. His personal concerns, however, are more apt to be confined to earth, which moves like a life boat in space with man himself seemingly the captain, without chart or compass. In addition to speculative philosophical issues, there is also Everyman's question (cf. the popular 15th century morality Dutch play "Everyman"): "Alas, whereto may I trust?" There is a vital need for every man's commitment to some overwhelming pattern for his everyday living.

Whereas science is neutral, scientists themselves are people who have to couple their scientific experience and religious experience. They, too, may behave like the prophet Elijah who heard a still small voice, or like the patriarch Job who discerned an act of God in a whirlwind. Religious men of science have subscribed to many different personal beliefs. There have been Anglicans like Clerk Maxwell and Isaac Newton; Congregationalists like Josiah Willard Gibbs and Robert Andrews Millikan; Friends like John Dalton and Arthur Stanley Eddington; Lutherans like Werner Heisenberg, Hermann von Helmholtz, and Max Planck; Presbyterians like Arthur Holly Compton; Sandemanians like Michael Faraday; Roman Catholics like Galileo Galilei, Albertus Magnus, Gregor Mendel, Blaise Pascal, and Louis Pasteur; Unitarians like Benjamin Franklin; *et al.*—to mention only a few about whose lives I am somewhat familiar. (An interesting study would be the reciprocal influence of science and of religion.)

One wonders why there is a widespread notion that there are apparent conflicts between science and religion. In the 18th century controversy was certainly focused on the physical sciences; in the 19th century it was centered in the biological and earth sciences; in the 20th century it is apparent in psychology and the social sciences. On college campuses it still lurks often beneath a veneer of academic sophistication. The laboratory is frequently too narrow to permit a look out upon the whole universe; the chapel door (usually closed) may be too narrow to let even God enter. The average person, I suppose, does not have any problem of science and religion. Here is a scientist: he has had genuine scientific experiences, he believes these experiences to be true, he hopes truth is single. If there is any apparent conflict between science and religion, he chooses science which he knows. Here is a man of religion: he has had genuine religious experiences, he believes these experiences to be true, he hopes truth is single. If there is any apparent conflict between religion and science, he rejects science which he does not understand. In both cases it is not a matter of science and religion, but rather of science or religion.

There is naturally a desire by some for simply a theoretical world of science alone or for simply a theoretical world of religion alone; occasionally one finds an individual trying to straddle the two worlds despite a wide gulf between them. In my own judgement, however, conflicts between science and religion are always inevitable. Although each field deals with a particular aspect of our one world, each is continually imperfect and incomplete; their overlap, therefore, is necessarily full of inconsistencies and lacunae. One would, nevertheless, hope that the conflicts of a person at age sixty would not be the same as those of the same person at age sixteen; over the years there should have been both scientific and spiritual growth.

We began our discourse with the concept of one world. As we now look back, we can discern three essentially different scientific outlooks: first, every man looks out on the world of phenomena as a whole; second, a scientist's outlook covers selected phenomena; third, an individual's outlook beyond phenomena per se. Does science, however, ever visualize a "real" world of nature? At times scientists have emphatically shouted, "Yes!" But physicists nowadays are inclined to be cautious; they are more apt to point to a possible disclosure without insisting on a logical proof. To illustrate, consider the continual doubling of the number of sides of a regular polygon. One can see a circle emerging as the doubling increases without end, but one cannot actually reach it. Likewise in the case of the infinite series $1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \ldots$ one expects the ultimate sum to be 2, although it will not ever be attained. In a similar manner, I believe, science in its successive approximations discloses the "real" world of nature; it points to it symbolically.

Everyone has to make his own choice with respect to the philosophical and religious implications he discerns personally in the world of phenomena. There are three primary attitudes. First of all, there are those who boastfully claim they do not know; they are called agnostics (or ignoramuses). (One wonders how they themselves know that they don't know.) Their closed minds, however, do not allow entrance into the storehouse of knowledge. Then there is a group of persons who modestly admit they do not know, but . . . These are skeptics who see the door ajar but hesitate to enter; their mind is open, but empty. Still others, admit that they do not know, but boldly enter and find out more and more. These are men of faith; their open mind steadily approaches answers to the perennial questions: where am I? who am I? what will I be? Civilization has not been built by agnostics and skeptics, but by men of faith.

People differ, however, as to what they put their faith in. Some have been thrilled by the gay flowers about them by day and the bright stars above them at night. They put their faith in the material environment to provide answers to the basic questions; they may be called materialists. Others, however, have been entrapped in floods or earthquakes, in hurricanes or dust storms. They fear to put their trust in impersonal matter. On the other hand, they have been entranced by man's music and painting, by his writings and buildings. They put their faith in man; they are atheistic humanists. Still others have seen man's inhumanity to man, in his city slums about and in atomic bombs above. They are compelled to look up for salvation to some higher power, which for want of a better name they call God; they are theistic humanists. Religion then becomes the binding together of the plane of man and his environment and God. One cannot prove that any of these attitudes is true or false. I myself have one life to live; I am a theistic humanist. I believe in the divine rights of man.

"The world stands out on either side
No wider than the heart is wide;
Above the world is stretched the sky,—
No higher than the sky is high.
The heart can push the sea and land
Farther away on either hand;
The soul can split the sky in two,
And let the face of God shine through.
But East and West will pinch the heart
That cannot keep them pushed apart;
And he whose soul is flat—the sky
Will cave in on him by and by."

Edna St. Vincent Millay ("Renascence")

Mortimer Demarest Leonard, Entomologist: Biographical Sketch and List of Publications

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Mortimer Demarest Leonard's diverse and unconventional career spanned more than half a century, beginning as an undergraduate in 1909 during the glory years of entomology under J. H. Comstock at Cornell University and officially closing in 1961 near the end of an era of chlorinated hydrocarbon insecticides and during the early days of integrated pest management. He has been described as one of the best-known members of his profession (2); the reasons for his extraordinary visibility are many. Dr. Leonard's career took him into the study of insect systematics, biology, and distribution in which he edited the New York State list of insects, revised the dipterous family Rhagionidae, and published on immature stages of Hemiptera and aphid distribution; into extension entomology where he was a pioneer in establishing services for fruit growers; and into industry where he developed uses for numerous agricultural insecticides as one of the first entomologists to serve commercial interests. He worked for industry in nearly all regions of the country and abroad where he collaborated with hundreds of state, federal, and foreign workers. His outgoing personality and genuine interest in others won friends wherever he went.

My first association with Dr. Leonard came shortly after I began my graduate work at Cornell in 1966. He promptly identified a collection of aphids I had made and urged me to do additional collecting that might add data for the second supplement to his list of the aphids of New York State. Possibly because I was associated with his beloved Cornell, he took a special interest in my graduate career, encouraging me throughout in correspondence from 1967 to 1971. I met Dr. Leonard just once, at the 43rd Annual Meeting, Eastern Branch, Entomological Society of America at Philadelphia in October 1971, shortly after I had finished my studies at Cornell. His encouragement and continued interest in my work prompted me to assemble more biographical material than space permitted Louise Russell to present in her excellent obituary written after Dr. Leonard's death in August 1975 (Russell 1975).

The preparation of this sketch and accompanying data was made easier for me because Dr. Leonard had maintained a partial list of his publications and had listed the species named in his honor, scientific societies to which he belonged, and the professional congresses he had attended. These personal items were given to Cornell University and were made available by L. L. Pechuman. I am also indebted to Donald D. Leonard, Mortimer's younger brother and former raw silk and yarn broker in New York City, for answering many of my questions about Dr. Leonard in a series of letters to me from November 1976 to April 1978. Much valuable information was available in letters by F. L. Campbell and J. S. Wade in recommending Leonard for membership in the prestigious Cosmos Club of Washington, D. C. C. P. Alexander provided details of his and Leonard's student years at Cornell. These sources have enabled me to discuss fully Leonard's fruitful career. I hope to avoid a mere sterile recording of his accomplishments but to capture some of his personality. To this end, the narrative is somewhat informal and anecdotal; at times I refer to Leonard affectionately as "Mort" since this was how most of his friends and colleagues knew him.

The Making of a Naturalist

M. D. Leonard, born on June 23, 1890, grew up in the comfortable Brooklyn home of his talented parents, Mortimer Haight Leonard and Elizabeth Reid Demarest. His father, whose ancestors had come to New York City from England in the 18th century (3), attended family-interest businesses of banking and insurance and was active in amateur theatricals. His mother (Fig. 1), of Scotch-French Huguenot ancestry (3), was a well-known contralto soloist in New York City churches and oratorio and teacher and conductor of womens' choral societies (4).

City born and bred, young Mort attended neighborhood schools at 81st and 91st streets. He was able to enjoy outdoor activities at his parents' summer home in Ridgewood, New Jersey, a country place with swimming holes, brooks, and open fields where he collected butterflies and pointed out insects to his parents. Mort worked in the garden and on the one-acre grounds of their summer home. Never a robust youth, he did not hold any other jobs since his parents considered the physical work good for their son. Mort's father died in 1908 when Mort was in high school and his brother Donald was 12 years old. Mrs. Leonard was a remarkably capable person who assumed the duties of mother and father, including buying and selling property and building a permanent home in Ridgewood (4, 5).

In 1904 Leonard entered Chesire Academy near New Haven, Connecticut, where he met Louis Dunham, a student of nearly his own age who had a keen interest in birds. Together they spent much of their spare time in the nearby woods and fields observing birdlife. Mort soon learned "almost by heart and rather effortlessly, the identifying characters of

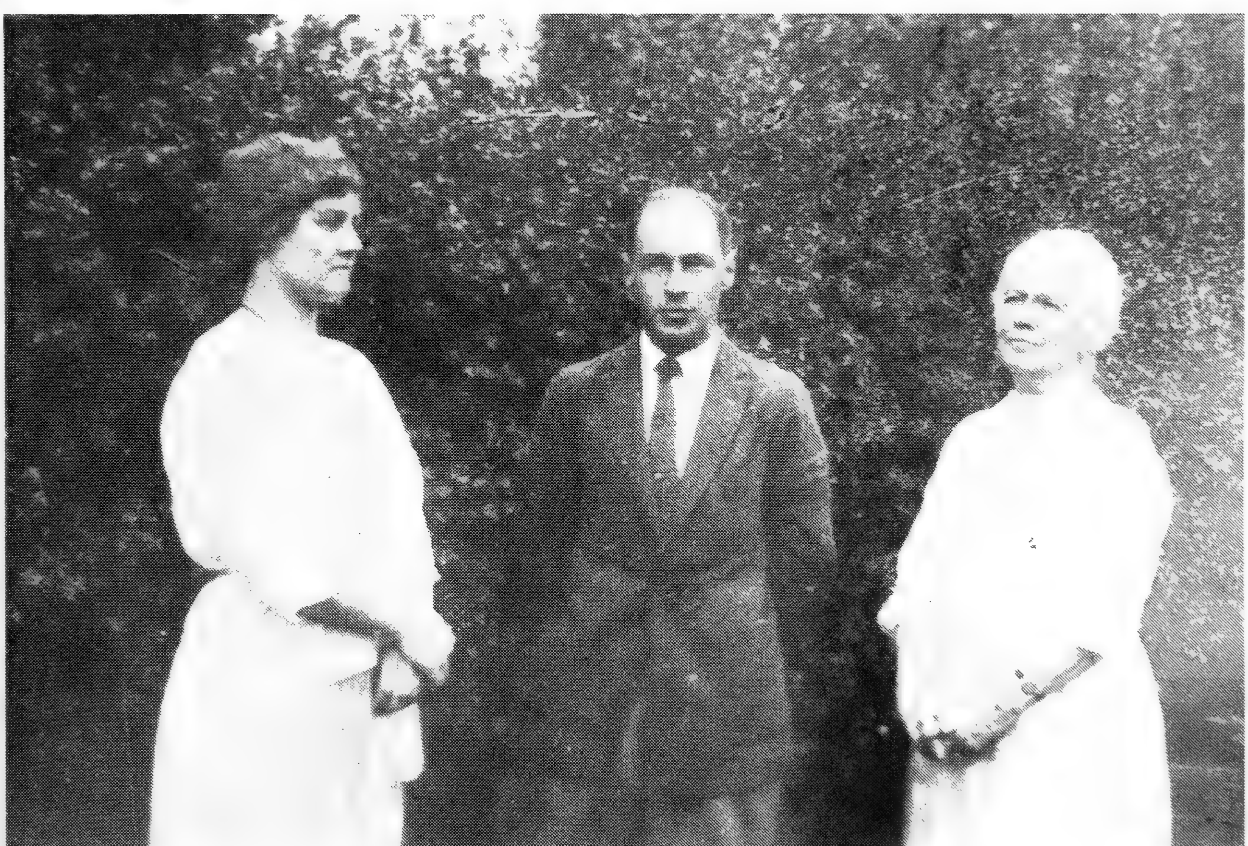

Fig. 1. M. D. Leonard with his wife, Doris Gardner Pratt (left), and his mother, Elizabeth Reid Demarest (right), ca. 1920. Courtesy of Donald D. Leonard

a great many of our Northeastern birds" (Leonard 1957).

Entomological Father.—After spending a year at Chesire, Leonard began to commute from Ridgewood to New York City's DeWitt Clinton High School, at the time this country's largest secondary school (ca. 2500 students) (6). Dr. George Washington Hunter, author of the most widely used textbook of high school biology, was head of the biology department; one of his staff members was the well-known student of Hemiptera, Harry G. Barber. By chance, Leonard was assigned to Barber's section of Botany and with his previous fascination with bird study, Mort showed an unusual interest in the class and attracted his teacher's attention. The following year, Mr. Barber asked that Leonard be placed in his zoology class and obtained permission for Mort to share his lunch periods with him. He told his student that entomology was a legitimate profession, and one spring Saturday he invited Mort to collect insects with him near his Rosell, N. J. home. Leonard described the impact this trip had on his career:

> I accepted at once, although I had not the slightest idea of what doing so entailed. This experience proved so fascinating that I decided then and there —that I wanted, more than anything else, to become an entomologist (Leonard 1957).

Noting Leonard's continued enthusiasm for insect collecting, Mr. Barber stressed that Cornell was *the* school to attend if one really aspired to a career in entomology. At Barber's suggestion, Mort's family gave him a copy of *A Manual for the Study of Insects* by Professor Comstock and his wife Anna Botsford Comstock at Christmas, 1908. Mr. Barber then convinced the family that entomology could be a reasonably lucrative profession; they eventually consented for Mort to attend Cornell (6).

Years later, Leonard gave credit to Barber for charting the course of the rest of his life, and he kept "in constant touch with him until the very day of his [Barber's] death" (Leonard and Sailer 1960: 127). Several reprints that Mort sent to his esteemed friend and teacher were fondly dedicated to his "Entomological Father."

Cornell, Comstock and Crosby

The Undergraduate Years.—Amidst the bustling activity in J. H. Comstock's department, even Leonard's first days on campus proved exciting. On September 24, 1909, the freshman approached another young student in the departmental library, then housed in Roberts Hall, asking: "Sir, could you tell me where I could find a copy of Aldrich's *Catalogue of North American Diptera*?" (7). After a moment, the surprised student told Mort that he too had an interest in the Diptera and had arrived in Ithaca only the day before. Together the two freshmen located a copy of the Aldrich catalogue and marvelled over the fascinating volume. The other young man was Charles P. Alexander, destined to describe more than 10,000 insect species and publish more than 1,000 papers on crane flies (Diptera: Tipulidae) in studies that continue today. Out of that chance meeting evolved several joint projects and two publications on crane flies during their freshman and sophomore years and arose a deep, life-long friendship.

Leonard's formal introduction to entomology was Professor Comstock's general lecture course. The textbook used was the *Manual* with which Mort already was well versed. Additional courses under J. C. Bradley (Systematic Entomology), G. W. Herrick (Economic Entomology), J. G. Needham (General Biology), A. D. MacGillivray (Systematic Entomology), and W. A. Riley (Medical Entomology and Parasitology) served only to pique Leonard's interest. He also benefitted from courses under other of Cornell's famous zoologists: Ornithology under A. A. Allen, Comparative Anatomy of Vertebrates under H. D. Reed, and Systematic Vertebrate Zoology under A. H. Wright (6). Leonard also had the opportunity of associating with students who later achieved some distinction in entomology: C. P. Alexander, R. N. Chapman, H. Dietrich, A. E. Emerson, H. E. Ewing, J. C. Faure, A. D. Funkhouser, S. W. Frost, S. A. Graham, G. H. Griswold, R. W. Harned, H. C. Huckett, H. B. Hungerford, H. H. Knight, H. Morrison, C. F. W. Muesebeck, E. M. Patch, H. Ruckes, R. C. Shannon, R. C. Smith, J. D. Tothill, J. R. Traver, and others I might have mentioned.

Cornell's faculty shared a camaraderie with their students, often entertaining them in their homes. Sunday night open house at the Comstock's, which Mort frequently attended, was a tradition. Edith Patch (quoted in Mallis 1971) described the student-faculty relationship:

> My first impression of Entomological Cornell was that it was sort of a family with the faculty acting as older brothers to the graduate students and everybody loving the Professor and Mrs. Comstock better than they did anybody else and that Cornell was the friendliest group of people in the world.

For such a distinguished group there was, as Prof. Bradley noted, a surprising lack of jealousy:

> In those early days, our Department was small enough so that the entire staff and graduate students could be sort of like a family. We all know each other well. . . . In so far as I have known, there were no jealousies—there was always harmony amongst the members of the staff (8).

Louis Agassiz Fuertes, the great bird artist, allowed Mort to accompany him to his studio to watch him paint; (6) Professor Bradley took Leonard with him to a December 1911 meeting of the New York Entomological Society. Mort also was privileged to participate in the Cornell Okefenokee Expedition as the first group of naturalists to explore that great southern Georgia swamp. Led by Bradley, other members of the expedition were C. R. Crosby (Cornell economic entomologist), A. H. Wright, W. D. Funkhouser (Headmaster of Ithaca's Cascadilla Preparatory School and specialist on the Membracidae), Lee Worsham (Georgia State Entomologist), and Leonard's fellow classmate Sherman C. Bishop, who later became State Zoologist of New York. During late May to mid-July 1912, the group prepared hundreds of bird skins and thousands of insects. Mort brought back 5 closely pinned Schmitt boxes of flies after identifying some of them during a week's stopover at the U. S. National Museum in Washington (6). Van Duzee (1915) named in Leonard's honor a dolichopodid fly Mort had collected in the swamp, the first named of many insects bearing the specific name *leonardi*.

Fig. 2. Mort at Gutland Vineyards, Patras, Greece, Sept. 18, 1911. Courtesy of D. D. Leonard.

The love Mort had developed for insect collecting as an undergraduate can be shown by relating an incident that took place on a Mediterranean trip (Fig. 2) he made with his mother, his brother, and a Greek friend during the summer of 1911 between his sophomore and junior years. When the other members of the party were sightseeing in Algiers, the Leonard boys wandered off to collect insects in the city square park. Mort became so fascinated with collecting exotic species that he and Donald overstayed their time. A search party located them, but Mort drew a sharp reprimand for delaying departure of the Martha Washington (4).

An obvious enthusiasm and aptitude for entomology brought Leonard into a close relationship with the department head, Prof. Comstock. When Leonard reported for his first class in the fall term of 1911, Dr. Riley informed him that the Professor wanted to see him in his office. Comstock had received a call from L. O. Howard, Chief Entomologist of the U. S. Department of Agriculture in Washington, who explained that Col. Gorgas urgently needed an entomologist to assist in malaria control in order to protect those working to build the Panama Canal. Anyone Comstock recommended could have the position. The man Comstock chose was Leonard, after first checking with Riley to see whether Mort had satisfactorily completed his Medical Entomology and Parasitology course. Leonard considered the offer overnight, then decided to decline; he appreciated the compliment to his ability, but he did not want anything to interfere with his obtaining a Cornell degree (6). At the completion of the spring term in 1913, the University awarded him a B.S. degree.

The Graduate Years.—At the urging of some of his professors, Leonard decided to stay at Cornell to pursue a Ph.D. Although his research (a revision of the dipterous family Rhagionidae of America north of Mexico) was begun under Professor Bradley and completed under O. A. Johannsen, Mort's graduate years were influenced more by an economic entomologist and spider taxonomist, C. R. Crosby.

Late in 1913 Leonard found several large notebooks in the Agriculture Library that contained clippings of short articles written by Prof. Mark V. Slingerland, who had died in 1909 at the age of 45. Leonard showed his find to Crosby, who then told Comstock about the discovery. Comstock considered the clippings to represent valuable information on injurious insects of New York State, and since Slingerland's writings were scattered in various popular magazines and in newspapers, he suggested that if Mort were interested in compiling them for publication, he would furnish a photograph of Slingerland and write an introductory biographical sketch (6). Thus, Leonard published in 1914 "A Bibliography of the Writings of Mark Vernon Slingerland," consisting of titles of more than 800 articles published mainly in the *Rural New-Yorker*. Apparently Crosby and Leonard had hoped to complete and publish an index to the Experiment Station literature of entomology, a project begun earlier by Prof. Slingerland. The Comstock Memorial Library at Cornell contains five bound volumes of Slingerland, Crosby, and Leonard's "Index to Experiment Station Literature, 1888 to 1913," the first two volumes dated 1915, the last three, 1916. For some reason this extensive compilation was never published.

Leonard further became involved in the practical aspects of entomology when he began to work with Crobsy to control the tarnished plant bug as a pest of peach nursery stock, part-time at first so he could continue his graduate studies. During the summers of 1913–15, he worked at Chase Brothers Nursery, a grower of fruit nursery stock and large importer of plant material, at Honeoye Falls, N. Y. In 1914 federal funds became available for extension work, and Leonard was appointed as assistant extension entomologist under Crosby during 1915–16. Together they described as new several chalcidoid wasps that parasitized economically important insects, published various bulletins relating to control of fruit pests, and their model bibliography of the tarnished plant bug, which contained 315 titles. Their joint publications culminated in a 1918 book on vegetable garden insects.

The teacher and student remained close friends long after Mort left Cornell. A series of letters from Crosby to Leonard, written daily or every few days while the professor was on an extended collecting trip through the south and west, reveals the depth of their relationship. In his first letter to Mort, dated February

22, 1936, and extracted by Osborn (1946), Crosby wrote:

> By this time you must realize that I am not merely writing you letters but keeping a diary. I never could keep a diary because I had no audience. By doing it this way I may be able to keep a record of the trip. I hope you find it of some interest. In spite of the bad weather we are getting a lot of stuff. Wish you were along.

Perhaps more important than the Crosby-Leonard publications was the method they helped devise for translating results of research work into practical use by farmers. With plant pathologists and other members of the Cornell extension group, they developed a spray service for the commercial fruit growers of the state. Special assistants of the New York State Food Supply Commission were placed in the field, beginning in Monroe and Niagara counties in 1917, to show the growers how and when to apply various insecticides and fungicides. This idea, soon copied by other states, helped growers reduce their losses to insects and disease and represented one of this country's first successful extension programs in entomology and plant pathology (2).

Despite the considerable influence of Prof. Crosby and the time-consuming work on control of the tarnished plant bug, Leonard must have initiated several of his own projects. During 1915–16, he managed to publish 4 papers containing descriptions and illustrations of the immature stages of plant bugs and leafhoppers, some of the first North American work on immatures of the Miridae and Cicadellidae. Some of his illustrations were used by Prof. Comstock in his 1918 treatise on the wings of insects. It was in this period that Leonard become interested in the plan to publish a list of New York State insects. J. C. Bradley was named Editor-in-Chief; the leading specialists in the major groups of insects were to serve as sub-editors.

Emergency extension work often took Leonard away from campus during the later years of his graduate studies. For short periods he worked on control of vegetable pests at Pennsylvania State College's Erie County laboratory in 1918, on truck crop insects on Long Island in 1919, and with Prof. Robert Matheson of Cornell on the European corn borer in Massachusetts in 1920. On October 28, 1918, shortly after he returned from his stay in Pennsylvania, Mort married Doris Gardner Pratt (Fig. 1), a former secretary at Cornell and daughter of the production manager of the *Ithaca Journal*.

Perhaps Crosby now thought his assistant had prolonged his graduate work long enough; he urged Leonard to complete his dissertation so he would be available to accept job offers (9). Leonard was awarded his Ph.D. in February 1921.

Entomological Jack-of-All-Trades

Off the Beaten Path.—In late 1921 Bowker Chemical Co. of New York City offered the new graduate the opportunity to direct its field research in the eastern states. To leave Cornell for industry was a radical step since Leonard perhaps was only the second well-trained member of his profession to enter the commercial field. Leonard credits Otto H. Swezey with being the first graduate entomologist to serve a profit-making organization (Leonard 1958). The new job subjected Leonard to ridicule from his colleagues in official positions who made it known that Mort had compromised his principles. Years after his move to Bowker, he wrote: "Few but the older entomologists can realize today the feeling which prevailed in this matter 25 or 30 years ago" (Leonard 1946). So great could be the opprobrium that J. G. Sanders (first State Entomologist of Wisconsin and later director of Pennsylvania's Bureau of Plant Industry), who joined the Sun Oil Co. in the early 1920's, felt compelled to respond to his tormentors: ". . . an economic entomologist still retains his identity and worth, irrespective of the source of his remunerations . . . ." (Sanders 1925).

As Bowker's director of field research Leonard was to determine new uses for an old copper-arsenical compound that had recently been modified. In cooperation with land-grant colleges in several eastern states he planned and carried out experiments with the new material on apples, potatoes, and other crops. In April 1923 he left to re-enter official entomology.

When New York's State Entomologist E. P. Felt was temporarily transferred to the State Conservation Department, Leonard was appointed Acting State Entomologist. At this time the editorial board of the New York Insect List was revised and Leonard succeeded Bradley as Editor. Among Mort's other duties in Albany was the investigation of the state's injurious and beneficial insects. When Felt returned, Leonard was appointed and sent to Spain as special investigator by the New York Fruit Exchange to determine the conditions surrounding the USDA's embargo against Almeria grapes infested with Mediterranean fruit fly.

Back to Cornell.—His assignment in Spain completed, Leonard returned to Cornell in December 1924 to see the New York Insect List through to completion as its Editor-in-Chief. He also wrote two fascicles for the List: Families Xylophagidae, Coenomyiidae, and Rhagionidae (Diptera) and (with A. B. Gahan and Crosby) the Superfamily Chalcidoidea (Hymenoptera). Mort truly delighted in seeing the insect fauna of his home state documented. In studies on chrysomelid beetles under Prof. Matheson, T. L. Bissell collected a rare species and recalls Mort's elation at having a new addition to the List (10). All possible sources of records were explored. As an example, he spent considerable time rummaging through W. T. Davis' attic in search of records of Long Island and Staten Island insects (Abbott 1949). The project was completed in 1925, but it was not until 1928 that the List was published as Cornell Memoir 101. With its more than 16,000 insects and related arthropods, the List remains as the most comprehensive work on the insect fauna of any geographic region in North America. More than 150 scientists had collaborated to do the collecting and taxonomic study necessary to complete the project.

Retreat from Blind Alleys.—Again Leonard had to leave Ithaca; once again, as F. L. Campbell aptly described (2), he was forced off the beaten path to explore this way and that, often having to retreat, never becoming entrenched in a permanent position. During 1925–27 Leonard conducted field experiments relating to control of citrus and vegetable pests for the Florida Agricultural Supply Co. of Orlando, a position similar to the one he had held with Bowker Chemical. For part of this period Leonard also worked for the Wilson & Toomer Fertilizer Co. of Jacksonville. In August 1927 he returned to Ithaca for a few months as a special agent in the joint Cornell-USDA campaign to clean up infestations of European corn borer.

The campaign completed, Leonard returned to industry, this time as research entomologist with Tobacco By-Products and Chemical Corporation of Louisville, Kentucky. He was stationed at Wenatchee, Washington, to test insecticides for control of codling moth. In slightly more than a year the experimental work was completed; Mort soon was back to official entomology.

Basic Biology Again.—In January 1930 Leonard became Chief of the Division of Entomology at Puerto Rico's Insular Experiment Station at Rio Piedros (Fig. 3). His duties were broad: to make general insect surveys and to investigate the control of insect pests of all crops grown on the island. Here Leonard was able to return to active publishing. He had published his first paper as a sophomore at Cornell and by the time he received his Ph.D. his scientific contributions numbered more than 30. But in nearly a decade away from Ithaca, mainly in industry, he had published fewer than 10 papers, most of those during his editorship of the New York list of insects. At the Insular Experiment Station he was able to carry out basic life history studies similar to those he and Crosby had conducted at Cornell. Leonard and his co-workers studied the biology of the lima bean pod borer, bean lace bug, pink bollworm, cottony cushion scale, sugar cane borer, a lepidopterous leaf-miner of cotton, a root weevil of cassava, a coreid bug that injures citrus, papaya fruit fly, as well as other species. The annotated bibliography of Puerto Rican entomology published by Leonard (1933) lists 38 of his own titles, only 7 of them with a co-author. With political changes in the insular government in late 1932, Mort was left without a position.

After working for a month or so as a consulting entomologist for United Chemical and Exterminating Co. of New York City, Leonard settled into relative security as a research entomologist for the John Powell Co. of New York. For 5-½ years he was stationed in Florida to conduct tests with pyrethrum and rotenone in control of vegetable and other crop pests.

His next three positions were short-lived: entomologist in charge of Du Pont's pest control exhibit at the New York World's Fair (Feb. 1939–Nov. 1940), and entomologist with Angier Products of Cambridge, Massachusetts (Dec. 1940–May 1941), and then with the Orange Manufacturing Co., Orlando, Florida (May–Oct. 1941). From December 1941 to late 1945 he served as business analyst for the Office of Price Administration and was in charge of price controls for insecticides during World War II. His residence at Dorchester House, 2480 Sixteenth Street NW (Fig. 4), about a mile north of the White House, would be his home for more than 30 years and would become the site of many "yellow-pan" collections of aphids.

Fig. 4. Mort near his Dorchester House apartment, spring 1948. Courtesy of D. D. Leonard.

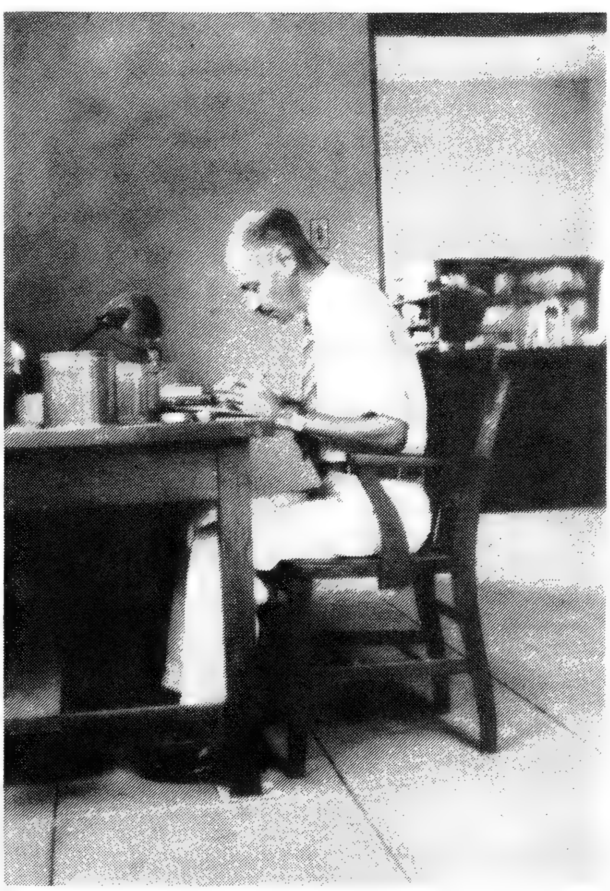

Fig. 3. Mort in Puerto Rico, ca. 1930. Courtesy of D. D. Leonard.

Looking for Security.—After the war Leonard sought security with the U. S. Bureau of Entomology and Plant Quarantine, then under the direction of E. R. Sasscer who had succeeded C. L. Marlatt. He was assigned to Sasscer to help collect data on exotic insect pests, which if introduced into the U. S., would prove the greatest threat to our agriculture. Sasscer intended for the Bureau to publish on all foreign insect pests that might enter the country, a work that would supersede the well-known manual published by W. D. Pierce (1917). Leonard helped prepare a draft of a manuscript treating exotic pests of cruciferous crops (11), but even this first part of the intended series was never published. Funds for the project had been depleted; Leonard was dropped from the payroll in 1947.

As noted by Campbell: "It is a tribute to his reputation and ability that at the age of 57 he was promptly employed by another insecticide manufacturer for developmental work (2)." In October 1948 Leonard joined the Julius Hyman Co. of Denver, Colorado, to aid in developing uses for new hydrocarbon insecticides in the eastern states. Shell Chemical Co. purchased Julius Hyman in 1952, acquiring exclusive rights to the compounds aldrin and dieldrin. In his position Leonard cooperated with numerous workers in state, federal, and foreign governments and functioned as an "Entomological Diplomat" in planning overseas uses for his company's insecticides and dealing with various agencies such as the Foreign Health Division of the U. S. Public Health Service, the Institute of Inter-American Affairs, and the Pan-American Sanitary Bureau. As an example of his involvement with foreign countries, he was instrumental in shipping to Egypt two airplanes loaded with insecticides to combat a locust plague. The promptness of his and Shell's action helped save most of the cotton crop (12). Upon his retirement in July 1961, Shell honored Dr. Leonard ". . . for his integrity as a scientist and for his many contributions to advance the interests of entomology and his fellow entomologists" (13).

Entomologist to the End

Aphids on a Rooftop—Leonard had not yet developed an interest in aphids when, on his return to Ithaca from the 1912 Okefenokee Expedition, he stopped at Plummers Island, Maryland to collect with H. S. Barber, W. L. McAtee, E. A. Schwarz, and H. L. Viereck (Leonard 1966). We know, however, that by 1916 he had begun to collect aphids; he sent a letter to Edith Patch informing her of a collection he had made from golden seal. Her reply of September 1, 1916, cited by Mallis (1971) to capture the "flavor of her personality," was essentially a reprimand to Leonard for his careless packing of the vials containing the specimens. The zeal with which Mort later was to pursue studies of aphid distribution was the result of a reunion with Crosby during a short vacation at Cornell in the fall of 1932. At Crosby's suggestion, Mort did some collecting in the Ithaca area and was impressed with the diversity of the aphid fauna. The recently published work on Illinois aphids (Hottes and Frison 1931) further stimulated Leonard's interest in the group. Separately and together Crosby and Leonard collected aphids until the Professor's death in 1937 (Leonard 1963). Mort published their new records of New York species in a 1937 paper, the first of his more than 50 papers on aphids.

Although he had begun to collect aphids in the Washington area in 1945, it was not until the mid-1950's that he concentrated on the group. As consulting entomologist with Shell Chemical Co., he had time to operate a Moericke ("yellow-pan") trap on the roof of his 9-story apartment building and accumulate records of the local fauna. Every six months or so, he and his wife Doris would visit her niece (Mrs. David Winters) in Haddonfield, N. J., and invariably Mort would set up his trap in the Winters' yard (14). Some members of the prestigious Cosmos Club in Washington must have looked askance when Mort collected from plants in the club's gardens. For Mort there was always time for collecting:

> If one keeps at it as he travels, a great deal of valuable stuff can be gotten by dropping by for a few minutes at a likely spot, or during noon hour or after supper as well as on Sundays & occasional holidays. Anyone who really wants to collect . . . can find time even tho busy with other matters" (15).

Leonard constantly encouraged his friends to collect aphids for him and, if they neglected to send specimens, he would remind them to be more diligent (9).

Roy Latham, a close friend and long-time naturalist on Long Island, made numerous collections of aphids from accurately determined host plants; Prof. L. L. Pechuman collected two new species of New York aphids and contributed many new state records; and C. P. Alexander and others also submitted numerous collections to Mort. It should be pointed out that Leonard was not a taxonomic specialist in the Aphididae and did not describe new species as he had for the Diptera and Hymenoptera earlier in his career. He did make many of his own identifications but usually submitted specimens to specialists for verification of his tentative determinations. Many of the world's aphid authorities were called on for assistance: T. L. Bissell, V. F. Eastop, M. E. MacGillivray, A. T. Olive, J. O. Pepper, F. W. Quednau, A. G. Robinson, L. M. Russell, C. F. Smith, H. L. G. Stroyan, and A. N. Tissot.

Through Mort's own collecting and his encouragement of others, our knowledge of the aphid fauna of New York is better known than that of any other state, with some 462 species having been recorded up to publication of his fourth supplement in 1975. He also published distribution records for the aphids of Arizona, California, Connecticut, Delaware, District of Columbia, Hawaii, Maryland, Massachusetts, Missouri, New Jersey, Oregon, Texas, Vermont, and Virginia, as well as Cyprus and Newfoundland.

The Last Years.—Mort remained an active entomologist until his final months; his ambition seldom waned. Even in his later years he still had hopes for finishing a supplement to his New York Insect List (15); he still mentioned the possibility of publishing sketches of entomologists he felt had been neglected (C. H. Hadley and J. G. Sanders for example) (16); and he was still having aphids sent to him. Less than a month before he died, he turned over to Prof. Pechuman the notes that were to comprise a fifth supplement to his New York list of aphids and asked him to oversee the typing of the manuscript (17).

When Doris' health began to fail, the Leonards moved to a Cherry Hill, N. J. nursing home in early August 1975. With his own health also beginning to decline and without the opportunity of daily telephone chats with his Washington friends and occasional visits to the Cosmos Club, Mort may literally have died of a broken heart. He died on August 26, 1975 and was buried in the family plot in Ridgewood, N. J. Doris died soon after on February 29, 1976.

Evaluation of a Career

Mortimer D. Leonard's more than 170 publications in insect biology, distribution, and control; in extension work; and on new uses of insecticides attest to a long and diverse career. He had the opportunity to be part of the Comstock years at Cornell and to associate with some of the greatest scientists in his field and to be active both in basic and applied research in official and commercial positions. His outstanding achievement probably was overseeing the completion of the New York State List of Insects. Such an ambitious compiling of a state's insect fauna may never again be attempted. The List is an invaluable reference for insect distribution records and, in a lighter vein, it inspired the long-running column "Autographa OO" by the editor of the *Bulletin of the Entomological Society of America.* Mort delighted in the explanation of how the name for the column (loosely expressed as "Oh! Oh! What have I written"!) was derived (with apology to grammarians) from the noctuid moth, *Autographa oo*, on page 627 of the List (18).

In economic entomology the development and testing of new agricultural insecticides was an outstanding contribution, although no single accomplishment or publication commemorates his developmental work. F. L. Campbell credits Mort with benefitting peoples the world over:

> There is no question . . . that the present effectiveness of chemical control of insects can be

attributed to the effort over the years of Dr. Leonard and men like him. To a considerable extent credit for this great development in food production should go to Dr. Leonard who has been a pioneer and leader in this field (2).

According to Leonard's own estimate, 40% of his time was spent in "official" entomology, 60% in "commercial" positions (Leonard 1957). He declined to select either as the more enjoyable, although he was justly proud of being one of the first well-trained entomologists to serve industry. He traced the development of commercial entomology in the United States (Leonard 1958) and, according to one of Mort's closest friends, the preparation of the paper truly was a labor of love (19).

But did Dr. Leonard fulfill the promise he showed as a taxonomist and general biologist during his student years at Cornell? Would Prof. Comstock and his friend and adviser Cyrus Crosby have been pleased with their student's accomplishments? Comstock might well have been disappointed that Mort so soon abandoned his life history and taxonomic studies and only briefly returned to biological investigations. As a pioneer in extension entomology, Crosby probably would have been pleased to see Mort develop new uses for agricultural chemicals which resulted in improved public health and increased food production throughout much of the world. He certainly would have been pleased to see Mort continue his studies on aphids.

In fairness to Leonard it should be emphasized that his wanderings were not intended, that a career characterized by an absence of stepwise progression was not planned (2). Sometimes he simply was the victim of bad luck. At various times political tampering (Puerto Rico), business failure (Orange Manufacturing Co.), and termination of funds (U. S. Bureau of Entomology and Plant Quarantine) cost him his position. In other cases Mort's own actions may have kept him from securing permanency in a certain job. One of Leonard's compelling desires was to return to Cornell, and Prof. Crosby indeed tried (unsuccessfully for reasons not known) to obtain a permanent faculty position for his friend (9).

For an entomologist as well known and admired as Leonard was, one might expect him to have held office in the many societies to which he belonged. His frequent shifting of positions and the extensive travel required by his developmental work in industry probably prevented him from holding office. In his later years he enjoyed counting ballots for the Entomological Society of America at their headquarters in College Park, Maryland (20), and he regularly attended meetings of the Entomological Society of Washington. In February 1975 he was elected to Honorary Membership in the Washington society.

In an evaluation of Leonard's work one should not be too critical of a career so diverse and fruitful. Earlier I referred to him as an "entomological jack-of-all trades," not disparagingly, but as a compliment to his achievements in several areas of his science. Perhaps his productivity (however that might be measured) would not have been enhanced had he remained at Cornell. Certainly he would never have had the opportunity to make such lasting contributions to world food production. In the end, what others thought of his productivity matters less than how Mort viewed his life's work. Clearly he enjoyed it:

> As I look back over the years, it seems to me that being an entomologist has been a very rewarding way of life. I have travelled widely and met hosts of interesting people, including many from foreign lands, and I have made many valued friends. I believe my activities have been of benefit to my fellow man (Leonard 1957).

Mort Leonard the Man

Russell's (1975) obituary of Dr. Leonard provides good insight into his personality. She described him as "kind, cordial, sociable, communicative, and intensely interested in people and their activities." Mort seldom failed to add a personal touch; nearly always he remembered his friends' anniversaries and birthdays (9). At the close of my graduate work at Cornell, Dr. Leonard learned that I had scheduled my "defense of thesis'' exam and took time to send a letter wishing me success.

When Mort's father died, he became and would remain a "tower of strength" (21) to his younger brother Donald and an affectionate son to his mother. Although he was seldom home after he enrolled at Cheshire Academy, he helped his mother when he could and did his best to return for high days (the Leonard's were Episcopalian) and holidays (5).

At Cornell Mort enjoyed a social life apart from activities associated with the Entomology Department and lectures and field trips of the Agassiz Club. He was a member of Eleusis, a local fraternity that was merged into the national Theta Kappa Nu and then into Lambda Chi Alpha. Mort was a great storyteller and, like his father, had a flair for mimicking a Jewish and a Spanish dialect. He often was called on to entertain his fraternity's "rushees"; he had some of his mother's musical ability and was a good "fiddler" (21). In the Agriculture College Mort was a member of the Violin Quartet and the Mandolin Club. Sometimes he made a small sum of money by playing at local dances. Over the years he sang and interpreted some of the humorous songs that his Aunt Neil, his mother's younger sister, had handed down (22).

A write-up prepared for the 1913 Cornell classbook vividly characterizes Mort the student:

> We call him "Bug" Leonard because of his proclivities not because of his state of mind. Despite his habitual church–deacon expression, Mort can, on occasion, give a very correct imitation of "The Missing Link." He is perfectly at home with his pipe and his "bugs," a master stuntster, and a charter member of the Bachelors Club (23).

To really capture the flavor of Mort's personality, more should be said about Cornell. When he finished his doctoral work, Leonard probably wanted to remain on the Cornell staff. Despite the disappointment of failure to land a permanent position, Mort always cherished memories of his years in Ithaca and relished the opportunity to visit with Cornell alumni. In 1967 he donated to Cornell his personal collection of aphids consisting of some 500 species and nearly 17,000 slides. Leonard's collection, together with the aphids assembled by former Cornell entomologist Grace H. Griswold, is known as the "Griswold-Leonard Collection of Aphididae" (Pechuman 1969). Shortly before he died, Leonard gave his books, reprints, reprint collection, diplomas, and microscope to the University (9).

Although not physically impressive (he was 5′7″ tall and weighed 125 lbs. as a Cornell student) (23), Mort was a handsome man, bearing (some thought) a resemblance to the actor Adolph Menjou. He was always well dressed, even dapper (Fig. 4); above all, he was a gentleman.

Like many entomologists, Leonard was not without his quirks. At times he could be stubborn. In restaurants his second cup of coffee had to be brought in a *clean* cup (20), and on his 50th reunion at Cornell he insisted on retracing his original route to Ithaca. Since train service was no longer available to Ithaca, Prof. Pechuman met Mort at the railroad station in Binghamton to take him and Doris to his reunion (9).

In short, Mort Leonard was a convivial, gregarious sort. Robert Hamman perhaps said it best: "Mort never met a stranger, only friends" (19).

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(Authorship of publication is in the order given)

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New Names Proposed by M. D. Leonard

Hemiptera-Homoptera

Cicadelloidea-Idioceridae
Idiocerus gemmisimulans Leonard & Crosby 1915, J. Econ. Entomol. 8:542 (a synonym of *I. decimaquartus* (Schrank)).

Diptera

Tipulidae
Geranomyia bezzii Alexander & Leonard 1912, Can. Entomol. 54:205.
Limnophila albipes Leonard 1913, Entomol. News 24:248 (listed as an unplaced species of *Limnophila* by Alexander 1965).
Limnophila nigripleura Alexander & Leonard 1914, in Alexander, Proc. Acad. Nat. Sci. Phil. 66:592 (a synonym of *Pseudolimnophila contempta* (Osten Sacken)).
Xylophagidae
Rachicerus niger Leonard 1930, Mem. Amer. Entomol. Soc. 7:13.
Xylomyidae
Xylomyia pallipes Loew var. *flavomaculata* Leonard 1930, Mem. Am. Entomol. Soc. 7:43 (a synonym of *Solva pallipes* (Loew)).
Rhagionidae
Chrysopilus andersoni Leonard 1930, Mem. Am. Entomol. Soc. 7:131.
Chrysopilus fasciatus var. *infuscatus* Leonard 1930, Mem. Am. Entomol. Soc. 7:141 (a subspecies of *C. fasciatus* (Say)).
Chrysopilus pilosus Leonard 1930, Mem. Am. Entomol. Soc. 7:152.
Ptiolina alberta Leonard 1931, in Curran, Can. Entomol. 63:250.
Ptiolina obsoleta Leonard 1931, in Curran, Can. Entomol. 63:250.
Rhagio brunneipennis Leonard 1930, Mem. Am. Entomol. Soc. 7:92.
Rhagio californicus Leonard 1930, Mem. Am. Entomol. Soc. 7:93.
Rhagio concavus Leonard 1930, Mem. Am. Entomol. Soc. 7:94 (a subspecies of *R. maculifer* (Bigot)).
Rhagio costatus var. *limbatus* Leonard 1930, Mem. Am. Entomol. Soc. 7:96. (a synonym of *R. costatus* (Loew)).
Rhagio pollinosus Leonard 1930, Mem. Am. Entomol. Soc. 7:116.
Symphoromyia algens Leonard 1931, Am. Mus. Novitates 497:1.
Symphoromyia currani Leonard 1931, Am. Mus. Novitates 497:2.

Hymenoptera

Mymaridae
Anagrus ovijentatus Crosby & Leonard 1914, Can. Entomol. 46: 181 (now placed in the genus *Anaphes* Haliday).
Gonatocerus ovicenatus Leonard & Crosby 1915, J. Econ. Entomol. 8:545 (now placed in the genus *Lymaenon* Haliday).
Eulophidae
Tetrastichus ovipransus Crosby & Leonard 1917, Entomol. News. 28:368.

Species Named in Honor of M. D. Leonard

Acarina

Tarsonemidae
Hemitarsonemus leonardi Smiley 1967

Odonata

Gomphidae
Gomphus mortimer Needham 1943 (a synonym of *G. descriptus* Banks)

Hemiptera-Homoptera

Aphididae
Calaphis leonardi Quednau 1971
Uroleucon leonardi (Olive 1965) (described in *Dactynotus*)

Coleoptera

Mordellidae
Mordellistena leonardi Ray 1946

Diptera

Tipulidae
Rhabdomastix leonardi Alexander 1930
Shannonomyia leonardi Alexander 1932
Dolichopodidae
Condylostylus leonardi (Van Duzee 1915) (described in *Sciapus*)
Tachinidae
Trochilodes leonardi (West 1925) (described in *Rhamphina*)

Hymenoptera

Scelionidae
Trimorus leonardi Fouts 1948
Platygasteridae
Inostemma leonardi (Fouts 1925) (described in *Acerota*)

M. D. Leonard: Membership in Scientific Societies

American Association of Economic Entomologists, Elected 1911
American Association for the Advancement of Science
Brooklyn Entomological Society, 1943
Entomological Society of America, 1910
Entomological Society of Japan, 1957
Entomological Society of Washington, 1921—Elected to Honorary Membership, February 1975
Florida Entomological Society
New York Entomological Society, 1921
Sigma Xi, 1915
Texas Entomological Society, 1933
Washington Academy of Sciences, 1958

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I am especially indebted to M. D. Leonard's younger brother, Donald D. Leonard, now a resident of Spartanburg, S. C., who kindly answered my numerous questions about Mort, supplied all photographs used in this paper, and read an early draft of the manuscript. C. P. Alexander, Amherst, Mass., and L. L. Pechuman, Department of Entomology, Cornell University, supplied valuable information and also reviewed the manuscript. I appreciate permission to refer to conversations or correspondence with: T. L. Bissell, Hyattsville, Md.; R. E. Hamman, Greensboro, N. C.; R. H. Nelson, Mechanicsburg, Pa.; L. L. Pechuman; P. M. Schroeder, USDA-APHIS, Hyattsville, Md.; and Mrs. David Winters, Haddonfield, N. J. My colleagues at the Bureau of Plant Industry in the Pennsylvania Department of Agriculture, T. J. Henry and Karl Valley, kindly criticized the manuscript.

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Footnotes

(1) Adjunct Assistant Professor of Entomology. The Pennsylvania State University, University Park, PA 16802.

(2) Letter dated May 31, 1952, from F. L. Campbell to Committee on Admissions, Cosmos Club, Washington, D. C.

(3) Letter dated February 27, 1978, from Donald D. Leonard to A. G. Wheeler, Jr.

(4) Letter dated January 27, 1977, from Donald D. Leonard to A. G. Wheeler, Jr.

(5) Letter dated January 18, 1978, from Donald D. Leonard to A. G. Wheeler, Jr.

(6) "Why I Went to Cornell," notes provided by M. D. Leonard, March 29, 1975, in a letter to E. H. Smith, Chairman, Department of Entomology, Cornell University; on file in Comstock Memorial Library, Cornell.

(7) Letter dated January 7, 1977, from Charles P. Alexander to A. G. Wheeler, Jr.

(8) Interview with J. Chester Bradley, December 18, 1962, by Gould P. Colman, Archivist, Department of Manuscripts and University Archives,

Cornell University; transcript on file in Comstock Memorial Library, Cornell.
(9) Personal communication with L. L. Pechuman, Department of Entomology, Cornell University.
(10) Letter dated December 17, 1977, from T. L. Bissell to A. G. Wheeler, Jr.
(11) Personal communication with P. M. Schroeder, USDA-APHIS, PPQ, Hyattsville, Md.
(12) Letter dated April 17, 1978, from Donald D. Leonard to A. G. Wheeler, Jr.
(13) Shell Chemical Agricultural News, New York, N. Y., August 1961.
(14) Letter dated January 13, 1978, from Mrs. David Winters to A. G. Wheeler, Jr.
(15) Letter dated January 22, 1945, from M. D. Leonard to L. L. Pechuman.
(16) Letter dated April 26, 1975, from M. D. Leonard to A. G. Wheeler, Jr.
(17) Letter dated July 30, 1975, from M. D. Leonard to L. L. Pechuman.
(18) Personal communication with R. H. Nelson, Mechanicsburg, Pa. (formerly Executive Secretary, Entomological Society of America); see "Autographa OO," inside front cover, Bull. Entomol. Soc. Am., Dec. 1968.
(19) Personal communication with Robert E. Hamman, Greensboro, N. C.
(20) Personal communication with R. H. Nelson, Mechanicsburg, Pa.
(21) Letter dated December 1, 1976, from Donald D. Leonard to A. G. Wheeler, Jr.
(22) Letter dated January 7, 1977, from Donald D. Leonard to A. G. Wheeler, Jr.
(23) From Alumni Office records, Cornell University, Ithaca, N. Y.

Contributions to the Ecology of the Cicada Killer, Sphecius speciosus *(Hymenoptera: Sphecidae)*

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ABSTRACT

The cicada killer *Sphecius speciosus* (Drury) emergence hole was linked to the wasp by a direct observation of an emergence. Wasps do not emerge via their burrows but tunnel directly from their cells to the surface. The fixed order of first emergences in the different populations appears related to the friableness of the soil. The harder the soil the later the emergence season begins. Males begin emerging before females, although there is considerable overlap. Males emerge from holes 10 mm and smaller and females emerge from holes 12 mm and larger. Holes of 11 mm are about one-half male and one-half female. The specific density or the total number of wasps over the tract inhabited by Population 1 was taken daily. The sex ratio of Population 1 was highly male biased, 2:1 based on the specific density and 3:1 based on the total number of emergence holes. *Sphecius* in the Brooklyn area apparently had no natural enemies, and wasps died of old age. The female life span is approximately 30 days and the male life span is approximately 15 days.

Studies of four populations of the solitary wasp *Sphecius speciosus* (Drury) were conducted during the summer of 1956–1963. The populations were designated 1, 2, 3, and 4, inhabiting tracts on opposite sides of 2 adjacent baseball diamonds in the Parade Grounds, a huge sandlot ball field area in Brooklyn, New York. Certain discrepancies uncovered in the literature concerning various aspects of the life history of the cicada killer are now reviewed in the light of new evidence.

Direct Observation of Emergence

The emergence hole was first described by Dambach and Good (1943) as the exit tunnel made by the young wasp in leaving the nest. It was also described as being nearly perpendicular to the surface. The emergence hole was definitely linked to the wasp in 1958, when a direct observation of emergence was made in population 1. On July 23, 1958, in the early afternoon, the surface of the ground suddenly broke in one spot, the wasp's face was visible, and after a minute's struggle the young adult was on the surface. It was inactive for 2 or 3 seconds and then flew off.

Description of the Emergence Hole

In hundreds of holes noted, nearly all were perpendicular to the surface of the ground. They are circular in shape, and the 145 holes to appear in Population 1 (1958) ranged from 6–16 mm in diameter at the surface with 10 mm being the mode diameter (N = 40). In depth they varied from 25 mm to 304 mm with more than half falling in the 76–203 mm range. The hole whose formation was observed was 88 mm deep and 10 mm in diameter.

Place of Emergence

Dambach and Good (1943) in their description of the nest found the burrow to be 30.4–45.7 cm in length from the entrance to the terminus where the first cell was excavated. A new cell was generally made immediately in front of the one just completed. As many as 4 have been found in one series. After a cell or series of cells is completely provisioned, a new lateral off the main tunnel is excavated, and the process is repeated.

Riley (1893) stated that the young wasp in leaving the nest passes through the burrow made by the female the year before. Considerable evidence to the contrary indicates that each wasp tunnels independently to the surface from its cell. The basis of this conclusion lies in the following evidence:

1. Of a total of 145 emergence holes to appear in Population 1 in 1958, all but 7 were more than 15.2 cm from a wire fence whose lower rim runs the length of the tract. Yet of the estimated 159 burrows dug in Population 1 in 1957, all but 13 had their entrance within 15.2 cm of the fence, and the bulk of these were against it. The same general picture was noticed from 1956–1963. The burrows were dug along the fence near the edge of the tract while the wasps emerged further out on the tract.
2. In Population 1 (1958) almost half of the emergence holes (44%) appeared within 3 days of another hole located not more than 35.6 cm away. Often holes appeared within centimeters of one another.
3. The emergence holes come to the surface of the ground vertically, while the burrow entrances are inclined at angles of about 45°.
4. In many years there was a much larger number of holes than of nests dug the previous year. For example, in Population 1 in 1960, there were 125 nests, yet these nests produced 939 emergence holes in 1961.

The different locations of the emergence holes and burrows are clearly expected if the wasps tunnel directly from their cells to the surface, since the cells as indicated are a distance from the entrance burrow.

The appearance of clusters of emergence holes is also to be expected if wasps from the same nest emerge about the same time from separate tunnels, and if, as according to Dambach and Good (1943), cells are made in series. The vertical emergence hole need hardly be pointed out as obviously distinct from the comparatively gently sloping entrance of the nest burrow.

Variations in the Emergence Period

In 1957 in Population 1 the date of first emergence was June 30, and the date of first emergence of Population 2 was July 1. In 1958 in Populations 1, 2, 3, and 4, the dates of first emergence were July 15, July 24, July 31, and August 7, respectively. In 1958 in Populations 1, 2, 3, and 4, the dates of last emergence were September 1, September 1, September 1, and August 14, respectively.

Seasonal fluctuations in the date of earliest emergence in a specific population can be quite large, with a difference of 23 days recorded between the first emergences in Population 2 during the years 1957 and 1958. When computed for different populations (1 and 4), a difference as great as 38 days was obtained between 2 generations (1957–1958). Climatic conditions are not entirely responsible for this fluctuation, since populations in the same field (1 and 4) under identical weather conditions can differ as much as 23 days in their date of first emergence during the same season (1958). This is hardly surprising, since a difference as great as 48 days was recorded between the first and last emergence hole to appear in a single population (Population 1, 1958). The friableness of the soil in Population 1 and its greater hardness in other populations probably explain the nearly fixed order of first emergences among the populations (see Lin 1966 and

Lin (personal communication) *in* Evans, 1966).

Dambach and Good (1943) (in computing the life span) considered the mean first date of adult life as July 1. By this they probably meant the date over a period of years which averaged the greatest number of emergences. This is apparently completely invalid for the Parade Ground populations during the summers 1957–1958, as the dates of first and last emergences show. In all cases there was only 1 emergence hole for a given population on the dates of first and of last emergence.

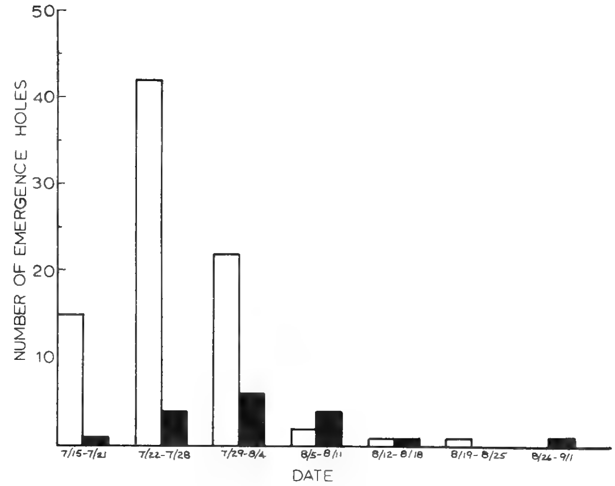

Fig. 1.—Evidence of earlier male and later female emergence is shown by the generally earlier appearance of "male" holes (clear bars) and later appearance of "female" holes (shaded bars).

Emergence Time in Relation To Sex

Considerable evidence indicates that the males generally emerge earlier than the females, although there is much overlapping. As is well known, the female is usually larger than the male (Riley, 1893; Dow, 1942). Accordingly, the diameter of the emergence hole seems to provide a good index of the sex of the emerged individuals. As indicated, emergence holes varied from 6–16 mm in diameter (Population 1, 1958). It was subsequently found (1958–1967) that males emerge from holes 10 mm and smaller, and females emerge from holes 12 mm and larger. Holes of 11 mm are about one-half male and one-half female. On July 27 (Population 1, 1958) the first nest appeared. Only 1 hole which had yet appeared was as large as 12 mm, further supporting the view that holes 12 mm and larger were formed by females.

Evidence of the relationship between the size of the emergence hole and the sex of the wasp is further shown in the following account. Of a total of 66 emergence holes appearing before July 28 (Population 1, 1958), none was larger than 12 mm. On that date, 1 appeared which was 14 mm. On July 29, 2 appeared which were 13 and 14 mm, and for the first time 2 females were seen. One very huge one, by far the largest wasp seen this season, was resting on a fence railing in section 39, the same 3-m quadrat in which the 14 mm hole was located, while another very large female and a male were flying around in copulo. Such a simultaneous appearance of large holes and large wasps on the same tract certainly suggests that the relationship is not fortuitous and that the appearance of large holes provides an excellent indication of the emergence of female wasps.

Fig. 1 plots the weekly total of male emergence holes against female emergence holes (Population 1, 1958) beginning on July 15, the date of first emergence. It is evident that the male holes are more common, accelerate faster, peak and decline earlier than the female holes. While the male holes are on the decline during the week beginning July 29, the female holes are in the peak stage. During the following week the decline of male holes was very sharp while the female holes were still near their peak. On July 25, 1957 (Population 1), when the emergence holes were well into the decline, 10 of the total of 14 were 12 mm or larger. What the graph does not show is the earlier appearance of the male holes. The first male hole appeared on July 15 and the first female hole on July 20. In that period before July 20, 11 male holes appeared.

Of the total 145 emergence holes to appear in Population 1 in 1958, 35 were not included in the graph for various reasons such as not having been measured because of their inaccessibility or

Table 1.—Specific density or the number of wasps present at a given time on the tract inhabitated by Population 1 in 1958. Every other date was deliberately omitted in the interests of condensing the table.

Date	Time	Specific density	Number of females	Number of males	Number unknown
7/20	0910	1	0	1	0
7/22	1803–2045	1	0	1	0
7/24	0737–0858	3	0	3	0
7/26	1520–1915	1	0	0	1
7/28	1340–1530	4	0	3	1
7/30	0821–1045	5	0	3	2
8/1	1045–1105	9	0	4	5
8/3	1045–1215	9	1[b]	3	5
8/5	0845–1008	16	1	1	14
8/7	1130–1145	9	1[a]	2	7
8/9	1355–1410	2	1[a]	1	1
8/11	1015–1050	6	2[c]	2	4
8/13	1000–1150	8	1[a]	0	8
8/15	0947–1430	7	1	3	3
8/17	1845–2020	1	1	0	0
8/19	1132	1	1	0	0
8/21	0950–1010	3	1[a]	1	2
8/23	1004–1140	3	2	0	1
8/25	1115–1130	0	0	0	0
8/27	1745–2003	3	3	0	0
8/29	1540–1700	3	3	0	0
8/31	1820	1	1	0	0
9/2	1630–1930	1	1	0	0
9/4	0800–0847	0	0	0	0
9/6	1905–1955	1	1	0	0
9/8	1040–1100	0	0	0	0
9/10	1745–1830	0	0	0	0
9/15	1820–1905	0	0	0	0

[a] = new nest or nests.
[b] = found dying.
[c] = paralyzed cicada.

having been damaged. During the first and sixth weeks only 1 11-mm hole appeared, and it was not counted as either male or female.

Daily sexing of living wasps, primarily on the basis of behavioral differences between the sexes, gives evidence in complete accord with that derived from the emergence holes. In the examination on 5 different dates (between July 30, 1958 and August 15, 1958) of the sex of wasps engaging in territorial behavior, without exception all were males (see Lin, 1963). In territorial behavior, the male defends a small area, about 2.5 m^2, against intruding males and conspicuous insects. These are chased from the area while the male continually returns to a usually localized spot (generally an emergence hole) within the territory. Territorial behavior thus becomes a means for recognizing the male. The female is likewise recognized by behavior such as the manner of flight, leaving or entering the nest, digging, or carrying a cicada to the nest.

Specific Density

Table 1 contains an exact, or nearly exact, determination of the specific density (total number of wasps over or on the tract inhabitated by Population 1, 1958) at any one point during the time listed. The specific density was determined by total counts repeated several times after which the same sum was usually obtained. It is the large size of the wasp and its tendency for localization, whether the male around his territory or the female around her nest, which makes this most accurate of methods possible. On some occasions when the number of wasps was greatest, the highest count with certainty that no wasp had been counted twice was taken as the density. The vertical bars on the fence broke the tract up into 51 3-m sections for a total of 153 m.

During most determinations of the specific density, a number of wasps completely at random (dependent on chance opportunity) were sexed, usually by behavioral determinations; sometimes by anatomical means consisting of body segment counts while in the field. As Table 1 shows, in complete agreement with the evidence from the emergence holes, the males appeared earlier, peaked earlier and declined earlier than the females. In Population 1 (1957) the first male was recorded on July 3 and the last on July 25. The first female was recorded on July 14 and the last on Aug. 27. In Population 3 (1958) the first male was recorded on Aug. 4 and the last on Aug. 23. The first female was recorded on Aug. 9 and the last on Sept. 3. Fig. 2, based upon data from Table 1 (including the data omitted to condense the table), with the exclusion of indirect signs, shows the weekly sex ratio for Population 1 in 1958. It is readily seen that numbers of males are on the decline before the females reach their peak. The males then disappear entirely while the females are still present. This graph bears a striking resemblance in the relative number of males to females for any week to that of the relative number of male to female emergence holes the week before, as shown in Fig. 1. In later years it was found that the females rejoin the society about a week after emergence, and males spend considerably more time in their territories after about a week after emergence. During the week July 15–21, only male emergence holes appeared, with one exception. In the week beginning July 20 only males were observed. In the week of July 22–28 there was an increase of female and male holes and in the following week the number of females relative to males was about what might be anticipated from the emergence holes. To give a final instance, in the week of August 5–11, the male holes had greatly declined so that the numbers of male holes and female holes were almost equal. The situation was almost the same for the relative numbers of males and females for the following week. This similarity between the graphs has a basis if males emerge predominately from holes 10 mm and smaller while females emerge from those which are 12 mm and larger. This similarity is also based on the extensive marking data of later years showing that wasps habitat imprint to the tract from which they emerged. The inevitable conclusion is that females were seen later in the season because they generally emerged later. Also, as will be shown, the female life span is approximately double the male life span.

The Sex Ratio

Dambach and Good (1943) in their review of the sex ratio gave the following account. "Of 25 adults emerging from stored larval cases, 15 were males and 10 were females. Seven collected in Muskhigum County were females, and of specimens at Ohio State University and Ohio State Museum, 29 were males and 37 were females. Denton (1931) obtained 13 females and 7 males from a group of 20 he collected from a colony on August 2, 1930 at Robbinville, North Carolina. These collections totaling 128 specimens indicate a sex ratio of 70 females to 48 males or 59.3% females to 40.7% males." Only their data obtained from stored larval cases can be considered reliable. Dow (1942) likewise obtained a male biased ratio from adults (6 females and 12 males) reared from 18 stored cocoons he collected.

Dambach and Good's (1943) method in determining the sex ratio is invalidated by their method of adding together the total males and females caught by different observers from completely unrelated populations. They failed to take into consideration such factors as the differ-

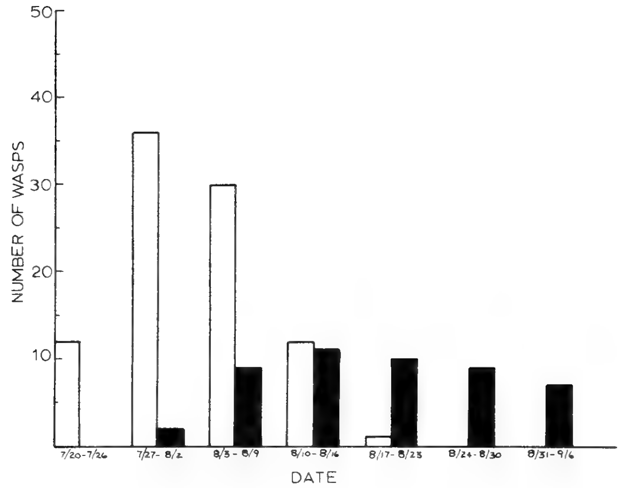

Fig. 2.—The weekly sex ratio (males clear bars, females shaded bars) based only upon the number of wasps sexed in determinations of the specific density, shows considerable fluctuation. Absolute numbers between any 2 weeks should not be compared, since more determinations of specific density were made in some weeks than in others.

ences in the time of emergence between the sexes, the longer active season of females, and the tendency of females to be present on the tracts the entire day, while the males seldom remain past the morning. To illustrate the former, if, as shown in Fig. 2 using Dambach and Good's method, collecting was done in Population 1 between July 20 and July 26, the conclusion arrived at would be a population of 100% males. Conversely, if collections were made between August 24 and September 6, the conclusion would be a population consisting of 100% females.

Lin and Michener (1972) state, "it seems that the evolution of the sex ratio depends more on the natural history of the species" in reference to male haploidy. According to White (1954) the entire order of Hymenoptera with the exception of a few species show haploid parthenogenesis. White states, "It is characteristic of groups with haploid males that the sex ratio fluctuates rather widely from species to species and from strain to strain within the species, and also to some extent with various environmental factors, showing no particular tendency to conform to any fixed percentage of males". Consequently the sex ratio becomes meaningful only in terms of the population and even here seasonal fluctuations are likely to be considerable, so that separate determinations should be made for each season.

In Population 1 (1958), 139 wasps were sexed during daily determinations of the specific density. A total of 121 wasps were not sexed although their behavior strongly suggested males. Only the wasps themselves, living or dead, were used in determining the sex ratio, since indirect evidence like new nests or paralyzed cicadas would obviously distort the picture in favor of the female. Fig. 2 plots the weekly sex ratio, which is seen to vary considerably. By taking the sum total for all the weeks of the season, a seasonal ratio of 91 adult males to 48 adult females (65% males to 35% females) in the Population 1 area (1958) is obtained. The high male frequency suggests possibly the easier recognition of the male behaviorly rather than so great a number of males. This possibility has been considered, and it appears that this conclusion would be unwarranted.

Of the 110 emergence holes Fig. 1 (Population 1, 1958) the ratio of male holes to female holes was 83 to 27 or 3:1. In 1959 the ratio was 132 to 22 or 6:1, in 1960, 137 to 45 or 3:1; in 1961, 630 to 212 or 3:1; in 1962, 596 to 235 or 2.5:1; and in 1963, 93 to 53 or 1.7:1.

Adult Longevity and Mortality

Dambach and Good (1943) consider July 1 and September 1 as the mean first and last dates of adult life and thus approximate the life span of the adult to be 65 days.

In 1956–58 dead and dying wasps were found on the tracts between August 3 and 31. The dead wasps were in most cases in perfect condition. Though wasps were usually present in considerable numbers before August, out of a total of 20 dead or dying, none was found in July. There was in these cases no evidence of predation though on the other hand the good condition of the dead wasps, the wasps found dying from no apparent outside

Table 2.—Adult *S. speciosus* longevity table.

Year	Location	First emergence hole	Dead wasp found	Sex	Maximum age of wasp (for population)
1957	Population 1	6/30	8/4	♀	35 days
1957	Population 1	6/30	8/7	?	38 days
1957	Population 1	6/30	8/8	♀	39 days
1957	Population 1	6/30	8/9	♀	40 days
1957	Population 1	6/30	8/14	♀	45 days
1958	Population 1	7/15	8/3	♀[a]	19 days
1958	Population 1	7/15	8/10	♂	26 days
1958	Population 3	7/31	8/11	♂[a]	11 days
1958	Population 3	7/31	8/12	♂	12 days
1958	Population 3	7/31	8/13	♂	13 days
1958	Population 3	7/31	8/14	?	14 days
1958	Population 1	7/15	8/16	♀	32 days
1958	Population 1	7/15	8/18	♀	34 days
1958	Population 1	7/15	8/19	?	35 days
1958	Population 4	8/7	8/19	?	12 days
1958	Population 1	7/15	8/20	♀	36 days
1958	Population 3	7/31	8/23	?	23 days
1958	Population 1	7/15	8/23	?	39 days
1958	Population 3	7/31	8/24	?	24 days
1958	Population 2	7/24	8/31	♀	38 days

[a] found dying.

causes, and the period in which dead wasps were found, make it highly improbable that death (at least in most cases) was due to anything other than old age. No natural predators of the adult cicada killer have been observed in Brooklyn during the period of study.

In 1957 the first emergence hole on the tract inhabitated by Population 1 appeared June 30. The last dead wasp on this tract was found on August 14, thus no wasp was older than 45 days. In 1958, the first emergence hole on the tract inhabited by Populations 1, 2, 3, and 4 appeared respectively July 15, 24, 31, and August 7. Table 2 gives the maximum age of wasps found on each tract.

In 1958 in Populations 1–4, 32% or more of the emergences took place on or after August 1. It is these later emergences which probably account for wasps seen in late August or September. Dambach and Good (1943) were probably unaware of these later emergences (since marking the emergence holes appears necessary), and attributed all wasps of the season to emergences in early July.

Table 2 reveals a pattern with 3 exceptions in which the maximum age of females dying were in their 30's. Males of which there were only 4 with 1 exception of 26 days, were 11, 12 and 13 days of age. In later years, a number of males and females were captured and marked on emergence and followed daily for their entire lives. This highly precise data indicates that Table 2 is roughly correct. Males live about a maximum of 15 days and females live a maximum of about 30–33 days.

Acknowledgments

I am indebted to Dr. Charles D. Michener and Dr. Howard E. Evans for constructive criticism of this paper.

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Colaspis quattuordecimcostata *Lefèvre and Its Close Relatives in Brazil*

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ABSTRACT

Colaspis quattuordecimcostata Lefèvre is redescribed from the type specimen, and nine additional Brazilian species of *Colaspis* are described and figured.

In my studies of the Chrysomelidae I have had difficulty in establishing the true identity of the species from Brazil described by Lefèvre in 1887 as *Colaspis quattuordecimcostata*. My study of Lefèvre's type was made possible by Nicole Berti, who sent the holotype from the Natural History Museum in Paris for my examination. There are 9 closely related new species of *Colaspis*, all from Brazil, which I am describing in this paper.

Colaspis quattuordecimcostata Lefèvre

(Fig. 1)

Colaspis 14-costata Lefèvre, 1887. Ann. Soc. Ent. France, 1887, p. 144–45.

Length 11 mm. Width 4.3 mm.

Oblong oval, shining black with mostly black antennae.

Head black with fine punctures, interocular space half width of head, a medium depression down front, labrum dark brown, antennae with only joints 2 and 3 pale. Prothorax twice as broad as long, margin with tooth below middle, disc with moderately dense punctures. Scutellum shining black. Elytra a little more than 3 times as long as prothorax and wider, punctures in geminate rows except near suture where in single row and near the apex of second row, with well marked costae. Body beneath with blue-green lustre. Legs black, hind tibiae short and almost the same length as other tibiae.

Holotype.—Female, Natural History Museum, Paris (from which I borrowed the type specimen and made a drawing).

Type-locality.—Brazil.

Remarks.—The most striking character in this species is the very short hind tibiae.

Colaspis paracostata, n. sp.

(Fig. 2)

Length 8 mm. Width 4 mm.

Elongate oblong oval, shining black with dark blue-black head and prothorax.

Head with dense fine punctures, labrum brown. Interocular space a little more than half width of head, antennae with only third joint pale. Prothorax approximately twice as wide as long, margin with tooth below middle, disc sparsely punctate. Elytra more than 3 times as long as prothorax and wider. Elytra with geminate punctures except near suture and at apex of next row with costae between rows. Body beneath shining blue-black. Prosternum with few punctures. Legs all black.

Holotype—Female, USNM Type No. 75744.

Type-locality.—Brazil.

Remarks.—This species so closely resembles *C. quattuordecimcostata* that I am naming it *C. paracostata* n. sp. It differs in having longer hind tibiae.

Colaspis braxatibiae, n. sp.
(Fig. 3)

Length 8 mm. Width 4 mm.

Very elongate oblong oval, black all over, antennae black.

Head densely punctate with a depression down front, interocular space half width of head, antennae all black. Prothorax with margin having tooth below middle, disc with dense punctures, prothorax not twice as wide as long. Scutellum black. Elytra more than 3 times as long as prothorax and wider, so densely punctate that arrangement of punctures is not clear, but with tendency to be geminate, costae fairly well marked. Hind tibiae short. Prosternum with punctures.

Holotype.—Female, USNM Type No. 75745.

Type-locality.—Curraliahe, Minas Gerais, Brazil.

Remarks.—This species has unusually long elytra and short hind tibiae.

Colaspis corumbensis, n. sp.
(Fig. 4)

Length 8 mm. Width 4 mm.

Elongate oblong oval, black with green lustre. Antennae with four basal joints pale.

Head small, interocular space less than half width of head, head rather sparsely punctate, antennae with seven apical joints dark. Prothorax approximately twice as wide as long, margin with tooth below middle, disc densely punctate. Scutellum black. Elytra more than 3 times as long as prothorax, and wider, with more or less geminate punctures when they are not in single lines separated by costae. Hind tibiae rather short for so long a body, and with green lustre.

Holotype.—Male, USNM Type No. 75747. One paratype.

Type-locality.—Corumbá, Mato Grosso, Brazil.

Remarks.—The unusually small head and interocular space are noticeable for so large a beetle. The aedeagus has a long narrow tip.

Colaspis ekraspedona, n. sp.
(Fig. 5)

Length 7.5 mm. Width 3.5 mm.

Oblong oval, shining black, antennae and legs black.

Head with interocular space more than half width of head, densely and finely punctate. Antennae all black. Prothorax with margin with tooth, disc very densely punctate. Elytra not 3 times as long as prothorax and somewhat wider, densely punctate, punctures in geminate rows except near suture, with costae near punctures. Body beneath with dense punctures on prosternum, dark brown, legs dark brown.

Holotype.—Male, USNM type No. 75748.

Type-locality.—Lombory, Minas Gerais, Brazil, collected by J. Halix in November.

Remarks.—The aedeagus of this species has an unusually broad tip and as a whole is longer than usual. The beetle itself is densely punctate.

Colaspis lampomela, n. sp.
(Fig. 6)

Length 7 mm. Width. 3.5 mm.

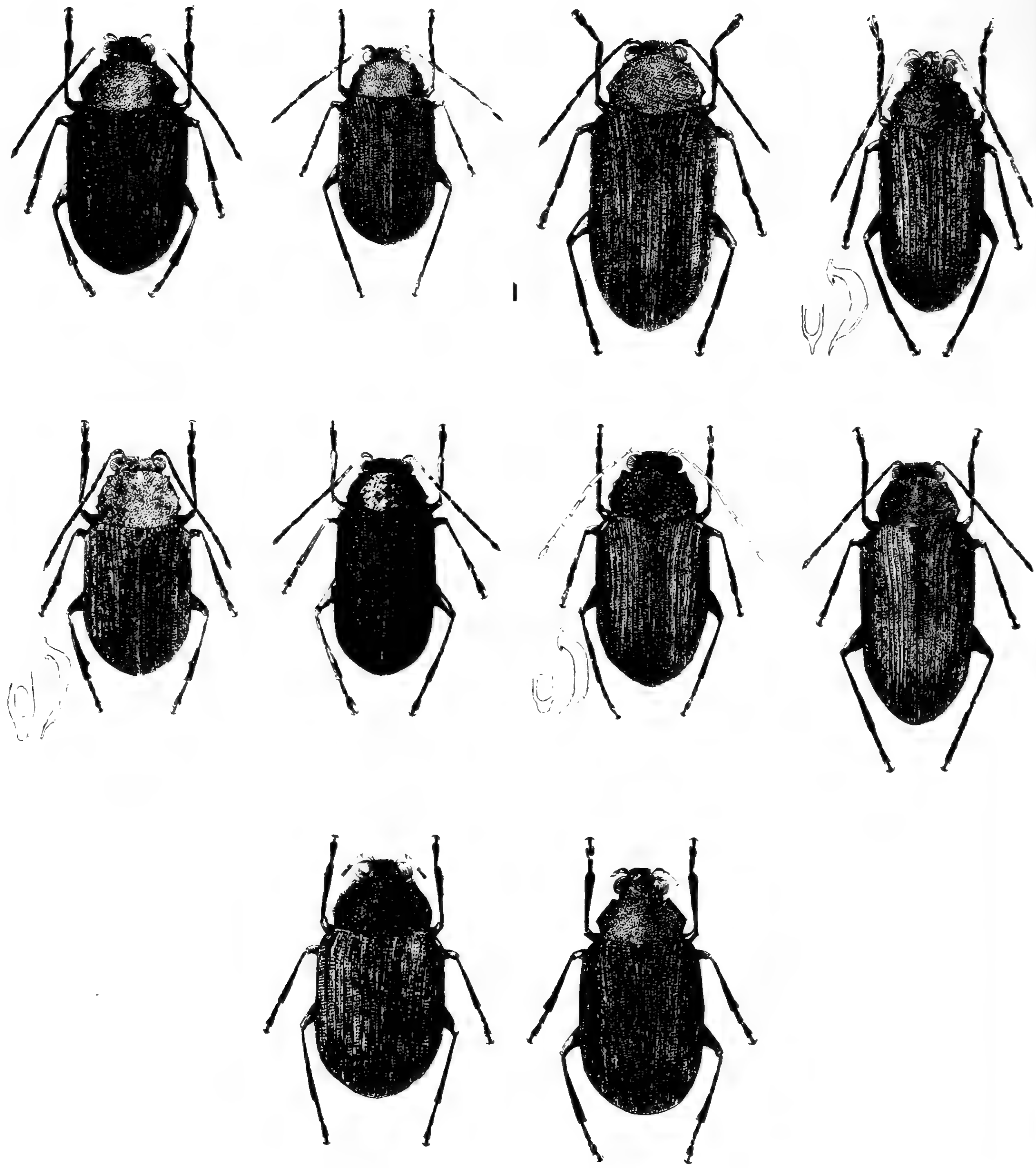
Elongate oblong oval, shining black with mostly black antennae, black legs, ventral surface very dark green.

Head with interocular space more than half width of head, finely and densely punctate, antennae with only joint 2 entirely pale, joints 1, 3, 5, and 6 partly pale, remainder black. Prothorax twice as wide as long, margin with tooth below middle, disc sparsely punctate with median elevations about punctures. Scutellum shining black. Elytra more than 3 times as long as prothorax and a little wider, densely punctate with geminate punctures except near suture and near apex, with costae between. Prosternum rather sparsely punctate. Ventral surface greenish black. Legs dark brown, nearly black.

Holotype.—Female, USNM Type No. 75749.

Type-locality.—Corotuba, Brazil. Collected Feb. 19, 1947. From Monros collection.

Remarks.—Unfortunately the only specimen is a female. However, this species differs from all the others described here in having few punctures on the prothorax.



Figs. 1–10 (left to right, top to bottom), species of *Colaspis*. Fig. 1, *Colaspis quattuordecimcostata* Lefèvre; fig. 2, *C. paracostata* Blake, n. sp.; fig. 3, *C. braxatibiae* Blake, n. sp.; fig. 4, *C. corumbensis* Blake, n. sp.; fig. 5, *C. ekraspedona* Blake, n. sp.; fig. 6, *C. lampomela* Blake, n. sp.; fig. 7, *C. flavantenna* Blake, n. sp.; fig. 8, *C. purpurala* Blake, n. sp.; fig. 9, *C. manausa* Blake, n. sp.; fig. 10, *C. juxaoculus* Blake, n. sp.

Colaspis flavantenna, n. sp.

(Fig. 7)

Length 10.5 mm. Width 5.0 mm.

Elongate oblong oval, dark brown, almost black, shining with a green lustre. Scutellum shining margins, legs dark brown, antennae pale.

Head with interocular space half width of head, densely punctate, antennae all pale. Prothorax twice as wide as long with margin having tooth below middle, disc rather irregularly punctate, shining with a green lustre. Scutellum shining with a dark green lustre. Elytra a little more than 3 times as long as prothorax and somewhat wider, punctures mostly in geminate rows except near suture and apex, where they occur in single or sometimes alternate rows, costae between very conspicuous. Body beneath shining dark blue-green, prosternum punctate. Legs with femora dark above and all dark near tip, tibiae all dark. Aedeagus long and broad with tip very broad, and widening somewhat behind tip.

Holotype.—Male, USNM Type No. 75751. One female paratype.

Type-locality.—not given (from Bowditch collection).

Remarks.—This species is very like *C. quattuordecimcostata* but larger, with a larger head and longer hind tibiae. No locality is given, but the fact that it resembles so many of the group leads me to believe that it, too, may have been collected in Brazil. It is the only one of the group with yellow antennae, which distinguishes it from the rest of the species. In addition, the aedeagus has an unusually broad tip.

Colaspis purpurala, n. sp.

(Fig. 8)

Length 9 mm. Width 4.5 mm.

Very elongate oblong oval, black, elytra with a rosy lustre and sides with a green lustre, antennae all black.

Head with interocular space half width of head, a median depression down front, finely and densely punctate, antennae all black. Prothorax approximately twice as wide as long, margin with tooth below middle, disc densely punctate. Scutellum black. Elytra nearly 4 times as long as prothorax with geminate punctation becoming alternate and then in single row below middle, costae prominent. Body beneath blue green. Prosternum with few punctures. Legs long and black.

Holotype.—Female, USNM Type No. 75752.

Type-locality.—Not given. (from Bowditch collection).

Remarks.—A member of the *quattuordecimcostata* group with unusually long elytra. It resembles *C. brachytibiae*, except that the legs are much longer. The specimen on the pin bears the name "*purpurala*," a name I cannot find in any catalogue.

Colaspis manausa, n. sp.

(Fig. 9)

Length 10.5 mm. Width 5.7 mm.

Elongate oblong oval, black shining with a green lustre in the light, undersurface dark green, antennae with first 2 joints and up to the tip of third joint pale, joint 4 all dark, remainder missing.

Head densely and finely punctate, a median depression down front, interocular space less than half width of head, labrum dark. Prothorax nearly twice as wide as long, margin with prominent tooth below middle, disc irregularly punctate with many bare spaces. Scutellum shining black. Elytra not 3 times as long as prothorax and wider, with punctures somewhat irregular but tending to be geminate, becoming single near suture and apex, costae between prominent. Body beneath dark green, prosternum with deep punctures. Femora near body dark green, becoming dark brown before end, tibiae dark brown, almost black.

Holotype.—Female, USNM Type No. 75753.

Type locality.—Manaus, Brazil.

Remarks.—This species appears black except in bright light, where it has a green lustre all over body. The interocular space is less than half the width of the head, in this feature resembling *C. corombensis* which is unusual in this group. It is also like *C. flavantenna* except that the antennae are not completely pale.

Colaspis juxaoculus, n. sp.

(Fig. 10)

Length 11 mm. Width 4.6 mm.

Elongate oblong oval, shining black.

Head with interocular space half width of head, densely punctate, antennae with first joint dark from above, joints 2 and 3 pale, remainder missing. Prothorax twice as wide as long with margin having a tooth below middle, disc densely punctate. Scutellum shining black. Elytra more than 3 times as long as prothorax and wider, with geminate punctures except near suture and apex of next row, where punctures are in single line. Legs and ventral surface black, mesosternum without punctures.

Holotype.—Female, USNM Type No. 75754.

Type locality.—Brazil.

Remarks.—This beetle bears the label "*Colaspis 14-costata* Lefèvre," and it is very close to Lefèvre's species, with the difference that the hind tibiae of *C. quattuordecimcostata* are very short and the hind tibiae of *C. juxaoculus* are much longer than those of the former.

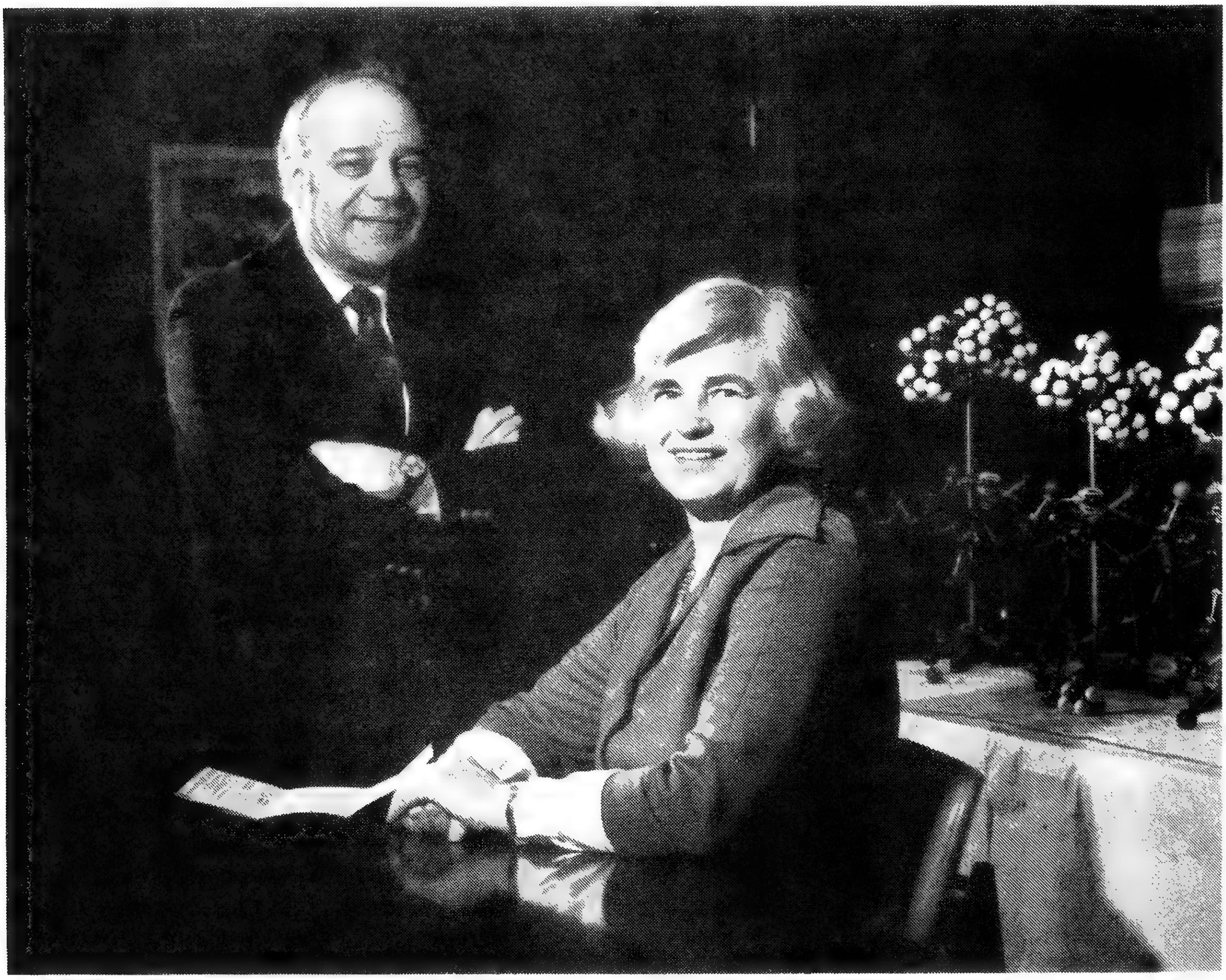
SCIENTISTS IN THE NEWS

Contributions in this section of your Journal are earnestly solicited. They should be typed double-spaced and sent to the Editor three months preceding the issue for which they are intended.

NAVAL RESEARCH LABORATORY

Dr. Isabella Karle has been elected to the National Academy of Sciences (NAS). She is the only female physical chemist in the Academy. Her husband, Dr. Jerome Karle, also a physical chemist at NRL, was elected to the Academy two years ago. The Karles are one of the few husband-wife teams elected to the Academy.

The National Academy of Sciences, a private organization of eminent scientists and engineers dedicated to the "furtherance of science and its use for the general welfare," was established in 1863 by a Congressional Act of Incorporation signed by President Lincoln. The Academy is frequently called upon to act as an official adviser to the Federal



Jerome and Isabella Karle

government in matters of science or technology.

Mrs. Karle, a native of Detroit, Michigan, joined the NRL staff in 1946 and holds BS and MS degrees in Chemistry and a PhD in Physical Chemistry, all from the University of Michigan. She heads NRL's X-ray Analysis Section in the Laboratory for Structure of Matter. Ever since Mrs. Karle developed the symbolic addition method of determining molecular structures directly from x-ray diffraction experiments 15 years ago, she has continued to make significant contributions in crystallography by her analyses of important materials particularly of interest in organic and biological chemistry. Mrs. Karle has gained world-wide recognition for her work in this field.

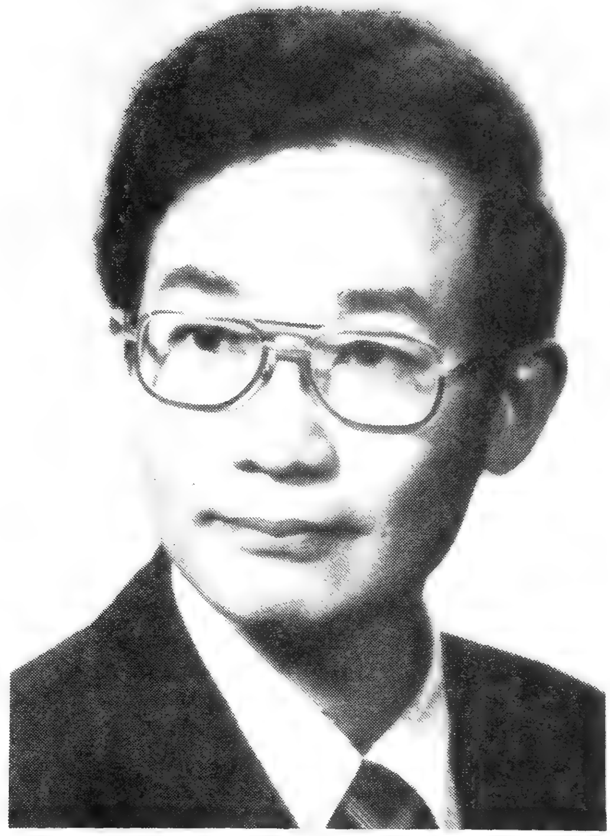
Dr. Jerome Karle, Chief Scientist of NRL's Laboratory for Structure of Matter, was elected to the Academy in 1976, at which time he was also named recipient of the 1976 Captain Robert Dexter Conrad Award for Scientific Achievement, the highest recognition the Navy can bestow on any of its scientists engaged in Naval R & D.

Mrs. Karle has been active in teaching, training many postdoctoral students in new analytical techniques. She and her husband are members of several scientific associations, including the American Chemical Society, the American Physical Society, the American Crystallographic Association, the Biophysical Society and the Washington Academy of Sciences.

The Karles live in Falls Church, Va. They have three daughters, Madeleine, Jean and Louise. Madeleine is a graduate of the Virginia Polytechnic Institute & State University. Jean, Louise and Louise's husband, Jonathan Hanson, have earned PhDs in Chemistry.

Drs. Ming-Chang Lin and **George Sigel, Jr.** are the 1978 recipients of the Pure Science and Applied Science awards from the Naval Research Laboratory's Chapter of Sigma Xi, the Scientific Research Society of North America.

Each year the NRL chapter presents awards to two outstanding NRL scientists who have made distinguished contributions to pure science and applied science while conducting research at the Laboratory. These awards are in keeping with the objective of the chapter, which is to encourage investigation in pure and applied science, and to promote the spirit of scientific research at NRL.



Ming-Chang Lin

Lin was cited for his discovery of the first chemical Transverse Electric-discharge Atmospheric (TEA) laser and its application to chemical systems. He is also noted for his discovery of numerous new chemical laser reactions, for his pioneering research in laser-accelerated chemical reactions and "for furthering our knowledge of chemical reaction mechanisms."

Sigel was recognized for providing new insights concerning the optical properties of oxide glasses, their atomic defect structures and their response to ionizing radiation, and for applying this knowledge to the selection and development of radiation resistant optical fibers for military data links.

Lin, a research chemist, joined the

George Sigel, Jr.

NRL staff in 1970. He received his BS from Taiwan National Normal University in 1959 and his PhD degree from the University of Ottawa, Canada, in 1965. He has authored or co-authored over 140 technical papers and scientific presentations in the area of chemical kinetics and lasers. He is a member of several technical societies and organizations and was the recipient of the 1975 Hillebrand Prize from the American Chemical Society of Washington, D. C., and the 1976 Physical Sciences Award of the Washington Academy of Sciences. He lives with his wife, Judy, and their three children, Karen, 11, Ellena, 7, and Linus, 10, in Oxon Hill, Md.

Sigel, who is a research physicist, came to NRL in 1966, working in the areas of glassy materials and radiation damage in glasses. He received his BS in physics from St. Joseph's College in Philadelphia, Pa. and his MS and PhD degrees in physics from Georgetown University in Washington, D. C. He is a member of the American Physical Society and the American Ceramic Society and has served as the Chairman of the Tri-Service Working Group on Radiation Effects in Optical Fibers. He has authored or co-authored over 50 technical papers in the area of glasses. Sigel lives with his wife, Jean, and their two children, Bobby, 9, and Laura, 7, in Great Falls, Va.

Dr. Theodore A. Jacobs, former Superintendent of the Optical Sciences Division at the Naval Research Laboratory, has been appointed an Associate Deputy Assistant Secretary of the Navy in the Office of Research and Advanced Technology. Prior to his employment at NRL in 1976, Dr. Jacobs had served in high level positions for the TRW Corporation, Aerospace Corporation, California Institute of Technology, Rocketdyne Division of North American Aviation and Douglas Aircraft Company. He was a research associate and lecturer in mechanical engineering at the University of Southern California in the late 1950s. Dr. Jacobs has held formal Defense Department appointments to the Army Missile Command Scientific Advisory Group, Defense Intelligence Agency Scientific Advisory Committee, and the Chief of Naval Operations. A native of Atlanta, Georgia, Dr. Jacobs holds an A.B. degree in chemistry from Emory University in Georgia, an M.S. in mechanical engineer-

Theodore A. Jacobs

ing from the University of Southern California and a Ph.D. in engineering and chemistry from the California Institute of Technology. He is a member of numerous professional and scientific societies, and holds one U. S. patent and has another pending.

In a change of command ceremonies held at the Naval Research Laboratory, Navy Captain **Edward E. (Buzz) Henifin** became the new NRL Commanding Officer on July 31, 1978. He relieved Captain Lionel M. Noel, who is retiring from the Navy. Captain Noel has been Commanding Officer of NRL since June, 1976. Prior to his new assignment, Capt. Henifin served as Deputy Director of Navy Technology.

Capt. Henifin was born in Madison, South Dakota, August 23rd, 1931. He was graduated from the U. S. Naval Academy and commissioned an Ensign in June 1954. He served aboard the USS THE SULLIVANS (DD-537) before volunteering for submarine duty. Following duty aboard HARDHEAD and BARBEL, Captain Henifin attended post-graduate school at the University of Washington, receiving a BA in Physical Oceanography in 1962. He then served aboard the USS ALBACORE (AGSS-569) in various capacities including Executive Officer. During this tour in 1963, Captain Henifin, on an additional duty assignment, participated in the search for the USS THRESHER. His next assignments were as Officer in Charge of the BATHYSCAPH TRIESTE II and then Commanding Officer USS POMFRET (SS-391), followed by an extended tour in the Deep Submergence Program Coordinators Office. In 1975 Captain Henifin reported to the Naval Material Command Headquarters and served as the Deputy Director of Navy Laboratories. He moved to the Deputy Director of Navy Technology billet in February of 1977.

Captain Henifin is a designated Deep Submergence Vehicle Operator and a designated subspecialist in Oceanography. He was awarded the Navy Achievement Medal for his performance

Edward E. Henefin

aboard TRIESTE II and the Meritorious Service Medal for the planning of and participation in deep submergence operations in 1971. Additionally, he is authorized to wear the Navy Unit Commendation Ribbon for participation in the THRESHER search, and in the Palomares bomb search in 1966.

Captain Henifin is married to the former Elisabeth Phillips of Drexel Hill, Pennsylvania. The Henifins have three children, Ann, David and Edward, and reside in Alexandria, Virginia.

Dr. Richard Tousey, a space scientist at the Naval Research Laboratory since 1941 and the physicist credited with pioneering NRL's rocket spectroscopy research, was honored with a seminar on solar radiation prior to his official retirement from the Laboratory on June 30. He is widely recognized throughout the scientific community for his outstanding leadership in solar spectroscopy investigations and was the principal investigator for four successful solar experiments carried out by astronauts aboard the Skylab space station in 1973–74. Dr. Tousey's experiments aboard Skylab provided a wealth of new

Richard Tousey

data on the physics of the sun, and color enhanced photos of solar activity taken by his instruments have been appearing in scientific journals and popular astronomy magazines throughout the world ever since.

The retiring NRL scientist received his doctorate in physics from Harvard in 1933, and from 1935 until his employment at NRL in 1941, he was a research instructor at Tufts University, . . . the school that granted him an honorary D.Sc. degree in 1961.

Appropriately enough, Dr. Tousey began his Navy career at NRL by initiating a program of upper atmosphere research to investigate the brightness of the sky and the visibility of the stars from aircraft in the daytime. In addition, Dr. Tousey headed the investigations into the fields of vision and atmospheric optics during World War II and received the Meritorious Civilian Service Award in 1945 for the design and development of a reflector gun sight for the Navy. In 1946 he began a series of experiments from high-altitude probes using captured German rockets with his spectrograph instrumentation aboard them. This enabled him to obtain the first detailed record of the sun's radiation in the far ultraviolet region and extreme short wavelengths that are otherwise hidden to an observer because of the absorption of the atmosphere.

His upper atmospheric research from rockets resulted in the first extension of the solar spectrum into the ultraviolet, high resolution solar extreme ultraviolet spectra, the discovery of many emission lines in the ultraviolet spectrum of the sun, the determination of the profile of the Lyman alpha line of hydrogen, and the direct measurement of the altitude of several night airglow emissions. During the late 1950's, Dr. Tousey also directed an NRL program of research on the visibility of earth satellites and was a member of the Science Program Committee of Project Vanguard. (Incidentally, the Navy's Vanguard satellite launched in 1958 is still traveling in space and is now the oldest man-made satellite in orbit. It is expected to be in orbit for about 400 years.)

Among his awards are the 1959 Progress Medal of the Photographic Society of America, the Frederick Ives Medal of the Optical Society of America for 1960, the Prix Ancel of the Societe Francaise de Photographie in 1962, the Draper Medal for investigations in astronomical physics and the NASA Medal for Exceptional Scientific Achievement.

Dr. Tousey is a member of many professional associations, including the National Academy of Sciences and the International Academy of Astronautics; and he is a fellow of the American Physical Society, the Optical Society of America, and the American Geophysical Union. His publications include some 200 papers.

Lendell E. Steele, associate superintendent of the Materials Science and Technology Division and head of the Thermostructural Materials Branch, has been named a recipient of the Award of Merit by the American Society for Testing and Materials (ASTM). Steele received the award from ASTM President William A. McAdams during ceremonies hosted by ASTM Standing Committee on Standards in Boston on 30 June 1978. Steele was cited for "distinguished service rendered in encouraging the transfer of research results to technology, furthering ASTM Committee E-10 on Nuclear Technologies and Applications goals and redirecting E-10 activities to a broader nuclear area, and leadership of the Committee on Standards."

OBITUARIES

Samuel B. Detwiler, Jr.

Samuel Bertolet Detwiler, Jr., a retired research administrator, U. S. Department of Agriculture, died in the Sleepy Hollow Nursing Home, Fairfax, after a long illness following a heart attack in 1973. He lived on Walter Reed Drive in Arlington.

Born in Wabasha, Minn. in 1909, son of Samuel B. and Kate E. Detwiler, he attended public schools in Arlington, the old Western High School in Georgetown, and received a BS degree in chemistry in 1934 from the George Washington University while working as a laboratory assistant at the National Bureau of Standards, then located at Connecticut Avenue and Van Ness Street. He was awarded an MA degree in organic chemistry by the University of Illinois in 1941. He served as research chemist at the USDA Regional Soybean Industrial Products Laboratory in Urbana, Ill., where his work helped lay the groundwork for the emergence of the soybean as the primary source of vegetable oil for shortenings and margarine in the United States. The Urbana laboratory was the prototype for a number of larger USDA laboratories, later established, dedicated to discovering new and wider uses for U. S. farm products. In 1944 he returned to the Washington area project officer of the Bureau of Agricultural and Industrial Chemistry, USDA, and became Assistant to the Administrator of the Agricultural Research Service in 1958, a position he held until his retirement in 1972. In the latter capacity he was intimately involved in the direction of agricultural research in foreign universities supported by proceeds from the sale of surplus U. S. agricultural commodities abroad. His official travels took him to most of the countries of Western Europe, Israel, and India. During the past several years he served as research associate with the Federation of American Societies for Experimental Biology, Bethesda. He was author of many scientific articles on chemistry and research administration.

He was manager, councilor, treasurer, and secretary of the Chemical Society of Washington and editor of its publication, the Capital Chemist. Mr. Detwiler received the Honor Scroll of the American Institute of Chemists and the Public Service Award of the Chemical Society of Washington. He was a member of the American Chemical Society, the American Institute of Chemists, the American Oil Chemists' Society, Alpha Chi Sigma, Phi Sigma Kappa, Omicron Delta Kappa, and the Cosmos Club. He was life member of the Hugenot Society of Pennsylvania. Among his many interests, any of which could have become a second vocation, were photography, military history, music, genealogy, mathematics, firearms, farming, and boating.

For a number of years Mr. Detwiler was a Fellow of the Washington Academy of Sciences. As editor of the Academy *Journal* in the recent past, he abundantly demonstrated his love and regard for his fellow scientists by the meticulous attention he devoted to promoting that activity. He also served in a number of offices in the Academy during his association with that organization.

Theodor C. von Brand

Dr. Theodor C. von Brand, 78, a retired physiologist and parasitologist for the National Institutes of Health and a former president of the American Society of Parasitologists, died on July 18, 1978 in Suburban Hospital after a heart attack. Von Brand was head of the physiology and biochemistry section of the parasitic diseases laboratory of the National Institute of Allergy and Infectious Diseases from 1947 until he retired from NIH in 1969. He was known internationally for his work in invertebrate physiology and biochemistry.

He was a member of many professional organizations and was on the expert advisory panel on parasitic diseases of the World Health Organization. At his retirement he was presented the Superior Service Honor Award of the Department of Health, Education and Welfare for "meritorious research on the chemical composition and metabolism of parasites."

Dr. von Brand was a true pioneer in the field of parasite physiology and biochemistry. It can be said with justification that he single-handedly through his research and scholarship founded and developed this area of parasitology in this country. His intellect, immense scholarship and productivity enabled him to become the author of more than 200 papers and 6 textbooks. Although he was mandatorily retired at age 70 from the NIH in 1969, he continued to be active until the end. His latest textbook will be published this autumn.

A native of Ortenberg, Germany, von Brand received a Ph.D. in zoology from the University of Munich and a M.D. from the University of Erlangen. After immigrating to the United States in 1936 he was a research fellow at Johns Hopkins University's school of hygiene. He also taught at Barat College in Illinois and at Catholic University before joining the NIH staff in 1946.

He leaves his wife, Margarethe, at the home on Hempstead Avenue in Bethesda; a son, Theodor P., of Bethesda; a sister and three grandchildren.

JOURNAL OF THE WASHINGTON ACADEMY OF SCIENCES

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Directory Issue

CONTENTS

Washington Academy of Sciences

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The Journal

This journal, the official organ of the Washington Academy of Sciences, publishes historical articles, critical reviews, and scholarly scientific articles; proceedings of meetings of the Academy and its Board of Managers; and other items of interest to Academy members. The *Journal* appears four times a year (March, June, September, and December)—the September issue contains a directory of the Academy membership.

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Philosophical Society of Washington	James F. Goff
Anthropological Society of Washington	Jean K. Boek
Biological Society of Washington	William R. Heyer
Chemical Society of Washington	Delegate not appointed
Entomological Society of Washington	Maynard Ramsay
National Geographic Society	T. Dale Stewart
Geological Society of Washington	Delegate not appointed
Medical Society of the District of Columbia	Inactive
Columbia Historical Society	Paul H. Oehser
Botanical Society of Washington	Conrad B. Link
Society of American Foresters	Thomas B. Glazebrook
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Delegates continue in office until new selections are made by the representative societies.

THE DIRECTORY OF THE ACADEMY FOR 1978

Foreword

The present, 53rd issue of the Academy's directory is again this year issued as part of the September number of the Journal. As in previous years, the alphabetical listing is based on a postcard questionnaire sent to the Academy membership. Members were asked to update the data concerning address and membership in affiliated societies by June 30, 1978. In cases in which cards were not received by that date, the address appears as it was used during 1978, and the remaining data were taken from the directory for 1977. Corrections should be called to the attention of the Academy office.

Code for Affiliated Societies, and Society Officers

1 The Philosophical Society of Washington (1898)

President:	George T. Armstrong, 1401 Dale Dr., Silver Spring, MD 20910
Vice-President:	William G. Maisch, 205 Yockum Parkway, Alexandria, VA 22034
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Delegate:	James F. Goff, 3405 34th Pl., N.W., Washington, D.C. 20016

2 Anthropological Society of Washington (1898)

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President-elect:	Marie Bourglaise, NIH, Bethesda, MD 20014
Secretary:	Mary F. Gallager, Montgomery College, Rockville, MD 20853
Delegate:	Jean K. Boek, National Graduate Univ., 1101 N. Highland St., Arlington, VA 22201

3 Biological Society of Washington (1898)

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4 Chemical Society of Washington (1898)

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Vice-President:	Walter Benson, FDA-HFD 420, 200 C St. S.W., Washington, D.C. 20204
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Delegate:	Not appointed

5 Entomological Society of Washington (1898)

President:	Douglas W. S. Sutherland, 125 Lakeside Dr., Greenbelt, MD 20770
Vice-President:	Donald R. Davis, Dept. of Entomology, Smithsonian Institution, Washington, D.C. 20560
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Delegate:	Maynard J. Ramsay, 3806 Viser Court, Bowie, MD 20715

6 National Geographic Society (1898)

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7 Geological Society of Washington (1898)

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Delegate:	Not appointed

8 **Medical Society of the District of Columbia (1898)**

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Delegate:	Not appointed

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11 **Society of American Foresters, Washington, Section (1904)**

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12 **Washington Society of Engineers (1907)**

President:	Jeffrey H. Rumbaugh, Potomac Electric Power Co., 1900 Pennsylvania Ave., N.W., Washington, D.C. 20068
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Delegate:	George Abraham, 3107 Westover Dr., S.E., Washington, D.C. 20020

13 **Institute of Electrical & Electronics Engineers, Washington Section (1912)**

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Delegate:	George Abraham, 3107 Westover Dr., S.E., Washington, D.C. 20020

14 **American Society of Mechanical Engineers, Washington Section (1923)**

Chairman:	Robert L. Hershey, 1255 New Hampshire Ave., N.W., Apt. 433, Washington, D.C. 20036
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15 **Helminthological Society of Washington (1923)**

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Delegate:	Robert S. Isenstein, FSQS, USDA, BARC-East, Beltsville, MD 20705

16 **American Society for Microbiology, Washington Branch (1923)**

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Secretary:	Phyllis D. Kind, The George Washington University School of Medicine, Dept. of Microbiology, Washington, D.C. 20037
Delegate:	Michael J. Pelczar, Jr., Vice President for Graduate Studies & Research, University of Md., College Park, MD 20742

17 Society of American Military Engineers, Washington Post (1927)

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Secretary: William I. Jacob, DAEN-FER-P, Washington, D.C. 20314
Delegate: Hal P. Demuth, 4025 Pine Brook Rd., Alexandria, VA 22310

18 American Society of Civil Engineers, National Capital Section (1942)

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Delegate: Robert Sorenson, Coastal Engineering Research Ctr., Kingman Bldg., Ft. Belvoir, VA 22060

19 Society for Experimental Biology & Medicine, D.C. Section (1952)

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Delegate: Donald F. Flick, 930 19th St., So., Arlington, VA 22202

20 American Society for Metals, Washington Chapter (1953)

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Vice-Chairman: Alan H. Rosenstein, Air Force Office of Scientific Res., 1400 Wilson Blvd., Arlington, VA 22209
Secretary: Joseph Malz, NASA, Code RWM, Washington, D.C. 20546
Delegate: Glen W. Wensch, U.S. Atomic Energy Comm., Washington, D.C. 20545

21 International Association for Dental Research, Washington Section (1953)

President: John D. Termine, Natl. Institute of Dental Research, Bethesda, MD 20014
Vice-President: William R. Cotton, Naval Medical Research Institute, Bethesda, MD 20014
Secretary: Stanley Vermilyea, Walter Reed Army Inst. of Res., Washington, D.C. 20012
Delegate: William V. Loebenstein, National Bureau of Standards, Washington, D.C. 20234

22 American Institute of Aeronautics and Astronautics, National Capital Section (1953)

Chairman: Robert O. Bartlett, 18333 Duchess Dr., Olney, MD 20832
Vice-Chairman: George J. Vila, General Dynamics, 1025 Conn. Ave., N.W., Washington, D.C. 20036
Secretary: Richard Hallion, 1003 Montrose Lane, Laurel, MD 20810
Delegate: George J. Vila

23 American Meteorological Society, D.C. Chapter (1954)

Chairman: Celso Barrientos, Natl. Weather Serv. W427, 821 Gramax Bldg., 8060 13th St., Silver Spring, MD 20910
Vice-Chairman: June Bacon-Bercey, Rm. 1310 Gramax Bldg., W 116X2, Silver Spring, MD 20233
Secretary: David H. George, Rm. 1424, Gramax Bldg., Silver Spring, MD 20233
Delegate: A. James Wagner, National Weather Service, World Weather Bldg., 5200 Auth Rd., Washington, D.C. 20233

24 Insecticide Society of Washington (1959)

Chairman: Neal O. Morgan, USDA, ARS, Bldg. 476, Rm. 100, BARC-East, Beltsville, MD 20705
Chairman-elect: Jack R. Plimmer, USDA, ARS, Bldg. 306, Rm. 313, BARC-East, Beltsville, MD 20705
Secretary: John Neal, ARS, ARC, Bldg. 467, Beltsville, MD 20705
Delegate: Robert Argauer, ARS, ARC, Bldg. 309, Beltsville, MD 20705

25 Acoustical Society of America (1959)

Chairman: John A. Molino, Sound Section, NBS, Washington, D.C. 20234
Vice-Chairman: Charles T. Molloy, 2400 Claremont Dr., Falls Church, VA 22043
Secretary: William K. Blake, Naval Ship R & D Ctr., Bethesda, MD 20034
Delegate: None appointed

26 American Nuclear Society, Washington Section (1960)

President:	Arthur Randal, Am. Nuclear Energy Council, 1750 K St., N.W., Washington, D.C. 20006
Vice-President:	S. Bassett, NUS Corp., Rockville, MD 20852
Secretary:	Ray Durante, Westinghouse Electric, 1801 K St., N.W., Washington, D.C. 20006
Delegate:	Dick Duffy, Nuclear Engineering, Univ. of Md., College Park, MD 20742

27 Institute of Food Technologists, Washington Section (1961)

Chairman:	Tannous Khalil, Giant Foods, Inc., Landover, MD 20785
Vice-Chairman:	Florian C. Majorack, Food & Drug Adm., Washington, D.C.
Secretary:	Glenn V. Brauner, National Canners Assoc., Washington, D.C. 20036
Delegate:	William Sulzbacher, 8527 Clarkson Dr., Fulton, MD 20759

28 American Ceramic Society, Baltimore-Washington Section (1962)

Chairman:	W. T. Bakker, General Refractories Co., P.O. Box 1673, MD 21203
Chairman-elect:	L. Biller, Glidden-Dirkee Div., SCM Corp., 3901 Hawkins Point Rd., Baltimore, MD 21226
Secretary:	Edwin E. Childs, J. E. Baker Co., 232 E. Market St., York, PA 17405
Delegate:	None appointed

29 Electrochemical Society, National Capital Section (1963)

Chairman:	David R. Flinn, Bureau of Mines, College Park Research Center, College Park, MD 20740
Vice-Chairman:	John R. Ambrose, National Bureau of Standards, Bldg. 223, Rm. B254, Washington, D.C. 20234
Secretary:	George Marinenko, National Bureau of Standards, Bldg. 222, Rm. A217, Washington, D.C. 20234
Delegate:	David R. Flinn

30 Washington History of Science Club (1965)

Chairman:	Richard G. Hewlett, Atomic Energy Comm.
Vice-Chairman:	Deborah Warner, Smithsonian Institution
Secretary:	Dean C. Allard
Delegate:	None appointed

31 American Association of Physics Teachers, Chesapeake Section (1965)

President:	William Logan, D.C. Teachers College, 2565 Georgia Ave., Washington, D.C. 20001
Vice-President:	Eugenie V. Mielczarek, George Mason Univ., 4400 University Dr., Fairfax, VA 22030
Secretary:	John B. Newman, Towson State College, Towson, MD 21204
Delegate:	None appointed

32 Optical Society of America, National Capital Section (1966)

President:	Mark Daehler, Naval Research Laboratory, Code 7122.2, Washington, D.C. 20375
Vice-President:	George J. Simonis, Harry Diamond Laboratory, Branch 32, 2800 Powder Mill Rd., Adelphi, MD 20783
Secretary:	Martin J. Koomen, Naval Research Laboratory, Code 7141, Washington, D.C. 20375
Delegate:	Lucy B. Hagan, National Bureau of Standards, Rm. B360, Physics, Washington, D.C. 20234

33 American Society of Plant Physiologists, Washington Section (1966)

President:	Anne H. Datko, NIMH Bldg. 32A, Rm. 101, Bethesda, MD 20014
Vice-President:	Werner J. Meudt, USDA, ARS Bldg. 50, Beltsville, MD 20705
Secretary:	Charles F. Cleland, Radiation Biology Lab., 12441 Parklawn Dr., Rockville, MD 20852
Delegate:	W. Shropshire, Jr., Smithsonian Institution, 12441 Parklawn Dr., Rockville, MD 20852

34 Washington Operations Research Council (1966)

President:	Charles Tiplitz, 8809 Bells Mills Rd., Potomac, MD 20854
Vice-President:	Thomas Sicilia, 113 N. Oakland St., Arlington, VA 22212
Secretary:	James Boisseau
Delegate:	John G. Honig, 7701 Glenmore Spring Way, Bethesda, MD 20034

35 Instrument Society of America, Washington Section (1967)

President:	Francis C. Quinn
President-elect:	John I. Peterson
Secretary:	Frank L. Carou
Delegate:	None appointed

36 American Institute of Mining, Metallurgical & Petroleum Engineers (1968)

Chairman:	Garrett R. Hyde, 6027 Springhill Dr., Greenbelt, MD 20770
Vice-Chairman:	John A. Patterson, 7705 Hamilton Spring Rd., Bethesda, MD 20034
Secretary:	John H. DeYoung, Jr., 12677 Magna Carta Rd., Herndon, VA 22070
Delegate:	Gus H. Goudarzi, 658 Pemberton Court, Herndon, VA 22070

37 National Capital Astronomers (1969)

President:	James Trexler, 5609 Otlarow St., Oxon Hill, MD 20021
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Secretary:	William R. Winkler, 15804 Pinecroft Lane, Bowie, MD 20716
Delegate:	Benson J. Simon, 8704 Royal Ridge Lane, Laurel, MD 20811

38 Maryland-District of Columbia and Virginia Section of Mathematical Assoc. of America (1971)

Chairman:	Orville Thomas, U.S. Naval Academy, Annapolis, MD 21401
Chairman-elect:	John Smith, 1837 Negel Ct., Vienna, VA 22180
Secretary:	Reuben Drake, 3701 Connecticut Ave., N.W., Washington, D.C. 20008
Delegate:	Patrick Hayes, 950 25th St., N.W., Washington, D.C. 20037

39 D.C. Institute of Chemists (1973)

President:	Kelso B. Morris, 1448 Leegate Rd., N.W., Washington, D.C. 20012
President-elect:	Leo Schubert, 8521 Beech Tree Rd., Bethesda, MD 20034
Secretary:	Fred D. Ordway, 2816 Fall Jax Dr., Falls Church, VA 22042
Delegate:	Miloslav Rechcigl, Jr., 1703 Mark Lane, Rockville, MD 20852

40 The D.C. Psychological Association (1975)

President:	John F. Borriello, St. Elizabeth's Hospital, Overholser Division, Washington, D.C. 20032
President-elect	Eugene Stammeyer, St. Elizabeth's Hospital, Overholser Division, Washington, D.C. 20032
Secretary:	Sylvia M. Tetrault, Howard Univ. College of Medicine, Washington, D.C. 20059
Delegate:	John J. O'Hare, Office of Naval Research, 800 N. Quincy St., Arlington, VA 22217

41 The Washington Paint Technical Group (1976)

President:	Maurice S. Moen, Sherwin Williams Co.
Vice-President:	Robert F. Brady, Jr., GSA
Secretary:	Mildred A. Post, National Bureau of Standards, Bldg. 226, Rm. B-348, Washington, D.C. 20234
Delegate:	Paul G. Campbell, National Bureau of Standards, B-348 Br., Washington, D.C. 20234

42 Potomac Division, American Phytopathological Society (1977)

President:	C. W. Roane, Dept. of Plant Pathology, Virginia Polytechnic Inst. and State University, Blacksburg, VA 24061
Vice-President:	J. R. Stavely, Tobacco Laboratory, USDA, Agric. Research Center, Beltsville, MD 20705
Secretary:	L. D. Moore, Dept. of Plant Pathology, Virginia Polytechnic Inst. and State University, Blacksburg, VA 24061
Delegate:	T. van der Zwet, Fruit Laboratory, USDA, Agric. Research Center, Beltsville, MD 20705

43 Metropolitan Washington Chapter of the Society for General Systems Research (1977)

Chairman:	Ronald W. Manderscheid, 6 Monument Ct., Rockville, MD 20850
Secretary:	Helen G. Tibbitts, 4105 Montpelier Rd., Rockville, MD 20853
Delegate:	Ronald W. Manderscheid, 6 Monument Ct., Rockville, MD 20850

44 Potomac Chapter, Human Factors Society (1977)

President:	M. Dean Havron, 6222 Edgewater Dr., Falls Church, VA 22041
Vice-President:	Michael L. Fineberg, 10707 Huntley Ave., Silver Spring, MD 20902
Secretary:	Erwin W. Bedarf, 12901 Livingston Rd., Oxon Hill, MD 20022
Delegate:	H. McIlvaine Parsons, 4701 Willard Ave., Chevy Chase, MD 20015

45 Potomac Chapter, American Fisheries Society (1978)

President:	Worrall R. Carter, III, Maryland Fisheries Admin., P.O. Box 68, Wye Mills, MD 21679
President-elect:	Galen L. Buterbaugh, Dep. Assoc. Director, Fish., U.S. Fish & Wildlife Service, U.S. Dept. Interior, Washington, D.C. 20240
Secretary:	Norville S. Prosser, Sport Fishing Institute, 608 13th St., N.W., Suite 801, Washington, D.C. 20005
Delegate:	Irwin M. Alperin, Exec. Director, Atlantic States Marine Fisheries Comm., 1717 Massachusetts Ave., N.W., Washington, D.C. 20036

Alphabetical List of Members

M = Member; F = Fellow; E = Emeritus member; L = Life Fellow. Numbers in parentheses refer to numerical code in foregoing list of affiliated societies.

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CONTENTS

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The Golden Age of Nutrition

Archibald T. McPherson

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ABSTRACT

Within recent years science, engineering, and technology have reached a stage at which one can see the possibility of producing food in any desired quantity by total synthesis from abundant raw materials. Food supplementing and eventually superseding food from agriculture can be provided for everyone on the earth. Beginnings have been made by the synthetic production of vitamins, amino acids, fats, and carbohydrates. The following actions are proposed: (1) preparation, by a select interdisciplinary group, of a comprehensive program for research, development, and production; (2) endorsement of the program by the scientific community; (3) consideration of the program by the World Food Council, and recommendation by the Council to the United Nations Development Program; (4) financing by the UNDP; (5) establishment of an agency for synthetic foods; (6) coordination of synthetic and agricultural production. The vicious circle of poverty and malnutrition is now a major handicap to vast numbers of people in the developing countries. This circle can be broken by a massive infusion of food. The cost of the food would be offset, in the long range, by the increased gross national product which would result from increased productivity and a higher standard of living.

This paper is a sequel to "Chemistry, Food, and Civilization," an address before the Washington Academy of Sciences by the author as retiring President on February 19, 1959 (McPherson, 1960). Publication of this address and citations in the literature led to a succession of requests for talks, papers, and participation in symposiums that has continued almost to the present. This paper is intended as a concluding statement by the author.

The attention to the address is in no way due to its originality or novelty. Indeed the basic idea of the production of human food by direct synthesis was presented by the celebrated German chemist, Emil Fischer (1906), in an address before the Royal Prussian Academy of Sciences. Even at that time the idea was so widely current that it had been ridiculed in cartoons. But what was once speculation has been brought within the range of practicality by signal advances in science, engineering, and technology within the past 70 years. We can now clearly foresee the possibility of developing a new source of food for man that will transcend the limitations that are imposed on agricultural production by rainfall, soil, climate, and the availability of arable land.

Golden Ages

Many accounts of golden ages in the long distant past have come down to us in legends. History records a number of golden ages such as the Golden Age of

Pericles. Such golden ages, whether of history or legend, were usually of short duration; indeed, they may have been scarcely recognized as golden during the time they occurred.

The Golden Age of Nutrition, in contrast, lies in the future, and will be continuing rather than ephemeral. Whereas the golden ages of the past resulted from some fortuitous or unusual combination of circumstances, the Golden Age of Nutrition will not be heaven-sent, but will come only through the concerted action and sustained efforts of men and nations.

What, then, is this new Golden Age to be? What is needed to bring it in? How may it be recognized when it shall have been attained? The ancients pictured this age as a time of abundance of milk and honey—two basic nutrients that were usually scarce and always highly prized. A familiar hymn pictures future life in "Jerusalem the golden, with milk and honey blest! . . ."

The Golden Age that we are speaking about will be realized when there will be *enough food* and *correct food* for everyone on earth. The food will not only be sufficient in quantity and optimal in nutritional value, but it will also appeal to the taste and afford pleasure in eating. The end sought is to assure that each child that is born will grow and develop to the maximum of his or her full physical, emotional, and mental capacity.

At the present juncture in human affairs the Golden Age of Nutrition may seem very remote because of the gloomy prospect that the population of the earth may far outrun the food supply before the increase in population can be brought under control. The recent biennial survey by the Food and Agriculture Organization (1978) supports this forecast. In two years the world population has increased by 2%, whereas the food supply has gone up by only 1.5%, even though weather has been generally favorable and vigorous efforts have been made to increase the output of agriculture. Furthermore, much of the increase has been attained in countries that need it least. But even if food production could be brought into step with the increase in population, it would serve only to maintain the unhappy *status quo* of hunger and malnutrition of nearly half of the people of the earth.

Looking ahead, and considering only agriculture, many can foresee only a long, slow, and painful period of adjustment of population to food supply, marked by small gains here, disastrous famines there, and the tragic failure of millions of children to attain normal growth and development. A few individuals, however, can see the present dismal outlook as a stimulus to go to the next stage beyond agriculture and produce man-made food by methods that have proven so successful in forestalling shortages of fiber, rubber, plastics, detergents, pharmaceuticals, and many other products that were formerly derived wholly from agriculture. The development of synthesis as a major source of food can, and ultimately will, usher in a new era in human affairs as significant as was the development of agriculture 10,000 years ago.

Food Through the Ages

The advancement of man over the past two million or so years has been closely associated with successive stages in the increase or the improvement of food supply. The discovery and use of tools for obtaining food marked the transition from anthropoid to man. The prehuman diet had consisted principally of fruit, tender shoots and leaves, grubs, insects, and very occasional small animals. It was greatly enriched by game, fish, nuts, and seeds that were obtained or utilized by the aid of tools. Man became omnivorous and was able to find subsistence over a much wider area. Then came the discovery of fire which further increased his range. His diet was greatly improved by the roasting or cooking of food, and many plants and roots that are toxic when eaten raw became safe and palatable on cooking.

The advent of agriculture about 10,000 years ago marked what was probably the greatest single advance in human affairs. The simultaneous domestication of sheep and goats and the cultivation of the wild grain, emmer, came about in the Fertile Crescent lying to the east, north, and west of the Tigris-Euphrates Valley. This made possible settled abode in village-farming communities such as Jarmo and Jericho. Similar developments occurred elsewhere in the world at about the same time, all possibly resulting from population pressure (Cohen, 1977). The simultaneous domestication of animals and grain met two essential needs. Animals in the herd and grain in storage assured a supply of food in winter, and the milk and meat were especially important for the survival and normal growth of children in the critical period after weaning.

In the historically brief span of a few thousand years after the domestication of animals and plants came the discovery of irrigation. Irrigation made possible the development of cities by the production of a large quantity of food within an area from which it could be transported readily to a center of population. Thus great cities arose in the valleys of the Tigris-Euphrates, the Nile, and the Indus. In these cities many facets of our civilization today had their beginning.

Factors Foreshadowing Man-Made Food

During the past 5,000 years agriculture and cities supported by agriculture have spread over the earth. As has already been mentioned agriculture is approaching its practical limits. We shall here sketch briefly some of the factors that are setting the stage for the transition from agriculture to synthesis as a major source of food. It is not anticipated that synthetic production will quickly or completely supersede agriculture. Rather, each will produce those items that it can make most efficiently. Indeed, the hunting, the gathering of wild plants, and especially the fishing of the pre-agricultural era are still practiced today, though with the use of more sophisticated tools.

Knowledge of Nutrition.—Basic to man-made food is the identification of the essential nutrients in food and the determination of the role of each in the growth and maintenance of the human body. It is only within very recent years that all (so we think) of the essential vitamins and trace elements have been clearly identified. Much current research is concerned with determining the optimal amounts of each nutrient and interactions among the nutrients. The validity of present knowledge has been demonstrated by feeding tests with animals and human subjects, using completely synthetic diets. In one experiment lasting 19 weeks, 15 subjects (men in good health) showed a definite improvement in nutrition over that at the beginning of the experiment (Winitz, 1965).

Synthetic Organic Chemistry.—The knowledge of chemistry is now such that it is possible to make nearly any desired substance, starting with the elements or with any conveniently available raw material containing the elements. The synthesis of large and complex molecules may be a long and difficult task, but if the demand for a substance is sufficiently great the synthesis can be accomplished and practical means of production can be found. This has been illustrated many times by the transition of a substance from a laboratory curiosity to a commercial product within a year or two.

Chemical Engineering.—Corresponding advances have been made in chemical engineering. The control of processes in the factory is such that it is often possible to obtain a purer product there than in the laboratory. Automation and control by computers now may enable an entire manufacturing process to be controlled by one person at a console. Even 30 years ago the capability of industry for speedily accomplishing a large and difficult task was illustrated by the production of synthetic rubber in World War II. In 1939 not a single pound of general purpose synthetic rubber was produced in the United States; in 1943 the output was over 400,000 tons.

Food Technology.—A few synthetic nutrients such as sugars and certain fats and oils might be used directly in the diet in the pure state. Most nutrients, however, would require admixture with other nutrients and with flavors, colors, and other ingredients, also synthetic, so as accurately to simulate familiar foods of plant or animal origin. The food processing industry has been reasonably successful in making simulated milk, meat, and other food products from products of vegetable origin. Given proteins, flavors, and colors identical to those of animal origin, it should experience no major difficulty in making food products identical to customary foods, except in origin.

Present Status of Essential Nutrients

The essential nutrients are now at widely different stages of development, ranging from vitamins which are now in commercial production in most industrialized countries, to polypeptides and proteins, only a few of which have been made in the laboratory.

Vitamins.—The synthetic production of vitamins has been commercially successful inasmuch as vitamins are products that can be made in relatively small quantity to command a high unit price. Pure vitamins range from about $8.00 per kilogram for ascorbic acid to $8.00 per gram for vitamin B_{12} or cyclocobalamin. Even at these prices the recommended daily allowance of cyclocobalamin costs only about one-onehundredth as much as that of ascorbic acid. Over the twenty-year period from 1945 to 1965 the price of ascorbic acid decreased from about $11.00 per pound to $2.00 or $.44 per kg. as production increased proportionately. The increase in price since 1965 reflects the current inflation.

Minerals.—Minerals in the amounts required for human nutrition present no problems from the standpoint of availability or price. Some elements, particularly iron, are absorbed by the body at different rates, depending on the particular compound in which they are provided. Certain vitamins and minerals are required by law to be added to cereal and other processed foods to compensate for losses in processing.

Fats.—Fats were made in quantity for human consumption in Germany under emergency conditions in World War II. The initial raw materials were coke, air, and water, use being made of the Fischer-Tropsch reaction. Production was not continued after the war because the price was not competitive with that of natural fats and oils. Fatty acids are said to be made synthetically now for industrial applications in eastern European countries in order to save the limited supply of natural fats for human consumption. Saturated fatty acids can be made readily by the catalytic oxidation of the corresponding hydrocarbons by oxygen of the air; conversion of fatty acids to fats is readily accomplished by combination with glycerol, also made from petroleum. The production of the polyunsaturated fats that are regarded as the more desirable for human nutrition is less direct and may require further research and development.

Fats are scarce and relatively expensive in some of the developing countries; as a consequence in some places special measures are required to keep motor oil from being used as an adulterant or otherwise mistakenly consumed for food. Thus, fats should be marked for early consideration in any program for the synthetic production of food.

Carbohydrates.—Extensive research has been conducted by the National Aeronautics and Space Administration on the production of carbohydrates and other sources of energy from respired carbon dioxide and water on space flights of long duration. An essential requirement is that the equipment be capable of operating within the narrow confines of a space vehicle. One of the more feasible processes is for the production of glycerol which is suitable as a source of energy and acceptable in the diet in any proportion.

When not limited by the constraints of space travel, an immediately practical method of making carbohydrates is by the hydrolysis of cellulose, the most abundant of all natural products. Over many years studies have been made of the acid hydrolysis of cellulose, but no means have been found that have proved commercially practical. Now, however, enzymatic hydrolysis for the production of glucose from waste paper has been carried to a promising pilot plant stage. Although the present objective is to make alcohol from the glucose, the glucose could be used for food or it could be converted to starch, also for food.

Non-Natural High Energy Foods.—1,3-butanediol and other substances that do not occur in nature have been shown to be readily used by the body as a source of energy and to be acceptable from the standpoint of taste when incorporated in the diet.

Amino Acids.—The 24 amino acids that constitute proteins have all been made by synthesis and are commercially available in lots of at least one kilogram. Glutamic acid is widely used as a condiment in the form of monosodium glutamate. Principal interest from the standpoint of nutrition, however, is in the nine so called "essential" amino acids that must be supplied in the diet since the body cannot synthesize them. Proteins of animal origin contain the essential amino acids in approximately the proportion required by the body, but plant proteins are virtually all deficient in one or more of the essential amino acids. In the use of plant proteins for food or as feed for animals the efficiency of the protein for growth or maintenance may be markedly increased by the addition of the limiting amino acids; the amounts required are only a few tenths of a per cent. Methionine and its hydroxy-analog are manufactured in car-load quantities for supplementing the protein of soybean meal used for the feeding of poultry and swine. Lysine is likewise used as a supplement to cereal grains; the addition of 0.375% to wheat is said to double the protein efficiency of bread. Threonine and tryptophan are also used as supplements in cereal grains.

A major problem with synthetic amino acids lies in the fact that chemical syntheses produce equal amounts of the dextro- and the laevo- form whereas the body utilizes only the laevo. With methionine and phenylalanine the body is able to convert the dextro- to the laevo- form, but with other amino acids the dextro- form can be used, if at all, only as a source of energy. Means are available for separating the isomers and for converting the dextro- to the desired laevo- form but the difficulty and cost of the additional steps seems to have limited their use. At present it seems more practical to make lysine by a fermentation process that yields only the laevo-form.

Present market prices of methionine and lysine are respectively, $2.20 and $3.59 per kilogram, whereas other amino acids are priced in the order of $100 per kilogram. The latter prices indicate that the demand has not been sufficient to warrant the development of simpler methods of synthesis or the use of large scale production methods.

Polypeptides and Proteins.—Two methods of synthesis have been employed in the laboratory. In one method, amino acid groups are added, one at a time, to a terminal amino acid group until the long chain polypeptide or protein molecule has been built up. (By convention, one hundred amino acids groups mark the dividing line between polypeptides and proteins.) In another method, a number of sub-groups are built up and are then linked together to make the desired large molecule. Neither method seems practical for use in manufacture. An alternative method would be to make polymers or multipolymers of amino acids by conventional methods of polymer science and to employ them as food in mixtures that would provide the optimal amino acid pattern. The major problem in implementing this plan would be the production of polymers that would be broken down on digestion to yield the constituent in just the same way as natural proteins.

A possibility for long range research is suggested by current studies of the origin of life on the earth. Proteinoids made up of amino acids are readily produced in a single stage from simple substances such as nitrogen, methane, water, and hydrogen cyanide. Modern knowledge of reaction mechanisms and thermodynamics might show the way to the production of proteins in a single-stage process from abundant simple substances.

Raw Materials for Synthesis

In the chemical industry today most syntheses employ liquid or gaseous petroleum to provide the carbon chain of the desired product and also to serve as a source of process energy. Petroleum, however, is not essential as shown by the Fischer-Tropsch employed in Germany during World War II. This process produced airplane fuel, fats, rubber, and many other products from coke, water, and air. Thus, coal, wood charcoal, or carbon from other sources could be used instead of petroleum and, as mentioned in a previous section, carbohydrates, starch, and other food products could be made from cellulose, the most abundant of all natural products.

Even if petroleum should be used, the amount required would be much less than that now used for fuel. The annual consumption of petroleum is equivalent to 35.1×10^{15} Cal, whereas all the food in the world provides only 3.6×10^{15} Cal, or only about one-tenth as much. Furthermore, even this consumption would be offset by the use of petroleum in modern agriculture as fuel for farm machinery and for the production of fertilizer and for other purposes. In some situations today the energy consumed may even be greater than the energy content of the food grown.

Nitrogen in the form of ammonia is used both as fertilizer and for the synthesis of amino acids and proteins. Most of the current production of ammonia is from nitrogen of the air, natural gas, and water, though some is made with the use of coal or liquid petroleum instead of natural gas. Looking to possible future dependence on the biomass as a renewable source of both materials and energy, methane produced by fermentation could be used instead of natural gas for the production of ammonia.

When ammonia is used for the synthesis of amino acids and polypeptides and protein there is no significant loss of material, whereas when ammonia is applied to the soil as fertilizer only a small fraction of the nitrogen is returned as food at the end of the food chain. The author estimated that for the year 1969 in the United States the amount was 15.6% (McPherson, 1972). The recovery of other elements was even less—8.7% for potassium and 5.5% for phosphorus. Thus synthetic production has a conspicuous advantage over agriculture in the saving of materials and the energy consumed in their production.

Accomplishing the Production of Food by Synthesis

The production of food by synthesis on a scale commensurate with world needs can be foreseen as inevitable at some time in the future. The undertaking, as now visualized, is too complex and too difficult to be done by industry. It can be seen as best accomplished by a unified, massive operation, in three stages. The first stage would be the preparation of a comprehensive program. The second would be the approval of the program by leading men and organizations of the world's scientific community. With their approval, the third stage would be consideration of the proposed program by political leaders who would be in a position to determine to support the program with the provision of manpower, funds, and priorities on a continuing basis. They would provide for the manufacture, distribution, and utilization of the products.

Planning the Program.—The preparation of an adequate program will, in itself, be an undertaking of the first magnitude, inasmuch as it will require the coordinated effort of persons drawn from a number of disciplines including nutrition, chemistry, engineering, polymer science, physiology, food technology, and social and political sciences. Fortunately, there is a small prototype of just such an operation. A summer workshop on synthetic carbohydrate was conducted at Stanford University in the summer of 1972 under the joint sponsorship of the University and the National Aeronautics and Space Administration (Berman and Murashige, 1973). The participants in this study were 18 young faculty members drawn from universities throughout the United States. The study dealt in detail with possible processes, yields, costs, and social and economic implications. Taking India as an example, the study showed that it would be possible to produce starch from sugarcane bagasse at a competitive price.

The study here contemplated would require a larger number of participants working together for a longer period of time. It is suggested that the participants be drawn from their positions in universities, industry, and government on special leave for an academic year. A supporting staff, organized well in advance, would be required to draft procedures and make necessary preparations. The cost might be of the order of one or two million dollars. In order to get started some person of vision and initiative must provide the spark and motivate a university or other organization to assume leadership of the planning operation and to secure, from whatever source possible, the necessary funds.

Endorsement by the Scientific Community.—The preparation of the program would necessarily involve frequent communication between the participants and a wide range of individuals and organizations both in the United States and abroad. There would probably be occasions in which committees or task forces would be set up to deal with particular questions or problems. Thus, scientists and others concerned with world food supply would have considerable knowledge of the proposed program in advance of its publication. With the release and wide dissemination of the proposed program the stage would be set to seek endorsement by cognizant scientific societies and other organizations, and, with endorsement, presentation of the program at the international level.

Implementation by International Action.—The World Food Council is the organization to which the proposed program should be addressed. The Council has been called by United Nations Secretary General Waldheim, "the highest political body in the world which deals exclusively with food problems." The Council is not an operating agency. Rather, it is concerned with stating global objectives, outlining the measures needed to attain them, and mobilizing political and financial support.

The organization to which the Council would logically turn for support of the program would be the United Nations Development Program. It is a financing, programming, and monitoring agency, funded by voluntary contributions from governments. Agriculture, as might be expected, is the largest single component of its program with an expenditure of $623 million in 1976. The UNDP projects are usually actually administered by other agencies such as the Food and Agriculture Organization. The synthetic production of food, however, differs so greatly from any activity now in progress that a wholly new organization would be required for its effective conduct. The new organization would, however, work closely with FAO so as to coordinate, insofar as possible, the output of man-made food with deficits in agricultural production. The aim would be to maintain the total amount of food produced by agriculture and by synthesis at a level determined by the World Food Council.

The new agency would engage in two important activities in addition to the production of essential nutrients and other constituents of natural food products. One activity would be food processing in which these various constituents would be combined so as to duplicate the composition and properties of a wide variety of conventional foods. A second activity would be distribution of food with particular concern for the poor and the underprivileged.

Poverty, Malnutrition, and Food

Vast numbers of people in the developing countries are caught in the vicious circle of poverty and malnutrition. Because they are poor, they cannot get adequate food. Lacking food, they are malnourished and lack vitality and energy. Lacking energy, their work output is low. With low output, they remain in poverty.

The vicious circle can be broken by a massive infusion of food—more calories and more protein for men and women, and especially for children. A continuing supply of more and better food should result in an almost immediate gain in productivity and, in the long range, the increase in productivity would lead to a higher standard of living. There is ample evidence of the relation between the number of calories in the diet and the useful work accomplished, but the time scale of the effect of increments of food on the standard of living is less well defined but equally certain in the long range.

Only with the production of man-made food would it be possible to raise the diet of a country or a region from a near starvation or bare subsistence level up to an optimal level in one major operation and to maintain the diet at that level without regard to variations in agricultural production. The cost of the operation will be large. It should not be regarded as a humanitarian activity but rather as an investment to be repaid in the long range by a large gain in the gross national product.

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What Price Should Society Pay for Conservation?[1]

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ABSTRACT

Numerous external forces can cause divergencies between the socially optimal prices and the prices that prevail in the market place. If prevailing market prices fail to reflect conservation values at their true values, the prices are suboptimal from the viewpoint of future generations and government intervention may be warranted. The real problem is in estimating the value of conservation from every vantage point in time.

Much has been said in recent years about the urgent need to conserve our material resources through conservation and recycling. Expressing the value of conservation in monetary terms, however, is extremely difficult. Market prices provide an indication of increasing scarcity but whether current and foreseeable market prices adequately reflect the value of conservation from a long-run perspective continues to be an issue.

This issue involves the economic well-being of future generations. Decision-makers must decide whether our natural resources, especially the nonrenewable resources, are being developed and consumed too rapidly and if so, what policies are needed to encourage conservation and recycling. A review of the historical concern over conservation sheds little light on the problem. The major point to be emphasized in this discussion is that there is great difficulty involved in placing a value on conservation, when viewed from different points in time.

The Conservation Movement

The virtues of conservation were expounded centuries ago by well known economists such as Malthus and Ricardo (1, 2). These writers expressed grave concern over what they considered the exploitation of natural resources resulting from rapid population growth. Later, an organized group known as the Conservation Movement asserted that natural resources prices were too low and were being wastefully exploited and nearing exhaustion. They maintained that ultimately this would result in depriving future generations of their rightful share of the earth's finite resources. As examples of waste they pointed to the flaring of natural gas from oil wells and flooding of inactive mines when useful ores remained. Their views were shared by others in the past, and still are today by many advocates of conservation.

The historical predictions of early exhaustion, however, generally turned out to be erroneous. For one reason, subsequent discoveries of additional deposits added to the existing reserves on which the gloomy predictions were based. And probably more important, the predictions usually failed to recognize that the demands were sensitive to rising prices, and that technological change and substitution also respond to rising prices.

Market Allocation of Resources

Whether a free and competitive market allocates exhaustible resources in a socially optimal fashion is crucial to the

[1] Adapted from the EPA report entitled "Evaluation of Economic Benefits of Resource Conservation" by Robert C. Anderson, Environmental Law Institute (EPA Grant No. R-803880.01-1).

Table 1.—Impact of selected tax provisions on market prices[a] (in percent).

Mineral	Federal tax depletion allowance	State severance taxes
Pig iron	−3	+3
Copper	−6	+1.5
Lead	−3	+1
Aluminum	−2	+0.2

[a] (For detailed information on the methodology used in estimating these impacts, see the recent EPA report, "The Impact of the Tax Code on Resource Recovery" [EPA-600/2-76-009]).

question of whether new policies are needed for conservation and recycling. The traditional Pareto Optimal test requires that a reallocation is desirable as long as the change benefits someone without adversely affecting someone else. This criterion, however, relates to a single point in time, while the problem of valuing conservation extends over many generations. The basic question is whether resources are worth more, less, or the same to succeeding generations as to the present generation?

It may be assumed that in the long run, prices of extractive resources will increase despite technological improvements because increased inputs of labor and capital are needed per unit of extractive output. This is because in a competitive market the high grade and readily available ores are usually extracted first, followed by extraction of the lower-grade and more costly deposits. Extractors of high-cost ores cannot compete as long as the low-cost, readily obtainable deposits exist.

The availability of some minerals, however, changes very little when extraction shifts to a lower grade of ore, and this makes for a relatively inelastic supply curve for such minerals. For other minerals, rising prices provide an incentive to mine a lower grade which is relatively plentiful. The Taconite ores are an example. These ores are about 27 percent ferrous, or 3.4 times the average of the earth's crust. If prices rose sufficiently, the entire earth's crust could conceivably become a potential supply of iron ore. Another example is the bauxite ores presently mined which contain about 2.2 times the average for the earth's crust. The relative abundance of these low-grade ores, referred to as "backstop technology," places an upper limit on the price of a resource whenever there exists an abundant though more expensive substitute.

Rising prices stimulate research for new ore deposits and also induce technological changes. This can result in greater output per unit of production input. The introduction of electric furnaces using practically 100 percent scrap resulted from the increased scarcity and rising costs of virgin iron ores and the readily available ferrous scrap. And the substitution of steel for iron greatly increased the strength to weight ratio, resulting in increased output of consumer goods per unit of iron ore input. Thus, the market pricing system permits prices to rise when scarcities loom, and the increased prices serve to constrain resource exploitation and excessive waste.

The Effects of Biased Market Prices

While a free and competitive market system may allocate resources in a socially optimal fashion, various external forces may tend to bias the optimal prices and cause distortions in allocations. These external forces include those of taxation, monopolies, externalities, and uncertainties. The extractive sector, for example, is affected by provisions in various tax laws, including depletion allowances, exploration and development expenses, severance taxes, and property and capital gains taxes. Their influence on prices can cause production to be either above or below the optimal rate. When prices are biased below the optimal, consumption and consequently extraction are above the optimal and vice versa. The estimated effect of the federal depletion allowance and state severance taxes on market prices for several minerals is indicated in Table 1.

Monopolistic ownership of natural resources can also bias the rate of extractions. Hotelling suggested that monopolists tend to delay production, thereby serving the interests of conservation groups (3). Taking the opposite view, Sweeney and Lewis believed that patterns of demand growth configurations might lead a monopolist to extract at a faster rate than he would under competitive ownership (4, 5).

The effects of uncertainty on production decisions are generally assumed to cause an acceleration in the rate of extraction. The uncertainty may be with regard to tenure or ownership, future technology and costs, future taxes or royalty payments. It is generally assumed that resource owners tend to be risk adverse. The conditions in politically unstable countries often make for uncertain tenure of ownership. Uncertainty may tend to discourage exploration, thus resulting in smaller known reserves and consequently higher prices. And when prices are above the true marginal cost of extraction, production is below the socially optimal rate (i.e., the rate which would maximize the present value of producer's and consumer's surpluses).

Market biases due to externalities is an area of concern to both resource and environmental economists. One example of a pecuniary type of externality is in the field of exploration, where the information generated upon the discovery of an important deposit often conveys valuable information to others searching for deposits. The traditional market mechanism generally fails to compensate those making the initial discovery; in this respect it also discourages expenditures for exploration. Another kind of externality is that associated with the wastes from mining, smelting, and refining activities. When such wastes impose costs on others instead of being internalized and reflected in the costs and prices, then social costs exceed private costs, and the quantity of output exceeds that which is socially optimal.

The Perspective of Conservation from the Future Generation's Vantage Point

As resources become more scarce and additional inputs of factors of reproduction are required per unit of output, prices tend to rise; thus providing market incentives for conservation, recycling, improved technology, and substitution. Given that these adjustments occur, the question that remains is whether prevailing market prices are sufficient indicators of the value of conservation from the perspective of future generations. The question is, "Do prevailing market prices correctly bring forth the rate of extraction based on the resource values as perceived by our children, grandchildren, great grandchildren, and generations yet unborn?" This is the long-run perspective of the value of conservation! If present prices do not perform this function, our present society is not conserving or recycling at the rate that is socially optimal. If the present rate of resource extraction and use is excessive from the long-run perspective, it means a lower standard of living for generations to

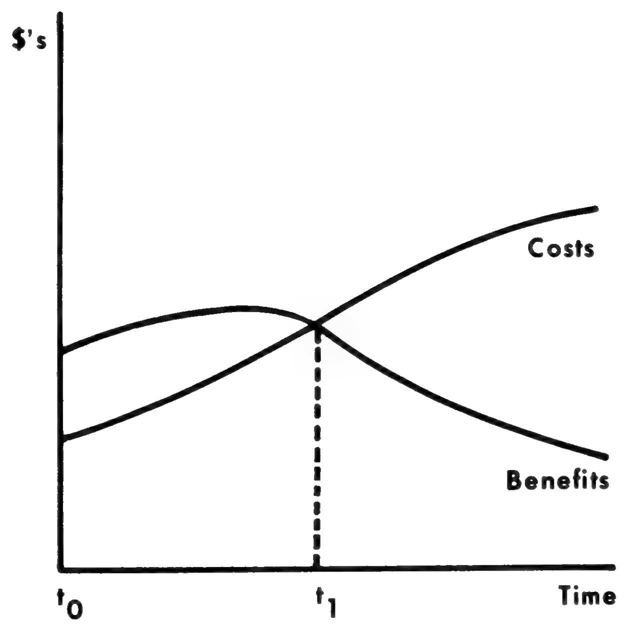

Fig. 1. Time profile of expected benefits and costs.

come. On the other hand, if conservation and recycling activities were carried to the extreme, as some now propose, the future might reveal that the present generations sacrificed unnecessarily, opting for themselves lower living standards in exchange for relatively higher living standards for future generations.

Summary

The problem in estimating the value of conservation arises in valuing resources from every vantage point in time. Competitive market prices, even in the absence of external biases, may not correctly determine resource use on the basis of what the future holds for generations concerning resource scarcities. Our present conservation goals and objectives must therefore rely heavily on our perception of the needs of future generations, admitting that we have inadequate information on which to base decisions. In prioritizing government projects, it is a common practice to discount future costs and benefits to arrive at a present value estimate. A discount rate has the effect of emphasizing the present, and discounting the future. The long-standing debate over rates and the appropriateness of discounting the effects on future generations is likely to continue for some time to come.

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A Programming Approach to Planning for Agricultural Resource Allocation and Irrigation System Design[1]

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ABSTRACT

With the increasing demand for food, regional growth may depend on the development of marginal lands for the purpose of increasing agricultural output. Linear programming can be effectively used in the initial planning and design of agricultural systems. Case studies are used to demonstrate the use of linear programming in selecting crops to yield the maximum profit, allocating land under conditions of constraints in water supply, and determining the optimum design of the necessary irrigation systems. The effect of crop rotation on the system design is also demonstrated. Post-optimal analyses are performed to determine the relative importance of the design variables on the optimum solution, the stability of the optimum solution and the relative impact of data error.

In planning for engineering systems and before an optimum design can be determined, it is necessary to specify many system characteristics, including physical characteristics of the site and its environment. It is also necessary to specify any physical, legal, or monetary constraints that the optimum design must satisfy. And finally, an optimality criterion must be formulated for choosing between alternate system designs. However, even after the optimum configuration has been determined, the engineer should subject a proposed design to a complete post-optimal analysis. Such an analysis is necessary to test the stability of the optimum design to error or variation in either the system constraints, the criterion used to test for optimality, or estimates of the system characteristics. Furthermore, a post-optimal analysis may also be useful for determining the relative importance of the design variables.

With the growing demand for food, one system of particular interest is the development of marginal lands for the purpose of increasing crop output. And in many areas, especially those in arid and semi-arid regions, the availability of water is an important constraint on the feasibility of reclaiming marginal lands for crop production. In such cases, the proper selection of crops, the allocation

[1] The contents of this paper do not necessarily represent the views of the U. S. Navy or any affiliation thereof.

of land parcels, and the installation of properly designed irrigation systems are three factors that may decide the profits obtained from farming these marginal lands.

Pipe networks are designed for use in water supply systems, in agricultural irrigation systems, and for transporting petroleum products. The use of linear programming as a planning tool for determining the optimum configuration of water distribution systems has previously been documented (Simonds and Kinney, 1972; Hoppe and Viessman, 1972). The objective of this paper is to demonstrate that the linear programming model has application in the analysis of agricultural systems. A methodology is outlined for sequentially determining the optimum distribution of land use and the water distribution system required to meet irrigation demands. Hypothetical case studies are used to demonstrate the proposed methodology. A methodology is then presented in which the optimum design is subjected to sensitivity analyses to determine the relative importance of key factors.

Model Formulation

Land Use Allocation.—To determine the optimum allocation of land use, a measure of optimality must be selected. For this case study, the expected return from the irrigation project was selected as a means of comparing alternatives in land use allocation. To determine the optimum allocation of land use, the following mathematical objective function was selected:

$$\text{Maximize } R = \sum_{i=1}^{m} r_i a_i \text{ where } a_i \geq 0 \quad (1)$$

where R is the total expected return from the development, r_i is the expected return from i^{th} land use classification (in dollars per unit area of land), and a_i is the optimum area allocated for land use classification i.

The objective function that is used to determine the optimum allocation of land use is subject to several constraints. First, the sum of the parcels of land allocated to different land use must equal the total area subject to development. This constraint can be represented in the linear programming model as:

$$\sum_{i=1}^{m} a_i = A \quad (2)$$

where A is the total area under development. Second, there may be a maximum amount of water W (volume/day) that is available for the irrigation demand of the proposed project. In agricultural planning, forecasts of the water yield during the growing season may be available during the spring measurement of snow water content in the mountainous parts of major watersheds (McCuen, 1977; Soil Conservation Service, 1972). These forecasts may be used to quantify W but because the forecasts may be in error, a proposed plan should be evaluated as to its sensitivity to error in the forecast of W. Mathematically, the water-availability constraint is:

$$\sum_{i=1}^{m} w_i a_i \leq W \quad (3)$$

where w_i is the water requirement for land use classification i (volume/area-day). The amount of land devoted to each land use classification can then be determined for given values of r_i, w_i, W and A. After the m areas (a_i) are determined, the expected return R can be determined from the linear objective function of equation 1.

Pipe Network Design.—The objective function used to determine the optimum pipe distribution is the minimization of the installation costs:

$$\text{Minimize } P = \sum_{i=1}^{m} c_j x_j \text{ where } x_j \geq 0 \quad (4)$$

where P is the total minimum installation cost of the distribution system ($), c_j is the unit cost per foot for installation of a pipe ($/foot), x_j is the optimum length of pipe (feet) in reach j, and n is the total number of pipe segments.

The cost of the pipe c_j is a function of pipe diameter, and the size of the pipe depends on the water requirements of the crop in subarea a_i. Thus, the optimization process must be executed sequentially; that is, the optimum subareas a_i allocated to a specific crop must be determined before the water requirements can be determined. And after determining the proper pipe network design, it is necessary to check the optimum allocation of land use for crops. However, in evaluating planning alternatives, it will usually not be necessary to make changes to the allocation of land use.

The objective function for the pipe distribution system is also subject to several constraints. Since a reach may include pipes of different diameters, the total length of pipes of different diameters in a reach must equal the total length of the reach; thus, the objective function, Equation 4, is subject to the constraint:

$$\sum_{i=1}^{k} x_i = L_j \quad j = 1, 2, \ldots, u \qquad (5)$$

where x_i is the optimum length of pipe of segment i in reach j, L_j is the total length of pipe in reach j, k is the total number of segments in reach j, and u is the number of reaches.

The head loss in the pipe distribution system is also important in determining the optimum pipe distribution system. The objective function is also subject to the following head loss constraint:

$$\sum_{j=1}^{n} s_j x_j \leq H \qquad (6)$$

where s_j is the friction loss (ft/ft) associated with pipe diameter d_j, and H is the elevation head (ft) measured from the discharge point to source elevation head. The friction loss s_j can be determined from Scobey's formula (Littleton, 1953):

$$s_j = K_s V_j^{1.9}/d_j^{1.1} \qquad (7)$$

where K_s is a constant having a value of 0.40 for welded steel irrigation pipe. The velocity V_j (ft/sec) is determined from the equation:

$$V_j = Q_j/(0.78 d_j^2) \qquad (8)$$

where Q_j is the flow in pipe segment j (ft^3/sec), and is determined from the equation:

$$Q_j = k_p w_i a_i \qquad (9)$$

where k_p is a conversion factor (acre-ft/day to ft^3/sec).

Case Study

The above objective functions and constraint equations were applied to a 10 acre (40470 m^2) plot subject to continuous cropping practices (Figure 1). The water source was capable of supplying 0.150 acre-feet/day (185 m^3/day). The values in Table 1 show the expected return from four crops and their water requirements. The expected return values are used to formulate the following objective function:

$$\text{Maximize } R = 500a_1 + 400a_2 + 300a_3 + 450a_4 \qquad (10)$$

The area constraints are:

$$a_1 + a_2 + a_3 + a_4 = 10 \qquad (11)$$

$$a_1 + a_3 \geq 5 \qquad (12)$$

$$a_2 + a_4 \leq 2 \qquad (13)$$

The water requirements of the four crops are used to formulate the following additional constraint equation:

$$0.0175a_1 + 0.0112a_2 + 0.0140a_3 + 0.008a_4 \leq 0.150 \qquad (14)$$

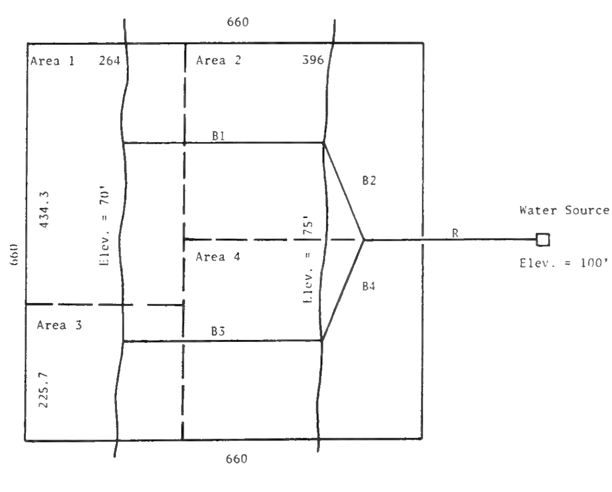

Fig. 1. Plot characteristics, continuous cropping.

Table 1.—Crop data for continuous and rotation cropping practices.

	Continuous Cropping			
Crop	Corn	Beans	Potatoes	Wheat
Expected Return (\$/acre)	500	400	300	450
Expected Return (\$/m^2)	.124	.099	.074	.111
Water Demand $\left(\frac{\text{ac ft}}{\text{day}}\right)$	.0175	.0112	.0140	.0080
Water Demand (m^3/day)	21.6	13.8	17.3	9.87
	Rotational Cropping			
Crop	Corn	Wheat	Clover	
Expected Return (\$/acre)	500	450	150	
Expected Return (\$/m^2)	.124	.111	.037	
Water Demand $\left(\frac{\text{ac ft}}{\text{day}}\right)$	.0175	.0080	.0100	
Water Demand (m^3/day)	21.6	9.87	12.3	

The simplex method was used to solve the linear programming problem. The optimum land use allocation for the four crops was determined to be $a_1 = 7.368$ acres (29818 m^2), $a_2 = a_3 = 0$, $a_4 = 2.632$ acres (10652 m^2), and the expected return was R = \$4868.40. By planting 7.368 acres of corn and 2.632 acres of wheat a maximum return of \$4868.40 will be achieved; such a land use allocation will require 0.150 acre-ft/day (185 m^3/day) of water, which is the maximum yield of the water source.

Having determined the areas used for the different crops the optimum configuration of the pipe distribution system can be determined. The proposed water distribution system is shown in Figure 1. Since wheat has a lower water demand than corn, the 2.632 acre (10652 m^2) plot devoted to wheat is placed at the end of the pipe distribution network. The physical characteristics of the plot and the water demand for each subarea are given in Table 2. The physical characteristics of the pipe network system and the unknowns are given in Table 3. The friction slopes s_j were computed from equation 10. The pipe cost C_j data includes purchase and installation per linear foot of pipe and was taken from Building Construction Cost Data (Means, 1973).

To determine the unknown lengths of pipe, the data from Table 3 was used to formulate the objective function:

$$\text{Minimize } P = 3.25X_1 + 4.10X_2 + 5.22X_3 + 1.75X_4 + 2.50X_5 + 2.50X_6 + 3.25X_7 + 1.75X_8 + 2.50X_9 + 2.50X_{10} + 3.25X_{11} \quad (15)$$

Because the total lengths of pipe of different diameters in each reach must equal the reach length, the objective function, equation 15, is subject to the constraints:

$$X_1 + X_2 + X_3 = 300 \quad (16)$$

$$X_4 + X_5 = 330 \quad (17)$$

$$X_6 + X_7 = 200 \quad (18)$$

$$X_8 + X_9 = 330 \quad (19)$$

$$X_{10} + X_{11} = 220 \quad (20)$$

The objective function is also subject to the following head loss constraints:

$$0.01554X_1 + 0.00380X_2 + 0.00052X_3 + 0.03168X_{10} + 0.00434X_{11} \leq 25 \quad (21)$$

$$0.01554X_1 + 0.00380X_2 + 0.00052X_3 + 0.10438X_8 + 0.00350X_9 + 0.03168X_{10} + 0.00434X_{11} \leq 30 \quad (22)$$

$$0.01554X_1 + 0.00380X_2 + 0.00052X_3 + 0.02938X_6 + 0.00403X_7 \leq 25 \quad (23)$$

$$0.01554X_1 + 0.00380X_2 + 0.00052X_3 + 0.08117X_4 + 0.00272X_5 + 0.02938X_6 + 0.00403X_7 \leq 30 \quad (24)$$

The above linear programming model was solved using the simplex method and provided the optimum pipe lengths shown in Table 4. A minimum cost of $3314.90 was determined for the objective function of Equation 15.

The Effect of Crop Rotation.—The objective functions and constraints defined by equations 1–9 were also applied to the same 10-acre plot shown in Figure 1 for a crop rotation system. Rotation sequencing for the system was based on standard agricultural practices using one year of corn, followed by one year of wheat, and then one year of clover. The values in Table 1 show the expected annual return for each crop and the corresponding daily water requirements. From this data the following objective function was formulated:

$$\text{Maximize } R = 500a_1 + 450a_2 + 150a_3 \quad (25)$$

subject to the following area constraints:

$$a_1 + a_2 + a_3 = 10 \quad (26)$$

$$a_2 + a_3 \geq 5 \quad (27)$$

$$a_3 \geq 2 \quad (28)$$

The objective function is also subject to

Table 2.—Plot characteristics: Continuous cropping.

Sub area	Area (acres)	Area (m^2)	Crop	Water demand (cfs)	Water demand (m^3/sec 10^{-3})	Pipe segment	Pipe flow (cfs)	Pipe flow (m^3/sec 10^{-3})	Pipe length (ft)	Pipe length (m)	Elevation (ft)	Elevation (m)
1	2.632	10652	wheat	.0212	.60	B1	.0212	.60	330	101	70	21.3
2	3.000	12141	corn	.0530	1.50	B2	.0742	2.10	200	61	75	22.9
3	1.368	5536	corn	.0242	.69	B3	.0242	.69	330	101	70	21.3
4	3.000	12141	corn	.0530	1.50	B4	.0772	2.18	200	61	75	22.9
						R	.1510	4.28	300	91	100	30.5

Table 3.—Pipe system data, continuous cropping.

Pipe reach	Pipe segment	Diameter (inches)	Diameter (cm)	Cost ($/ft)	Cost ($/m)	Friction slope (ft/ft)
R	X_1	3	7.62	3.25	10.66	.01554
	X_2	4	10.16	4.10	13.45	.00380
	X_3	6	15.24	5.22	17.13	.00052
B1	X_4	1	2.54	1.75	5.74	.08117
	X_5	2	5.08	2.50	8.20	.00272
	X_6	2	5.08	2.50	8.20	.02938
	X_7	3	7.62	3.25	10.66	.00403
B3	X_8	1	2.54	1.75	5.74	.10438
	X_9	2	5.08	2.50	8.20	.00350
B4	X_{10}	2	5.08	2.50	8.20	.03168
	X_{11}	3	7.62	3.25	10.66	.00434

the following water demand constraints:

$$0.0175a_1 + 0.0080a_2 + 0.0010a_3 \leq 0.15 \tag{29}$$

$$0.0080a_1 + 0.0100a_2 + 0.0175a_3 \leq 0.15 \tag{30}$$

$$0.0100a_1 + 0.0175a_2 + 0.0100a_3 \leq 0.15 \tag{31}$$

Using the simplex method the optimum land use allocation was determined to be $a_1 = 5.0$ acres (20235 m²), $a_2 = 3.0$ acres (12141 m²), and $a_3 = 2.0$ acres (8094 m²). The expected return for this allocation is \$4150.00 for the first year. The water demand is 0.132 acre-ft/day (163 m³/day), which is less than the maximum yield of the water source. The total return for the three year rotation cycle is 1000, regardless of the initial land allocation.

After determining the optimum land allocation, the optimum pipe distribution system, as shown in Figure 2, can be determined. Since the irrigation system must supply the water demands for all three years of the rotation cycle the water demand for each year of the cycle must be used for the determination of the optimum pipe system. The physical characteristics and water demands for the plot and pipe system are given in Table 5. Physical characteristics of the pipe system are given in Table 6. The pipe cost C_j includes purchase and installation and was taken from Building Construction Cost Data (Means, 1973).

Determination of the optimum pipe lengths in the system were based on minimizing the construction cost given by the following objective function:

$$\text{Minimize } P = 3.25X_1 + 4.10X_2 + 5.22X_3 + 1.75X_4 + 2.50X_5 + 2.50X_6 + 3.25X_7 + 1.75X_8 + 2.50X_9 + 2.50X_{10} + 3.25X_{11} \tag{32}$$

Using the reach lengths shown in Table 2 the objective function is subject to the following length constraints:

$$X_1 + X_2 + X_3 = 300 \tag{33}$$

$$X_4 + X_5 = 330 \tag{34}$$

$$X_6 + X_7 = 200 \tag{35}$$

$$X_8 + X_9 = 330 \tag{36}$$

$$X_{10} + X_{11} = 200 \tag{37}$$

Table 4.—Optimum pipe network design, continuous cropping.

Pipe reach	Pipe segment	Pipe length (ft)	Pipe length (m)
R	X_1	300.0	91.4
B1	X_4	236.6	72.1
	X_5	93.4	28.5
B2	X_6	200.0	61.0
B3	X_8	176.9	53.9
	X_9	153.1	46.7
	X_{10}	200.0	61.0

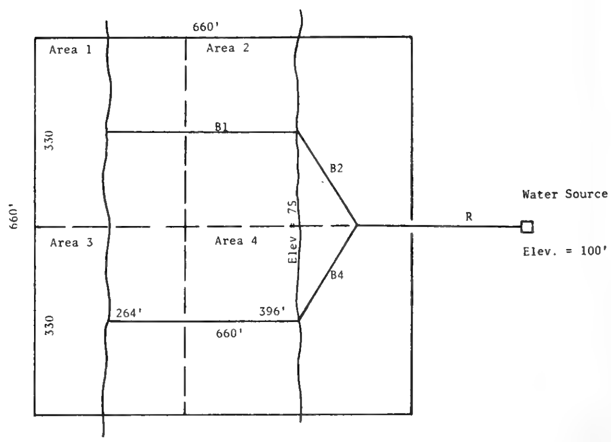

Fig. 2. Plot characteristics, rotational cropping.

The objective function is also subject to the following head loss constraints for the three-year rotation cycle:

$$0.01221X_1 + 0.00298X_2 + 0.00041X_3 + 0.01107X_6 + 0.00152X_7 \leq 25 \quad (38)$$

$$0.01221X_1 + 0.00298X_2 + 0.00041X_3 + 0.07405X_4 + 0.00248X_5 + 0.01108X_6 + 0.00152X_7 \leq 30 \quad (39)$$

$$0.01221X_1 + 0.00298X_2 + 0.00041X_3 + 0.04116X_{10} + 0.00564X_{11} \leq 25 \quad (40)$$

$$0.01221X_1 + 0.00298X_3 + 0.00041X_3 + 0.21272X_8 + 0.00712X_9 + 0.04116X_{10} + 0.00564X_{11} \leq 30 \quad (41)$$

$$0.00791X_1 + 0.00193X_2 + 0.00026X_3 + 0.02312X_6 + 0.00317X_7 \leq 25 \quad (42)$$

$$0.00791X_1 + 0.00193X_2 + 0.00026X_3 + 0.21272X_4 + 0.00712X_5 + 0.02312X_6 + 0.00317X_7 \leq 30 \quad (43)$$

$$0.00791X_1 + 0.00193X_2 + 0.00026X_3 + 0.00926X_{10} + 0.00127X_{11} \leq 25 \quad (44)$$

$$0.00791X_1 + 0.00193X_2 + 0.00026X_3 + 0.04869X_8 + 0.00163X_9 + 0.00926X_{10} + 0.00127X_{11} \leq 30 \quad (45)$$

$$0.01004X_1 + 0.00245X_2 + 0.00034X_3 + 0.02602X_6 + 0.00357X_7 \leq 25 \quad (46)$$

$$0.01004X_1 + 0.00245X_2 + 0.00034X_3 + 0.04869X_4 + 0.00163X_5 + 0.02602X_6 + 0.00357X_7 \leq 30 \quad (47)$$

$$0.01004X_1 + 0.00245X_2 + 0.00034X_3 + 0.01409X_{10} + 0.00193X_{11} \leq 25 \quad (48)$$

$$0.01004X_1 + 0.00245X_2 + 0.00034X_3 + 0.07405X_8 + 0.00248X_9 + 0.01409X_{10} + 0.00193X_{11} \leq 30 \quad (49)$$

The above linear programming model was solved to yield the pipe sizes shown in Table 7. The objective function yielded a cost of \$3492.20 for the pipe distribution system. This system was designed to

Table 5.—Plot characteristics—rotational cropping.

Rotation year	Sub area	Area (acres)	Area (m²)	Crop	Water demand (cfs)	Water demand (m³/sec 10⁻³)	Pipe segment	Pipe flow (cfs)	Pipe flow (m³/sec 10⁻³)	Pipe length (ft)	Pipe length (m)	Elevation (ft)	Elevation (m)
1	1	2	8094	clover	0.0202	0.57	B1	0.0202	0.57	330	101	70	21.3
	2	3	12141	wheat	0.0242	0.68	B2	0.0444	1.26	200	61	75	22.9
	3	2	8094	corn	0.0352	1.00	B3	0.0352	1.00	330	101	70	21.3
	4	3	12141	corn	0.0534	1.51	B4	0.0886	2.51	200	61	75	22.9
							R	0.1330	3.77	300	91	100	30.5
2	1	2	8094	corn	0.0352	1.00	B1	0.0352	1.00	330	101	70	21.3
	2	3	12141	clover	0.0302	0.86	B2	0.0654	1.85	200	61	75	22.9
	3	2	8094	wheat	0.0162	0.46	B3	0.0162	0.46	330	101	70	21.3
	4	3	12141	wheat	0.0242	0.68	B4	0.0404	1.14	200	61	75	22.9
							R	0.1058	3.00	300	91	100	30.5
3	1	2	8094	wheat	0.0162	0.46	B1	0.0162	0.46	330	101	70	21.3
	2	3	12141	corn	0.0534	1.51	B2	0.0696	1.97	200	61	75	22.9
	3	2	8094	clover	0.0202	0.57	B3	0.0202	0.57	330	101	70	21.3
	4	3	12141	clover	0.0302	0.86	B4	0.0504	1.43	200	61	75	22.9
							R	0.1200	3.40	300	91	100	30.5

Table 6.—Pipe system data—rotational cropping.

Pipe reach	Pipe segment	Pipe diameter (inches)	(cm)	Pipe cost ($/ft)	($/m)	Friction slope (ft/ft or m/m)
R	X_1	3	7.62	3.25	10.66	0.01221 0.00791 0.01004
	X_2	4	10.16	4.10	13.45	0.00298 0.00193 0.00245
	X_3	6	15.24	5.22	17.13	0.00041 0.00026 0.00034
B1	X_4	1	2.54	1.75	5.74	0.07405 0.21272 0.04869
	X_5	2	5.08	2.50	8.20	0.00248 0.00712 0.00163
B2	X_6	2	5.08	2.50	8.20	0.01108 0.02312 0.02602
	X_7	3	7.62	3.25	10.66	0.00151 0.00317 0.00357
B3	X_8	1	2.54	1.75	5.74	0.21272 0.04869 0.07405
	X_9	2	5.08	2.50	8.20	0.00713 0.00163 0.00248
B4	X_{10}	2	5.08	2.50	8.20	0.04116 0.00926 0.01409
	X_{11}	3	7.62	3.25	10.66	0.00564 0.00127 0.00193

meet the irrigation needs of the study plot for the three-year rotation cycle.

Post Optimal Analysis

In reference to a post optimal analysis, Dantzig (1963) stated, "In many applications, the information thus obtained is as valuable as the specification of the optimum solution itself". Most post optimum analyses involve the derivation of sensitivity estimates. Sensitivity can be expressed in either absolute or relative form (McCuen, 1972). Absolute sensitivity, $\$_a$, is defined as the rate of change of output 0 with respect to change in input or a system characteristic P:

$$\$_a = \frac{\Delta O}{\Delta P} \quad (50)$$

However, since the magnitude of an

absolute sensitivity estimate is a function of the units of both the output and system characteristics, absolute sensitivity estimates cannot be used for making comparisons of the relative importance of different system characteristics. The relative sensitivity is not a function of the units of measurement and thus, it is frequently used to compare the relative importance of the input and system characteristics. The relative sensitivity R_s is defined as the percentage change ΔO in the system output O that results from a one percent change in a system characteristic or input:

$$R_S = \left(\frac{\Delta O}{O}\right) \Big/ \left(\frac{\Delta P}{P}\right) = \frac{P}{O}\left(\frac{\Delta O}{\Delta P}\right) = \frac{P}{O}\ \$_a \qquad (51)$$

where ΔP is the change in an input or system characteristic P.

The optimum land use distribution was subjected to sensitivity analyses. Specifically, analyses were performed to determine the sensitivity of the optimum land use distribution and profit to changes in water requirements of and profit from the crops in the optimum solutions. The results are shown in Tables 8 and 9. The profit is comparatively sensitive to changes in the profit from the crops, especially the profit in corn. For the continuous cropping system, a 10% change in the profit from corn and wheat will cause a 7.6 percent and 2.4 percent change in total profit, respectively. Error or changes in the water requirements of corn and wheat produce a relatively smaller change in profit. A 10 percent change in water requirements of corn and wheat cause changes of 1.5 and 0.2 percent, respectively, in the total profit. For the rotational cropping system a 10 percent change in the profit from corn, wheat and clover produced a change of 4.6, 4.1 and 1.4 percent, respectively, in the total profit for the three year rotation period. The maximum sensitivity during any of the three years to changes in crop profits is dependent on the relative size of the expected profit for each crop and the respective area under cultivation. Changes in the water demand had no effect on the optimum solutions since the maximum demand at the optimum solution is less than the available supply. A 12 percent reduction in the available water

Table 7.—Optimum pipe network design, rotation cropping.

Pipe reach	Pipe segment	Pipe length (ft)	Pipe length (m)
R	X_1	300.0	91.4
B1	X_4	100.5	30.6
	X_5	229.5	70.0
B2	X_6	200.0	61.0
B3	X_8	76.6	23.3
	X_9	253.4	77.2
B4	X_{10}	200.0	61.0

Table 8.—Sensitivity analyses land use allocation—continuous cropping.

Problem	Area in corn (acres)	Area in corn (m^2)	Area in wheat (acres)	Area in wheat (m^2)	Profit, $	Change in profit, $	Relative sensitivity
Optimum solution	7.368	29820	2.632	10650	4868.40	—	—
cost coefficient for corn changed from $500 to $490	7.368	29820	2.632	10650	4794.70	−73.70	.755
cost coefficient for wheat changed from $450 to $440	7.368	29820	2.632	10650	4842.10	−26.30	.241
water requirements of corn changed from 0.0175 to 0.0170 acre-feet/day (70.82 to 68.80 m^3/day)	7.778	31480	2.222	8990	4888.90	20.50	.145
water requirements of wheat changed from 0.008 to 0.0075 acre-feet/day (32.37 to 30.35 m^3/day)	7.500	30350	2.500	10120	4875.00	6.60	−.021

Table 9.—Sensitivity analyses pipe network design—continuous cropping.

Length of pipe segment	Optimum solution feet	Optimum solution meters	Head reduced by one foot (0.305 m) feet	Head reduced by one foot (0.305 m) meters	Cost of pipe increased by 5% feet	Cost of pipe increased by 5% meters	Friction slope increased by 10% feet	Friction slope increased by 10% meters
X_1 (3")	300	91.4	300	91.4	300	91.4	300	91.4
X_4 (1")	237	72.2	224	68.3	237	72.2	202	61.6
X_5 (2")	93	28.3	106	32.3	93	28.3	128	39.0
X_6 (2")	200	61.0	200	61.0	200	61.0	200	61.0
X_8 (1")	177	53.9	167	50.9	177	53.9	150	45.7
X_9 (2")	153	46.6	163	49.7	153	46.6	180	54.9
X_{10} (2")	200	61.0	200	61.0	200	61.0	200	61.0
Total cost of pipe network	$3314.90		$3331.90		$3484.10		$3361.20	
Change in total cost			$17.00		$169.20		$46.30	
Relative sensitivity			−0.141		1.02		0.140	

supply could be absorbed without changing the optimum land use allocation. The results of the post optimal analyses suggest that the profit from the investment is more dependent on small changes in profit from the individual crops than in small fluctuations in water requirements. When the cost of pipe is increased by 5 percent the cost coefficients of equation 18 must change. For the continuous

Table 10.—Sensitivity analysis land use allocation—rotational cropping.

Problems	Rotation year	Area: Corn (acres)	Corn (m²)	Wheat (acres)	Wheat (m²)	Clover (acres)	Clover (m²)	Profit	Change in profit	Relative sensitivity
Optimum solution	1	5.0	20235	3.0	12141	2.0	8094	$4150.00	—	—
	2	2.0	8094	5.0	20235	3.0	12141	$3700.00	—	—
	3	3.0	12141	2.0	8094	5.0	20235	$3150.00		
								$\sum$ = $11000.00		
Cost coefficient for corn changed from $500 to $490	1	5.0	20235	3.0	12141	2.0	8094	$4100.00	$−50.00	.602
	2	2.0	8094	5.0	20235	3.0	12141	$3680.00	$−20.00	.270
	3	3.0	12141	2.0	8094	5.0	20235	$3120.00	$−30.00	.476
								$\sum$ = $10900.00	$−100.00	.455
Cost coefficient for wheat changed from $450 to $440	1	5.0	20235	3.0	12141	2.0	8094	$4120.00	$−30.00	.325
	2	2.0	8094	5.0	20235	3.0	12141	$3650.00	$−50.00	.608
	3	3.0	12141	2.0	8094	5.0	20235	$3130.00	$−20.00	.286
								$\sum$ = $10900.00	$−100.00	.409
Cost coefficient for clover changed from $150 to $140	1	5.0	20235	3.0	12141	2.0	8094	$4130.00	$−20.00	.072
	2	2.0	8094	5.0	20235	3.0	12141	$3670.00	$−30.00	.122
	3	3.0	12141	2.0	8094	5.0	20235	$3100.00	$−50.00	.238
								$\sum$ = $10900.00	$−100.00	.136
Water requirement corn changed from 0.0175 to 0.0180 ac-ft/day (70.82 to 72.84 m³/day)		No change in optimum solution							$0.00	0.000
Water req. wheat changed from 0.009 to 0.0085 ac/ft/day (32.37 to 34.40 m³/day)		No change in optimum solution							$0.00	0.000
Water req. clover changed from 0.0100 to 0.0105 ac-ft/day (40.47 to 42.49 m³/day)		No change in optimum solution							$0.00	0.000

Table 11.—Sensitivity analysis pipe network design—rotational cropping.

Length of pipe segment	Optimum solution (ft)	(m)	Head reduced by one foot (.305 meters) (ft)	(m)	Cost of pipe increased by 5% (ft)	(m)	Friction type increased by 10% (ft)	(m)
X_1 (3″)	300	91.4	300	91.4	300	91.4	300	91.4
X_4 (1″)	100	30.5	96	29.3	100	30.5	87	26.5
X_5 (2″)	230	70.1	234	71.3	230	70.1	243	74.1
X_6 (2″)	200	61.0	200	61.0	200	61.0	200	61.0
X_8 (1″)	77	23.5	72	21.9	77	23.5	63	19.2
X_9 (2″)	253	77.1	258	78.6	253	77.1	267	81.4
X_{10} (2″)	200	61.0	200	61.0	200	61.0	200	61.0
Total cost of pipe network	$3492.20		$3499.50		$3670.90		$3512.10	
Change in total cost			7.30		$178.70		19.90	
Relative sensitivity			−.057		1.02		.057	

cropping system, this produced a relative change in the total cost of 1.02; that is, a 10 percent change in the cost of pipe will result in a 10.2 percent change in total project cost. A change of 10 percent in either the total head or the friction slope produces a change of approximately 1.4 percent in total cost.

For the rotational cropping system an increase in pipe cost again produced a relative sensitivity of 1.02. Changes in the total head or friction slope yielded a relative sensitivity of 0.057. Thus, the optimum solution is much more sensitive to changes in pipe cost than either error or changes in source elevation, head, or the friction slope (see Tables 10 and 11).

Conclusions

Linear programming can be employed effectively in the initial planning and design phases of agricultural systems. The linear programming model can provide reasonable estimates of land use distribution and pipe network designs. Depending on the project objectives, a more complex objective function and additional constraint equations may be introduced to reflect additional factors such as the rental cost of the land, machinery costs, and labor requirements. The linear programming model can also be used to optimize regional land use allocation as well as small scale development.

A post optimal analysis that includes a sensitivity study can provide valuable information about the stability of the optimum solution. A sensitivity analysis can be used to study the effect of uncertainty in measured quantities (McCuen, 1974). The requirements to thoroughly examine fluctuations in the water supply was demonstrated herein. Thus, it is necessary to have a reliable and sufficient quantity of hydrologic data.

Notation

A_{ij} = jth structural coefficient for ith constraint equation
A = total project area
a_i = area of ith parcel of land
b_i = ith stipulation in linear programming model
C_i = weighting (cost) coefficient for the ith decision variable
c_j = unit cost per foot of pipe for installation of pipe of diameter d_j
d_j = diameter of pipe segment j
K_s = empirical coefficient in Scobey's formula
K = number of pipe segments in reach j
k_p = conversion factor (acre feet/day to cubic feet/second)

H = elevation head measured from the water source to the point of discharge
L_j = total length of pipe in reach j
m = number of land use classifications
n = total number of pipe segments from water source to outlet
o = output of the system
P = optimum total installation cost of the pipe network
Q_j = flow in pipe reach j
r_i = expected return from i^{th} parcel of land
R = total expected return from the project
R_s = relative sensitivity
S_j = friction loss associated with pipe diameter d_j of segment j
u = total number of pipe reaches
V_j = velocity of water in pipe of diameter d_j in segment j
w_i = water requirements for ith parcel of land
W = total water demand for project
X_i = optimum length of pipe i in a reach
$\$_a$ = absolute sensitivity

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Anuran Locomotion—Structure and Function: The Jumping Forces of Frogs

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The flight of a jumping frog has been frequently compared to the trajectory of a missile or projectile (Gray, 1953; Gans and Rosenberg, 1966; Calow and Alexander, 1973). As such, the general ballistic equation and its related equations with minor modifications have been accepted as adequate mathematical descriptors of a frog's jump. To date, these equations have been examined only by using a single value of terminal velocity at liftoff or distance jumped (Gray, 1968; Calow and Alexander, 1973). Our goal has been to record the maximum force at liftoff in a variety of frog species in order to determine if our measure of force and the general ballistic equation or a modification thereof provide a reasonable estimate of terminal velocity and distance jumped.

Materials and Methods

Adult males of 10 species of frogs (scientific names and sample sizes listed in Table 1) were collected in Oktibbeha and Hancock Counties, Mississippi, during the spring of 1975. The weight (nearest 0.1 g), snout-vent length, and right hindlimb length (nearest 0.1 mm) were recorded for each frog immediately following its jumping test. In most cases, the frogs were tested within 24 hr of capture.

The force platform was a water-filled tambor constructed from a plastic funnel (64 mm mouth diameter) covered by a thin plastic diaphragm. The tambor was connected via Tygon tubing through a Strathmore pressure transducer to a Beckman Dynagraph. The tambor was calibrated by placing metal balance weights on the diaphragm. The resulting Dynagraph records provide a summation of the forces applied during jumping and the duration of these forces.

For the tests, the tambor diaphragm was covered with moist absorbent paper in order to provide sufficient friction to enable the frog to jump normally. The frog was placed on the diaphragm with its hindfeet in the center, thus permitting maximum downward displacement of the diaphragm. Each frog was tested once.

Results and Discussion

The initial data are summarized in Table 1. Since the samples were restricted to adult males, variations in the length measurements of each species are low (coefficients of variation, 5–8). In contrast, weight variation is higher (cv, 10–35), and the force and its duration are even higher (cv, 15–50 and 20–85, respectively). A portion of variation in the latter 2 parameters undoubtedly results from the design of the force platform and experimental procedure; however, consecutive leaps of a frog are seldom equidistant (Zug, 1978). Thus, the jumping distances of a single frog or a sample of equal-sized frogs will show considerable variation as will also the force and duration that are responsible for propelling the frog forward.

The naturalness of the force data may be evaluated by using these data to estimate the terminal velocities prior to liftoff and the distances traveled (Table 2). In most cases, these estimates differ only slightly from actual jumping distances, i.e., distances from Zug (1978). The estimated velocities and distances, hence the forces, are lower than "normal" for *Hyla chrysoscelis*, *H. gratiosa*, and *Pseudacris triseriata*. Presumably, the individuals of these species were not jumping normally, because the similarity of actual

Table 1.—A summary of the jumping tests. The first number in each column is the mean, the second the standard deviation.

	N	Snout-vent length (mm)	Hindlimb length (mm)	Body weight (g)	Force (g)	Duration of force (sec)
Hylidae						
Acris gryllus	4	21.5 ± 1.7	40.6 ± 1.3	1.0 ± .32	6.3 ± 2.7	.054 ± .047
Hyla avivoca	23	34.8 ± 2.1	53.3 ± 3.5	2.5 ± .54	11.4 ± 3.0	.030 ± .017
H. chrysoscelis	5	44.2 ± 3.0	61.2 ± 4.9	6.4 ± 1.4	12.9 ± 3.0	.027 ± .011
H. cinerea	8	55.6 ± 2.8	86.3 ± 5.8	9.2 ± 1.2	23.3 ± 7.4	.058 ± .034
H. crucifer	3	30.8 ± 1.4	47.0 ± 5.1	1.8 ± .15	9.1 ± 1.4	.035 ± .008
H. femoralis	3	32.4 ± 0.8	47.4 ± 2.0	2.2 ± .60	8.4 ± 4.2	.042 ± .013
H. gratiosa	3	63.2 ± 4.0	91.1 ± 3.3	11.4 ± 4.2	22.2 ± 1.4	.066 ± .034
Pseudacris nigrita	1	28.0	41.1	1.0	3.2	.027
P. triseriata	1	31.7	45.0	1.8	2.8	.037
Microhylidae						
Gastrophryne carolinensis	1	29.5	33.1	2.1	6.0	0.047

Table 2.—A comparison of estimated jumping distances to actual jumping distances (from Appendix, Table B in Zug, 1978).[a]

Taxon	Estimated Velocity (cm/sec)	Estimated Distance (cm)	Mean Distance	Difference
A. gryllus	223.9	51.2	47.4	3.8
H. avivoca	218.3	48.6		
H. chrysoscelis	155.5	24.7	44.6	−19.9
H. cinerea	207.0	43.7	49.7	−6.0
H. crucifer	215.8	47.5	50.5	−3.0
H. femoralis	187.5	35.9	39.5	−3.6
H. gratiosa	186.5	35.5	47.0	−11.5
P. nigrita	160.6	26.3	26.5	−0.2
P. triseriata	117.1	14.0	44.3	−30.3
G. carolinensis	136.2	18.9	19.1	−0.2

[a] Velocities were calculated from Gray's (1968) force equation $F = (WV^2) \div (2\ g\ s)$; W, body weight; g, gravity; s, hindlimb length. The estimated distances were calculated from the ballistic equation (Gans and Rosenberg, 1966), $D = (V^2 \sin 2\theta) \div g$; the angle was assumed to be 45°. Note that a deviation from 45° will decrease jumping distance but not significantly so until about ±10°.

and estimated distances for the other species indicate that the force platform and experimental procedure were providing an accurate measure of the forces applied during natural jumping.

We must emphasize that the close similarity between the estimated and observed jumping distances derives only from Gray's and Gans' equations (see legend of Table 2). The equations $V = s \div t$ and $D = V^2 \div g$ (where V is average velocity during propulsive phase of jump; s, distance during propulsion or hindlimb length; t, time or duration of force; D, distance jumped) greatly underestimate velocity and jumping distance. An overestimate of velocity and jumping distance was obtained from the equations $A = Fg \div W$, $V = A \div t$, and $D = (V^2 \div g) \sin 2\theta$.

Table 3.—A linear correlation coefficient matrix comparing five jumping parameters in *A. gryllus*, *H. cinerea*, *H. crucifer*, *H. femoralis*, *P. nigrita*, and *G. carolinensis*.

	BW	F	Du	Di	HL
Body weight	1.00	0.96[a]	0.55	0.22	0.93[a]
Force		1.00	0.43	0.47	0.94[a]
Duration			1.00	0.10	0.37
Distance (estim.)				1.00	0.35
Hindlimb length					1.00

[a] A significant correlation at 0.05 level.

An interspecific comparison of several jumping parameters (Table 3) shows significant positive correlations between force (Y) and body weight (X), force (Y) and hindlimb length (X), and body weight (Y) and hindlimb length (X). More force is required to propel a heavier frog; more force is produced by longer hindlimbs; and as a frog becomes larger, its body weight and hindlimb length increase. Although these correlations would be expected in an intraspecific comparison, they might not occur in an interspecific comparison, which includes frog species with different jumping behaviors and abilities. We suspect our results obtain from the preponderance of hylid species in the sample, because they are similar in behavior and ability. The low correlations between jumping distance and force or hindlimb length are surprising; force and hindlimb length are strongly correlated and are used to estimate the jumping distance, hence jumping distance would also be assumed to show a high correlation to both of them.

Gans and Rosenberg (1966) proposed that the force of a jump was proportional to 7/6 power of body weight in *Bufo marinus*. Although our data show a significant correlation between force and weight (Table 3: $Y = 3.47 + 2.19X$; Y

$= 4.69X^{0.74}$, $r = 0.90$, Y, force; X, body weight), they are not suitable for testing this relationship, because bufonids are weak jumpers and our sample is dominated by strong jumpers. We do, however, wish to correct the typographical error in Gans' and Rosenberg's derivation, because $F^2M^{-2} \sim M^{1/3}$ becomes $F^2 \sim M^{7/6}$ or $F \sim M^{7/12}$ and not $F \sim M^{7/6}$.

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New World Opiinae (Hymenoptera: Braconidae) Parasitic on Tephritidae (Diptera)

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ABSTRACT

A key is presented for the New World species of Opiinae that have been recorded as parasites of Tephritidae, including species introduced and established in the New World. A brief discussion is given for each species including distribution, hosts, biological references, and distinguishing characteristics. One new species is described, *Biosteres sublaevis*, n. sp., and the following new synonymies are indicated: *Biosteres tryoni* (*=Parasteres acidusae*), *Doryctobracon* (*=Parachasma*), *D. crawfordi* (*=D. conjugens*), *Opius anastrepha* (*=O. argentina* and *O. mombinpraeoptantis*), *O. bellus* (*=O. gomesi* and *O. turicai*), *O. canaliculatus* (*=O. lectus* and *O. lectoides*), and *O. frequens* (*=O. glasgowi*).

A large number of opiine braconids has been described from the New World. Although nothing is known concerning the biology of the majority of these, 39 species have been reared from various members of the dipterous family Tephritidae. This paper is an aid to the identification of these species and brings some of the literature pertaining to them together in one place. A key is presented to 39 species followed by a brief discussion of each species including distribution, host records, biological references, and distinguishing characteristics. Tobias (1977) has discussed the European species of *Opius* parasitic on fruit flies.

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We have included here only those species for which there is reliable information concerning their hosts, either from the literature or from labels on specimens in the National Insect Collection in Washington. We have discussed briefly a few species that have been introduced but not established in the New World but these are not included in the key. A few synonymies will affect names of parasites, some of which are being actively studied at the present: *Parasteres* Fischer is returned to *Biosteres* Foerster and *P. acidusae* Fischer is synonymized with *B. tryoni* (Cameron); *Parachasma* Fischer is synonymized with *Doryctobracon* Enderlein; *D. areolatus* (Szepligeti) replaces *Parachasma cereum* (Gahan); *D. conjugens* Enderlein is synonymized with *D. crawfordi* (Viereck); *Bracanastrepha argentina* Brèthes and *Opius mombinpraeoptantis* Fischer are synonymized with *O. anastrephae* Viereck; *O. gomesi* Costa Lima and *O. turicai* Blanchard are synonymized with *O. bellus* Gahan; *O. lectus* Gahan and *O. lectoides* Gahan are synonymized with *O. canaliculatus* Gahan; and *O. glasgowi* Fischer is synonymized with *O. frequens* Fischer. One new species is described from Texas.

The tephritid hosts and their Opiinae parasites are summarized in the list that follows.

Anastrepha sp.
- *Doryctobracon capsicola* (Muesebeck)
- *Doryctobracon tucumanus* (Turica & Mallo)
- *Opius hirtus* Fischer

Anastrepha benjamini Costa Lima
- *Doryctobracon areolatus* (Szépligeti)

Anastrepha consobrina (Loew)
- *Doryctobracon areolatus* (Szépligeti)

Anastrepha fraterculus (Wiedemann)
- *Doryctobracon areolatus* (Szépligeti)
- *Doryctobracon brasiliensis* (Szépligeti)
- *Doryctobracon fluminensis* (Costa Lima)
- *Doryctobracon zeteki* (Muesebeck)
- *Opius anastrephae* Viereck
- *Opius bellus* Gahan

Anastrepha interrupta Stone
- *Doryctobracon anastrephilus* (Marsh)

Anastrepha ludens (Loew)
- *Doryctobracon areolatus* (Szépligeti)
- *Doryctobracon crawfordi* (Viereck)

Anastrepha montei Costa Lima
- *Doryctobracon areolatus* (Szépligeti)
- *Opius bellus* Gahan

Anastrepha obliqua (Macquart)
- *Biosteres tryoni* (Cameron)
- *Doryctobracon areolatus* (Szépligeti)
- *Opius anastrephae* Viereck
- *Opius bellus* Gahan

Anastrepha pickeli Costa Lima
- *Doryctobracon areolatus* (Szépligeti)

Anastrepha rheediae Stone
- *Opius vierecki* Gahan

Anastrepha serpentina (Wiedemann)
- *Doryctobracon areolatus* (Szépligeti)
- *Doryctobracon auripennis* (Muesebeck)
- *Doryctobracon trinidadensis* (Gahan)
- *Opius bellus* Gahan

Anastrepha striata Schiner
- *Doryctobracon crawfordi* (Viereck)
- *Doryctobracon trinidadensis* (Gahan)
- *Doryctobracon zeteki* (Muesebeck)
- *Opius vierecki* Gahan

Anastrepha suspensa (Loew)
- *Biosteres longicaudatus* Ashmead
- *Doryctobracon anastrephilus* (Marsh)
- *Opius anastrephae* Viereck
- *Opius concolor* Szépligeti

Ceratitis capitata (Wiedemann)
- *Biosteres longicaudatus* Ashmead
- *Biosteres oophilus* (Fullaway)
- *Biosteres tryoni* (Cameron)
- *Opius bellus* Gahan

Dacus ciliatus Loew*
- *Biosteres longicaudatus* Ashmead

Dacus cucurbitae Coquillett**
- *Biosteres longicaudatus* Ashmead

Dacus curvipennis (Froggatt)**
- *Biosteres longicaudatus* Ashmead

Dacus dorsalis Hendel***
- *Biosteres longicaudatus* Ashmead
- *Biosteres tryoni* (Cameron)

Dacus frauenfeldi Schiner*
- *Biosteres longicaudatus* Ashmead

Dacus incisus Walker*
- *Biosteres longicaudatus* Ashmead

Dacus latifrons (Hendel)*
Biosteres longicaudatus Ashmead
Dacus limbifer (Bezzi)*
Biosteres longicaudatus Ashmead
Dacus nubilus Hendel*
Biosteres longicaudatus Ashmead
Dacus passiflorae (Froggatt)*
Biosteres tryoni (Cameron)
Dacus pedestris (Bezzi)*
Biosteres longicaudatus Ashmead
Dacus psidii (Froggatt)*
Biosteres longicaudatus Ashmead
Dacus tryoni (Froggatt)*
Biosteres longicaudatus Ashmead
Biosteres tryoni (Cameron)
Dacus xanthodes (Broun)*
Biosteres tryoni (Cameron)
Dacus zonatus (Saunders)*
Biosteres longicaudatus Ashmead
Eutreta xanthochaeta Aldrich
Biosteres tryoni (Cameron)
Gerrhoceras sp.
Opius tafivallensis Fischer
Myoleja limata (Coquillett)
Biosteres melleus (Gahan)
Opius aciurae Fischer
Procecidochares utilis Stone
Biosteres longicaudatus Ashmead
Biosteres tryoni (Cameron)
Rhagoletis basiola (Osten Sacken)
Opius baldufi Muesebeck
Opius rosicola Muesebeck
Rhagoletis berberis Curran
Opius downesi Gahan
Rhagoletis boycei Cresson
Biosteres juglandis (Muesebeck)
Rhagoletis cingulata (Loew)
Biosteres melleus (Gahan)
Diachasma ferrugineum (Gahan)
Opius frequens Fischer
Rhagoletis indifferens Curran
Diachasma muliebre (Muesebeck)
Opius rosicola Muesebeck
Rhagoletis completa Cresson
Biosteres sublaevis Wharton
Biosteres tryoni (Cameron)
Rhagoletis cornivora Bush
Opius canaliculatus Gahan
Rhagoletis fausta (Osten Sacken)
Diachasma ferrugineum (Gahan)
Opius canaliculatus Gahan
Opius frequens Fischer
Rhagoletis juglandis Cresson
Biosteres juglandis (Muesebeck)
Rhagoletis mendax Curran
Biosteres melleus (Gahan)
Opius canaliculatus Gahan
Rhagoletis pomonella (Walsh)
Biosteres melleus (Gahan)
Diachasma alloeum (Muesebeck)
Diachasma ferrugineum (Gahan)
Opius canaliculatus Gahan
Opius downesi Gahan
Opius richmondi Gahan
Rhagoletis suavis (Loew)
Biosteres melleus Gahan
Rhagoletis tabellaria (Fitch)
Opius canaliculatus Gahan
Opius downesi Gahan
Opius juniperi Fischer
Opius tabellariae Fischer
Rhagoletis zephyria Snow
Opius canaliculatus Gahan
Tomoplagia sp.
Opius itatiayensis Costa Lima
Tomoplagia rudolphi (Lutz & Costa Lima)
Opius tomoplagiae Costa Lima
Toxotrypana curvicauda Gerstäcker
Doryctobracon toxotrypanae (Muesebeck)
Zonosemata electa (Say)
Biosteres sanguineus (Ashmead)
Zonosemata vittigera (Coquillett)
Biosteres sanguineus (Ashmead)

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* Not known to occur in the New World.
** Trapped in California on a few occasions, but extensive surveys showed no subsequent infestations.
*** Established in California on several separate occasions but successfully eradicated each time.

The key to species that follows is aimed at the non-specialist in braconid taxonomy, for whom some terms may be unfamiliar. Some of these terms are defined below.

Malar space. The space between the eye and base of mandible.

Mesonotal midpit. A pit on the mesonotum just in front of the prescutellar furrow (see below), sometimes represented only by a small circular shallow pit, other times by an extended tear-drop-shaped depression.

Notauli. Two furrows on the mesonotum extending posteriorly from the anterior lateral corners and meeting at the prescutellar furrow. They are usually smooth but sometimes have cross carinae at regular intervals appearing to be a row of pits, in which case they are termed crenulate. They are synonymous with parapsidal furrows of older descriptions.

Occipital carina. A carina or ridge that goes around the back of the head separating the occiput from the temples and vertex.

Prescutellar furrow. A transverse furrow in front of the scutellum separating it from the mesonotal lobes; usually with distinct cross carinae dividing it into sections.

Propodeum. The last segment of the thorax, actually the morphological first abdominal segment fused with the thorax.

Sternaulus. A groove on the lower part of the mesopleuron extending from the middle coxa forward usually to the middle of the pleuron. It can be either smooth or crenulate (see notauli for definition of crenulate).

Wing venation. See Fig. 1 for explanation of terms.

As is the case with most braconids, males not associated with females are difficult to identify. Therefore, the key that follows is based mainly on the females.

Key to the New World Opiinae Reared from Tephritidae

1. Second radial segment of fore wing longer than first intercubitus (fig. 1, R1, I1); postnervellus of hind wing (see fig. 5, Pn) usually absent or only weakly indicated 2
   Second radial segment equal to or shorter than first intercubitus (fig. 5); postnervellus present, often strongly pigmented 19

2(1). Second abdominal tergite always and base of third often distinctly striate; lower border of mandible notched 3
   Abdomen unsculptured beyond first tergite; lower border of mandible evenly curved 4

3(2). Ovipositor about as long as first abdominal tergite; first tergite usually rugulose or granular .... *Opius baldufi* Muesebeck
   Ovipositor at least as long as abdomen beyond first tergite; first tergite usually striate .... *Opius downesi* Gahan

4(2). Recurrent vein of fore wing entering first cubital cell (fig. 6) 5
   Recurrent vein entering second cubital cell (as in fig. 5), very rarely interstitial with intercubitus (as in figs. 1, 4) 8

5(4). Propodeum with well developed longitudinal median carina; third segment of discoidal vein of fore wing (D3) absent or nearly so (fig. 2, 3) 6
   Propodeum without carinae; third segment of discoidal vein present and well developed (fig. 6) .... *Opius tafivallensis* Fischer

6(5). Stigma of fore wing nearly linear (fig. 3), about 9 times longer than wide .... *Opius hirtus* Fischer
   Stigma broad (fig. 2), roughly 4 times longer than wide 7

7(6). Opening present between mandibles and clypeus when mandibles closed; stigma yellow .... *Opius concolor* Szépligeti
   Opening absent between mandibles and clypeus when mandibles closed; stigma brown .... *Opius bellus* Gahan

8(4). Occipital carina absent 9
   Occipital carina present and well developed 13

9(8). Mesonotal midpit absent .... *Opius bucki* Costa Lima
   Mesonotal midpit present and nearly always deep 10

10(9). Eye small, at most 2.5 times longer than malar space; width of clypeus less than 2.5 times height (figs. 14, 16) 11
   Eye larger, usually at least 3 times longer than malar space; width of clypeus more than 2.75 times height 12

11(10). Propodeum distinctly areolate; facial carina present between antennae but weak .... *Opius tomoplagiae* Costa Lima
Propodeum with only a pair of short carinae at apex; facial carina strong, nearly spinose, between antennae .... *Opius itatiayensis* Costa Lima

12(10). Eyes large, strongly bulging in dorsal view (fig. 9), more than 4 times longer than temples .... *Opius vierecki* Gahan
Eyes moderately sized, not strongly bulging in dorsal view (fig. 10), less than 3.5 times longer than temples .... *Opius anastrephae* (Viereck)

13(8). Ovipositor extending beyond apex of abdomen by distance equal to or shorter than first abdominal tergite 14
Ovipositor extending beyond apex of abdomen by distance greater than first tergite 16

14(13). Carinae on first abdominal tergite weak or absent; propodeum weakly rugose medially; temples as seen from above bulging slightly beyond margin of eye .... *Opius juniperi* Fischer
Carinae on first tergite strong; propodeum strongly rugose; temples sloping inward, not bulging beyond eye margin 15

15(14). Mesopleuron always marked with black, propodeum usually black or dark brown .... *Opius canaliculatus* Gahan
Mesopleuron honey yellow, propodeum usually honey brown .... *Opius acicurae* Fischer

16(13). Dark colored species, most of thorax and abdomen dark brown or black .. 17
Light colored species, body entirely orange, rarely propodeum brown 18

17(16). Prescutellar furrow divided into two distinct pits by strong central carina; second radial segment of fore wing not more than 3 times longer than second intercubitus; abdominal tergites 2 and 3 usually black .... *Opius frequens* Fischer
Prescutellar furrow not divided into two pits, all carinae of equal size; second radial segment about 4 times longer than second intercubitus; tergites 2 and 3 yellow .... *Opius tabellariae* Fischer

18(16). Ovipositor not longer than one-half abdomen; body length 4–5 mm .... *Opius rosicola* Muesebeck
Ovipositor about as long as abdomen; body length 2–3 mm .... *Opius richmondi* Gahan

19(1). Opening present between mandibles and clypeus when mandibles closed; apical margin of clypeus concave, truncate, or sinuous (figs. 11, 13) 20
Opening absent between mandibles and clypeus when mandibles closed; apical margin of clypeus convex (fig. 12) 33

20(19). Apical margin of clypeus sinuous (fig. 13); recurrent vein entering first cubital cell, sometimes nearly interstitial with intercubitus; occipital carina absent 21
Apical margin of clypeus concave to truncate (fig. 11); recurrent vein entering second cubital cell; occipital carina well developed, at least at lower edges 31

21(20). Propodeum areolate (fig. 8); head of most species yellow or orange, sometimes black dorsally but at least lower face yellow 22
Propodeum bearing only a pair of short apical carinae (fig. 7), never areolate; head dark brown to black 28

22(21). Fore wings yellow with black apical border 23
Fore wings predominately concolorous, hyaline to infuscated 24

23(22). Head and hind femur largely black; first abdominal tergite roughly 1.2 (♀) and 1.5 (♂) times longer than apical width ... *Doryctobracon zeteki* (Muesebeck)
Head and hind femur yellow or yellow orange; first tergite 1.0 (♀) and 1.2 (♂) times longer than apical width ..... *Doryctobracon auripennis* (Muesebeck)

24(22). Fore and middle tibiae and femora dark brown to black, at least in part 25
Fore and middle tibiae and femora yellow or yellow orange 26

25(24). Ovipositor slightly but distinctly shorter than body; stigma without black border .... *Doryctobracon anastrephilus* (Marsh)

Ovipositor slightly but distinctly longer than body; stigma with black border .... *Doryctobracon tucumanus* (Turica & Mallo)

26(24). Wings hyaline or nearly so; posterior femur yellow .... *Doryctobracon areolatus* (Szépligeti)
Wings infuscated except for a small light patch beyond stigma; posterior femur dark, at least in part 27

27(26). Apical abdominal tergites of female yellow .... *Doryctobracon capsicola* (Muesebeck)
Apical abdominal tergites of female dark .... *Doryctobracon fluminensis* (Costa Lima)

28(21). Stigma yellow .... *Doryctobracon brasiliensis* (Szépligeti)
Stigma brown 29

29(28). Head and thorax black, abdomen yellow; clypeus strongly sinuous .... *Doryctobracon toxotrypanae* (Muesebeck)
Head often dark brown, thorax and abdomen orange; clypeus usually not as strongly sinuous 30

30(29). Frons with dense area of hair directly behind antennae .... *Doryctobracon crawfordi* (Viereck)
Frons smooth and hairless behind antennae .... *Doryctobracon trinidadensis* (Gahan)

31(20). First abdominal tergite smooth apically, median pair of carinae absent posteriorly .... *Diachasma muliebre* (Muesebeck)
First tergite rugose apically, median pair of carinae strong throughout 32

32(31). Antennae usually 38–42 segmented; ovipositor subequal to length of body .... *Diachasma ferrugineum* (Gahan)
Antennae usually 43–47 segmented; ovipositor much longer than body .... *Diachasma alloeum* (Muesebeck)

33(19). Second abdominal tergite heavily striate 34
Second abdominal tergite smooth, or nearly so 37

34(33). Notauli distinct and deeply impressed throughout their length 35
Notauli absent posteriorly, not reaching mesonotal midpit 36

35(34). Thorax and abdomen dark brown; notauli crenulate .... *Biosteres oophilus* (Fullaway)
Thorax and abdomen orange; notauli smooth .... *Biosteres longicaudatus* Ashmead

36(34). Second cubital cell of fore wing large, third radial segment less than 3.5 times length of second segment .... *Biosteres melleus* (Gahan)
Second cubital cell small; third radial segment more than 4.2 times longer than second segment (fig. 5) .... *Biosteres sublaevis* Wharton, n. sp.

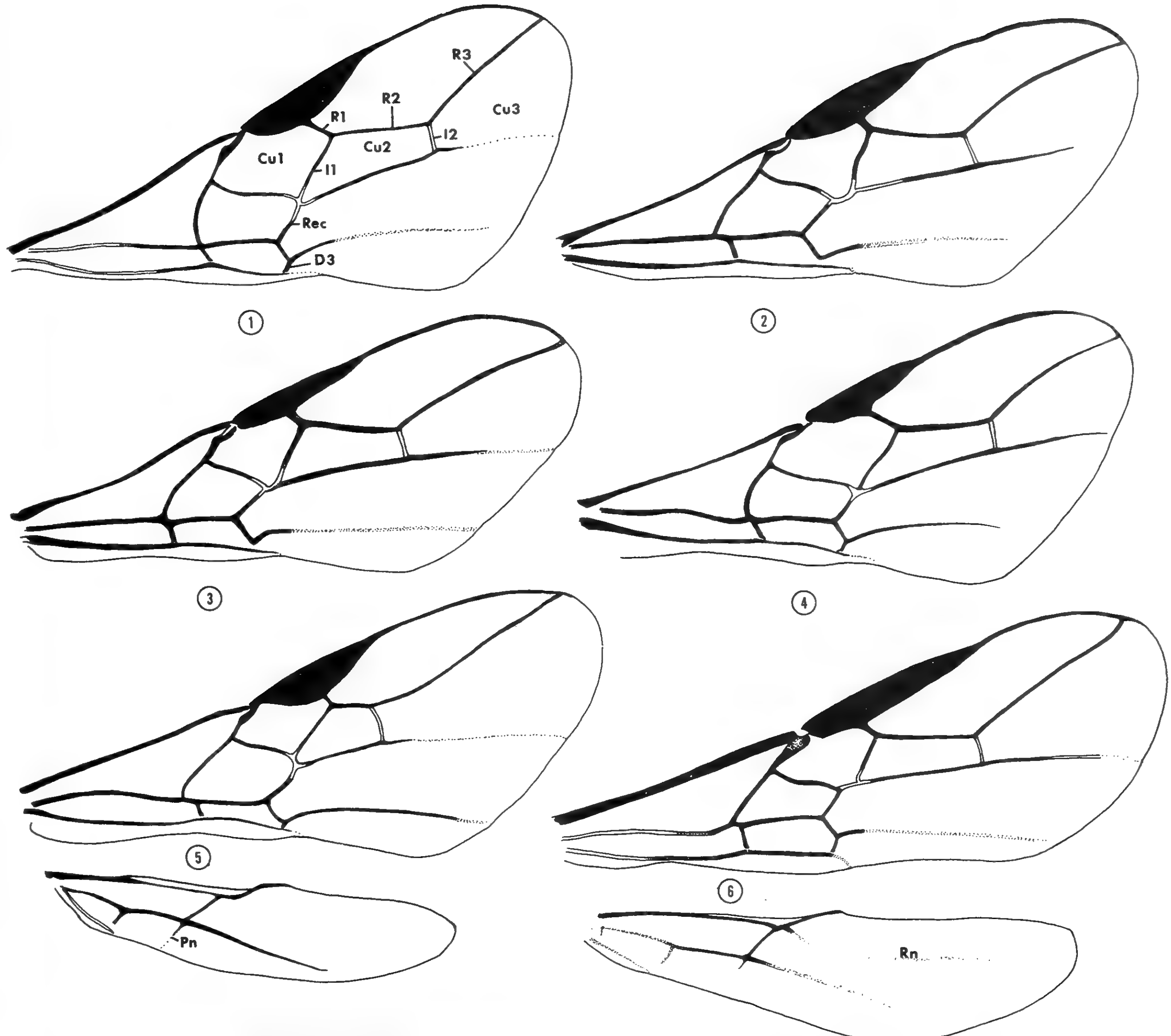
37(33). Wing hyaline; hind femur yellow to yellow orange .... *Biosteres juglandis* (Muesebeck)
Wing membrane distinctly infuscated; hind femur dark brown 38

38(37). Abdominal tergites largely dark brown to black; ovipositor about 1.5 times longer than thorax plus abdomen; fore and middle femora yellow .... *Biosteres tryoni* (Cameron)
Abdominal tergites orange; ovipositor subequal to length of thorax plus abdomen; fore and middle femora dark brown .... *Biosteres sanguineus* (Ashmead)

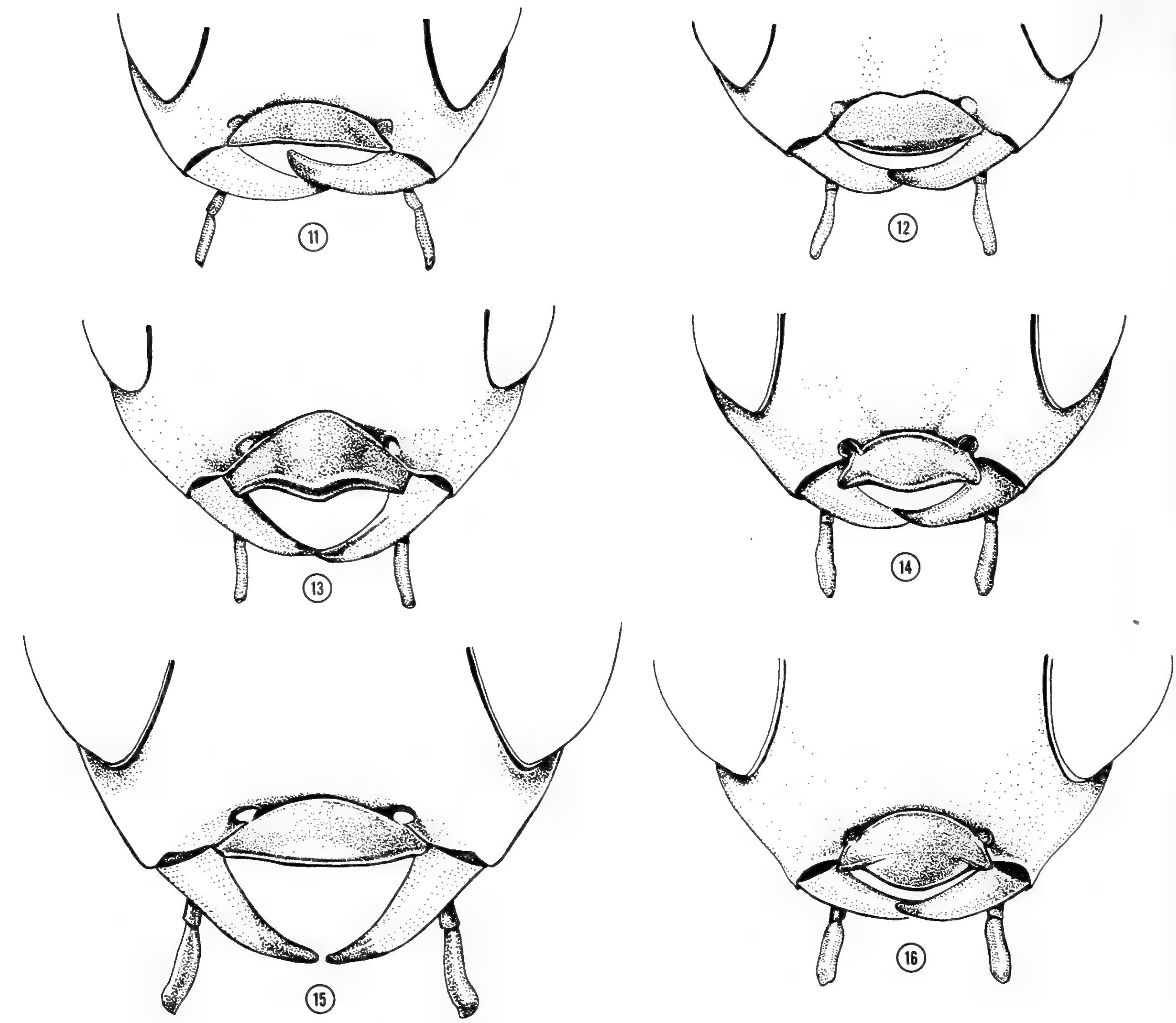
In the discussion below, the distribution, hosts, and most significant literature references are given for each species. Many distribution records and literature references pertaining to areas outside the New World have been omitted for some of the introduced species, but they can be found in Fischer (1971).

Genus ***Biosteres*** Foerster

Biosteres Foerster, 1862:259.
Zetetes Foerster, 1862:258.
Chilotrichia Foerster, 1862:258.
Stenospilus Foerster, 1862:259.
Rhandospilus Foerster, 1862:259.
Opiellus Ashmead, 1900:368.
Celiestella Cameron, 1903:343.
Diachasmimorpha Viereck 1913:641.



Figs. 1–6. Wings: 1, *Opius rosicola* Muesebeck; 2, *O. bellus* Gahan; 3, *O. hirtus* Fischer; 4, *O. anastrephae* (Viereck); 5, ***Biosteres sublaevis*** Wharton, n. sp.; 6, *O. tafivallensis* Fischer. Figs. 7–8. Propodeum: 7, *Doryctobracon trinidadensis* (Gahan); 8, *D. anastrephilum* (Marsh). Figs. 9–10. Head, dorsal view: 9, *O. vierecki* Gahan; 9, *O. anastrephae*. Abbreviations: Cu1, Cu2, Cu3 = 1st, 2nd, and 3rd cubital cells; D3 = 3rd segment of discoideus; I1, I2 = 1st and 2nd intercubiti; Pn = postnervellus; R1, R2, R3 = 1st, 2nd, and 3rd segments of radius; Rec = recurrent vein; Rn = radiellen vein.



Figs. 11–16. Lower portion of face, anterior view: 11, *Diachasma muliebre* (Muesebeck); 12, *Biosteres melleus* (Gahan); 13, *Doryctobracon anastrephilum* (Marsh); 14, *Opius itatiayensis* Costa Lima; 15, *O. vierecki* Gahan; 16, *O. tomoplagiae* Costa Lima.

Biosteres (*Parasteres*) Fischer, 1967:3. **New synonymy.**

Fischer (1967) originally described *Parasteres* as a subgenus of *Biosteres* and later (Fischer 1971) gave it full generic status. Still later (Fischer 1973) separated it from *Biosteres* by placing *Parasteres* in a different tribe, the Desmiostomatini, which he characterized as having the occipital carina completely absent. This seems to be an unnatural arrangement, however, as the occipital carina is variously reduced in both *Biosteres* and *Opius* of the tribe Opiini. The relative development of the occipital carina appears to be an attribute of species or possibly subgenera rather than a generic or tribal characteristic. And in at least one species, the development of such a carina is intraspecifically variable. Variables involving the shape of the mandibles and clypeus and the presence, absence, and relative lengths of various wing veins, are much more significant and useful for discriminating higher categories. And even these characters are insufficient in themselves and are best used in combination for the accurate characterization of genera in the Opiinae. Fischer's Opiini and Desmiostomatini need to be reassessed to determine the true cross-tribal relationships of the included genera. Tobias (1977) has rejected the generic separation of *Biosteres*, *Diachasma*, and *Opius*, retaining them as subgenera of *Opius*. We have seen the male holotype of the type-species of *Parasteres*, and it agrees well with the genus *Biosteres*. Further it is conspecific with *B. tryoni*.

The genus *Biosteres* is characterized as follows: second cubital cell short, second radial segment usually shorter than first intercubitus; post-nervellus well developed; clypeus large, opening between clypeus and mandibles absent when mandibles closed.

Biosteres juglandis (Muesebeck)

Opius juglandis Muesebeck, 1961:57.

Distribution.—Arizona, New Mexico; laboratory reared in California.

Hosts.—Rhagoletis boycei, *R. juglandis*.

Biosteres juglandis differs from its close relatives in the *longicaudatus* complex by the absence of well-developed sculpture on the second abdominal tergite. Some sculpture is discernible on a few specimens but this is always limited to the base of the tergite. The biology of this species has recently been studied by Buckingham (1975).

Biosteres longicaudatus Ashmead

Biosteres longicaudatus Ashmead, 1905:970.

Distribution.—First described from the Philippines; also collected in Costa Rica and Mexico. Released and successfully established in Hawaii and recently in southern Florida (Baranowski 1974) and Trinidad (Bennett *et al.* 1977).

Hosts.—Anastrepha suspensa, *Ceratitis capitata*, *Dacus ciliatus* (?), *D. cucurbitae*, *D. curvipennis*, *D. dorsalis*, *D. frauenfeldi*, *D. incisus*, *D. latifrons*, *D. limbifer*, *D. nubilus*, *D. pedestris*, *D. psidii*, *D. tryoni*, *D. zonatus*, *Procecidochares utilis*.

Additional references.—Ashley *et al.* 1977(1976) (adult emergence); Beardsley 1961 (status of varieties and forms); Fullaway 1951, 1953 (discussion and description of new varieties); Greany, Allen *et al.* 1977 (laboratory rearing); Greany, Ashley *et al.* 1976 (detailed life history and rearing techniques from laboratory cultures in Florida); Greany, Tumlinson *et al.* 1977 (host finding); Lawrence *et al.*, 1976 (effect of host age on development); Lawrence *et al.* 1978 (oviposition behavior); van den Bosch *et al.* 1951 (one of numerous status reports following introduction into Hawaii).

A large amount of additional literature is available concerning the introduction, mass rearing, and use of *longicaudatus* for biological control of fruit flies in Hawaii and other regions of the World.

Biosteres longicaudatus is similar to both *melleus* and *sublaevis*. Populations of *longicaudatus* introduced into the New World differ from these two species in the possession of distinctly lighter basal flagellomeres. It should be noted, however, that some of the described varieties of *longicaudatus* do have a completely dark flagellum. In addition to characters mentioned in the key, specimens of *longicaudatus* often have a dark apical or subapical band on the abdomen, and the posterior ocelli are more widely spaced than in *melleus* and *sublaevis*. Another distinguishing character for *longicaudatus* is the distinctive kink near the tip of the ovipositor.

The status of the numerous varieties belonging to the *longicaudatus* complex needs to be examined in much more detail. The mass rearing and introduction of large numbers of these varieties into the same habitats has undoubtedly altered some of the physiological (and perhaps morphological) barriers which may still persist in the Oriental Region.

Biosteres melleus (Gahan)

Opius melleus Gahan, 1915:73
Biosteres rhagoletis Richmond, 1915:294.

Distribution.—Minnesota and Nova Scotia south to Florida.

Hosts.—Rhagoletis cingulata, *R. mendax*, *R. pomonella*, *R. suavis*, *Myoleja limata*? (numerous specimens from Florida have been reared from *Ilex* spp., and *M. limata* is the only tephritid known from this host plant (Wasbauer 1972)).

Additional references.—Lathrop and Nickels 1932; Lathrop and Newton 1933 (detailed biology on the blueberry maggot, includes essential details of all earlier reports).

This species is most closely related to *sublaevis* n. sp. It differs primarily in the configuration of the second cubital cell. In addition, the sternaulus is strongly crenulate in *melleus* but nearly smooth in *sublaevis*. Specimens of *melleus* from Florida, although reared from a different host and unrelated host plant, appear essentially identical to those reared from *Rhagoletis mendax* and *R. pomonella* in Maine. There are some slight differences in the shape of the second cubital cell. Because of the unusual host, some doubt must be attached to the Florida material until further biological information can be obtained. *Biosteres melleus* differs from the species of *Opius* attacking *R. pomonella*, *R. mendax*, and *R. cingulata* by lacking an opening between the clypeus and mandibles, the strigose tergite two, and the shorter second radial segment.

Biosteres oophilus (Fullaway)

Opius oophilus Fullaway, 1951:248

This Oriental species has been reared in the laboratory in Costa Rica on *Ceratitis capitata* and is included here in the event that it becomes established. It can be distinguished from all New World species on tephritids by the crenulate notauli.

Biosteres sanguineus (Ashmead)

Phaedrotoma (?) *sanguineus* Ashmead, 1889(1888): 655.

Distribution.—Maryland to Florida and west to Missouri and Arizona

Hosts.—*Zonosemata electa*, *Z. vittigera*.

Additional references.—Ashmead 1892 (brief note on host association with the weed *Solanum carolinense*); Cazier 1962 (brief note on biology).

This species is characterized by the dark wings, dark legs, and completely orange body in both sexes. In addition, it has a shorter ovipositor and a much more robust appearance than other species of *Biosteres*. Other than the brief notes by Ashmead and Cazier, nothing is known about the biology of *sanguineus*.

Biosteres sublaevis Wharton, new species[2]
(Fig. 5)

Head.—1.67–1.80 (M = 1.74, H = 1.76)[3] times broader than long, 1.20–1.34 (M = 1.24, H = 1.21) times broader than mesonotum; eyes slightly bulging beyond temples in dorsal view, eyes roughly twice as long as temples. Temples, occiput and frons (laterally) moderately densely hairy; eyes bare. Occipital carina strong to mid eye height; face distinctly hair-punctured, slightly protruding medially, usually with weak median carina above middle. Face nearly twice wider than high; clypeus roughly three times wider than high. Lower border of clypeus evenly convex; opening almost completely absent between clypeus and mandibles when mandibles closed. Mandible roughly 1.8 times broader at base than at apex, upper and lower borders gradually diverging at apex, more strongly diverging over basal third; upper tooth larger, extending distinctly distad of lower. Malar space ⅓ to ¼ eye height, roughly 0.7 times basal width of mandible. Distance between antennal bases about equal to distance between antennae and eyes; antenna roughly 1.5 times longer than body, 41–45 segmented. Maxillary palps distinctly longer than head.

Thorax.—1.24–1.36 (M = 1.30, H = 1.26) times longer than high; 1.32–1.41 (M = 1.34, H = 1.32) times higher than wide. Mesonotum strongly declivous anteriorly; densely hairy and weakly punctured throughout, hairs longer, more erect, and less dense posteriorly and on scutellum; notauli very deep, but short, very weakly impressed to absent beyond anterior-lateral corners; mesonotal midpit deep, tear-drop shaped. Prescutellar groove 3 to 4 times broader than long, with well-developed midridge and distinct lateral ridges of varying strength. Apical half of propodeum strongly declivous; propodeum rugulose, sparsely hairy throughout; median areola occasionally discernible. Metapleuron and mesopleural disc sparsely hairy centrally; hairs on mesopleuron shorter and more numerous than on metapleuron. Sternaulus distinctly impressed, but nearly unsculptured. Hind femur nearly 3.5 times longer than mid-width.

Wings (fig. 5).—stigma broad, discrete, 2.65–3.30 (M = 3.06, H = 2.67) times longer than broad; first

[2] The description of this new species is to be credited solely to R. A. Wharton.

[3] M = median, H = holotype.

segment of radius short, arising from near middle of stigma, ⅓ to ⅕ length of second segment, third segment 4.20–5.50 (M = 4.96, H = 4.21) times longer than second segment and ending before wing tip; first intercubitus 1.32–1.73 (M = 1.46, H = 1.52) times longer than second segment of radius, roughly 1.65 times longer than second intercubitus; recurrent vein postfurcal by ⅓ to ²⁄₉ its own length, 0.51–0.59 (M = 0.56, H = 0.51) times length of first segment of discoideus; nervellus postfurcal by about its own length; subdiscoideus arising from well below middle of closed brachial cell; first mediellan segment roughly 1.3 times longer than second; postnervellus long, nearly reaching wing margin, weakly sclerotized posteriorly.

Abdomen.—petiole 1.10–1.25 (M = 1.16, H = 1.13) times longer than apical width; apex nearly twice wider than base; surface striate and bicarinate, the carinae often weak and indistinguishable beyond middle, especially in smaller specimens. Tergite 2 densely striate medially, smooth laterally; gaster smooth beyond tergite 2. Ovipositor sheath densely hairy, with at least 5 rows of moderately long hairs; ovipositor more than twice length of thorax.

Color.—orange; ovipositor sheaths, mandibular teeth, flagellum, pedicel, and scape (dorsally) dark brown; hind tibiae dorsally and most of hind tarsi often lighter brown; wings hyaline, veins dark brown.

Length.—2.2–3.5 mm.

Holotype.—female; Texas, Jefferson Davis County, Davis Mountains, August 1974, ex. *Rhagoletis completa*, S. Berlocher. Deposited in USNM.

Paratypes.—7 ♀♀, 3 ♂♂, same data as holotype. Deposited in USNM and personal collection of K. Hagen, University of California, Berkeley.

This species is closely related to *melleus*, particularly the Florida populations of that species (see discussion above), but differs primarily in the possession of a distinctly shorter second radial segment. In addition, the sternaulus is much more deeply impressed and sculptured in *melleus* than in *sublaevis*. *B. sublaevis* is also similar to *B. giffardii* (Silvestri) and *B. carinatus* Szépligeti but differs in having more extensive abdominal sculpture and a broader stigma. It differs from *longicaudatus* primarily in having much weaker notauli. One of the specimens from the type locality appears to be deformed. The striations on tergite 2 are very weak although still extending to the apex of the segment.

The specimens of the type-series were made available by Dr. K. Hagen, University of California, Berkeley, who originally suggested that they might represent a new species.

Biosteres tryoni (Cameron)

Opius tryoni Cameron 1911:343.
Biosteres (*Parasteres*) *acidusae* Fischer, 1967:3. **New Synonymy.**

Distribution.—Originally described from Australia; introduced into California (Boyce 1934), Puerto Rico (Bartlett 1941), and Hawaii (Pemberton and Willard 1918b); not recovered in California.

Hosts.—*Anastrepha obliqua*, *Ceratitis capitata*, *Dacus dorsalis*, *D. passiflorae*, *D. tryoni*, *D. xanthodes*, *Eutreta xanthochaeta*, *Procecidochares utilis*, *Rhagoletis completa*.

Additional references.—Pemberton and Willard 1918a (competition with *Opius humilis*); Pemberton and Willard 1918b (life history as *Diachasma tryoni*); Bartlett 1941 (rearing, release, recovery, and then apparent loss in Puerto Rico). Further information on this species can be found in the numerous accounts of the rearing, release, and status of fruit fly parasites for attempts at biological control especially in Hawaii.

This species is characterized by the poorly developed to absent occipital carina. It is similar to the Australian *deeralensis* in this regard but is otherwise unrelated due to strong differences in the shape of the clypeus. The clypeus is weakly indented as seen from below in *tryoni*, similar to *longicaudatus*, but *tryoni* is easily separated from the other *Biosteres* species included here by the color pattern of darkened wings and dark abdomen in both sexes.

B. acidusae was described from a single male taken in Puerto Rico by K. A. Bartlett (Fischer, 1967). It agrees in all respects with other Puerto Rican material collected by Bartlett in the same year and from the same host following the introduction and establishment of *tryoni*.

Genus **Diachasma** Foerster

Diachasma Foerster, 1862:259.
Bathystomus Foerster, 1862:235.
Atoreuteus Foerster, 1862:241.

Like *Biosteres* and *Doryctobracon*, *Diachasma* is characterized by the short second cubital cell and the presence of a postnervellus in the hind wing. *Diachasma* differs from *Biosteres* by the presence of a broad opening between the clypeus and mandibles, and from *Doryctobracon* by the shorter more evenly margined clypeus and the well-developed occipital carina.

Diachasma alloeum (Muesebeck)

Opius alloeus Muesebeck, 1956:101.

Distribution.—Ontario to New Brunswick; Connecticut, Florida, Maine, New York, Pennsylvania.

Host.—Rhagoletis pomonella.

Additional references.—Boush and Baerwald 1967 (courtship behavior, evidence for a sex pheromone); Cameron and Morrison 1977 (mortality factor of *R. pomonella*); Rivard 1967 (distribution and rearing records).

This species has been bred from *R. pomonella* in all of the above areas. As Muesebeck (1956) has noted, this species is closely related to *ferrugineum*, but *alloeum* has a distinctly longer ovipositor and is a somewhat larger species. The metapleuron is also usually more heavily sculptured.

Diachasma ferrugineum (Gahan)

Opius ferrugineus Gahan, 1915:75.

Distribution.—Northeastern United States and eastern Canada; Florida, California (?).

Hosts.—Rhagoletis cingulata, R. fausta, R. pomonella.

Additional references.—Harper 1962, 1963 (release, recovery, and successful establishment in California); Fleschner 1963 (record of release in California against *R. cingulata*); Porter 1928 (discussion of reasons for low percentage of parasitism on *P. pomonella*). Other references listed in Fischer (1971) are limited to rearing records. Apparently *ferrugineum* attacks *R. pomonella* only rarely.

Harper (1962) and Fleschner (1963) indicate that *ferrigineum* was released in California and Harper (1963) stated that it was recovered, but we have not seen any specimens from California to substantiate that fact. Parasites recovered from release sites of *ferrugineum* in California are apparently all *muliebre*.

Muesebeck (1956) separated *muliebre* from eastern *ferrugineum* on the basis of a minor, but apparently constant difference in sculpture of the first abdominal tergite, that of *muliebre* being smooth apically. The two species also have differing biologies, *muliebre* being parthenogenetic and *ferrugineum* being bisexual. Further biological studies are needed to determine if the two species are indeed distinct.

Diachasma muliebre (Muesebeck)
(Fig. 11)

Opius muliebris Muesebeck, 1956:100.

Distribution.—Washington to California.

Host.—Rhagoletis indifferens.

See the discussion under *ferrugineum* for relationships of *muliebre* and *ferrugineum*.

Genus **_Doryctobracon_** Enderlein

Doryctobracon Enderlein, 1920(1918):144.
Parachasma Fischer, 1967:7.

Fischer (1967) proposed the name *Parachasma* for this distinctive group but apparently overlooked Enderlein's *Doryctobracon* since it was not originally placed in the Opiinae. Fischer (1973) later recognized *Doryctobracon* in a generic key implying, but not directly stating, that *Parachasma* was a synonym. The synonymy and new combinations were later published in Fischer (1977).

Members of this genus are probably all parasites of Tephritidae. Species are quite closely related and separated primarily by color differences (Fischer 1964b, 1965b, 1967) but need to be more carefully examined with respect to biology and intraspecific variations to determine their exact identities.

Doryctobracon is characterized by the distinctive shape of the clypeus (fig. 13), the short second cubital cell, strong postnervellus, recurrent vein entering first cubital cell, and the absence of an occipital carina.

Doryctobracon anastrephilus (Marsh)
(Figs. 8, 13)

Parachasma anastrephilum Marsh, 1970:31.

Distribution.—Southern Florida.

Host.—Anastrepha interrupta, A. suspensa.

This species is characterized by the complete propodeal areola, dark legs, and relatively short ovipositor. Nothing is known about its biology other than the host rearing listed.

Doryctobracon areolatus (Szépligeti), new combination

Biosteres areolatus Szépligeti, 1911:286.
Opius cereus Gahan, 1919:169. **New synonymy.**
Opius saopaulensis Fischer, 1961:290. **New synonymy.** Unnecessary new name for *areolatus* Szépligeti 1911.

Distribution.—Argentina, Brazil, Mexico, Panama, Trinidad, Venezuela; Florida, recently introduced and established.

Hosts.—Anastrepha benjamini, A. consobrina, A. fraterculus, A. ludens, A. montei, A. obliqua, A. pickeli, A. serpentina.

Additional references.—Baranowski and Swanson 1970, 1971 (release and recovery in Florida, as *cereum*); Clausen, Clancy, and Clock 1965 (unsuccessful attempts against Hawaiian fruit flies due to specificity on *Anastrepha*, as *cereum*); Plummer, McPhail, and Monk 1941 (host records, as *cereum*).

The type of *areolatus* agrees very well with specimens of *cereus* from Brazil; the clypeus is slightly less sinuate, but we feel they are definitely the same species. Fischer (1967) places this species in *Diachasma*. The clypeus on the type is not very sinuate, but there is no occipital carina and the recurrent vein is antefurcal, placing *areolatus* in *Doryctobracon*.

Little information has been published on the biology of this species despite the numerous introductions (as *Doryctobracon cereus*). It is readily distinguished by the relative hyalinity of the wings and appears to be quite close to *anastrephilus*, but the legs are predominately yellow rather than black.

Doryctobracon auripennis (Muesebeck)

Opius auripennis Muesebeck, 1958:453.

Distribution.—Panama.

Host.—Anastrepha serpentina.

This species is quite similar to *zeteki* but differs in having both head and hind femora yellow or yellow orange instead of predominately dark brown to black. The only biological information is the host record above.

Doryctobracon brasiliensis (Szépligeti)

Biosteres brasiliensis Szépligeti, 1911:285.
Coeloides anastrephae Brèthes, 1924:7.
Opius (*Diachasma*) *brasilianus* Fischer, 1963:392. Unnecessary new name for *brasiliensis* Szépligeti 1911.

Distribution.—Argentina, Brazil.

Host.—Anastrepha fraterculus.

Additional references.—Costa Lima 1937 (host and distributional records).

The only biological information available for *brasiliensis* is the host record listed. This species is easily distinguished by the brightly colored stigma of the fore wing. The few individuals available for study indicate that the body is usually dark but variable in color.

Costa Lima (1937) synonymized *anastrephae* with *Biosteres brasiliensis* Szépligeti 1902. This should be 1911, since Szépligeti described *Opius brasiliensis* in 1902 which is definitely not the same as *Biosteres brasiliensis*. We have seen the types of *Biosteres brasiliensis* and *Coeloides anastrephae*, and they are definitely the same species.

Doryctobracon capsicola (Muesebeck)

Opius capsicola Muesebeck, 1958:450.

Distribution.—Panama.

Host.—Anastrepha sp. in *Manihot esculenta* seed capsules.

The only biological information is that listed above taken from the specimen labels. This species is nearly identical with *fluminensis*, but the vertex is darker and the apical abdominal tergites lighter in the female of *capsicola*. These two species differ from other *Doryctobracon* with a complete propodeal areola by the color of the legs and fore wings.

Doryctobracon crawfordi (Viereck)

Diachasma crawfordi Viereck, 1911:181.
Doryctobracon conjugens Enderlein, 1920(1918): 144. **New synonymy.**

Distribution.—Central America, Colombia, Ecuador.

Hosts.—Anastrepha ludens, A. striata.

Additional references.—Baker *et al.* 1944 (summary and interpretations of previous biological accounts); Crawford 1927 (host records); Darby 1933, Darby and Kapp 1934 (importance of temperature and humidity in development compared to *A. ludens*); Keilin and Picado 1913 (description of larvae and adults, as species of *Diachasma*); Keilin and Picado 1920 (rearing techniques); McPhail and Bliss (parasitism on *A. ludens*); Plummer, McPhail, and Monk 1941 (host records). Several other workers have discussed the unsuccessful attempts to introduce this species into other areas.

We have seen the type of *conjugens* and it is identical with that of *crawfordi*. This species is characterized by reduced propodeal sculpture, uniformly dark wings, and orange body. It is similar to *trinidadensis* in coloration but has a more extensively punctate and densely hairy frons.

Doryctobracon fluminensis (Costa Lima)

Opius fluminensis Costa Lima, 1938:69.

Distribution.—Brazil, Venezuela.

Host.—Anastrepha fraterculus.

This species is very similar to *capsicola* but the apical abdominal segments are darker and the vertex lighter in the females of *fluminensis*. The only biological information known is the host record listed.

Doryctobracon toxotrypanae (Muesebeck)

Opius toxotrypanae Muesebeck, 1958:451.

Distribution.—Costa Rica, Mexico.

Host.—Toxotrypana curvicauda.

No additional information is available concerning this species. It is very similar to *crawfordi* but has a darker thorax. The extent of the dark markings on the thorax is sometimes variable, and the two species, which are sympatric over part of their ranges, are best separated by their host preferences.

Doryctobracon trinidadensis (Gahan)
(Fig. 7)

Opius trinidadensis Gahan, 1919:168.

Distribution.—Trinidad.

Hosts.—Anastrepha serpentina, A. striata.

There is no information about this species other than the rearing records mentioned by Gahan (1919). It is very similar to *crawfordi* but is distinguished by smooth and hairless frons behind the antennae.

Doryctobracon tucumanus (Turica and Mallo), new combination

Opius tucumanus Turica and Mallo, 1961:149.

Distribution.—Argentina.

Host.—Anastrepha sp. on "ubajay."

Additional references.—Blanchard 1966 (redescription, as new species, listed as common in Loreto); Hayward 1941, 1943 (rearing and releases in Tucuman against unnamed fruit flies).

Almost nothing has been published on the biology of this species. It is similar in coloration and propodeal sculpture to *anastrephilus* but has a distinctly longer ovipositor.

Doryctobracon zeteki (Muesebeck)

Opius zeteki Muesebeck, 1958:454.

Distribution.—Panama.

Hosts.—Anastrepha fraterculus, A. striata.

The only biological information known about *zeteki* is the host records mentioned. This species is similar to *auripennis* but has a darker head and darker femora.

Genus ***Opius*** Wesmael

Opius Wesmael, 1835:115.

At least 21 synonyms are associated with *Opius*, and we are not listing them here. The complete list of synonyms can be found in Fischer 1971.

Most of the New World *Opius* species reared from tephritids have the postnervellus of the hind wing lacking or weakly developed. Otherwise, the genus contains a number of distinct morphological groups. The differences between these groups appear to be as great as those separating some of the other genera discussed above. In fact, Fischer (1973, 1977) has resurrected *Bracanastrepha* Brèthes for those species lacking an occipital carina and having an opening between the clypeus and mandibles. This genus, whose type-species is the same as *Opius anastrephae* Viereck (see below), has not been further characterized or discussed, however, and it seems premature to split off some of the species discussed below before the genus *Opius* has been adequately studied as a whole and the relationships of the various included groups are sufficiently understood.

The members of Fischer's *truncatus*-group subgroup II (Fischer 1964:271) appear to form a distinct morphological unit and all are probably parasites of the Tephritidae. Most are separable only with difficulty and even then only on the basis of slight differences in color and ovipositor length. Unassociated males are extremely difficult to identify. Some of the species are undoubtedly synonyms, but more work is needed on intraspecific variation and host preferences before such synonymies can be resolved. Differences in biology and internal anatomy may eventually prove of more importance than color and ovipositor length in separating these species.

Opius aciurae Fischer

Opius aciurae Fischer, 1964a:272.

Distribution.—Florida.

Host.—*Myoleja limata* on *Ilex* spp.

Almost nothing is known concerning this species. It is nearly identical to *canaliculatus* except for the lighter coloration. The difference in host range appears sufficient in itself to separate the two species.

Opius anastrephae Viereck
(Figs. 4, 10)

Opius anastrephae Viereck, 1913:563.
Bracanastrepha argentina Brèthes, 1924:8. **New synonymy.**
Opius mombinpraeoptantis Fischer, 1966:116. **New synonymy.**

Distribution.—Argentina, Brazil, Central America, West Indies; Florida.

Hosts.—*Anastrepha fraterculus*, *A. obliqua*, *A. suspensa*.

Additional references.—Clausen, Clancy, and Chock 1965 (introduction attempts, host records, limitations in biological control); Gowdy 1925, Plank 1938, 1939, Bartlett 1941 (host records and rates of parasitism).

We have compared the types of *argentina* and *mombinpraeoptantis* with that of *anastrephae* and they are identical, apparently representing a color variable species. It can be distinguished by the absence of an occipital carina, large eyes, short malar space, and temples not bulging. This species was introduced into Hawaii and apparently into the continental U. S. but not established. The Florida record indicated above is based on specimens in the National Collection reared at Key Biscayne from *A. suspensa*.

Opius baldufi Muesebeck

Opius baldufi Muesebeck, 1949:256.

Distribution.—Illinois, Michigan, Minnesota, Wisconsin.

Host.—*Rhagoletis basiola* (Muesebeck's original description states host as *R. alternata*, which is a misidentification of *basiola*).

Additional references.—Balduf 1958 (effect of parasites on host size), 1959 (detailed life history).

This species belongs to the morphologically distinct *ochrogaster* group (Fischer 1964a:350) which differ from other species discussed here by the shape of the mandibles which bear a distinct notch on their lower edge. *O. baldufi* is similar to *downesi* but has a somewhat shorter ovipositor.

Opius bellus Gahan
(Fig. 2)

Opius bellus Gahan, 1930:1.
Opius gomesi Costa Lima, 1938:71. **New synonymy.**
Opius turicai Blanchard, 1966:24. **New synonymy.**

Distribution.—Argentina, Belize, Brazil, Costa Rica, Panama, Trinidad, Venezuela.

Hosts.—*Anastrepha fraterculus*, *A. montei*, *A. obliqua*, *A. serpentina*, *Ceratitis capitata*.

Additional references.—Bartlett 1941 (record of laboratory rearing in Puerto Rico and unsuccessful establishment); Costa Lima 1937, 1938 (host records); Guagliumi 1963 (host records).

Despite a widespread distribution, very little seems to have been published concerning this species. It is characterized by the antefurcal recurrent vein, broad stigma, complete absence of notauli, absence or near absence of sternaulus, and absence of the third discoidal segment of the fore wing.

Both *gomesi* and *turicai* were described as being quite close to *bellus* but differing in the color of the mesonotum. Gahan, in his original description of *bellus*, mentioned the color variation in this species, but this fact was apparently overlooked in the description of *gomesi* and *turicai* as new species. We have not been able to see the types of *gomesi* and *turicai* and the synonymy is based on the original descriptions.

Opius bucki Costa Lima

Opius bucki Costa Lima, 1938:71.

Distribution.—Brazil.

Host.—Unknown species of Tephritidae.

Nothing is known concerning this species other than the reference by Costa Lima. This species is characterized by the absence of both an occipital carina and a mesonotal midpit and by the presence of a postfurcal recurrent vein and a broad stigma. It does not appear to be similar to any of the other species treated here. The lower face appears unusually elongate because the eyes are fairly small.

Opius canaliculatus Gahan

Opius canaliculatus Gahan, 1915:80.
Opius lectus Gahan, 1919:167. **New synonymy.**
Opius lectoides Gahan, 1930:2. **New synonymy.**

Distribution.—Quebec south to Maryland, west to Oregon; Florida.

Hosts.—*Rhagoletis cornivora*, *R. fausta*, *R. mendax*, *R. pomonella*, *R. tabellariae*, *R. zephyria*.

Additional references.—Cameron and Morrison 1977 (mortality factor of *R. pomonella*); Middlekauff 1941 (rearing records); Rivard 1967 (rearing and emergence records). All references are to *lectus*.

We have been unable to adequately distinguish between *canaliculatus*, *lectus*, and *lectoides* on morphological grounds. Foote and Blanc (1963) have discussed the relationships between the two main host species of *Rhagoletis*, *pomonella* and *zephyria*, but there does not seem to be any differences in the parasites. We have seen four specimens from Florida reared from *R. cornivora* and they also are identical to *canaliculatus*.

This species is very similar to *acicurae* and differs primarily in its darker coloration and host range.

Opius concolor Szépligeti

Opius concolor Szépligeti, 1910:244.
Opius fuscitarsus Szépligeti, 1913:605.
Opius perproximus Silvestri, 1914:103.
Opius siculus Monastero, 1931:195.

This Mediterranean species is being studied in Florida and has been successfully reared for several generations on *Anastrepha suspensa* (Baranowski, pers. comm.). It is included here in the likely event that it will be established. It is similar to *bellus* but is distinguished by its yellow stigma and the opening between clypeus and mandibles when the mandibles are closed.

Opius downesi Gahan

Opius downesi Gahan, 1919:164.
Opius (*Opius*) *berberidis* Fischer, 1964a:358.

Distribution.—British Columbia, Michigan, New Brunswick, New York, Ontario, Washington. Probably widely distributed across northern U. S. and southern Canada.

Hosts.—Rhagoletis berberis, R. pomonella, R. tabellaria.

Almost nothing is known concerning this species. Downes (1919) mentioned it as a parasite of *R. pomonella*; the other records are based on reared specimens in the National Collection. This species is characterized by the unusual mandible and wing venation as in *baldufi* but differs from *baldufi* in the possession of a slightly longer ovipositor.

Opius frequens Fischer

Opius (Opius) frequens Fischer, 1964a:279.
Opius (Opius) glasgowi Fischer, 1964a:286. **New synonymy.**

Distribution.—Maine west to Washington and Oregon.

Hosts.—Rhagoletis cingulata, R. fausta.

Aside from rearing records based on label information, nothing appears to be known about this species.

O. glasgowi is based on a male specimen which differs from typical female *frequens* specimens only in its slightly lighter coloration. A female from the same series as the male type of *glasgowi*, found in the National Collection, is identical to specimens from the type series of *frequens* in both coloration and sculpture. This species is characterized and separated from other members of the nearctic *truncatus*-group as follows: dark body, weakly infuscated wings, and moderately long ovipositor. It most closely resembles the slightly lighter colored *tabellariae* but is distinguished by the length of the second intercubitus and the strong central carina in the prescutellar furrow.

Opius hirtus Fischer
(Fig. 3)

Opius (Opius) hirtus Fischer, 1963:376.

Distribution.—Costa Rica, Dominican Republic.

Host.—Anastrepha sp.

The host record above is from label information on a single specimen reared from guava in Costa Rica. This species is readily recognized by the narrowly elongate stigma, antefurcal recurrent vein, lack of an opening between clypeus and mandibles, unsculptured mesonotum, and weak radiellan vein of hind wing. It is perhaps closest to *tafivallensis*, but the later is black and white and *hirtus* is orange.

Opius itatiayensis Costa Lima
(Fig. 14)

Opius itatiayensis Costa Lima, 1937:24 (in key); 1938:70 (description).

Distribution.—Brazil.

Host.—Tephritidae, possibly *Tomoplagia* (Costa Lima, 1937:23).

The only biological information on *itatiayensis* is the brief note by Costa Lima mentioned above. This species is separated from the other *Opius* species lacking an occipital carina by the relatively small eyes, postfurcal recurrent vein, and moderately sized clypeus. It is similar to *tomoplagiae* but has a strong facial carina and a more weakly sculptured propodeum.

Opius juniperi Fischer

Opius (Opius) juniperi Fischer, 1964a:288.

Distribution.—Arizona.

Host.—Possibly *Rhagoletis tabellaria*

The holotype and one paratype were reared from juniper berries in association with the above tephritid. Fischer also listed a specimen from Manitoba, but, since we have not seen this specimen and the wide range of localities seems too great, we have not included this record in the distribution. This species is separated from other Nearctic members of the *truncatus*-group by the near absence of sculpture on the petiole, the greatly reduced sculpture of the propodeum, and the bulging eyes.

Opius richmondi Gahan

Opius richmondi Gahan, 1919:165.

Distribution.—Maine, Minnesota.

Host.—Rhagoletis pomonella.

Additional references.—Lathrop and Nickels 1932 (rearing record).

Very little is known concerning this species. It is readily distinguished from other nearctic members of the *truncatus*-group by the much longer ovipositor, the petiolar carinae which usually extend to the apex as well-developed ridges, and the orange body.

Opius rosicola Muesebeck
(Fig. 1)

Opius rosicola Muesebeck, 1949:254.

Distribution.—California, Illinois, Minnesota, Oregon, Saskatchewan, Washington, Wisconsin.

Hosts.—Rhagoletis basiola, R. indifferens.

Additional references.—Balduf 1958 (effect of parasite on host size), 1959 (detailed life history).

The material from western U. S. was reared from the cherry fruit fly in *Prunus emarginatus* but appears to be identical to the type material reared from rose hips. The biology of this species is apparently identical to that of *baldufi* despite strong morphological differences.

O. rosicola is similar to the other nearctic members of the *truncatus*-group with moderately long ovipositor but differs in the lighter coloration, the nearly hyaline wings, and the weak carinae on the petiole.

Opius tabellariae Fischer

Opius (*Opius*) *tabellariae* Fischer, 1964a:305.

Distribution.—Minnesota, New York.

Host.—Rhagoletis tabellaria.

The only biological information known is the host record listed above. This species is similar to *frequens* but differs in its shorter second intercubital vein and the prescutellar furrow not having a strong central dividing carina.

Opius tafivallensis Fischer
(Fig. 6)

Opius tafivallensis Fischer, 1968:69.

Distribution.—Argentina, Peru.

Host.—Gerrhoceras sp.

The above host record is from labels on three specimens collected in San Mateo, Peru. This species is quite different from all other opiines discussed here because of its black and white color. In addition, it has the petiole and propodeum unsculptured with the mesonotum and mesopleuron nearly so, the petiole narrowly elongate, the propodeum densely covered with long hairs, the postnervellus and third discoidal segments well-developed, the recurrent vein entering first cubital cell, and the stigma narrow.

Opius tomoplagiae Costa Lima
(Fig. 16)

Opius tomoplagiae Costa Lima, 1937:24 (in key); 1938:69 (description).

Distribution.—Brazil.

Host.—Tomoplagia rudolphi.

This distinctive species is similar to *itatiayensis* but differs by its distinctly areolated propodeum and weak facial carina. The only biological information is the host record mentioned by Costa Lima (1937).

Opius vierecki Gahan
(Figs. 9, 15)

Opius vierecki Gahan, 1915:76.

Distribution.—Mexico, Panama.

Hosts.—Anastrepha rheediae, A. striata.

Viereck stated in the original description that the type was "probably" reared from *A. striata*. The National Collection contains a specimen reared from *A. rheediae*. This species belongs to the neotropical complex of *Anastrepha* parasites which lack an occipital carina. It differs from other members of this group in having greatly enlarged eyes.

Other Species Not Included in Key

Biosteres fullawayi (Silvestri): Introduced into Puerto Rico but apparently not established.

Opius fletcheri Silvestri: Introduced into Puerto Rico but not established.

Opius humilis Silvestri: Introduced into California and Puerto Rico but apparently not established.

Opius macrocerus Thompson: Occurs in Europe, Japan, and is recorded from Michigan; a parasite of Agromyzidae but Fischer (1964c:9) lists it also as attacking *Trypeta* sp. which needs to be confirmed; apparently not related to any species discussed in the present paper and the tephritid host is suspect.

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CONTENTS

Features:

Research Reports:

Academy Affairs:

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Science and Society[1]

Russell W. Peterson

Director, Office of Technology Assessment, U. S. Congress, Washington, D. C. 20510

"Mankind," T. S. Eliot once remarked, "cannot bear very much reality." I imagine most Americans must feel they've had about as much reality as they can handle over the last 10 to 15 years.

For a time, in the mid-60's, it seemed as if there was almost nothing we didn't have the know-how and the wherewithall to do. We had, we believed, nearly succeeded in perfecting a perpetual growth machine—an economy whose enormous productive power we had, at long last, learned how to manage and manipulate. The learned and the popular journals alike were busily sketching glowing scenarios for the soaring 70's and dazzling visions of what life would be like in the year 2000.

We have since suffered through a series of seismic shocks that seems to have left us unsteady and unsure. In the wake of the Vietnam War, of the environmental, the energy and the economic crises—which I believe are simply different aspects of the same crisis—we seem no longer certain of where we are and where we're going.

I think, in fact, that we have reached a watershed in American society, that we are now in a period of transition toward a future that, in ways we only dimly understand, must be built on far different assumptions than those that have sustained us for more than two centuries.

I believe also that, despite the pain and the anguish we are going through, this transition period offers us enormous opportunities—if we have the courage to take advantage of them—for turning our tremendous scientific and technological resources toward the creation of a genuinely strong and stable society whose distinguishing characteristic is the high quality of life it offers to all its citizens.

The progress and prosperity we have achieved in this country, and the great technological advances we have made, have all been based on the assumption that, in this vast and richest of lands, we would never run out of room or of resources and that we could, therefore, be free and easy with both. And if, for a time, we ran into some obstacle or another, we could either move on or, if things really got bad and there was no way out, we could count on technology—like the seventh cavalry—to come to the rescue.

Throughout most of our history, we have, so to speak, lived off the fat of the land. There is no longer that much fat left. For, while we have plenty of resources left, they are becoming in-

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[1] Address presented to the Academy at its meeting on January 30, 1979.

creasingly expensive—especially that vital resource, energy.

Our entire economy, and the vast technological structure that helps sustain it, were built on the assumption that cheap energy was going to be abundantly available.

We are lately learning that there is, in fact, no such thing as a free lunch, even in a country as lavishly endowed as we are, and that the days of cheap energy are over.

As a result, a good deal of modern technology—designed, as it is, to make lavish use of energy and other resources—is no longer modern, or is becoming increasingly less so. We can no longer seek to secure real economic growth on the assumption that waste makes wealth, for it is the waste of increasingly expensive energy and other resources that lies at the root of much of our economic difficulties.

The task before us, then, is to act now, while we have the time.

Nor can we continue to act on the basis of old habits and approaches. For as our energy and other crises are demonstrating, we cannot act simply on the basis of narrow and near-term concerns. The really serious concerns before us are not the immediate and isolated ones, but the interrelated and long-term ones. The long-term has, in fact, become the short-term. The world of the year 2000 is already well "within the pipeline"—we are shaping it by what we do and fail to do today.

It is true that we have been able to muddle through in most cases, but this is a luxury which we are no longer able to afford. The pace of technical developments, the fact that we are approaching real limits of both our natural resources and the capacity of our environment to absorb the abuse we are inflicting on it, and the staggering scale and power of the technologies we are now able to master, have forced us out of an age of innocence in resolving technical problems. Our planning simply must mature if we are to survive.

One can suppose that the government would be able to take a longer view on the issues, but inertia and lack of imagination in government can be part of the problem. It has been said that there is only one thing more certain than change, and that is resistance to change. We are being carried into the future by the momentum of the status quo.

Take this example. Our inability to deal adequately with energy problems results in part from the assumption on the part of both the Federal government and major electric utilities that the solution to the problem will be more of the enormous centralized generating facilities which are providing an increasing share of our electric power. Once this assumption was made, it was largely self perpetuating. The enormous Federal investments in developing, commercializing, fueling, insuring, protecting and providing waste disposal for nuclear facilities have greatly accelerated the development of this technology with respect to possible competitors. The clear and continuing Federal commitment to the development of new centralized facilities has given the centralized technologies prestige which discouraged private investment in alternatives. The subsidies for this approach have had the effect of creating a large constituency of scientists, engineers, and investors which has developed its own political momentum. Federal bureaucracies have mushroomed with an institutional interest in proving the wisdom of decisions they have made. Moreover, the size and complexity of new centralized plants mean that investors must be convinced to commit over a billion dollars to facilities which may not begin providing useful power for over a decade. These investors must somehow be assured that energy growth rates and consumption patterns will be maintained at predictable levels during the expected life of the plant. The need to protect these investments by assuring this demand could severely constrain our ability to make energy policy in the future.

One of the casualties of the assumption that energy will always be best provided by centralized facilities is an inability to think clearly about the advantages of solar energy and energy conservation technologies. Both of these technologies work best when an attempt is made to match the energy resources to the immediate requirements of the buildings or industrial facilities served; they can be built quickly, usually as a part of the building served, and can be changed quickly to meet new energy needs. The implementation of these technologies will not require any profound reshaping of industrial, financial, or governmental institutions since they can be built, financed, insured, and maintained by the kinds of organizations now providing similar services for heating and air conditioning equipment, for example. The technology is of a scale that permits concepts to be developed and brought to the market by many different kinds of organizations. Competition in these technologies is feverish and probably always will be. Since the small technologies do not fit neatly into the competition for new centralized generating facilities, we have never developed a coherent plan for promoting them and have never funded them as serious long-term solutions to the energy problem. Supporting the decentralized technologies will not be easy and will require an unprecedented amount of imagination, flexibility, and restraint on the part of policy makers. But what would happen if the Federal government made a commitment to the development of small, renewable energy sources equivalent to the commitment we made to develop fission reactors two decades ago?

The advantages of the enormous energy resource which these solar and conservation technologies represent can only be properly understood if social and environmental issues are considered along with the technical ones. It will, however, probably be easier to resolve the technical questions associated with the development of new energy technologies than it will be to understand the ways in which they can be integrated into a society we would like to perpetuate. This difficulty must not deter us, since, unless we are careful, we may find ourselves in a position where we must adjust our society and institutions to fit the technologies which we develop instead of the other way around.

As this discussion has suggested, the task for science and technology is far different, but surely no less challenging, than it was in days when energy and other resources were plentiful and cheap. We must increasingly design, develop, and deploy a finer-tuned technology that—unlike much of the so-called advanced technology we have in place—makes the most, and wastes least, of our exhaustible and increasingly expensive resources and makes possible our growing reliance on renewable resources.

The task for all of us is to create the kind of climate in which that kind of scientific effort and technological development can flourish.

This is far from a simple task, because old habits die exceedingly hard.

Scientists, engineers, innovators face a special challenge in trying to create this new kind of climate. For while they have much to contribute, they often find it hard to get the attention of the top decision-makers. Nearly all decision-makers are oriented toward the near term. They are besieged by a multitude of urgent problems. Tomorrow's problems can wait. But the scientists' business is with tomorrow. And it's increasingly urgent that they get to see the boss today. With today's trends in the world leading to catastrophe, the decision-makers better get close to the practitioners of change.

At the same time it would do well for scientists to establish the habit of stepping back occasionally from the immediate task to reflect on what kind of a world he or she wants for his or her children or grandchildren and consider whether the work he or she is doing is leading in the right direction. If not, the scientist should have the courage to alter his course, even if it means some near-term personal sacrifice. It requires courage to speak and act effectively against the status quo. But educators and scientists can bring about the essential changes. We should pursue responsible, professional goals, but at the same time we need to work toward worldwide goals. We need to become generalists. Traditionally, scientists have broken their endeavors down into specific disciplines for their own convenience, and hence have perceived reality from many different perspectives. Such specialization has been necessary for scientific and technological advance; and we have learned much and learned it quickly by breaking phenomena down into various compartments and studying them from the standpoints of biology, physics, chemistry, and so forth. But we must remember that our world does not exist in compartments; it comes in single interrelated communities, each part of which affects other parts.

The distinguished scientist, Lewis Thomas, has observed that: "The men who run the affairs of nations today are, by and large, our practical men. They have been taught that the world is an arrangement of adversary systems, that force is what counts, aggression is what drives us at the core, only the fittest survive, and only might can make more might." In fact, however, we are, so far as we know, the only species on this Earth that believes or behaves this way. Instead, Thomas says, "Most of the associations between the living things we know about are essentially cooperative ones. . . When they have the look of adversaries, it is usually a standoff relation, with one party issuing signals, warnings, flagging the other off. "We do not," he concludes, "have solitary beings. Every creature is, in some sense, connected to and dependent on the rest."

We cannot afford the same old atomistic, accidental approach that is, in my judgment, responsible for many of the problems we face today. Nor can we let ourselves be drawn into that increasingly centralized approach that some advocate and many fear we are inevitably heading for.

What we need, I believe, is an approach which fully recognizes and reflects the fundamental interdependence of individuals, institutions, nations at the same time that it nurtures and draws on the rich diversity of outlook and activity that characterizes not only our society, but all life. We need, especially among the leaders in every field of human endeavor, an approach I call "holistic pluralism"—an approach in which each individual, institution, nation takes the larger, longer view into account as each pursues its own particular interests and goals. It is, in my view, only through such an approach that, in such an incredibly and increasingly interdependent world, we can realistically expect to serve our own self-interests.

We have, I think, reached that point in human history where, for our own survival, let alone for our continued success, we can no longer ignore, as we all too often have during our relatively brief duration here on Earth, the essential community of interest among humans everywhere and between humans and the Earth they inhabit.

We have, I earnestly hope, come increasingly to understand and to appreciate the simple and surpassing idea that T. S. Eliot once expressed in these lines:

We shall not cease from exploration;
And the end of our exploring
Will be to arrive where we started
And know the place for the first time.

How to Balance Chemical Equations

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ABSTRACT

It is shown that an algebraic method may always be used to balance chemical equations. The method is equally applicable to REDOX reactions, complex organic reactions, ionic reactions, etc. It is not necessary to determine the oxidation numbers of the elements which comprise the various molecules, nor is there any advantage to be gained by doing so. In rare instances more than one "correct" solution can be found for the balanced equation. When this occurs, the method reveals the fact that it is the result of independent chemical processes taking place simultaneously.

The balancing of chemical equations is a task usually confronted for the first time by students in high school or by freshmen in college. They start with the simplest of equations and are taught to balance by "inspection." As they appear to gain confidence, the equations grow in complexity until it becomes obvious that something more dependable than a method of inspection is required to complete the process. Before his initial enthusiasm gives way to total frustration, the student is introduced to REDOX equations, oxidation numbers, valences, electron transfer, etc., along with that method of equation balancing suggested by R. J. Carney in 1928.[1] This is explained in different ways depending upon the textbook used, but essentially it boils down to the fact that the total increase in oxidation number (loss of electrons) must exactly balance the total decrease in oxidation number (gain of electrons). Many of the student's problems are solved, but not all. He has difficulty with valences in such substances as tetrathionates, peroxides, etc., while the method is entirely inapplicable in many organic reactions.

I have used a method for balancing chemical equations successfully for more than 40 years. Although I am not aware of it having been published previously, the concept is so simple that it is difficult to believe that it wasn't discovered independently many times before. I shall refer to it simply as the algebraic method and show by several examples how it may be applied successfully in balancing *any* chemical equation, without exception.

The method requires no prior knowledge of valence or oxidation state. An algebraic symbol, say, x, is arbitrarily assigned as the coefficient of the most complicated compound on either side of the equation (i.e., the compound with the greatest number of different atoms). The equation is then balanced in terms of x as far as one can proceed. In some instances the entire equation can be balanced in this manner and it only remains to assign a small integer for the value of x in order to complete the problem. This can be illustrated by the REDOX equation involving an iodide and an iodate:

$$KIO_3 + KI + HCl = KCl + H_2O + I_2$$

The coefficient x is assigned to KIO_3. Since all of the oxygen on the left side of the equation appears in the KIO_3, there are $3x$ atoms total. These are found only in the H_2O on the right hand side so $3x$ becomes the coefficient of this molecule. The partially balanced equation now may be written:

$$\overset{x}{KIO_3} + KI + HCl = KCl + \overset{3x}{H_2O} + I_2$$

This now determines the coefficient of

the HCl because hydrogen is found nowhere else on the left hand side and also appears only combined in the H_2O on the right side. There are $6x$ atoms of hydrogen altogether (two for each molecule of H_2O). Therefore $6x$ becomes the coefficient of HCl. By the same reasoning applied to the Cl atoms, $6x$ becomes the coefficient of KCl. At this point the equation becomes:

$$\overset{x}{KIO_3} + KI + \overset{6x}{HCl} = \overset{6x}{KCl} + \overset{3x}{H_2O} + I_2$$

In order to obtain a balance for the K atoms, it is necessary to affix $5x$ as the coefficient of the KI because $1x$ K atoms already appear in the KIO_3. The iodine balance is all that remains. There are $6x$ atoms on the left hand side $(x + 5x)$ and since it all appears with 2 atoms to the molecule in the I_2, the coefficient of that molecule would have to be $3x$. Now the smallest value of x to give integer values to each of the coefficients would be $x = 1$ and the balanced equation becomes:

$$KIO_3 + 5KI + 6HCl = 6KCl + 3H_2O + 3I_2$$

A second example of this first type is found in the equation:

$$K_2Cr_2O_7 + KI + H_2SO_4 = K_2SO_4 + Cr_2(SO_4)_3 + H_2O + I_2$$

Let x be the coefficient of the $K_2Cr_2O_7$. Then, by virtue of the Cr atom, there will also be x molecules of $Cr_2(SO_4)_3$. Now since the oxygen which is combined with the S in the SO_4^{-2} remains intact, the only other oxygen appears in the $K_2Cr_2O_7$ on the left hand side of the equation and in the H_2O molecule on the right. There are, consequently, $7x$ molecules of H_2O. The other coefficients are found as follows:

$H \rightarrow H_2SO_4{:}(7x)$

$S \rightarrow K_2SO_4{:}(7x - 3x = 4x)$

$K \rightarrow KI{:}(8x - 2x = 6x)$

$I \rightarrow I_2{:}(6x \div 2 = 3x)$

Now all of the coefficients are accounted for and again the simplest solution results by letting $x = 1$. The balanced equation becomes:

$$K_2Cr_2O_7 + 6KI + 7H_2SO_4 = 4K_2SO_4 + Cr_2(SO_4)_3 + 7H_2O + 3I_2$$

As a final illustration of this first type, consider the reaction between lead chromate and potassium iodide:

$$PbCrO_4 + KI + HCl = PbCl_2 + KCl + CrCl_3 + H_2O + I_2$$

Let x be the coefficient of $PbCrO_4$. The following sequence shows the order in which each succeeding coefficient may be found along with its value (in terms of x):

$Pb \rightarrow PbCl_2{:}(x)$

$Cr \rightarrow CrCl_3{:}(x)$

$O \rightarrow H_2O{:}(4x)$

$H \rightarrow HCl{:}(8x)$

$Cl \rightarrow KCl{:}(8x - 2x - 3x = 3x)$

$K \rightarrow KI{:}(3x)$

$I \rightarrow I_2{:}(3x \div 2 = (3/2)x)$

It can be seen that the smallest integer values for all of the coefficients are obtained by letting $x = 2$. The balanced equation, therefore, is

$$2PbCrO_4 + 6KI + 16HCl = 2PbCl_2 + 6KCl + 2CrCl_3 + 8H_2O + 3I_2$$

The examples illustrated so far represent a minority group where one unknown, x, was sufficient to balance the equation. In the great majority of cases, this cannot be done. For this second type, therefore, one proceeds as follows: Choose an unknown coefficient, x, as before and continue until all possibilities have been exhausted. Then choose a second coefficient, y, and continue until every other remaining molecule has its coefficient determined in terms of x and/or y. Next, determine the ratio of x to y. The simplest integer values of x and y which satisfy that ratio and result in integer values for the coefficients will give the correct solution. As a first illustration of this type, consider the (unbalanced) equation:

$$V_2O_2 + KMnO_4 + H_2SO_4 = V_2O_5 + K_2SO_4 + MnSO_4 + H_2O$$

Let x be the coefficient of K_2SO_4 then proceed as usual:

$$K \rightarrow KMnO_4{:}(2x)$$

$$Mn \rightarrow MnSO_4{:}(2x)$$

$$S \rightarrow H_2SO_4{:}(2x + x = 3x)$$

$$H \rightarrow H_2O{:}(3x)$$

This is as far as one can go using x, alone, and the equation has coefficients for every molecule except V_2O_2 on the left and V_2O_5 on the right. Let V_2O_5 be given the coefficient y, then:

$$V \rightarrow V_2O_2{:}(y)$$

completes the coefficients, symbolically. The result is:

$$\overset{y}{V_2O_2} + \overset{2x}{KMnO_4} + \overset{3x}{H_2SO_4} = \overset{y}{V_2O_5} + \overset{x}{K_2SO_4} + \overset{2x}{MnSO_4} + \overset{3x}{H_2O}$$

It can be verified that all atoms have been used with the exception of the oxygen. The oxygen balance is given by:

$$2y + 8x + 12x = 5y + 4x + 8x + 3x$$

$$5x = 3y$$

$$\frac{x}{y} = \frac{3}{5}$$

Therefore, $x = 3$ and $y = 5$ may be substituted back to satisfy the coefficients of the balanced equation:

$$5V_2O_2 + 6KMnO_4 + 9H_2SO_4 = 5V_2O_5 + 3K_2SO_4 + 6MnSO_4 + 9H_2O$$

A second example of this type is illustrated by the potassium dichromate oxidation of ferrous chloride:

$$K_2Cr_2O_7 + FeCl_2 + HCl = FeCl_3 + KCl + CrCl_3 + H_2O$$

Let x equal the coefficient of $K_2Cr_2O_7$. Then, continuing,

$$K \rightarrow KCl{:}(2x)$$

$$Cr \rightarrow CrCl_3{:}(2x)$$

$$O \rightarrow H_2O{:}(7x)$$

$$H \rightarrow HCl{:}(14x)$$

Next, let y = coefficient of the $FeCl_3$, then:

$$Fe \rightarrow FeCl_2{:}(y)$$

The only element that has not been used yet in this example is the chlorine. Therefore, it is called upon to furnish the x/y relationship. The Cl balance is:

$$2y + 14x = 3y + 2x + 6x$$

$$6x = y$$

$$\frac{x}{y} = \frac{1}{6}$$

Thus, $x = 1$ and $y = 6$ leads to:

$$K_2Cr_2O_7 + 6FeCl_2 + 14HCl = 6FeCl_3 + 2KCl + 2CrCl_3 + 7H_2O$$

In some cases it may be found necessary to introduce the second variable so early that some of the coefficients become sums or differences involving both variables. An illustration of this is given next:

$$Mn(NO_3)_2 + NaBiO_3 + HNO_3 = NaNO_3 + Bi(NO_3)_3 + H_2O + HMnO_4$$

Let x = coefficient of $Mn(NO_3)_2$. Then

$$Mn \rightarrow HMnO_4{:}(x)$$

Since no other coefficient can be determined in terms of x alone, the second variable must be assigned at this time. Let y = coefficient of $Bi(NO_3)_3$.

$$Bi \rightarrow NaBiO_3{:}(y)$$

$$Na \rightarrow NaNO_3{:}(y)$$

$$N \rightarrow HNO_3{:}(y + 3y - 2x = 4y - 2x)$$

$$O \rightarrow H_2O{:}(6x + 3y + 12y - 6x - 3y - 9y - 4x = 3y - 4x)$$

The equation with symbolic coefficients

is therefore given by:

$$\overset{x}{Mn(NO_3)_2} + \overset{y}{NaBiO_3} + \overset{(4y - 2x)}{HNO_3}$$
$$= \overset{y}{NaNO_3} + \overset{y}{Bi(NO_3)_3}$$
$$+ \overset{(3y - 4x)}{H_2O} + \overset{x}{HMnO_4}$$

The hydrogen balance supplies the relationship between x and y:

$$4y - 2x = 6y - 8x + x$$
$$5x = 2y$$
$$\frac{x}{y} = \frac{2}{5}$$

It follows that the simplest sequence of integer numerical coefficients is:

2, 5, 16, 5, 5, 7, and 2, respectively.

Ionic equations are accommodated with equal facility as illustrated by the next example:

$$H_2O + As_2S_3 + NO_3^{-1}$$
$$= AsO_4^{-3} + SO_4^{-2} + NO + H^{+1}$$

Let x = coefficient of As_2S_3.

$$As \rightarrow AsO_4^{-3}:(2x)$$
$$S \rightarrow SO_4^{-2}:(3x)$$

Let y = coefficient of H_2O.

$$H \rightarrow H^{+1}:(2y)$$

Now the partially balanced equation looks like this:

$$\overset{y}{H_2O} + \overset{x}{As_2S_3} + NO_3^{-1}$$
$$= \overset{2x}{AsO_4^{-3}} + \overset{3x}{SO_4^{-2}} + NO + \overset{2y}{H^{+1}}$$

The coefficient of the NO_3^{-1} can now be obtained from the charge balance:

$$3(2x) + 2(3x) - 1(2y) = 2(6x - y)$$

which also becomes the coefficient of the NO by virtue of the nitrogen content. It may be verified from the oxygen balance that $x = 3$ and $y = 4$. Consequently, the sequence of coefficients that comprise the balanced equation is:

4, 3, 28, 6, 9, 28, and 8, respectively.

For the final example in this category an organic reaction will be used which does not adapt itself readily to the oxidation number (or valence change) method currently taught in secondary schools. This reaction involves the preparation of azoxybenzene from nitrobenzene:

$$C_6H_5NO_2 + CH_3ONa$$
$$= C_{12}H_{10}N_2O + HCOONa + H_2O$$

Let x = coefficient of $C_{12}H_{10}N_2O$.

$$N \rightarrow C_6H_5NO_2:(2x)$$

Let y = coefficient of CH_3ONa.

$$Na \rightarrow HCOONa:(y)$$
$$O \rightarrow H_2O:(4x + y - x - 2y = 3x - y)$$

Finally, the hydrogen balance yields:

$$10x + 3y = 10x + y + 6x - 2y$$
$$\frac{x}{y} = \frac{2}{3}$$

and the balanced equation may be written by substitution:

$$4C_6H_5NO_2 + 3CH_3ONa$$
$$= 2C_{12}H_{10}N_2O + 3HCOONa + 3H_2O$$

A third classification of equations is that for which an infinite number of "correct" solutions exists. Typical of this group are certain reactions involving hydrogen peroxide as one of the reactants. The first illustration is the following reaction involving auric chloride:

$$AuCl_3 + H_2O_2 + NaOH$$
$$= NaCl + H_2O + O_2 + Au$$

One may proceed as usual by letting x = coefficient of $AuCl_3$, then:

$$Au \rightarrow Au:(x)$$
$$Cl \rightarrow NaCl:(3x)$$
$$Na \rightarrow NaOH:(3x)$$

Now assign y = coefficient of H_2O_2.

$$H \rightarrow H_2O: (2y + 3x)/2$$

$$O \rightarrow O_2: [(2y + 3x) - (2y + 3x)/2] \div 2 = (2y + 3x)/4$$

While this appears to be straightforward, careful examination will disclose that all of the atoms have been used to obtain the coefficients, leaving none for determining a unique ratio of x to y. Therefore, no such relationship exists! Consequently, any combination which gives non-reducible integer values for the coefficients while satisfying the functional requirements must be as acceptable as any other:

$$\overset{x}{AuCl_3} + \overset{y}{H_2O_2} + \overset{3x}{NaOH} = \overset{3x}{NaCl} + \overset{(2y+3x)/2}{H_2O} + \overset{(2y+3x)/4}{O_2} + \overset{x}{Au}$$

It is interesting that in some of the older chemical handbooks[2] the above reaction is given corresponding to $x = 2$, $y = 3$ while a simpler solution would be satisfied by $x = 2, y = 1$. The chemical reason why these different combinations (as well as many others) are all consistent is that independent processes with one or more molecules common to each process can take place simultaneously. In the present example, part of the H_2O_2 is used to reduce the auric chloride to metallic gold as shown here:

$$2AuCl_3 + H_2O_2 + 6NaOH = 6NaCl + 4H_2O + 2O_2 + 2Au$$

while, at the same time and quite independently, any number of molecules may undergo spontaneous decomposition according to:

$$2H_2O_2 = 2H_2O + O_2$$

When these two reactions are added together, the result corresponds to $x = 2$, $y = 3$. It may come somewhat as a shock, however, that the same equation whose sequence of coefficients is:

6, 17, 18, 18, 26, 13, 6

corresponding to $x = 6$, $y = 17$ is also equally valid!

As a second example of this type, I submit the well known reaction of potassium permanganate with hydrogen peroxide in the presence of sulfuric acid:

$$\overset{x}{H_2O_2} + \overset{y}{KMnO_4} + \overset{2y}{H_2SO_4} = \overset{y}{KHSO_4} + \overset{y}{MnSO_4} + \overset{(2x+3y)/2}{H_2O} + \overset{(2x+5y)/4}{O_2}$$

The symbolic coefficients appearing above the corresponding molecules can easily be verified by means of the method described. The sequence of coefficients:

1, 2, 4, 2, 2, 4, 3

while simpler, is no more "correct" than, say, the sequence:

8, 12, 24, 12, 12, 26, 19

or even the sequence:

12, 20, 40, 20, 20, 42, 31.

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(1) Carney, R. J.: *Outline of the Methods of Qualitative Analysis*, 13th Ed. Copyright by George Wahr, Publisher, Ann Arbor, Mich. (1928).

(2) See, for example, *Handbook of Chemistry and Physics*, 17th Ed., Chemical Rubber Co., Cleveland, Ohio (1932), p. 1421.

RESEARCH REPORTS

Descriptions of New Braconidae (Hymenoptera) Parasitic on the Potato Tuberworm and on Related Lepidoptera from Central and South America

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ABSTRACT

Six new species of braconids are described: *Orgilus jennieae* and *Chelonus kellieae* from Costa Rica which are being reared in California for possible release against the potato tuberworm; *Chelonus johni*, *Apanteles oatmani*, *Bracon lucileae*, and *Mirax malcolmi* from Colombia, parasites of *Scrobipalpula* sp. *Orgulis parcus* Turner, previously released into California, is diagnosed and compared to *O. jennieae*.

Descriptions of the following new species of Braconidae are being provided at the request of E. R. Oatman, University of California, Riverside. Two of these species, *Orgilus jennieae* n. sp. and *Chelonus kellieae* n. sp. from Costa Rica, are being studied and reared for release against the potato tuberworm, *Phthorimaea operculella* (Zeller), in Southern California. The other 4 species were collected by Dr. Oatman and colleagues during searches in Colombia for parasites of the potato tuberworm and the tomato pinworm, *Keiferia lycopersicella* (Walshingham). Colonies were not obtained for any of these 4 parasites, but they are described at this time in the event they are collected again for future study.

Orgilus jennieae Marsh, new species

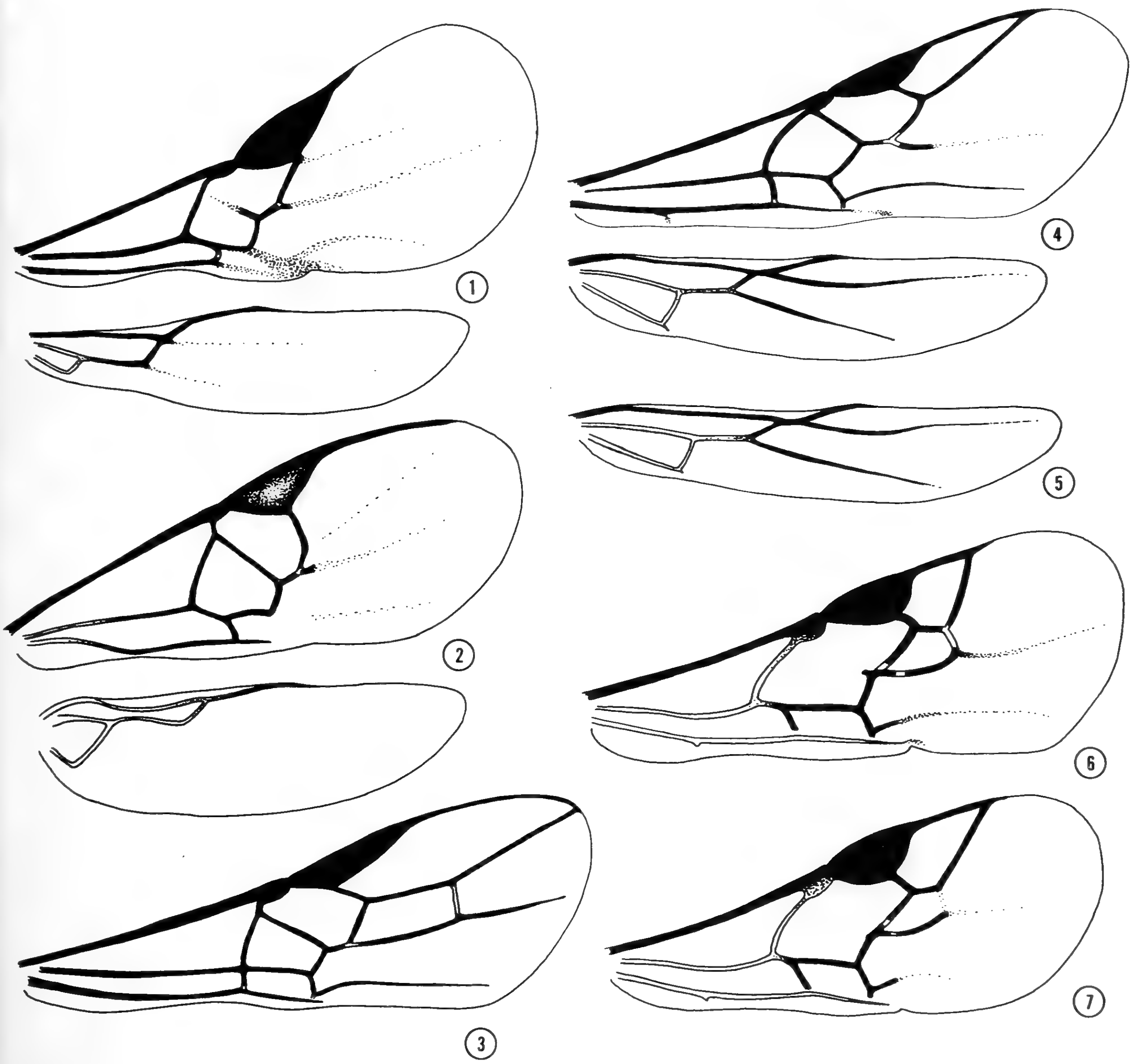
Female. Length of body, 3.5–4.0 mm; ovipositor, 2.5–3.0 mm. Color: head including antennae, thorax and abdomen black; fore and middle legs with coxa light brown, first trochanter black, second trochanter light brown, femur light brown, black dorsally, tibia light brown but sometimes black on apical ⅓, tarsus black; hind leg with coxa black basally and light brown apically, first trochanter black, second trochanter brown, femur brown ventrally, black dorsally and laterally, tibia brown on basal ⅔, black on apical ⅓, tarsus black; tegula and wing base black, wing uniformily lightly infumated. Head: in dorsal view 1.5 times broader than long, face about 1.25 times as broad as eye height, clypeus strongly convex; frons smooth and polished except for hair pits; ocellocular distance about twice diameter of lateral ocellus; antenna 29 segmented, segments in apical ¼ about as long as broad. Thorax: mesonotal lobes smooth and polished except for numerous hair pits, notauli deep and strongly crenulate, scutellar disc smooth and shining, prescutellar furrow deep and with numerous low carinae; propleuron strongly rugose, granular along dorsal edge; mesopleuron smooth and polished, hairless above sternaulus, sternaulus arched and strongly crenulate; propodeum rugose, longitudinal carinae at posterior margin strong, spiracles set into shallow circular impression, sides of propodeum rugose ventrally, granular dorsally. Abdomen: first tergite about 1.5 times longer than apical width, rugulopunctate, smooth at extreme base, basal longitudinal keels well developed; second tergite about 1.3 times as long as broad at base, finely granular medially, smooth and polished along apical and lateral edges; second suture fine but distinct; remainder of terga smooth and polished; ovipositor about as long as abdomen plus ½ thorax. Wings (fig. 4): radial cell along wing margin as long as stigma; second segment of radius at a slight angle with intercubitus; stub of third segment of cubitus slightly longer than second segment; nervulus nearly interstitial with basal vein, only slightly postfurcal; hind wing 4.5 times as long as greatest width; second segment of mediella slightly longer than nervellus. Legs: hind coxa granular, rugulose dorsally at base; hind femur 4 times as long as wide; inner spur of hind tibia more than ½ as long as basitarsus; tarsal claws simple.

Male. Essentially as in female; apical antennal segments longer than broad.

Holotype.—Female, Cartago, Costa Rica, Central America, IV-24-73, E. R. Oatman collector, ex. *Phthorimaea operculella* on potato. Deposited in the U. S. National Museum (USNM).

Paratypes.—18 ♀♀, 20 ♂♂, same data as holotype; 4 ♀♀, 4 ♂♂, Cartago, Costa Rica, IV-25-73, E. R. Oatman, ex. Gelechiid on potato; 3 ♀♀, 3 ♂♂, Cartago, Costa Rica, IV-19-73, coll. Oatman, ex potato tuberworm. Deposited in USNM and the University of California, Riverside (UCR).

This species is similar to the Nearctic *Orgilus ferus* Muesebeck but differs by the legs being brown or black, the



Figs. 1–7. Wing venation: 1, *Mirax malcolmi*, n. sp.; 2, *Apanteles oatmani*, n. sp.; 3, *Bracon lucileae*, n. sp.; 4, *Orgilus jennieae*, n. sp.; 5, *O. parcus* Turner; 6, *Chelonus* (*Microchelonus*) *kellieae*, n. sp.; 7, *C.* (*M.*) *johni*, n. sp.

antennae black, and the radius being angled with the intercubitus. The legs of *ferus* are testaceus and the radius is on a straight line with the intercubitus. This species is named for my wife, Jennie Suderman Marsh.

Orgilus parcus Turner

Orgilus parcus Turner, 1922. Ann. Mag. Nat. Hist. (Ser. 9) 10: 276.

Diagnosis.—Length of body, 3.5–4.0 mm; ovipositor, 2.5–3.5 mm. Color: head, thorax, and abdomen black, basal flagellomeres dark brown, apex of fore femur, fore tibia and tarsus brown, middle tibia and tarsus dark brown, wings uniformly lightly infumated. Face coarsely punctate and shining, temples and vertex smooth and shining, frons weakly rugose; mesonotum coarsely punctate and shining; abdominal terga one and two completely rugose, third tergite weakly rugose medially at base; ovipositor as long as abdomen plus ½ thorax; second segment of radius slightly angled with intercubitus, nervulus only slightly postfurcal, hind wing (fig. 5) about 6 times as long as wide.

Type locality.—Mossel Bay, Cape Province, South Africa.

This species is similar to the Nearctic *Orgilus arcticus* Muesebeck but is easily distinguished by the smooth and shining temples and vertex, and the wing venation, particularly the angle of the radius and intercubitus (they are on a straight line in *arcticus*) and the nervulus being postfurcal by about ⅓ its length. It is also similar to *O. jennieae* described above but differs in its black legs, narrower hind wing, and more strongly sculptured second abdominal tergite.

Orgilus parcus was introduced from South Africa and released in 1968 at Moreno Valley, Riverside County, California, against the potato tuberworm. It was colonized but apparently not established (E. R. Oatman, pres. comm.). Further surveys in this area for potato tuberworm parasites are being made and this species is included here in the event it does become established.

Chelonus (Microchelonus) kellieae Marsh, new species

Female. Length of body, 3.0 mm. Color: entire body black except for scape, pedicle, base of first flagellomere, apex of fore femur, fore tibia, fore basitarsus, base and apex of middle femur, middle tibia, middle basitarsus, base and apex of hind femur, and basal ⅔ of hind tibia which are honey yellow. Head: slightly wider than long; face granular and dull, clypeus weakly granular and shining, frons rugose, a definite carinate ridge between antennae extending half way down face, vertex rugulostriate, temples finely striate, malar space about equal to length of first flagellomere, antenna 16 segmented, short, not extending beyond propodeum, flagellomeres 12–15 as wide as long, level of lower eye margins slightly above dorsal margin of clypeus. Thorax: mesonotum rugose, somewhat areolate where notauli meet before prescutellar furrow, mesonotal lobes granular, mesopleuron rugose, areolate; propodeum rugose, caudal margin defined by transverse ridge, outer pair of projections large and distinct, inner pair weak. Abdomen: carapace rugose basally, rugulose apically, basal carinae short but distinct, apex of ventral opening reaching about to apex of carapace. Wings (fig. 6): stigma about as long as wide, radial cell along wing margin half as long as stigma, first and second segments of radius about equal in length.

Male. Essentially as in female; opening at apex of carapace (fig. 8) somewhat flattened heart-shaped, about 2.5 times wider than high, center tubercle with scattered short hair, carapace formed into a low rounded tubercle below this apical opening.

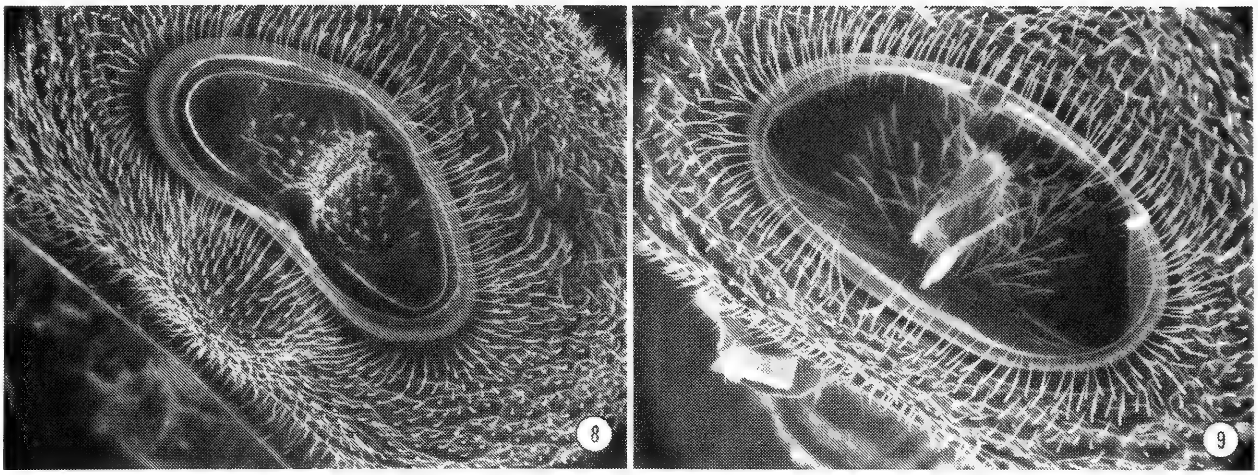
Holotype.—Female, Cartago, Costa Rica, April 1973, coll. E. R. Oatman. Deposited in USNM.

Paratypes.—17 ♀♀, 20 ♂♂, same data as holotype; 5 ♀♀, 8 ♂♂, Cartago, Costa Rica, 4-25-73, E. R. Oatman, ex Gelechiid on potato. Deposited in USNM and UCR.

This species is similar to the Nearctic *Chelonus* (*Microchelonus*) *cosmopteridis* McComb, both species having striate temples, but *kellieae* differs from *cosmopteridis* by having a shorter radial cell which is half as long as stigma, and shorter apical flagellomeres which are as wide as long. It does not appear to be similar to any of the described Neotropical species. This species is named for my daughter, Kellie Lyneé Marsh.

Chelonus (Microchelonus) johni Marsh, new species

Female. Length of body, 3 mm. Color: black except scape, apex of fore femur, fore tibia, fore



Figs. 8–9. Opening at apex of male carapace, *Chelonus* (*Microchelonus*) species: 8, *kellieae*, n. sp.; 9, *johni*, n. sp.

basitarsus, apex of middle femur, middle tibia, middle tarsus, basal ½ of hind tibia, and hind basitarsus which are honey yellow. Head: wider than long, entirely striate, clypeus granular and shining medially; malar space slightly longer than first flagellomere; antenna 16 segmented, short, not quite reaching base of propodeum, flagellomeres 10–15 as wide as long; level of lower eye margins slightly above dorsal margin of clypeus. Thorax: mesonotum rugose, strongly areolated where notauli meet, along notauli, and along median line of middle mesonotal lobe; mesopleuron strongly rugose and areolate; propodeum rugose, caudal margin defined by strong transverse ridge, both pair of projections strong. Abdomen: carapace strongly rugose and areolate, particularly at base, basal carinae strong and reaching to basal ¼ of carapace; apex of ventral opening reaching almost to apex of carapace. Wings (fig. 7): stigma twice as long as wide; radial cell along wing margin ¾ as long as stigma; first and second segments of radius about equal in length.

Male. Essentially as in female; opening at apex of carapace (fig. 9) evenly oval, about 1.5 times wider than high, inner tubercle with scattered long hair.

Holotype.—Female, Palmira, Colombia, So. America, 5-8-73, coll. E. R. Oatman, gelechiid on *Solanum* sp. Deposited in USNM.

Paratypes.—4 ♀♀, 5 ♂♂, same data as holotype; 1 ♀, 1 ♂, Palmira, Colombia, 9-15-75, A. Saldarriaga, ex. *Scrobipalpula* sp. on *Solanum saponaceum*. Deposited in USNM and UCR.

This species is similar to *Chelonus* (*Microchelonus*) *kellieae* but is distinguished by the longer radial cell which is ¾ as long as stigma, and the stronger sculpturing on the mesonotum and head. It is named for my father-in-law, Mr. John H. Suderman.

Apanteles oatmani Marsh, new species

Female. Length of body, 2.5 mm; ovipositor, 1 mm. Color: black except palpi, apical ⅔ of fore femur, fore tibia, fore tarsus, apex of middle femur, middle tibia, middle tarsus, hind trochanter 2, and basal ½ of hind tibia which are honey yellow; stigma brown and margined on all sides by darker brown. Head: distinctly punctate, densely covered with short white hair; malar space shorter than clypeus; face only slightly narrower at clypeus than at antennae, at its narrowest part equal to eye height; antenna about equal to body length. Thorax: mesonotum distinctly punctate, punctures dense along course of notauli and somewhat rugose posteriorly, densely covered with short white hair; disc of scutellum flat, shining, slightly punctate, polished area on lateral face of scutellum semicircular; propodeum rugose, central areola strongly margined by carinae, occasionally open at base, costulae absent; meso- and metapleuron smooth and shining. Wings (fig. 2): stigma broad, about 2.5 times as long as broad; metacarpus longer than stigma; radius longer and slightly narrower than intercubitus; nervellus of hind wing slightly curved toward wing base, vanal lobe straight or slightly convex and without fringe of hair. Legs: inner spur of hind tibia considerably longer than outer and as long as ½ hind basitarsus. Abdomen: first tergite slightly longer than apical width, sides parallel or very slightly bulging medially, base and apex of equal width, strongly rugose, occasionally a slight median depression indicated at apex; second tergite extremely short, about 5.5–6.0 times as wide as long, rugose, suture between second and third terga strongly crenulate; hypopygium acute and extending beyond apex of abdomen; ovipositor about as long as hind tibia, slightly evenly curved downward.

Male. Essentially as in female except antenna longer and legs darker.

Holotype.—Female. Palmira, Colombia, Sept. 15, 1975, A. Saldarriaga V., ex. *Scrobipalpula* sp. on *Solanum saponaceum*. Deposited in USNM.

Paratypes.—7 ♀♀, 4 ♂♂, same data as holotype. Deposited in USNM and UCR.

This species is distinguished by its very short second abdominal tergite which is about 6 times as wide as long. It appears to be similar to the Neotropical *Apanteles bruchi* Blanchard but differs by the black tegula and rugose second abdominal tergite. This species is named for Earl R. Oatman.

Bracon lucileae Marsh, new species

Female. Length of body, 2.0–3.0 mm; ovipositor, 0.50–1.25 mm. Color: entirely honey yellow except antenna, ocellar triangle, and ovipositor sheaths which are black, and apical segments of fore and middle tarsi, apex of hind tibia, and entire hind tarsus which are brown; wings lightly infuscated on basal half, veins brown, stigma light brown, transparent and edged with dark brown. Head: entirely smooth and polished; eyes large and bulging well beyond temples which are strongly receding; malar space about ½ eye height and with a distinct smooth groove extending from base of eye to base of mandible; transverse diameter of circular mouth opening nearly as long as distance from opening to eye; antenna 26–29 segmented. Thorax: smooth and polished; notauli weakly indicated at least anteriorly and thickly hairy; sternaulus absent; propodeum without any indication of median carina, with a smooth oblique groove under each spiracle. Abdomen: entirely smooth and polished; first tergite about 1.25 times longer than apical width, central and oblique furrows smooth; suture between second and third terga smooth and slightly arched medially; ovipositor about ½ as long as abdomen. Wings (fig. 3): second segment of radius nearly 3 times as long as first. Legs: tarsal claws with large basal tooth.

Male. Essentially as in female; length of body, 1.5–2.5 mm; antenna 25–30 segmented; apical abdominal segments sometimes marked with black.

Holotype.—Female. Palmira, Colombia, Sept. 15, 1975, A. Saldarriaga V. collector, ex. *Scrobipalpula* sp. on *Solanum saponaceum*. Deposited in USNM.

Paratypes.—6 ♀♀, 4 ♂♂, same data as holotype. Deposited in USNM and UCR.

This species is similar to the Nearctic *Bracon psilicorsi* Viereck but is distinguished by its entirely yellow body, lack of oblique furrows on second abdominal tergite, and strongly receding temples. It is also similar to *B. vulpinus* Szépligeti from Brazil but differs by the entirely smooth second abdominal tergite. This species is named for my mother, Lucile Garges Marsh.

Mirax malcolmi Marsh, new species

Female. Length of body, 2.0–2.5 mm; ovipositor, 0.5 mm. Color: face and temples honey yellow, vertex brown, occiput black, antenna black, palpi whitish, thorax black, abdomen black beyond second segment, median plate of first tergite honey yellow, median plate of second tergite brown, lateral parts of second tergite black, membranous areas of first and second tergites whitish-yellow, ovipositor sheaths black; wings lightly infumated, stigma black, tegula and wing base honey yellow; legs yellow, apical tarsal segments brown. Head: face lightly punctate, vertex and temples more strongly punctate; vertex with a weak polished groove extending from median ocellus to occiput; frons with a slight raised ridge extending between antennae a short distance down face; temples about as wide as eyes and not receding behind eyes, bulging slightly; antenna 14 segmented, first and second flagellomeres about equal in length. Thorax: mesonotum and scutellum mostly smooth with only scattered punctures; notauli deeply impressed anteriorly, absent posteriorly; mesopleuron smooth and polished, sternaulus represented by a wide, shallow, rugulose impression; propodeum coarsely rugose with strong median carina; metapleuron and sides of propodeum smooth. Abdomen: plate of first tergite smooth, very narrow on basal ½, suddenly widening near apex and then narrowing at apex (i.e., somewhat spoon-shaped); second tergite mostly membranous, median plate smooth, narrow at base, gradually widening to apex and then extending across entire apex of tergite; remainder of tergites smooth; ovipositor about as long as hind basitarsus. Wings (fig. 1): cubitus weak or absent at base so first cubital and first discoidal cells are not completely separated; radius almost completely absent.

Male. Essentially as in female.

Holotype.—Female, Palmira, Colombia, Sept. 15, 1975, A. Saldarriaga V. collector, ex. *Scrobipalpula* sp. on

Solanum saponaceum. Deposited in the USNM.

Paratypes.—6 ♀♀, 6 ♂♂, same data as holotype. Deposited in the USNM and UCR.

This species is easily distinguished from the only other described Neotropical species, *Mirax brasiliensis* Brues and *M. insularis* Muesebeck, by its dark thorax. In North America it is similar to *M. lithocolletidis* Ashmead but is distinguished by its darker color and more coarsely rugose propodeum. This species is named for my father, Malcolm B. Marsh.

Natural History Notes on Craspedoglossa stejnegeri *and* Thoropa petropolitana *(Amphibia: Salientia, Leptodactylidae)*

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ABSTRACT

Larvae are described for the first time for the burrowing leptodactylid frog, *Craspedoglossa stejnegeri*. The terrestrial larvae resemble those of *Zachaenus parvulus* in several distinctive features. Territoriality is described for the first time for any frog in SE Brazil; male *Thoropa petropolitana* defend calling sites and egg clutches.

During the month of December 1977, we obtained some natural history observations on previously unreported life history parameters for *Craspedoglossa stejnegeri* and *Thoropa petropolitana*. Our observations were made near the city of Teresópolis in the State of Rio de Janeiro, Brazil. Specimens are in the collections of the Museu de Zoologia da Universidade de São Paulo and the National Museum of Natural History, Washington, D. C.

Craspedoglossa stejnegeri

We obtained a series of 29 juvenile and adult *C. stejnegeri* from burrows in hillsides or under logs. During the day, specimens were found in the burrow systems under logs. At night, the frogs were near the mouths of the burrows. In six cases, *Craspedoglossa* and microhylids (a single species, as yet unidentified) shared the same burrows; four of the burrows contained one microhylid and one *C. stejnegeri*, two burrows, two microhylids and one *C. stejnegeri*.

On the morning of 10 December, the second author found a female *C. stejnegeri* with 40 larvae on her back under a 15 cm. diameter log beside a stream. The female sat in a depression below the level of the surrounding soil. Egg capsules were next to the female and one egg had been parasitized. The egg capsules were in a bead-like string. The larvae were very light in color, the yellow yolk being the most striking feature.

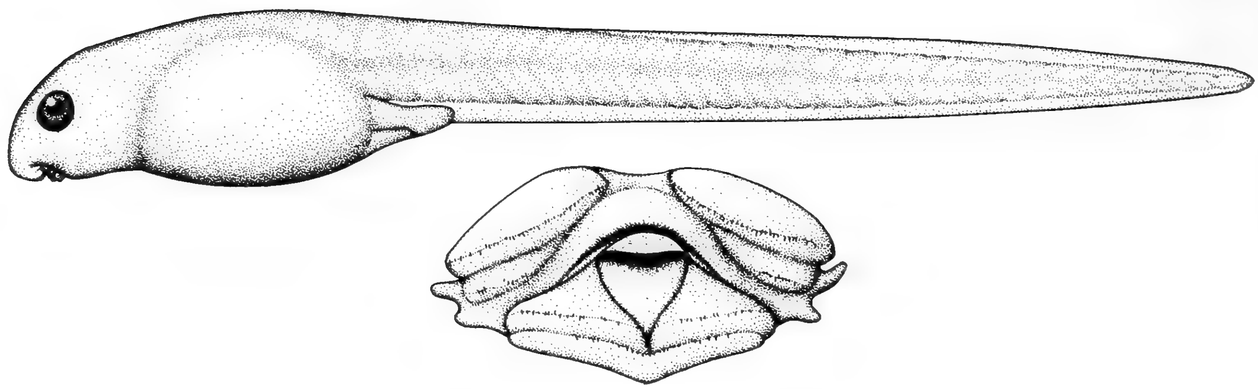

Fig. 1. Lateral view and mouthparts of larva of *Craspedoglossa stejnegeri*.

Thirty-eight of the larvae are stage 31 (Gosner, 1960), two are stage 30. Abundant yolk stores at this stage are obvious (Fig. 1). The oral disk is distinctive in having only two papillae at the lateral margins (Fig. 1). The denticles are not well developed and not clearly visible in all specimens at low magnification. At high magnification, the following tooth row formula is characteristic: 2-2/1$_{\bar{1}}$1. The larvae lack a spiracle, the anus is median and usually bifid. Of 10 larvae measured, the head-body length/total length average is 0.30; the longest larva is 25.2 mm total length.

The larvae of *C. stejnegeri* share the following distinctive features with the larvae of *Zachaenus parvulus* as described by Lutz (1944): No spiracle; general shape of oral disk (Lutz's figures appear almost identical to the mouthparts of Fig. 1); and peculiar bilobed anal tube (see Figure 16 in Lutz, 1944, for a comparable view of the condition in the series of *C. stejnegeri* at hand). The larvae differ in tooth row formulae, the tooth row formula for *Z. parvulus* is 1-1/1 (Lutz, 1944). Lutz describes the upper and lower lips of the disk being connected by 2 or 3 large papillae (as in *C. stejnegeri*), but that the lower lip has shorter, continuous papillae. The lower part of the disk in *C. stejnegeri* is emarginate (Fig. 1). Lutz gives the maximum length of *Z. parvulus* larvae as 19 mm.

The distinctive larvae of *Craspedoglossa stejnegeri* and *Z. parvulus* suggest close relationship, supporting Lynch's (1971) synonymization of these two genera. The distinctive adult morphologies argue for generic recognition, however (Heyer, 1975). The close similarities of larval morphologies indicate that the larvae of *C. stejnegeri* are terrestrial larvae, completing metamorphosis on the nutrients from the large yolk stores.

Lutz (1944) found a *Z. parvulus* egg mass which contained 30 eggs; no adult was in attendance. We found one egg mass of 12 eggs of *Z. parvulus* with an attendant female. It is difficult to imagine a larger clutch size for *Zachaenus parvulus* than what we found, owing to the large eggs and small size of adult females. Lutz may have uncovered a communal nesting site. The eggs of *Zachaenus* are in a clump, not a string as in *Craspedoglossa*.

Thoropa petropolitana

Our observations extend the information provided by Bokermann (1965), who discussed the general ecology of adults and larvae and described the larval morphology and mating call of *Thoropa petropolitana*. Most of our observations were made on a road cut rock wall with a high population density of *T. petropolitana*.

On the night of 4 December, the second author found an amplectant pair (axillary amplexus) in the final process of egg laying. Most of the eggs had been deposited in the characteristic circular mass when discovered. The following sequence was observed to be the same for deposition of 3 eggs. The male called sporadically (1–3 times), then squeezed the female 2–3 times. The female extruded a single egg. The male then pushed the egg onto the substrate (a vertical bare rock surface, surrounded by rock covered with algal and moss slime) with his right hind foot. The female rotated counterclockwise 5°, and the process was repeated. After the last egg was deposited, the male dismounted and moved about 30 mm from the clutch facing it, calling emphatically. The female straddled the circular clutch and sat on top of the clutch with her nose buried in moss. The total clutch was 16 eggs.

We checked the egg clutch almost daily, and at every observation period but 2, we found the male in attendance. One time when we did not see the male, he was attendant 15 minutes later when we rechecked the clutch. The embryos were at least at the neurula stage on the 4th day and several had died. On the 6th day, tails and movement were evident. On the 9th day, only eight embryos were still alive, the rest were dead. A small hydrophilid water beetle (*Oocyclus* sp.) was in the midst of the egg clutch, where it had apparently eaten its way in. We prodded the beetle. When the beetle moved, the male *Thoropa* reacted in the jerky motions which territorial males perform. The frog advanced on the beetle, bumped it with his chin, put his front foot on it, moved past it, and tried to dislodge it with a kick of his hind foot. The frog made no attempt to eat the beetle. On the 10th day, two larvae had hatched and were still on the jelly. On the 11th day, all but one larva had hatched; all larvae remained on or around the jelly. On the 12th day, all larvae had hatched; two were on the edge of the jelly, the others were gone. The male was absent. On the 13th day, no larvae were around the jelly; the male sat facing the jelly 10 cm away.

We found no males defending more than one clutch of eggs. Male *T. petropolitana* are territorial. Males defend calling sites and egg clutches from other males. One natural agonistic encounter was observed. The resident male gave what we interpret to be a territorial call (a creaking, attenuated note in contrast to the short chirps we interpret as the advertising call), then grabbed the face to face interloping male around the neck and wrestled. The resident released the invader and gave a territorial call followed by 5–6 rapid advertising calls. The invader remained flat on the substrate. The resident turned back towards his calling site, and the invader quickly left with two long hops.

We experimentally introduced males into the territories of other males, who were defending either calling sites or egg clutches. In all cases, the resident male called and postured toward the invading male. In one instance, calling and posturing was adequate to drive off the invader. In all others, physical contact, either wrestling or kicking, occurred. The adpression of the invader to the substrate was a common response. The defended territories are small. We found several instances of males calling 20 cm apart with no interference.

As Wells (1977) recently summarized, "Attachment to a fixed site will be advantageous if this gives the occupant exclusive or priority access to resources in short supply." We suggest that the resource in short supply for *T. petropolitana* is the egg deposition site for the following 2 reasons: (1) The males defend the site against other males only. When males are attending egg clutches, they do not remove spoiled eggs or clean the clutch of predatory insects. The clutch is defended only in terms of other *T. petropolitana*. (2) We discovered only one site where *T. petropolitana* was in a natural habitat—a waterfall. In contrast to the road cut, the population density of *T. petropolitana* here was very low. Our impression was that there were few protected but open rock surfaces with a film of water flowing over that were suitable for *T. petropolitana* egg deposition sites. The males of *Thoropa miliaris* do not attend egg clutches, and we saw no instances of territorial behavior in *T. miliaris*. Eggs of *T. miliaris* occur in much more exposed and horizontal situations than those of *T. petropolitana*, suggesting that the egg deposition sites of *T. miliaris* are not as limited a resource as for *T. petropolitana*.

In his recent review, Wells (1977) listed 2 species each of *Leptodactylus* and *Eleutherodactylus* as the only Neotropical leptodactylids for which territorial behavior had been reported. The occurrence of territoriality in the distantly related *Thoropa petropolitana* suggests that territoriality in leptodactylid frogs may be much more common than previously thought.

We thank Maria Christina Duchêne and Francisca Carolina do Val for assistance in the field. Paul Spangler identified the water beetle. Frances McCullough drew the figure. This is a contribution to the research project, "Evolutionary zoogeography of the Atlantic forest system of Brasil: The anuran example," supported jointly by the Museu de Zoologia da Universidade de São Paulo and the Smithsonian Institution's Amazon Ecosystem Research Program.

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Accuracy of Land-Use Sampling Methods

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ABSTRACT

Estimates of land-use proportions are required for many engineering planning and design models, as well as some environmental impact statements. Four methods are commonly used to estimate the proportion of various land uses in a study area: 1) planimetering of aerial photographs, 2) land-use sampling with aerial photographs, 3) prediction using regionalized relationships that require estimates of demographic characteristics, and 4) a weighted mean of the materials associated with each land-use classification. Because the methods give different answers, it is important to know the accuracy of each estimate. While planimetering and sampling provide almost exact estimates, the empirical estimation techniques are only accurate within 10% of the true value. Remote sensing techniques appear to provide an alternative method that should provide a high degree of accuracy.

Over the past few decades the proportion of the U. S. population that resides in urban/suburban areas has increased significantly (10). One result of this pattern of urban development has been noticeable changes in land uses, especially increased concentrations of imperviousness. Recognizing the physical significance of increases in imperviousness on the stormwater runoff process, hydrologists have used the percentage of impervious area as a measure of urbanization. This has led to attempts to relate the percentage of impervious area with peak discharge and other flood characteristics (11, 15). Such relationships can be used by planners to examine the hydrologic impact of proposed developments (12) or the effect on flood characteristics of continued urbanization with time (20).

Recognizing the impact of urbanization on runoff characteristics of a watershed, hydrologists have used the percentage of imperviousness as a parameter in hydrologic models (4, 15). The percentage of impervious area has been shown to be just as important as other watershed and climatic characteristics (15). Due to the relative importance of the percentage of imperviousness, accurate predictions of the hydrologic response of an urban watershed require accurate estimates of the impervious area.

The percentage of impervious area in a watershed can be estimated using any of the following 4 methods: 1) planimetering of aerial photographs, 2) land use sampling with aerial photographs, 3) prediction using empirical relationships having demographic characteristics as predictor variables, and 4) a weighted mean of the average percentage of impervious area associated with each land-use classification. While the first 2 methods require aerial photographs, methods 3 and 4 make use of regionalized information and readily available census tract information. While the regionalized estimation techniques are less costly, the method selected for any one site will depend on both accuracy and cost considerations.

The objective of this paper is to evaluate and compare the accuracy of these 4 methods of estimating the impervious area. The accuracy levels are also applicable to other land use types.

Planimetering

The most accurate estimates could be obtained by planimetering from aerial photographs. Planimetering of areas should provide almost exact values, with the accuracy of an estimate dependent upon the resolution of the aerial photograph and the availability of ground truth information. Requirements for ground truth depend on the relative importance of the land use in the study area. For larger areas and where there is little spatial homogeneity, such as in urban and suburban areas, planimetering may require an excessive amount of time, technical capability, ground truth verification, and cost. And Stafford, et al. (16) made the following important conclusion:

> The use of a planimeter to measure parcels of land in each land use class on aerial photographs may produce area measurements with higher accuracy than are actually required when the accuracy of other elements of the procedure are examined. Consequently, the use of a land use sampling approach rather than making area measurements with a planimeter is a reasonable modification to the procedure described herein which can significantly reduce the time and labor required to obtain data on the distribution of land use from aerial photographs.

Land-Use Sampling

The land use sampling approach may be a reasonable alternative for estimating percentages of different land uses, including the proportion of impervious area. The sampling approach has been used in hydrologic analyses (11, 20) and in resource identification studies (14).

When sample size is the factor that controls accuracy, a confidence interval can be used to indicate the accuracy of land-use proportion that is estimated by land-use sampling. For large samples, such that the sampling distribution of the proportion is approximately normal, the $100(1 - \alpha)\%$ 2-sided confidence limits for a proportion P are given approximately by:

$$\frac{N}{N + Z^2}\left[P + \frac{Z^2}{2N} \pm Z\sqrt{\frac{P(1 - P)}{N} + \frac{Z^2}{4N^2}}\right] \quad (1)$$

where N is the sample size, Z is the standardized normal variate that cuts off the upper $\alpha/2$ proportion, and α is the level of significance. Large samples can be expected when using methods of automatic classification by remote sensing and equation 1 reduces to (19):

$$P \pm Z\sqrt{\frac{P(1 - P)}{N}} \quad (2)$$

Either equation 1 or 2 can be used to determine an interval about an observed land-use proportion and determine the probability that the true land-use proportion lies within this range.

Equations 1 and 2 can also be used to estimate the sample size required to provide a specified degree of accuracy. A proportion of 0.5 is the most critical proportion and thus has the widest confidence interval. For a proportion of 0.5 and a degree of confidence of 99%, equation 2 indicates that a sample size of 16,577 would be required to provide an estimate of a proportion within 1% of the true value. For a proportion of 0.25, which is similar to the proportion of impervious area in a suburban area, the required sample size would be 12,433. Ragan (14) used a sample size of over 94,000 to estimate the proportion of the land use in 10 mutually excusive categories.

Prediction Using Demographic Characteristics

But both the planimetering and sampling methods assume that aerial photographs are available. For many watersheds current aerial photographs may not be available. And for many planning problems only the spatial extent of future trends in urbanization is known. Thus, the planimetering and land-use sampling techniques are not always applicable.

When planimetering or land-use sampling are not applicable or the resources required to use these methods are not available, it may be possible to estimate imperviousness and other land-use characteristics using empirical prediction equations having demographic characteristics, such as population and housing densities, as predictor variables (8, 9, 18). Estimates of demographic characteristics, which can be used for prediction, may be available from past census summaries or planning projections of future development.

The standard error of estimate of the prediction equations can be used to indicate the accuracy of land-use estimates. The prediction equation approach may provide estimates of imperviousness and other land-use characteristics that are within 10% of the true value. Graham (9) reported a standard error of estimate of 11.8% of imperviousness when using housing density as the predictor variable. Gluck (8) reported a standard error of estimate of 6.3% of imperviousness when using the population density and the distance from the central business district as predictor variables.

Land-Use Class Averaging

Aerial photographs for planimetering and land-use sampling and estimates of demographic characteristics for use with prediction equations are often not available or require too much effort for evaluating many different planning alternatives. Furthermore, planning projections often include estimates of specific land uses without distinguishing between the proportion of pervious and impervious surface cover. Specifically, specifying the percentage of residential land use does not provide the information needed for many planning models. When gross areas devoted to specific land uses are available, a means of transforming these estimates to impervious area estimates is required. In such cases, a second empirical method of estimating imperviousness may be a feasible alternative. An estimate of the imperviousness of a study area can be obtained using a weighted mean of the average impervious area associated with each land use in the study area; the estimate can be obtained from:

$$IA = \sum_{j=1}^{n} I_j P_j \tag{3}$$

where I_j is the average percentage of impervious area associated with land-use classification j, P_j is the fraction of the study area devoted to land use j, n is the number of different land-use categories in the study area, and IA is the estimated percentage of impervious area in the study area.

Stankowski (18) provided low, intermediate and high estimates of impervious land area for 6 land-use categories; these values are reproduced in Table 1. These estimates were based on general field observations and studies by Carter (3), Felton and Lull (7), Antoine (2), and Stall, Terstriep, and Huff (17). However, the separation of land-use categories in Table 1 may not be sufficiently disaggregated for some hydrologic planning and design activities.

To provide impervious area estimates that can be used in many research activities, a land-use classification system, Table 2, that was proposed (1) for use with remote sensor data was adopted

Table 1.—Impervious Land Area Within Land-Use Categories.

Land-use category	Impervious land area (percentage)		
	Low	Intermediate	High
Single-family residential	12	25	40
Multiple-family residential	60	70	80
Commercial	80	90	100
Industrial	40	70	95
Public and quasi-public	50	60	70
Conservational, recreational and open	0	0	0

Table 2.—Land-Use Classification System.

Level I	Level II
01. Urban and Built-up Land	01. Residential
	02. Commercial and services
	03. Industrial
	04. Extractive
	05. Transportation, Communications and Utilities
	06. Institutional
	07. Strip and Clustered Settlement
	08. Mixed
	09. Open and Other
02. Agricultural Land	01. Cropland and Pasture
	02. Orchards, Groves, Bush Fruits, Vineyards, and Horticultural Areas
	03. Feeding Operations
	04. Other
03. Range Land	01. Grass
	02. Savannas
	03. Chaparral
	04. Desert Shrub
04. Forest Land	01. Deciduous
	02. Evergreen (Coniferous and other)
	03. Mixed
05. Water	01. Streams and Waterways
	02. Lakes
	03. Reservoirs
	04. Bays and Estuaries
	05. Other
06. Nonforested Wetland	01. Vegetated
	02. Bare
07. Barren Land	01. Salt Flats
	02. Beaches
	03. Sand and Other Beaches
	04. Bare Exposed Rock
	05. Other
08. Tundra	01. Tundra
09. Permanent Snow and Icefields	01. Permanent Snow and Icefields

herein, with 1 modification and several deletions. The structure of the classification system provides for 2 levels of classification, but can be refined further. A detailed description of each category was provided by Anderson, et al. (1).

In the study reported herein, land-use classification 01.01, residential, was further separated into three categories:

01. Recent residential,
02. Older residential,
03. Multiple-family housing.

This refinement of the classification system was necessary because of the wide differences in impervious area within the residential category and the importance of residential areas in determining the degree of imperviousness in a watershed. Older residential housing consists of those areas developed prior to the early 1950's. In addition to having a different average percentage of imperviousness, older residential housing has different visual characteristics on aerial photographs when compared with recent residential areas.

The average percentage of impervious area for 13 land-use categories were derived herein. An aerial photograph at a scale of 1:24000 was obtained from a U2 flight (60,000 ft or 18,300 m) for an area of approximately 830 km^2. The averages were obtained by planimetering the percent of impervious area for a number of parcels of land in each land-use category. The parcels ranged in total area from approximately 0.01 km^2 to 0.4 km^2. Using these impervious area averages and a weighting function such as equation 3, urban planners may obtain estimates of impervious area as input to hydrologic models.

Several Level I and Level II categories were omitted in this study either because they are not associated with impervious areas (e.g., 05. Water), or because data were not available from the aerial photographs (e.g., 07.02. Beaches). For the remaining land-use categories, average impervious area estimates were obtained as previously discussed and are given in Table 3.

Impervious area estimates were obtained for 3 residential land-use categories. Mean values of 24.4% and 22.6% were computed for recent and older single-family residential housing, respectively. Standard deviations of approximately 9% of imperviousness were determined herein for these forms of residential housing. The standard deviation provides a measure of the accuracy of an estimated value when additional information is not available. The computed mean values and ranges for single-family residential housing were in close agreement with the values reported by Stankowski (18).

For many urban watersheds single-family residential land use represents a significant portion of the total watershed. For such cases, the observed variation in imperviousness of 9% may have a significant effect on the accuracy of impervious area estimates computed using equation 3. The accuracy of estimates can be improved by using additional information to estimate the impervious area associated with single-family residential land use.

Carter (3) observed that the percentage of impervious area in residential areas decreased with increases in lot size. To test this observation, relationships were derived relating impervious area IA to lot size L. Equations 4 and 5 are for recent and older residential housing, respectively:

$$IA = \begin{cases} 17.62 + e^{(4.10-6.30L)} & 0 \leq L \leq 0.6 \text{ acres} \\ 24.50 - 9.167L & 0.6 < L \leq 1.8 \text{ acres} \end{cases} \quad (4)$$

$$IA = \begin{cases} 14.93 + e^{(4.28-6.41L)} & 0 \leq L \leq 0.6 \text{ acres} \\ 22.71 - 10.40L & 0.6 < L \leq 1.8 \text{ acres} \end{cases} \quad (5)$$

When the average lot size is also available to the planner, equation 4 and 5 should provide more accurate estimates of imperviousness than the averages given in Table 3. For lot sizes less than 0.2 acres (809 m^2) the average impervious area for older residential is greater than for recent residential; this reflects the high percentage of imperviousness for row houses in urban areas. For lot sizes greater than 0.2 acres (809 m^2) the impervious area for recent residential was slightly higher; this results from the higher proportion of parking areas, patios, and swimming pools included with recent residential housing.

Table 3.—Impervious Area Estimates.

Land use category	Sample size	Impervious area: Mean	Low	High	Standard deviation
01. Urban and Built-up Land					
01. Residential					
01. Recent residential	37	24.4	9.7	62.1	8.6
02. Older residential	28	22.6	8.1	58.8	8.9
03. Multiple-family residential	13	80.4	67.3	90.6	5.8
02. Commercial and services	12	93.6	85.4	100.0	4.4
03. Industrial	5	71.9	63.8	81.5	7.7
04. Extractive	3	75.7	67.2	82.0	7.8
05. Transportation, Communications and Utilities	31	35.7	0.0	78.3	21.3
06. Institutional	17	26.4	8.3	54.5	13.7
07. Strip and Clustered Settlement	8	84.3	71.6	91.9	6.1
09. Open and Other	11	2.8	0.0	9.4	1.7
02. Agricultural Land					
01. Cropland and Pasture	13	0.8	0.0	5.2	0.6
02. Orchards, Groves, etc.	2	1.1			
04. Forest Land	7	0.4	0.0	2.1	0.7

Multiple-family residential housing has a mean impervious area and a standard deviation of 80.4 and 5.8%, respectively. This mean is approximately 10% higher than that reported by Stankowski (18). There are 2 points that must be considered when assessing the significance of this difference. First, the degree of imperviousness will depend on the delineation of the boundary of the housing development. Quite often, new multiple-family housing developments are adjacent to cleared land and the degree of imperviousness will depend on the amount of cleared land included as part of the open space for the development. Since most of the developments examined in this study were adjacent to commercial or transportation land uses it was not difficult to delineate the boundaries. Second, housing developments located in metropolitan areas are often developed more intensively than those in suburban areas. Since most of the housing developments analyzed herein were in the Washington, D. C. Metropolitan area, the higher percentage should have been expected. In this study the sites within the delineated area had a mean percentage of imperviousness that was approximately 5% greater than the sites located in suburban areas. A significant relationship was not observed between percent impervious area and developed area for multiple-family residential developments.

Twelve commercial and service developments were analyzed with a mean imperviousness of 93.6%; Stankowski (18) reported an intermediate value of 90%. For many newer commercial developments it is difficult to delineate the boundary and this affects the computed percentages. And the intensity of land use appeared to decrease as the distance from the central business district increased. This observation is in agreement with the prediction equation reported by Gluck (8).

From 5 industrial sites, a mean imperviousness of 71.9% was computed; this was in good agreement with the mean of 70% reported by Stankowski (18). A standard deviation of 7.7% was observed. This variation should not have a significant effect on the computed impervious area of an urban watershed unless the proportion of industrial land use is high.

Estimating statistical characteristics for the land-use classification 01–05 (Transportation, Communications and Utilities) is somewhat complicated because of the diversity in land use within this level II category. Specifically, in this study some rights-of-way for transmission lines had impervious areas of zero % while some urban highway areas were almost completely impervious. Furthermore, highway interchanges ranged in imperviousness from 23.9% to 57.7%, with a mean and standard deviation of 40.5% and 12.2%, respectively. However, there was a noticeable tendency for interchanges having a smaller total area to be more intensively developed, i.e., a higher percentage of impervious area. The percentage of impervious area for highways depends primarily on the size of the right-of-way. In the central business district transportation routes are almost completely impervious while in rural and agricultural areas the percentage may have a mean of approximately 20%. Airports, which are also included in category 01–05, ranged in imperviousness from 20 to 35%, with the smaller airports more intensively developed. Rights-of-way for transmission lines were characterized by small levels of imperviousness (0% to 4%), although at sites where transmission equipment shelters are located the percentage of imperviousness may be as high as 20%. In summary, due to the large variation in both imperviousness and spectral signatures within the 01–05 land-use category, it should be separated either by forming 2 or more level II categories or at level III.

Mean percentages of impervious area for other land-use categories were also determined by planimetering and are reported in Table 3.

When using average values such as

those from Table 3, the resulting accuracy will depend in part on the disaggregation of the land-use classification system. The system of classification used herein provided average impervious area estimates for 13 land uses associated with urban and suburban areas. Furthermore, relationships, equations 4 and 5, were provided that relate impervious area and residential lot size. These relationships are especially important because residential land use is often the primary land use in the watershed and thus the equations may result in increased accuracy in impervious area estimates for single-family residential land use.

To provide a test of the accuracy of the average values given in Table 3, these values were used to estimate the percentage of imperviousness of the Anacostia Watershed. A land-use sampling approach indicated that the watershed was 23.51% impervious (14). Areas of 7 land uses were planimetered herein from a land-use map provided as part of the same study (13). The land-use maps did not provide sufficient detail to evaluate different materials (i.e., concrete, grass, trees) so it was not possible to directly evaluate imperviousness. Thus, the land-use averaging technique was appropriate. The areas planimetered from the land-use map were weighted by the impervious area estimates of Table 3 to compute a weighted mean percentage of imperviousness. The computations shown in Table 4 indicate an estimate of 25.49%, which is a reasonable approximation to the value of 23.51% obtained by a land-use sampling survey. A higher degree of accuracy may have been realized if the same land-use categories shown in Table 3 had been used in developing the land-use map.

Table 4.—Estimated Impervious Area for the Anacostia Watershed.

Land use	Average impervious area (%)*	Fraction of total area**	Weighted value (%)
Residential			
single-family	23.5	.575	13.51
multiple-family	80.4	.050	4.02
Commercial	93.6	.031	2.90
Industrial	71.9	.044	3.16
Institutional	26.4	.044	1.16
Federal	3.0	.115	0.35
Open-space	2.8	.141	.39
		1.000	25.49

* Obtained from Table 3.

** Planimetered from land use map in reference 11.

Discussion and Conclusions

In comparing the accuracy of the different methods of estimating imperviousness it is evident that the empirical approaches may provide estimates of imperviousness that are within 10% of the true value. Planimetering and land-use sampling should provide almost exact estimates. The test case reported herein suggests that the method of averages may provide estimates that are just as accurate as those obtained using prediction equations with demographic characteristics as predictor variables. While the method of averages certainly requires less input, the prediction equation has the advantage of being able to show directly the effect of changes in demographic characteristics. However, for many planning problems, the method of averages of equation 3 may be preferred due to the minimal amount of computational effort required and the reasonably accurate estimates provided.

Recent advances in technology include the development of remote sensoring equipment that is capable of collecting and storing large quantities of data on the reflective and emissive properties of a watershed. The Landsat Multispectral Scanner System (MSS) is currently being used to acquire vast amounts of data that can be used to compile land-use maps (5, 6). Dornbach and McKain (5) concluded that most of the Level I and II categories of Table 2 could be detected using Landsat data and spectral pattern recognition techniques.

If remote sensing data is to be useful in urban hydrologic modeling, a means of converting land use estimates to parameters needed for hydrologic models must be provided. The values reported in Table 3 provide the means of transforming land-use estimates obtained from Landsat to impervious area estimates. Thus, automatic computer-aided machine classification can be used to identify generalized land-use proportions. Combining these with mean impervious area proportions will provide accurate estimates of imperviousness at a minimum cost.

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Bridge Response and Damage

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ABSTRACT

As part of a NSF cooperative program between the University of Maryland and National Central University, Taiwan, and the R.O.C. National Science Council, the live load response of various bridges throughout Taiwan were to be studied. The study included in part; 1) the examination of the response of a welded plate girder highway bridge when subjected to random truck loadings and the measurement of induced stresses and traffic patterns, 2) the evaluation of the damping ratio and fundamental frequency of (14) pedestrian bridges using various analytical methods when examining the experimental data. The results from these tests and the analytical correlations are presented herein.

Plate Girder Bridge Test

1) Test Results

Field Studies.—As described previously part of the cooperative study involved examination of the response of a A36 steel bridge located in Taipei, Taiwan, shown in Figs. 1 and 2. This structure consists of 5 welded steel composite plate girders, spaced at 3120 mm, of variable cross section, as shown in Fig. 3. The flange plates had variable widths and depth, which were built welded at the junction of the change. The main structure, of the Taipei Bridge, consists of these plate girders, comprising 5 spans @62.3 meters long as shown in Fig. 1. The bridge was designed using the 1961 AASHTO design code, using A36 steel.

In order to evaluate the response of this bridge when subjected to random traffic loading, a series of strain gages was attached to the lower flange of 2 outside girders, on the second interior girder span. These strain gages were monitored during random traffic.

Stress Distribution.—During the passage of traffic, a continuous 24-hour-strain recording was made from 4 strain

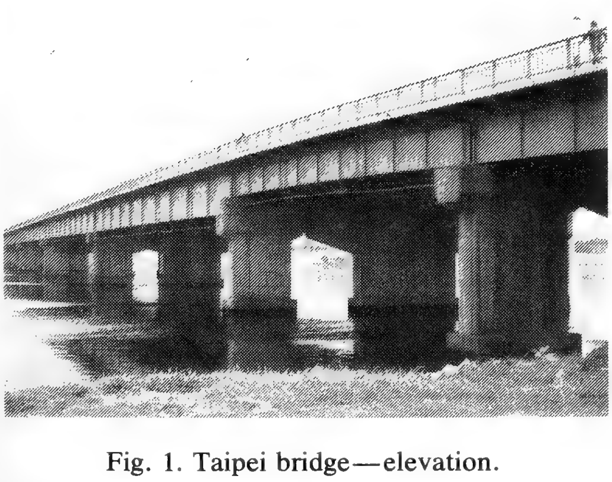


Fig. 1. Taipei bridge—elevation.

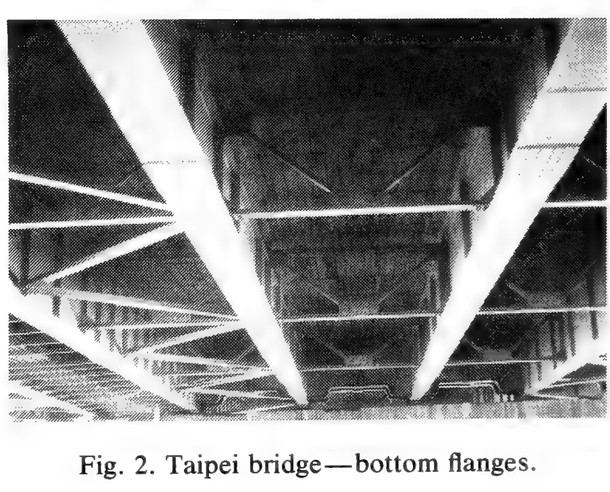


Fig. 2. Taipei bridge—bottom flanges.

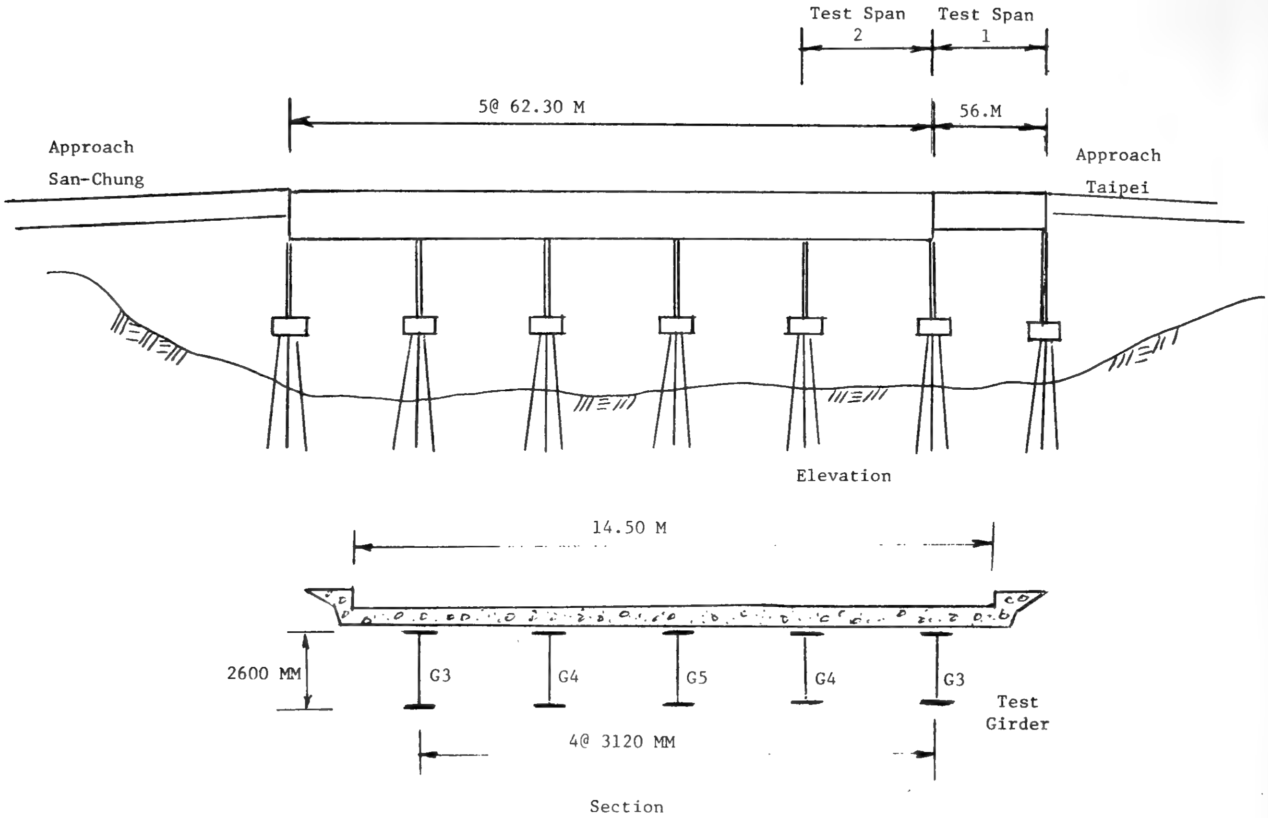


Fig. 3. Bridge details.

gages. These gages were located on the bottom flange of the outside of a 52-m girder and a 62-m girder, as shown in Fig. 4. The resulting strip chart recordings, taken from 3 AM (8/12/77) to 3 AM (8/13/77), were subsequently reduced in the form of number of occurrences during a time interval at a given stress range.

The resulting time-frequency data have

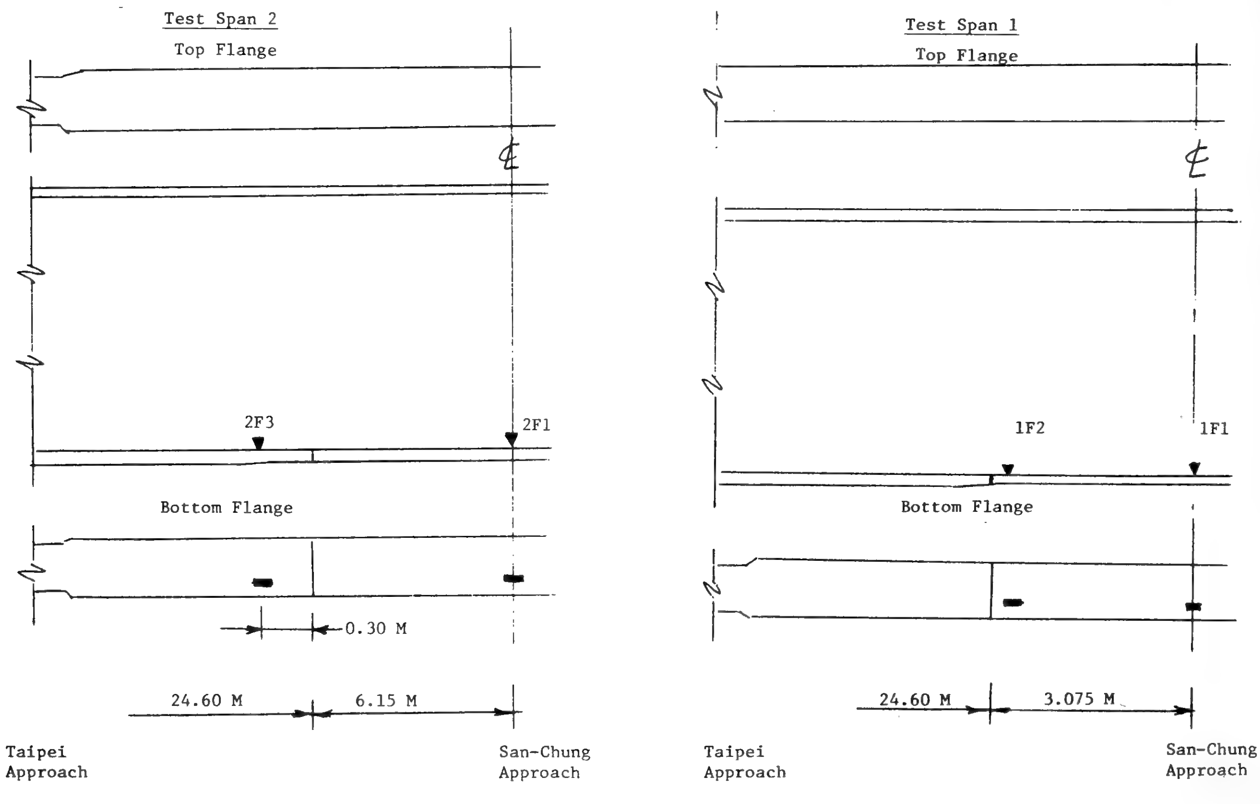


Fig. 4. Gage locations.

Table 1.—Gage 1F1 Time–Frequency Data.

Hour	1 ksi	2 ksi	3 ksi	4 ksi	5 ksi
3–4 AM	21	4	0	0	0
4–5	27	1	0	0	0
5–6	50	5	0	0	0
6–7	75	7	0	0	1
7–8	156	6	0	0	0
8–9	116	10	1	0	0
9–10	114	5	1	0	0
10–11	102	15	1	0	0
11–12	100	18	4	0	0
12–1	80	19	1	0	0
1–2	81	6	1	1	0
2–3	123	10	0	0	0
3–4	117	12	1	0	0
4–5	115	16	2	0	0
5–6	131	8	0	0	1
6–7	128	11	0	0	0
7–8	96	7	1	0	0
8–9	95	6	1	0	0
9–10	106	2	0	0	0
10–11	66	3	0	0	0
11–12	37	8	0	0	0
12–1	32	7	0	0	0
1–2	30	8	0	0	0
2–3	33	3	1	0	0

been reduced and are given in Tables 1 through 4. These data have been reduced in the form of percentages, for each 12 hour period, as given in Table 5.

Table 2.—Gage 2F1 Time–Frequency Data.

Hour	1 ksi	2 ksi	3 ksi
3–4 AM	32	1	
4–5	20	1	
5–6	45		
6–7	75		
7–8	78	5	
8–9	162	11	
9–10	157		
10–11	142	4	
11–12	144	15	3
12–1	100	21	2
1–2	126	7	
2–3	112	12	
3–4	120	9	
4–5	136	5	2
5–6	132	9	2
6–7	129	10	
7–8	94	5	
8–9	123	5	
9–10	122	5	
10–11	101	3	
11–12	57	4	
12–1	48	1	
1–2	52	1	
2–3	56	1	

Table 3.—Gage 2F3 Time–Frequency Data.

Hour	1 ksi	2 ksi	3 ksi
3–4 AM	14	1	
4–5	7		
5–6	8		
6–7	11		1
7–8	21		
8–9	84		
9–10	64	1	
10–11	57		
11–12	54		
12–1	44		
1–2	27	1	
2–3	30		
3–4	31		
4–5	40	1	
5–6	35	2	
6–7	31	10	
7–8	15	1	
8–9	22		
9–10	26		
10–11	27		
11–12	15		
12–1	8		
1–2	13		
2–3	13		

Vehicle Distribution.—In addition to recording continuous strains (stresses), vehicle types and frequencies were also recorded. The trucks were classified

Table 4.—Gage 1F2 Time–Frequency Data.

Hour	1 ksi	2 ksi	3 ksi
3–4 AM	7		
4–5	4		
5–6	10		
6–7	7		
7–8	24		
8–9	19	1	
9–10	55	4	
10–11	297	10	
11–12	315	5	
12–1	209	4	
1–2	136	1	1
2–3	108	3	
3–4	179	1	
4–5	98	2	
5–6	145		
6–7	109		
7–8	15		
8–9	20		
9–10	27		
10–11	19		
11–12	12	1	
12–1	19		
1–2	21		
2–3	88		

Table 5.—Summary—Time-Frequency Data (percentage).

Hour	1 ksi	2 ksi	3 ksi	4 ksi	5 ksi	Gage
3am/3pm	89.9	9.1	0.8	0.1	0.1	1F1
3pm/3am	91.0	8.4	.5	0	.1	1F1
3am/3pm	93.6	6.0	.4	0	0	2F1
3pm/3am	95.7	4.0	.3	0	0	2F1
3am/3pm	99.1	.7	.2	0	0	2F3
3pm/3am	98.6	1.4	0	0	0	2F3
3am/3pm	97.6	2.3	.1	0	0	1F2
3pm/3am	99.5	.5	0	0	0	1F2

as types 2D, 3, and 2S2, as shown in Fig. 5. Also recorded were the frequencies of buses, pick-ups, and taxi/sedans. The results of this data, in terms of frequency versus truck type for 3 twelve-hour periods, are given in Figs. 6, 7, and 8.

2) Comparison of Results

Vehicle Data.—As explained in the previous section, some vehicle data were collected during the field testing of the Taipei Bridge. These data consisted of vehicle types (Figures 6, 7, and 8) and frequencies. Examination of these data, during the entire test period, indicates that the trucks have the following frequency distribution;

Type	Frequency (%)
2D	61
3	23
2S2	16

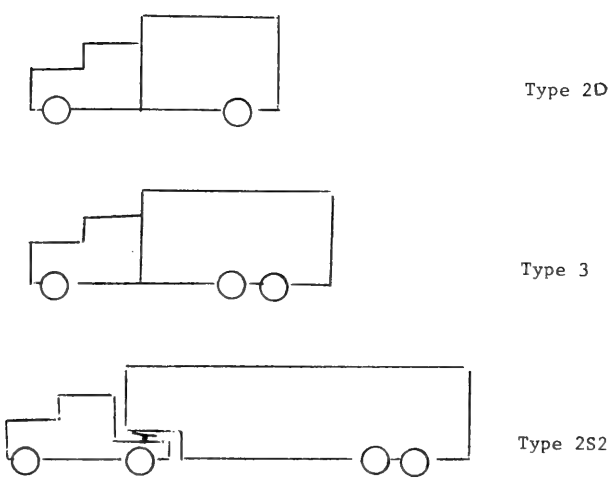
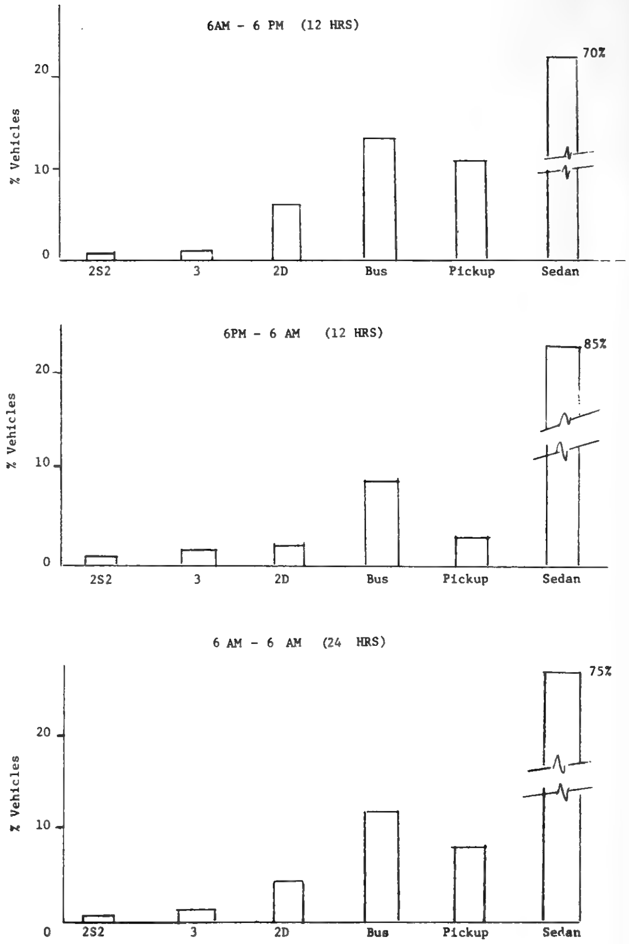


Fig. 5. Truck types.



Figs. 6–8 (top to bottom). Percentage distribution of vehicle types at various time periods.

These percentages exclude the influence of buses, pick-ups and sedans given in Figs. 6, 7, and 8.

Examination of data collected throughout the USA (1–16) results in vehicle distribution as given in Table 6. Comparisons between the results given in Table 6 and those obtained during the Taipei Bridge show similarities for the metropolitan area. In order to relate the results between the 2 countries, truck types 2S-1 and 3S-2 have been excluded from the USA data. Although vehicle weights and distributions which traversed the Taipei Bridges were not

Table 6.—Average Distribution of Trucks by Type.

Truck type	Metro-politan	Urban	Rural
2D	51	30	40
3	33	7	12
25-2	16	63	48

Table 7.—Truck Characteristics from Various Countries.

Truck classification	Truck gross weight (kips) Mean	Maximum	Percent axle load distribution (% of gross weight)	% Truck type distribution (population)	Country	Traffic data (*)
2D	14	50	25–75	35	USA	*
	—	24,32	30–70	—	India	*
	—	22	36–64	56	Belgium	*
	—	31,38	—	80	France	*
	—	40	50–50	—	Canada	
	—	38	32–68	59	Belgium	*
	—	32	50–50	—	France	
3	35	80	25–37.5–37.5	23	USA	*
	—	50	20–40–40	—	India	*
	—	36	25–38–37	7	Belgium	*
	—	52	—	4.4	France	*
	—	60	33–33–33	—	Canada	
	—	52	24–38–38	6	Belgium	*
	—	60	20–40–40	—	France	
2S2	41	100	10–40–25–25	11	USA	*
	—	60	16–30–27–27	—	India	*
	—	56	14–29–29–28	30	Belgium	*
	—	70	—	10.6	France	*
	—	146	12–34–20–34	—	Sweden	
	—	100	20–40–20–20	—	Canada	
	—	76	13–35–26–26	27	Belgium	*

* Data observed from typical traffic, otherwise data is suggested design loading.

obtained, results from other countries have been collected as given in Table 7 and are given herein for reference.

Stress Data.—The induced girder stresses, obtained on the Taipei Bridge, are listed in detail in Tables 1 through 4 and are summarized in Table 5. These stresses are given as stress ranges, which are important in establishing fatigue damage and bridge life. The establishment of fatigue design criteria requires traffic patterns and relationships between the induced stresses and those vehicle types which induce the particular stress. Such a technique has successfully been employed (16) for bridges in the USA.

Examination of the resulting stress data, given in Table 5, indicates that

Fig. 9. Pedestrian bridge—tests.

Fig. 10. Pedestrian bridge.

Table 8. Empirical Damping Ratio of P.C. Bridge.

No.	Bridge Name	Free Vibration	Random Decrement	Auto Correlation Function	Spectrum Analysis	Span (M)	Remark
1*	Chung-Li	0.022	0.024	0.019	0.018	21.0	
2*	Taipei Station(A)	0.011	0.009	0.016		30.2	
3*	Taipei Station(B)	0.053	0.034	0.043		34.1	
4*	Taipei Station(C)	0.032	0.012	0.010		36.6	
5*	Nan Ching West Rd.(A)	0.015	0.016	0.013		24.0	
6*	Nan Ching West Rd.(B)	0.019	0.018	0.019		25.0	
7	Chung Hsing Bridge	0.051	0.067	0.062	0.019	39.1	
8**	Hua Chung Bridge		0.026			50.0	
9	Chung Cheng Bridge		0.125			23.0	
10	Pai Ling Bridge		0.065			28.0	
11	Shin-Lin Chung Cheng Bridge		0.134			25.0	
12	Sung Chiang Bridge		0.114			31.0	
13*	Nan Men Market		0.018			33.0	
14*	Sung Chiang Rd.		0.026			25.6	

* Pedestrian Bridge

** Overhanged-Simple Supported

90% or more of the stress range has a magnitude of 1 ksi or less. In fact, the maximum observed stress was only 5 ksi and occurs only 0.10% of the time. Such trends are similar to those observed in the USA for this type of structural detail (cover plate), and indicates a long fatigue life.

Table 9. Fundamental Frequency of P.C. Bridge, Cycles Per Sec.

No.	Bridge Name	Free Vibration	Random Decrement	Auto Correlation Function	Spectrum Analysis	Theoretical Values	Span (M)	Depth / Span
1*	Chung-Li	7.10	7.14	7.14	7.16		21.0	
2*	Taipei Station(A)	3.00	2.94	2.94	2.94		30.2	
3*	Taipei Station(B)	2.76	2.70	2.78	2.70		34.1	
4*	Taipei Station(C)	2.70	2.77	2.78	2.79		36.6	
5*	Nan Ching West Rd (A)	4.20	4.16	4.17	4.20		24.0	
6*	Nan Ching West Rd (B)	3.60	3.70	3.85	3.67		25.0	
7	Chung Hsing Bridge	2.80	3.01	2.63	2.79	2.573	39.1	1.34/25
8**	Hua Chung Bridge		2.63		2.71	3.15	50.0	0.975/25
9	Chung Cheng Bridge		6.67		5.73		23.0	
10	Pai Ling Bridge		4.72		4.62		28.0	
11	Shin-Lin Chung Cheng Bridge		4.73		4.62		25.0	
12	Sung Chiang Bridge		3.76		3.66	2.567	31.0	1.03/25
13*	Nan Men Market	2.50	2.56		2.55		33.0	
14*	Sung Chiang Rd.	4.40	4.39		4.46		25.6	

* Pedestrian Bridge

** Overhanged-Simple Supported

Pedestrian Bridge Test

1) Test Results

The induced dynamic responses of 14 pedestrian crossing bridges located throughout Taipei, Taiwan have been obtained by using accelerometers which were located at various locations on the bridges. A typical bridge of this type is shown in Figs. 9 and 10. The induced vibrations on the bridges were instituted by human motions across the structure. The resulting vibration records were then obtained, using a strip chart recorder. From such data the damping ratio and fundamental frequency have been computed, as given in Tables 8 and 9.

2) Comparison Between Theory and Tests

Theory.—Various methods can be employed in obtaining the structural damping and free vibration of structures, when subjected to applied forces.

One such method in use is the spectral power density, where damping is measured by the half power point band width (17, 18). This method, however, has large measurement variances, especially when the band width is small and when the system is nonlinear.

Another method, auto-correlation (17, 18), involves use of the Logarithmic Decrement. This method is sensitive to the intensity of the random input and cannot be utilized for nonlinear systems.

A new method, designated Random Decrement (19, 20) has recently been formulated and considers the random excitation of a bridge when only response data is available. The application of this method, in addition to those described above, has been employed in analyzing the 14 bridges. The results of each are given in Tables 8 and 9.

Acknowledgment

The work performed under this study was supported by National Science Foundation Grant 14750, AO1, under the direction of Dr. Allen Holt. Their support and interest is gratefully appreciated.

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SCIENTISTS IN THE NEWS

Contributions in this section of your Journal are earnestly solicited. They should be typed double-spaced and sent to the Editor by the 10th of the month preceding the issue for which they are intended.

NATIONAL INSTITUTES OF HEALTH

Dr. Alfred D. Steinberg, senior investigator with the Arthritis and Rheumatism Branch of the National Institute of Arthritis, Metabolism, and Digestive Diseases, is the 1978 recipient of the Award in Biological Sciences of the Washington Academy of Sciences.

The award was presented at the organization's annual awards dinner held in Bethesda on Mar. 15.

Dr. Steinberg, an immunologist, was recognized for his investigations of the pathogenesis and treatment of systemic lupus erythematosus (SLE), a serious connective tissue disease that primarily affects women of childbearing age. At present, the cause of SLE is unknown.

In the course of his basic research, Dr. Steinberg and his colleagues have studied both humans with SLE as well as New Zealand mice that serve as an animal model for SLE.

Dr. Steinberg was the first to show that nucleic acids were antigens, and he developed radioimmunoassays for measurement of antibodies to nucleic acids. He has contributed to understanding of immune regulation and its derangement in SLE; genetic factors associated with autoimmunity; and the role of sex hormones in the expression of autoimmunity.

Recent studies suggest that spontaneously produced antilymphocyte antibodies play an important role in the immune abnormalities observed in both SLE mouse models and humans with SLE. In addition to basic studies, Dr. Steinberg has carried out evaluations of newer therapeutic modalities in mice and has initiated clinical studies in SLE patients in an attempt to improve treatment of SLE.

In 1974, Dr. Steinberg received the Philip Hench Award of the Association of Military Surgeons for his outstanding contributions in the field of rheumatology and arthritis.

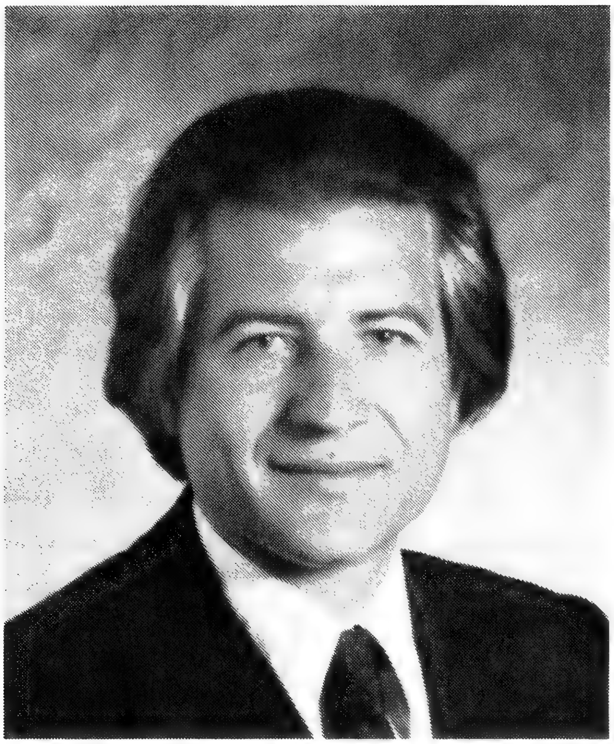
Dr. Steinberg graduated from Princeton University and from Harvard Medical School. He joined the intramural research program of NIAMDD in 1968 as a clinical associate.

Dr. Steinberg is an associate editor of the *Journal of Immunology*, and is on the editorial board of the *Journal of Immunopharmacology*. He is a fellow of the American College of Physicians and serves as the NIH coordinator for the Medical Student Immunology Program.

NAVAL RESEARCH LABORATORY

Dr. Dennis Papadopoulos, a consultant in plasma physics at the Naval Research Laboratory, is the winner of the 1978 Washington Academy of Sciences Award for scientific achievement in the physical sciences. Papadopoulos was cited for his "scientific achievements and leadership in plasma physics."

The award was presented at the awards dinner (March 15) at the Kenwood Country Club in Bethesda, Md. in conjunction with the commemoration of the 100th anniversary of Albert Einstein's birth.



Dennis Papadopoulos

A graduate of the University of Athens (Greece), Papadopoulos received his MS in nuclear engineering from the Massachusetts Institute of Technology and his PhD in physics from the University of Maryland. He joined the NRL staff in 1969 as a research physicist and was appointed senior consultant to the Plasma Dynamics Branch in 1973. In 1975 he was appointed to his present position.

At the request of the Office of the Assistant Secretary of Energy for Energy Technology, Papadopoulos is presently serving as Science Advisor to the Director of the Applied Physics Division of the Office of Fusion Energy.

Papadopoulos' research interests cover a wide range of scientific projects from space physics and communications to magnetic and laser fusion.

The renowned scientist was the recipient of NRL's E. O. Hulburt Award for Science in 1977 for his outstanding achievements in the field of plasma physics.

Papadopoulos is the author of more than 70 publications and has presented over 30 technical papers at international scientific meetings. He also has served on many National Aeronautics and Space Administration and Department of Energy advisory panels.

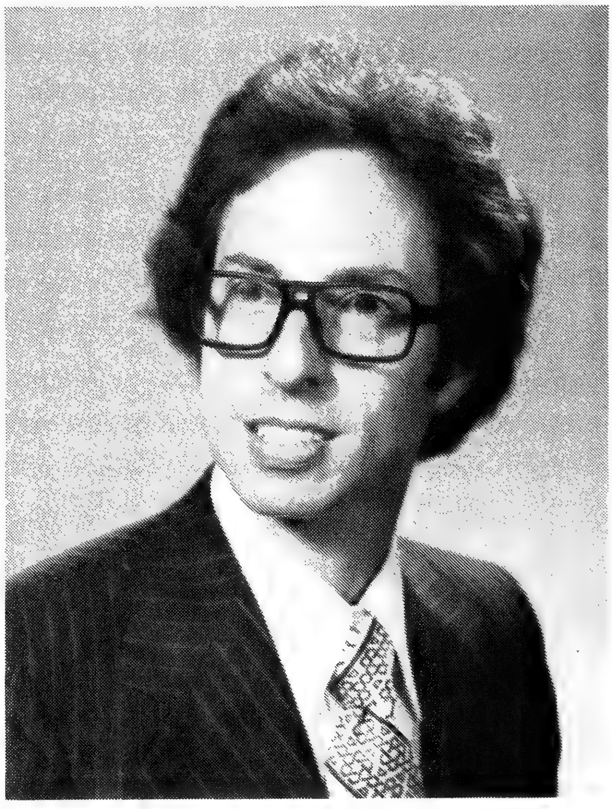
A native of Larissa, Greece, Papadopoulos is married to the former Susan Tepper, an attorney with the National Labor Relations Board. They live in Washington, D.C.

Dr. Jay Boris, Head of the Laboratory for Computational Physics at the Naval Research Laboratory, has won the 1978 Washington Academy of Sciences Award for scientific achievement in mathematics and computer sciences.

The award was presented at the awards dinner (March 15) at the Kenwood Country Club in Bethesda, Md. in conjunction with the commemoration of the 100th anniversary of Albert Einstein's birth.

Boris was cited for his "outstanding contributions in computational physics and numerical analysis."

Boris received his BA in physics in 1964, and his MA and PhD degrees in astrophysical sciences in 1966 and 1968



Jay Boris

from Princeton University. Throughout his academic years, his work was recognized by numerous honors and awards. In addition to being his class valedictorian in high school and an Honorary National Merit Scholar and member of the High School National Honor Society, Boris won the Kusaka Memorial Physics Prize and was graduated Magna Cum Laude. He is also a member of Phi Beta Kappa and Sigma Xi honorary societies.

Boris joined the NRL staff in 1970 as a senior research physicist in the Plasma Physics Division where he was responsible for the development of computational capabilities within the division. These include the development of large computer simulation models for nonlinear plasma physics, fluid mechanics, magnetohydrodynamics, chemically reactive flows and computational physics. Much of his present work includes consulting on plasma, fluid and computational physics projects for NRL, the Navy, DOD and the Department of Energy.

Last year, Boris was named to a Chair of Science, the most enduring recognition of scientific excellence established at NRL. Chair of Science holders are selected by the Laboratory for unique and sustained research accomplishments leading to international reputations as founders of or acknowledged leaders in a field of basic or applied science.

The NRL physicist has authored many technical papers. He received the Navy Superior Civilian Service Award in 1975, and the Arthur S. Flemming Award in 1976, for his development of new computational techniques for the numerical simulation of ionospheric and atmospheric phenomena associated with natural and man-made disturbances.

Boris lives with his wife, Elizabeth, and their sons, David and Paul, in Falls Church, Virginia.

Dr. Wayne A. Hendrickson, a biophysicist at the Naval Research Laboratory, is one of the ten recipients of the Arthur S. Flemming Award, in ceremonies held at the Capital Hilton hotel.

The Flemming Award is granted annually by the Downtown Chapter of the District of Columbia Junior Chamber of Commerce to the ten young men and women in the federal service who have performed unusual and outstanding work of distinct benefit to the government.

Dr. Hendrickson was recognized for his advancement of NRL's structural research program on complex biological molecules of great molecular weight that are of significance in the medical field. In particular, he has worked out the atomic arrangements in several oxygen carrying protein molecules.

Through Dr. Hendrickson's development of experimental and computational models of the proteins, a deeper insight has been gained into the way in which these giant molecules work. Scientists also hope to use his models of the crucial oxygen-binding sites in blood proteins as a kind of blueprint for synthesizing small molecules that can mimic the natural products. Such synthetic substitutes could eventually be used as blood supplements for treating severely anemic patients or in heart-lung machines during surgery.

Dr. Hendrickson also collaborates with his colleagues at NRL and with outside research laboratories and universities in a variety of computational projects to derive accurate atomic pictures for large biological molecules from the x-ray scattering by crystals of these molecules.

In addition to his involvement in the scientific community, Dr. Hendrickson participates in a number of activities dedicated to the improvement of the health and social welfare of the people throughout the world.

A native of Spring Valley, Wisconsin, Dr. Hendrickson obtained his BA degree at the University of Wisconsin at River Falls in 1963 and his PhD in biophysics at Johns Hopkins University in 1968, where he remained as a research associate until 1969.

In 1969 he joined the Naval Research

Laboratory as a Postdoctoral Research Associate of the National Research Council, and in 1971 was hired by the Laboratory in his present position.

Dr. Hendrickson won the Washington Academy of Sciences Award in Biological Sciences for 1975 and the Navy Meritorious Civilian Service Award for 1978. He and his wife, Gerry, and their two children, Helen Margaret and Inga Marie, live on Capitol Hill in Washington, D.C.

NEW FELLOWS

Suheil F. Abdulnur, Senior Research Scientist, Chemistry Dept., American Univ. In recognition of his contributions in the field of theoretical chemistry, particularly his work in elucidating the theoretical principles underlying the mutagenic and carcinogenic phenomena. *Sponsors*: Mary Aldridge, Leo Schubert.

Cyrus R. Creveling, Chemist, Lab. Chem NIAMDD, NIH. In recognition of his contribution to neuropharmacology and in particular his researches on the biosynthetic and degradative pathways for biogenic amines; the synthesis and mechanisms of action of the specific neurotoxic amines, 6-hydroxydopamine and 5,7-dihydroxytryptamine; and the development of methodology for the measurement of hormonally sensitive adenylate cyclase systems in preparations of rodent cortex. *Sponsors*: Mary Louise Robbins, Carleton Treadwell.

Elise A. Brandenburger Brown, Research Pharmacologist, Section on Experimental Therapeutics, NIH. In recognition of her contributions to the science of pharmacology and in particular, for comparative metabolic studies. *Sponsors*: Charles Naeser, Theodore P. Perror.

Joseph P. Hanig, Pharmacologist, FDA. In recognition of his contribution to pharmacology, and in particular his research on the enhancement of blood-brain barrier permeability to catecholamines, and the neurotoxicology of hexachlorophene and lindane. *Sponsors*: Mary Louise Robbins, Carleton Treadwell.

Martha C. Sager, Professor of Biology & Director of Environmental Systems Management Program, American University. In recognition of her contributions to increasing public knowledge of water pollution control technology through some 50 lectures throughout the U. S., and for her contribution to international understanding and cooperation in environmental resource planning management through her direction and participation in symposia in both Europe and South America. *Sponsors*: Mary H. Aldridge, Leo Schubert.

Guillermo C. Gaunaurd, Research Physicist, Naval Surface Weapons Ctr., Silver Spring, Md. In recognition of his work in Acoustics, particularly for his contribution to the development of the theory of resonant scattering and its applications to sound-absorbers for coated underwater structures. *Sponsors*: George E. Hudson, Victor C. D. Dawson.

Doris E. Hadary, Professor of Chemistry, American Univ. In recognition of her contribution to the development of a program for the teaching of art and science to blind, deaf and emotionally disturbed children in a mainstream setting. *Sponsors*: Mary Aldridge, Martha C. Sager.

Nina M. Roscher, Professor of Chemistry, American Univ. In recognition of her contributions to scholarship, to teaching, to administration, and to the promotion of women in science. *Sponsors*: Mary Aldridge, Martha Sager.

Alayne A. Adams, Research chemist, U. S. Army Mobility Equipment R&D Command, Fort Belvoir, Va. In recognition of her work in electrochemistry, particularly for the role of organic superacid electrolytes on the mechanism and kinetics of reactions on electrocatalysts and their applications in fuel cell energy conversion devices. *Sponsors*: Kurt H. Stern, Mary Aldridge.

MINUTES—BOARD OF MANAGERS

The 634th Meeting was called to order by President Aldridge on Jan. 10, 1979 in the Beaumont Conference Room at FASEB at 8:00 p.m.

1. *Minutes*: The previous minutes should have been numbered 633rd. The minutes were accepted as corrected.

2. *Treasurer's Report*: There was no report. The treasurer's report will be given at the next meeting.

3. *Membership Committee*: Two nominees for fellowship: Dr. Doris E. Hadary, American University, and Dr. Nina M. Roscher, American University, were accepted unanimously.

4. *Program Committee*: Assistance was requested for Comsat visit arrangements. Guy Hammer volunteered.

There was a general discussion of the attendance. The norm is 30–50 attendees with an occasional 100. The point was stressed that a central location, a definite time, and a published program would help increase attendance.

The program serves to attract delegates and to give coherence to the Board. G. Abraham suggested we should work more closely with the affiliates by holding joint meetings.

5. *New Business*: Meaning of Academy: There was a short discussion of the meaning of the Academy. Rita Colwell suggested that the Academy promotes discussion, thought, and exchange of ideas. She felt that there should be only two meetings a year on some chosen subject and perhaps 2 symposia. There was some discussion on behalf of more general interest subjects.

6. *Board of Managers Meetings*: Jean Boek brought up a discussion of the frequency of Board of Managers meetings. There was a general discussion in which it was argued that we did not want too many meetings but yet enough to preserve a member's sense of continuity even though he might be occasionally absent. She moved to amend the Bylaws as follows:

It is mandatory that business meetings of the Board of Managers be held in October, February, and May, and at times not in conjunction with a program meeting. Three other business meetings will be called by the President to be held immediately preceding program meetings at some time during the annual session.

The motion was seconded by G. Vila. The motion carried with one dissenting vote.

Agenda: The agenda at each business meeting should consist of:

Minutes of preceding meeting.
Reports
Old Business
New Business.

Reorganization: G. Abraham suggested that the Bylaws be changed so that the President be a well-known person assisted by a presiding executive officer. This proposal will be discussed in February.

Plans and Goals Committee: A Committee was appointed to consist of: A. Forziati, G. Irving, K. Stern, G. Vila, A. Weissler, and H. Alter.

Other Academies: G. Sherlin will summarize the activities of the other 50 academies in the U. S.

Sub-Divisions of the Academy: The sub-divisions will be discussed at the next meeting.

Dinner/Beer: The advisability of dinner/beer at the program meetings will be discussed at the next meeting.

The meeting was adjourned at 10:15 p.m.—James F. Goff, *Secretary*.

The 635th Meeting was called to order by President Aldridge on Feb. 28, 1979 at 8:00 p.m.

1. *Minutes of Last Meeting*:

The motion to specify the number and type of meetings of the Board of Managers should have been given as an amendment to the Standing Rules rather than to the By-laws.

A Plans and Goals Committee was recommended rather than appointed. A. Weissler was designated chairman.

The minutes were accepted as corrected.

2. *Announcements*:

There were no announcements.

3. *Report of the Secretary*:

It requested that the Agenda of the meetings of the Board of Managers follow the format given in the Standing Rules.

It is requested that copies of the correspondence of all committees be sent to the two secretaries and the President for their records and information.

4. *Report of the Treasurer*:

The Treasurer was not present. A sheet tabulating receipts and expenses was forwarded. This sheet has been filed in a file labeled Treasurers Reports.

Alter commented that this sheet does not show our assets. Weissler said that he was uncertain as to the disposition to the Academy's securities account. The procedures stipulated in Article IV, Section 5 of the By-laws which require both the President and Treasurer to jointly assign and endorse financial papers have not been followed.

Honig recommended that the Executive Committee meet with the Treasurer to prepare a definitive report. The Board concurred. The Executive Committee will consist of: President: Aldridge; President-elect: Weissler; Secretary: Goff; Treasurer: Rupp; Appointed: J. O'Hare, J. Wagner and M. Townsend.

The Treasurer's Report was not accepted.

5. *Reports of Standing Committees*:

Executive: No report.

Membership: Dr. Alayne A. Adams was proposed for fellowship and unanimously accepted.

Scientific Achievement: The awards for 1978 are as follows:

For Behavioral Sciences:	*Stephen M. Kerst, Catholic Univ. of America* For his creative and illuminating research on the role of visual imagery in human memory.
For Biological Sciences:	*Alfred D. Steinberg, National Institutes of Health* For concepts of the pathogenesis and treatment of systemic lupus erythematosus.
For Engineering Sciences:	*Robert E. Berger, National Bureau of Standards* For development of improved test methods to reduce head and eye injuries.
For Mathematics & Computer Sciences:	*Jay B. Boris, Naval Research Lab.* For outstanding contributions in computational physics and numerical analysis.
For Physical Sciences:	*Konstantinos Papadopoulos, Naval Research Lab.* For scientific achievements and leadership in plasma physics.

For Teaching of Science: The Leo Schubert Award for teaching of College Science	*Milton M. and Zaka I. Slawsky, Univ. of Md.* For pioneering work in the development of a highly successful physics tutoring program and for demonstrating an innovative approach to the involvement of retired scientists in the teaching of physics.
The Berenice G. Lamberton Award for teaching of High School Science	*Ronald R. Myers, T. C. Williams High School, Alexandria, Va.* For excellence in motivating and teaching ordinary students to do extraordinary work in chemistry.
	Ronald J. Smetanick, Thomas S. Wootton High School, Rockville, Md. For an outstanding teacher and humanitarian.

These awards will be presented at the next meeting in the form of citations but no speeches.

Encouragement of Science Talent: E. Shafrin reported that the Berenice G. Lamberton Science Fair Award recipient has been selected. The school will receive a plaque and the student a medallion. It was suggested that the student be given a plaque in the future.

It was moved that the WAS continue to sponsor the dinner for the Joint Board on Science and Engineering/Jr. Academy of Sciences. The motion carried.

6. *Reports of Special Committees*:

Committee on Election: The Tellers' Report was given and is on file under special committees. Elections: the following were elected for 1979–80:

President-elect:	Marjorie R. Townsend
Secretary:	James F. Goff
Treasurer:	Nelson W. Rupp
Managers-at-Large:	John J. O'Hare Michael J. Pelczar, Jr.

7. *Report of the Editor*:
There was no report.
8. *Report of the Archivist*:
There was no report.
9. *Report from the JBSEE:*
There was no report.
10. *Unfinished Business*:

Reorganization (G. Abraham) no discussion.

Other Academies (G. Sherlin) no report.

Sub-divisions of the Academy, no discussion.

Dinner/Beer, no discussion.

11. *New Business*:

Office Secretary, Ms. Ostaggi should attend meetings. The meeting was adjourned at 10:55 p.m.—James F. Goff, *Secretary*

ANNUAL REPORT OF THE TREASURER, 1978

Receipts and Income

Dues (Members and Fellows) '78 & '79	$13,760.50
Journal	
Subscriptions	5,011.25
Sale of Reprints (Reimbursements from authors)	1,566.00
Sale of Back Issues	220.34
Page Charges ($25 per pg.)	2,500.00
Investment Income	4,819.20

Reimbursements	
JBSEE (includes quarterly service charge & payment for services)	824.74
Dinners (reimbursed by members, monthly, awards and annual)	1,652.70
Grants-in-Aid (Summer Science at AU)	360.00
Miscellaneous	
Loan	4,000.00
Misc.	35.42
Total	$34,750.15
Checking Acct. bal. beg. '78	3,425.89
Total for '78	$38,176.04

Expenses and Disbursements

Journal	
Publishing cost including mailing	$ 6,540.29
Reprints (reimbursed by authors)	621.11
Honorarium to Editor	1,000.00
Operating Expenses	
Rent (Jan. thru Dec.)	2,021.28
Telephone	218.39
Supplies	24.77
FASEB Misc.	147.62
Salary	12,087.47
FICA	743.29
Personnel benefits	1,503.25
Meetings	
Arrangements (includes print, mail, computer, Xerox, Zip Codes, Board, Committees, & Gen. Office)	2,791.69
Reimbursable Items	
Dinners (reimbursable by members)	2,078.80
Services ordered by JBSEE	93.71
Grants-in-Aid (Summer Science at AU)	360.00
Miscellaneous	
Encouragement of Science Talent, Jr. Acad. '77 & '78	483.10
Contribution (memory of Mr. Detwiler)	25.00
Loan	3,338.92
Misc.	538.46
Total for '78	$34,617.15

JOURNAL OF THE WASHINGTON ACADEMY OF SCIENCES

Instructions to Contributors

General

Type manuscripts on white bond paper either 8½ by 11 or 8 by 10½ inches. Double space all lines, including those in abstracts, tables, legends, quoted matter, acknowledgments, and references cited. Number pages consecutively. Place your name and complete address in the upper right hand corner of the title page.

Title, Author, and Affiliation

Page 1 of your manuscript should contain only this information and your name and address. Choose a concise but complete and meaningful title. In research papers concerning biological subjects, include an indication of the order and family of the taxa discussed. Academic degrees will not normally be included unless the author so specifies. If possible, combine your affiliation and mailing address (including Zip) so that readers can write to you directly.

Abstract

Type on a separate sheet at the end of the manuscript. Make the abstract intelligible without reference to the text of the paper. Write an informative digest of the significant content and conclusions, not a mere description. Generally, the abstract should not exceed 3% of the text.

Footnotes

Use footnotes as sparingly as possible. Number text footnotes consecutively with Arabic numerals and type them on a separate sheet of paper at the end of the manuscript. Type table footnotes, if any, below each pertinent table on the same page.

Illustrations and Legends

The quality of all original illustrations must be high enough to facilitate good offset reproduction. They should have ample margins and be drawn on heavy stock or fastened to stiff cardboard to prevent bending. They should be proportioned to column (1 x 3) or page (2 x 3) type-dimensions, leaving space for legend material. Photographs should have a glossy finish. They reproduce best when the contrast is fairly high. Identify each illustration with number and author in light pencil marks on the reverse side. Submit all illustrations separately – please do not glue or clip them to the pages of the manuscript.

Do not type or write legends directly on the illustrations. Type legends on a separate sheet or sheets at the end of the manuscript. Indicate where you want illustrations to appear in the printed paper by writing the figure numbers lightly in the text margins, and be sure that each figure is properly referenced in the text itself. Original "art" will be returned only at the author's request and expense.

Tables

Include tables only when the same information cannot be presented economically in the text, or when a table presents the data in a more meaningful way. Consider preparing extremely complicated tabular matter in a form suitable for direct reproduction as an illustration. In such cases, the use of the typewriter is not recommended.

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Limit references within the text and in synonymies to author and year (and page if needed). In a "Reference Cited" section, list alphabetically by senior author only those papers you have included in the text. Likewise, be sure all the text references are listed. Type the "References Cited" section on a separate sheet after the last page of text. Abbreviations should follow the *USA Standard for Periodical Title Abbreviations*, Z39.5-1963.

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Send completed manuscripts and supporting material to the Academy office (see address inside front cover) in care of the Editor. Authors will be requested to read Xerox "proofs" and invited to submit reprint orders prior to publication.

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CONTENTS

Washington Academy of Sciences

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ACADEMY OFFICE

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The Journal

This journal, the official organ of the Washington Academy of Sciences, publishes historical articles, critical reviews, and scholarly scientific articles; proceedings of meetings of the Academy and its Board of Managers; and other items of interest to Academy members. The *Journal* appears four times a year (March, June, September, and December)—the September issue contains a directory of the Academy membership.

Subscription Rates

Members, fellows, and patrons in good standing receive the *Journal* without charge. Subscriptions are available on a calendar year basis only, payable in advance. Payment must be made in U.S. currency at the following rates:

U.S. and Canada	$17.00
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Single Copy Price	6.00

Single-copy price for Vol. 66, No. 1 (March, 1976) is $7.50.

Back Issues

Obtainable from the Academy office (address at bottom of opposite column): **Proceedings:** Vols. 1–13 (1898–1910) **Index:** To Vols. 1–13 of the *Proceedings* and Vols. 1–40 of the *Journal* **Journal:** Back issues, volumes, and sets (Vols. 1–62, 1911–1972) and all current issues.

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Address changes should be sent promptly to the Academy office. Such notification should show both old and new addresses and zip number.

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Philosophical Society of Washington	James F. Goff
Anthropological Society of Washington	Jean K. Boek
Biological Society of Washington	William R. Heyer
Chemical Society of Washington	JoAnne Jackson
Entomological Society of Washington	Douglas Sutherland
National Geographic Society	T. Dale Stewart
Geological Society of Washington	Marian M. Schnepfe
Medical Society of the District of Columbia	Inactive
Columbia Historical Society	Paul H. Oehser
Botanical Society of Washington	Conrad B. Link
Society of American Foresters	Thomas B. Glazebrook
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Institute of Electrical and Electronics Engineers	George Abraham
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Human Factors Society	H. McIlvaine Parsons
American Fisheries Society	Irwin M. Alperin

Delegates continue in office until new selections are made by the representative societies.

GUEST EDITORIAL

Samuel B. Detwiler, Jr.

Editor, 1960–1969

A tribute to the late Sam Detwiler for his services to the Academy is a tribute as well to all, like him, who devote themselves to learned society tasks where the main reward is the strange satisfaction that comes from doing them. But for Sam it would have been stranger still if he had not been in the vanguard of volunteers.

Sam believed in making full use of the days' hours. He finished high school in three years, elected to work full-time in Government laboratories while earning his B.S. in chemistry in evening school at The George Washington University, and managed to complete his Master's in organic chemistry at the University of Illinois while employed at the U. S. Regional Soybean Industrial Products Laboratory then in Urbana. Sandwiched in were active, continuing and often leadership roles in GW's glee club, its student newspaper and dramatics group, a professional and a social fraternity, as well as such frivolous indulgences as tennis, canoeing, and automobile trips just for the adventure of it. It's no wonder that these habits persisted post-graduation and on his return to the Washington area. Despite an important and demanding career in research administration in the U. S. Department of Agriculture, he held a number of offices in the Academy, the Chemical Society of Washington, and Alpha Chi Sigma's professional chapter and edited their journals. He was active in the American Oil Chemists' Society, the American Institute of Chemists, and the Cosmos Club, and still found time to pursue his hobbies of military history, boating, photography, music, mathematics, firearms, farming and genealogy.

To each of these tasks he brought manifold skills, a great diversity of knowledge, stoutness and earnestness, meticulous attention to accuracy and detail, and a knack for making other dedicated people enjoy working with him. He established standards of excellence for the Academy's Journal that have persisted, making it an effective medium for scientific communication and a publication of which members can be proud.

Emerson, in his essay on self-reliance, called an institution the lengthened shadow of one man. While the institution we call the Journal of the Washington Academy of Sciences has not been, of course, the work of one man alone, we can be grateful that the shadow Editor Sam Detwiler cast was a long one.

This issue of the Academy's *Journal* is dedicated to him with the deepest respect and gratitude.

—George W. Irving, Jr.

FEATURE

Neutrino Beams: A New Concept in Telecommunications

Herbert Überall

Catholic University, Washington, D. C. 20064 (Consultant, Naval Research Laboratory, Washington, D. C. 20375)

F. J. Kelly and A. W. Sáenz

Naval Research Laboratory, Washington, D. C. 20375

ABSTRACT

This paper describes the potential use of high-energy neutrino beams for telecommunication purposes—a new concept in telecommunications advanced recently. The present possibilities and future requirements of beam production, as well as possible schemes for signal reception, are outlined. The proposed system is not meant to replace present means of communication, but to fulfill special needs for which conventional telecommunication systems may prove unsuited.

Communication methods in current use are based on the propagation of acoustic and electromagnetic signals. The bulk of telecommunications is achieved by electromagnetic waves, including wire-guided and optical signals. Radio waves attain global distances by reflection from the ionosphere. Microwaves, like optical signals, only permit point-to-point communications along the line of sight, but can be made to reach larger distances by the use of relay stations, including satellite transmitters. However, they can be obstructed by physical barriers and almost none of the wave-borne signals is capable of penetrating matter to any appreciable degree, except for blue-green laser light and extremely-low-frequency electromagnetic waves which can penetrate the upper ocean depths. This latter fact is used, e.g., in the Navy's Project Seafarer, where communications with submerged submarines are attempted by means of 40 Hz ELF electromagnetic waves. (Acoustic and seismic waves also penetrate the ocean and the earth at low frequencies, but have relatively small speeds.)

Radio communications are susceptible to jamming and other types of interference, such as atmospheric noise, solar flare activity, and high-altitude nuclear explosions. In addition, wave-borne signals are often prone to interception by others besides the intended recipient, due to their wide-ranging nature.

Particle Communications

The use of particle beams for purpose of point-to-point telecommunications would constitute a step forward comparable to that from wire-guided to wireless telegraphy following the work of Hertz and Marconi in the 1880s and 1890s, insofar as it introduces the application of a new basic principle. It is, however, neither expected nor envisaged to replace conventional telecommunications systems, but may complement these by fulfilling certain specialized needs of communication in which it would be superior to present systems.

Telecommunication by means of elementary particle beams is necessarily restricted to beams of stable or sufficiently long-lived particles. Four types of stable elementary particles are known: photons, electrons, neutrinos and protons.

The electromagnetic waves employed in telecommunication can be viewed, of course, as coherent assemblies of photons with wavelengths in the radio, microwave, or optical regions. Photon beams of shorter wavelength, say x-ray photons, are strongly absorbed by matter and hence are less suitable for long-range communication. Electrons also have relatively short ranges in matter, even if their initial energies are in the GeV region [1 GeV (gigaelectron volt) = 10^9 eV (electron volts)], so that they too are less suitable. Besides interacting electromagnetically with matter as do photons and electrons, proton beams are depleted to such an extent by nuclear scattering processes in their passage through matter that they are not used for telecommunication.

Before discussing the long-distance communication potentialities of neutrinos, we consider those of the muon, the only unstable particle whose lifetime ($\sim 2 \times 10^{-6}$ sec for muons at rest) is sufficiently long to make it a realistic candidate as a long-distance communication carrier as proposed by Arnold (1). Since the muon is about 207 times heavier than the electron, its electromagnetic interaction with matter is greatly reduced and, unlike the proton, it has no strong interactions with matter. It can be shown from these facts that the useful communication range of a muon beam of tens of GeV energy is primarily determined by its decay rate in flight, provided that its path traverses mainly the rarified air of the upper atmosphere. Thus, a 100 GeV muon beam could be used to communicate over 1,000 km under favorable circumstances by exploiting the earth's magnetic field to curve the beam into such a path. At this energy, the radius of curvature of the muon beam produced by the field would be approximately equal to the earth's radius. Hence, 1,000 km is a rough upper limit for global-type muon telecommunication (without relays). Besides this drawback, muons directed through the atmosphere would constitute a radiation hazard, as would x-ray, electron, and proton beams. However, muons could furnish an alternative to microwave point-to-point communications which would function even in the presence of moderate physical barriers (a 10, 20 or 50-GeV muon penetrates a depth of 50, 100 or 250 m of water, respectively, and hence muon beams could be sent into the ocean from a satellite for communication purposes).

Neutrino Communications

There remains to discuss neutrino beams as candidates for global telecommunications (neutrinos and antineutrinos of both electron and muon type will be called "neutrinos" here). Neutrinos were postulated to explain ordinary nuclear beta decay by Pauli in 1933 and then by Fermi in 1934. Their existence was proved experimentally by Reines and Cowan in 1956. Neutrinos have no charge and zero or extremely small mass, and therefore travel at exactly or essentially the speed of light for the neutrino energies of interest here. They interact so weakly with matter that up to energies of $\lesssim 10^4$ GeV neutrino beams traversing the entire earth were predicted by Volkova and Zatsepin (2) to suffer negligible attenuation. Accordingly, neutrino beams of the kind mentioned below could provide almost instantaneous,

Table 1.—Parameters of Existing and Future High-Energy Proton Accelerators and of Their Neutrino Beams. "Tevatron" Designates the Energy-Doubled FNAL Accelerator, and the Last Column Refers to a 5 TeV Accelerator.

	Present accelerators		Future accelerators			
	FNAL	CERN	Tevatron	Serpukhov		VBA
E_p (TeV)	0.4	0.4	1	2–5		$\gtrsim 10$
ppp	2×10^{13}	10^{13}	5×10^{13}		$\sim 10^{13}$	
E_ν (GeV)	5–50	5–50	10–80		40–120	
	(20)	(20)	(35)		(80?)	
ϑ_ν (mrad)	3	3	1		0.2	

direct-line communication to any point on or below the surface of the earth, including locations that are inaccessible by any other means of telecommunications.

The largest single difficulty of such a communications scheme is caused by the property of neutrinos that gives them their extreme penetrating power: their weak interaction with matter. This property will render their reception difficult, so that for effective communications massive neutrino detectors will be necessary as well as intense, and hence well-collimated, neutrino beams. Narrowly collimated beams restrict one to point-to-point communications, but these could be made to possess a high degree of privacy and absence of message interception. Two further desirable properties of neutrinos for communication are the impossibility of blocking their propagation (in contrast to electromagnetic waves) and the fact that they do not constitute an environmental hazard (in contrast to muons).

The possibility of neutrino communication was briefly mentioned by Arnold (1) and was quantitatively analyzed in an earlier paper of Sáenz *et al.* (3). Kotzer and his associates (4) are now considering an experiment for detecting neutrinos at large distances from an accelerator source.

In the following, we shall describe briefly present and future prospects of neutrino communications as regards available neutrino sources, suitable detector arrangements, expected and required signal reception or counting rates, and possible information content of the messages to be transmitted.

Neutrino Sources.—Since according to the experiments of Barish *et al.* (5), the interaction cross section of muon neutrinos ν_μ (the type most copiously produced by high-energy accelerators) in the reaction by which they are mainly detected,

$$\nu_\mu + n \rightarrow \mu^- + \text{hadrons} \qquad (1)$$

(n = neutron, μ = muon, hadrons = strongly interacting particles), increases linearly with neutrino energy up to the highest measured energies of 200 GeV, the use of neutrinos with maximum obtainable energies is preferable for telecommunications purposes. Hence it is desirable to employ as neutrino sources accelerators such as the existing proton synchrotrons at the Fermi National Accelerator Laboratory (FNAL), Batavia, Ill., and at CERN, Geneva, Switzerland. Both of these produce proton beams of 400 GeV energy. As described e.g. by Wilson (6), the energy of the FNAL accelerator is to be raised to 1000 GeV = 1 TeV (Tera-electron volt) by 1980 and it will then be called the Tevatron. Designs for a 2–5 TeV accelerator are underway at Serpukhov, USSR, and the possibilities of a very big accelerator (VBA) of 10 TeV have been explored as described e.g. by Adams (7).

Table I shows the relevant parameters of these accelerators, the first row giving the proton energy E_p. The existing accelerators are located in a ring-shaped tunnel, with a ring radius of 1 km, and a tunnel diameter of 3 m. (This installation could easily be hardened.) At FNAL, the circulating proton beam is extracted once every eight seconds in a 20 μsec pulse of intensity $\sim 2 \times 10^{13}$ ppp (protons per pulse), which is directed into a metal target where it produces π and K mesons, as well as other hadrons. The mesons, focused in a magnetic horn, decay mainly into muons and neutrinos while passing through a 400 m tunnel. The muons are absorbed by a 1 km earth shield and in this way an essentially pure neutrino beam is obtained. Its full opening angle is $\vartheta_\nu = 3$mrad. The energy E_ν of these neutrinos is concentrated in an interval of 5–50 GeV, with a maximum located at ~ 20 GeV, the total flux being about 10^{10} neutrinos per pulse. Figure 1 shows schematically how such an accelerator could be used for neutrino telecommunications, with the dacay tunnel aimed in the desired direction for point-to-point communications, and Fig. 2 depicts the neutrino beam's traversal of the earth and reception by the detector. Note that with $\vartheta_\nu = 3$ mrad, the beam diameter is ≈ 38 km on the opposite side of the globe.

Neutrino Detectors.—The neutrino message may be received by a detector sensitive to the reaction Eq. (1). As mentioned, massive targets are required for obtaining reasonable counting rates. With the possible exception of scintillation detectors, the best detection scheme

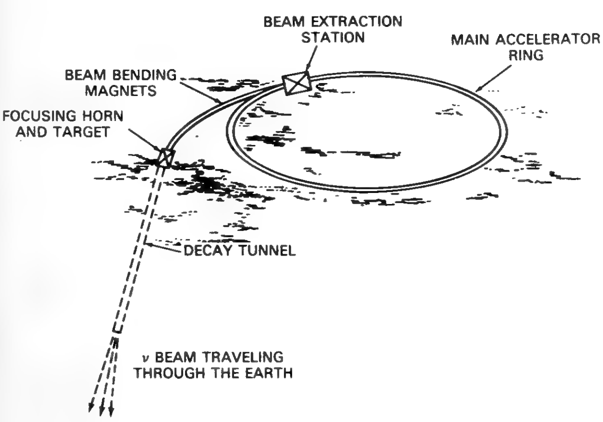

Fig. 1. Scheme for generating a neutrino beam for telecommunication.

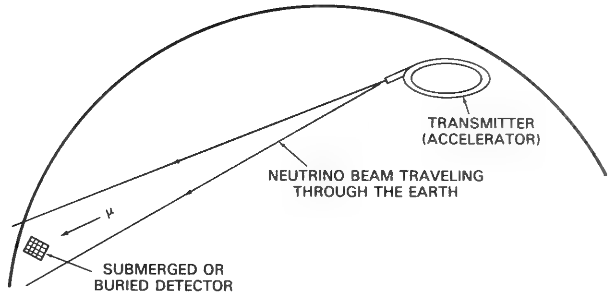

Fig. 2. Neutrino telecommunication with a submerged or buried detector.

for neutrinos in the energy range considered appears to be one proposed a number of years ago by the late C. L. Cowan and one of the present authors (8). This method consists in using a very large (10^6 tons or more) body of water (in the ocean, a deep lake, or a flooded mine) as the target as well as the detector. The muons produced in Eq. (1) which on the average carry off half of the original neutrino energy, propagate a mean distance of 50 m in the water (see above), emitting all along their path a cone of blue-green Čerenkov light of forward-opening angle 41°, at a rate of 200 or more photons per cm path length (Fig. 3). This light in turn propagates over a length of about 20 m in clear water, and can be trapped in a system of light collectors (e.g., lucite plates or rods) with attached photomultipliers which register the light flash of the muon.

Because of the limitation imposed by the short absorption length of visible light in water, we envisage a large cubic array of detector modules (Fig. 4), spaced 20 m apart from each other and perhaps consisting each of a 1 m^2 horizontal lucite plate with one (pressurized) photomultiplier attached to its upper face. [Note that as described in workshop proceedings edited by Roberts (9), an analogous detector array has also been proposed for project DUMAND (deep underwater muon and neutrino detection), designed to detect cosmic neutrinos]. In Ref. (3), it was estimated that such a detection scheme would have a muon detection efficiency of close to 100%. The effective target volume of the detector is larger than that of the array, because a

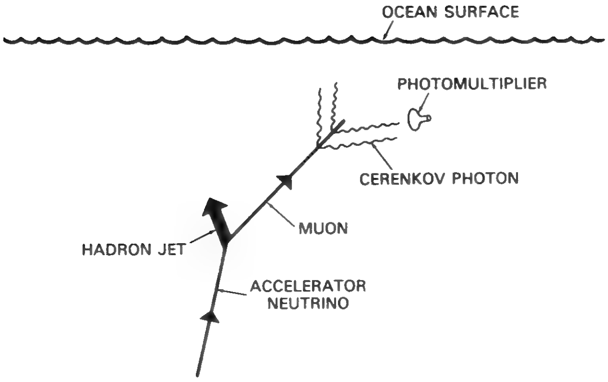

Fig. 3. Čerenkov neutrino detector.

muon produced by reaction Eq. (1) can travel a significant distance in water from its point of origin to where it can be detected by the array.

Counting Rates and Background— For a muon beam from the present FNAL accelerator, Ref. (3) gives event rates of 25 counts/hr with an 80-module (10^6 tons of water) array at a distance of 10^3 km from the source, or with an 11,400-module array (10^8 tons) at 10^4 km (which is roughly the diameter of the earth). For the Tevatron case, the latter rate was stated to increase to 2,500 counts/hr, see Sáenz *et al.* (3), but more careful estimates based on calculated neutrino flux distributions as quoted by Lach (6) raise this to $\sim 10^4$ counts/hr. Such a rate would be quite sufficient for practical neutrino communication, but could be further increased (or the detector size decreased) by additional improvements in the neutrino beam quality. (Note that accelerators specifically designed for neutrino communications should, by definition, produce neutrino beams that are better suited to this purpose than those of the general purpose research accelerators such as FNAL). Such improvements could be obtained by increasing the primary proton beam intensity, better beam collimation (which is automatic with higher proton energies), and a longer decay tunnel (factor 3 improvement by extending the tunnel from 400 m to 2 km). For example, we estimate that for an accelerator such as in the last column of Table I, with $E_p = 5$ TeV, 2×10^{13} ppp, $\vartheta_\nu = 0.2$ mrad, and a 2-km decay tunnel, even a small (10^6 ton) detector array would lead to as many as 3×10^4 events/hr at a distance of 10^4 km (where the 1.5-km diameter neutrino beam would still illuminate the detector array of about 100 m linear dimension).

Background to the signals is provided mainly by sunlight, Čerenkov light from cosmic-ray muons, and bioluminescence. Flashes of the latter origin typically last for milliseconds, and can thus be discriminated against the nanosecond Čerenkov flashes from the muons produced in the reaction of Eq. (1). On the basis of data got by Higashi and by Oster and Clarke (10), we estimated that for 10^4 signal counts/hr immersion depths of 300–400 m and 600–700 m would provide adequate shielding depths against cosmic ray muons and sunlight in the ocean, respectively (of course, sunlight could be eliminated by enclosures). With higher counting rates, the immersion depths could be correspondingly reduced.

Communications Considerations.— Although neutrinos are unique in their penetrating ability, the concepts that govern pulsed neutrino beam communications are not much different from those governing pulsed laser beam modulation, as discussed by Gagliardi or by Bar David (11). This technique for transferring information consists in placing a pulsed signal into one of a large possible

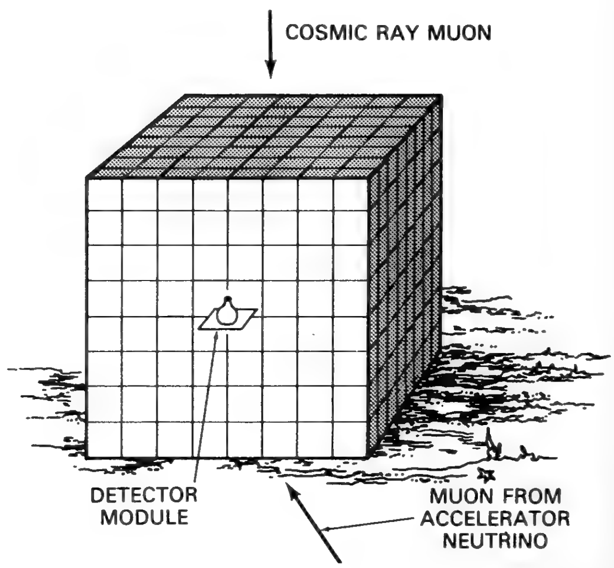

Fig. 4. Čerenkov neutrino detection array.

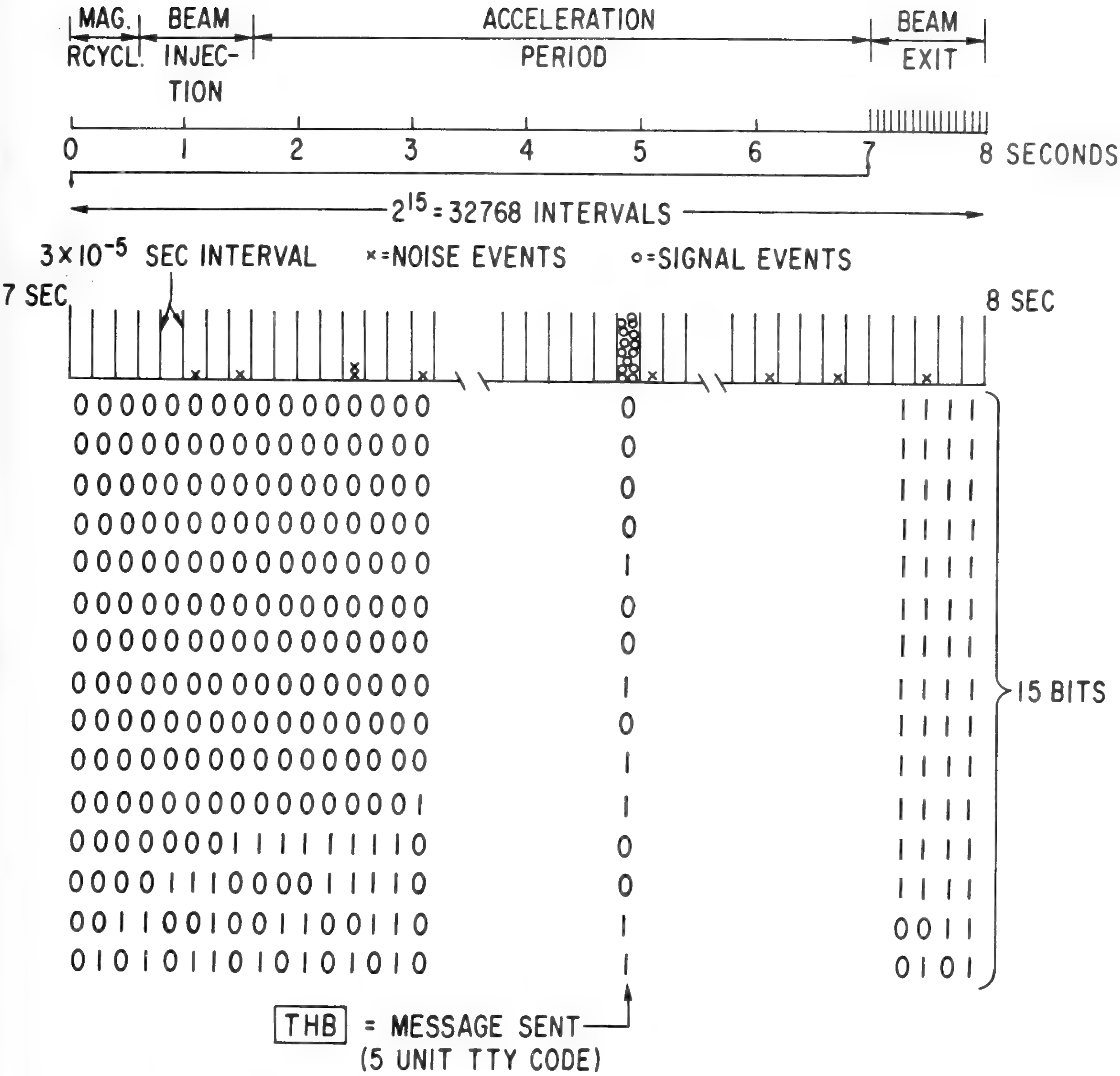

Fig. 5. Pulse position modulation: The upper portion of the figure shows the synchrotron repetition period for the systems described in the text. First there is a 6-second initial period in which the ring magnet is returned from its highest field to its initial field condition. Then the protons are injected into the synchrotron over the period of a second. The protons are accelerated to their maximum energy during the following 5.4 seconds. During some short interval between the seventh and eighth seconds the ejection of the proton beam from the synchrotron by the use of a "kicker" magnet causes neutrino events in the corresponding time interval at the detector, thereby transmitting the three letters THB in international telegraphic code.

sequence of time intervals. To show how a neutrino beam communications system could use pulse position modulation, assume that a transmitting accelerator and a receiving array have been constructed such that 10^4 neutrino events per hour (22 events per eight second cycle) may be reliably observed in the detector. Assume that the synchrotron transmitter of one km radius requires seven seconds to bring a proton beam to its maximum energy [see, e.g., Sanford (12)]. It will then take $\sim 2 \times 10^{-5}$ sec for the entire circulating beam to emerge from the accelerator ring after an internal magnetic field "kicker" is triggered.

Assume that the transmitter and receiver have synchronized clocks and that the receiver takes into account the propagation delay between the triggering of the kicker and the receipt of a neutrino pulse. After each seven second acceleration period (see Fig. 5) the transmitter is prepared to send its message. The next second may be divided into 32768 ($=2^{15}$) equal intervals of time, each of duration 3.05×10^{-5} seconds. A unique 15-bit binary message may be associated with each time interval as shown in Fig. 5. The time at which the kicker is triggered is selected according to the binary message to be sent. After the triggering event the neutrinos are generated and travel through the earth with the speed of light to the receiving array. There the neutrino pulse causes about 22 events to occur in the array during the 2×10^{-5} sec interval corresponding to the proton beam spill time. Clocks and counter electronics are arranged to decode the observed time of occurrence of these events and hence to reconstruct the 15-bit binary message. The system would then operate at a communication rate of $\sim$1.9 bits/sec of fifteen bits per eight seconds.

It should not prove difficult to construct and deploy a receiving array in which false neutrino pulse events are unlikely to arise spontaneously from the background noise. Using a simple detection algorithm which interprets the presence of eight or more events within the detector array during a 3×10^{-5} sec interval as a valid neutrino signal, the probability of message error will be less than 10^{-3} if the average single neutrino-like (false) event rate is less than 0.4 events per 3×10^{-5} sec interval or 1.3 $\times 10^{4}$ events/sec. For the above mentioned example of a 10^{8} ton water detector at 10^{4} km from the neutrino source, the latter rate could be achieved by immersion to 300 m or more, assuming that cosmic-ray muons furnish the only significant background, i.e., assuming that sunlight has been excluded by suitably covering the detector.

Conclusions

Telecommunication over global distances by means of neutrino beams is proposed as an alternative to the conventional electromagnetic-wave communication methods. Assuming the use of suitable underwater Čerenkov detectors, neutrino telecommunication is shown to approach feasibility if presently existing high-energy proton accelerators are employed as neutrino sources, and to be definitely feasible with the advent of higher-energy accelerators which are already in the design stage. Special advantages of this type of communications as compared to other types are that they could be made essentially safe from jamming and disruption as well as to furnish a high degree of privacy. The method may prove useful as a low-data link to buried or submerged receivers with which communications might otherwise be difficult.

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Portland Pozzolan Cement

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ABSTRACT

The research described herein is concerned with evaluating the effect of Portland-Pozzolan cement (American Society for Testing and Materials Designation Type 1P) as it was used for structural concrete. The use of Portland-Pozzolan cements for structural concrete has been limited due to inadequate knowledge of their performance characteristics. These performance characteristics include rate of strength development, workability, resistance to freezing and thawing, and salt scaling. This research hopes to add to the literature by indicating that Portland-Pozzolan cement may be used successfully for structural concrete.

In view of the world need to conserve natural resources, to utilize waste products, and to prepare for possible problems in the supply of Portland cements, blended cements will, at least partially, be substituted for Portland cements. Blended cements are used extensively in many countries and are increasing rapidly each year in all types of construction. Their use for structural concrete has been limited due to inadequate knowledge of their performance characteristics. These performance characteristics include rate of strength development, workability, resistance to freezing and thawing, and salt scaling. Knowledge of the factors affecting the performance of blended cements and methods of characterization of blended cements are needed to facilitate their acceptance for use in structural concrete without compromise on quality.

A blended cement is a cement in which a pozzolan (usually fly ash) is pre-blended or interground with the cement. This type of cement, Portland-Pozzolan, is designated by the American Society for Testing and Materials (ASTM) as Type 1P. The Portland-Pozzolan mixtures presently in use, in limited amounts, are not the stoichiometry optima for the chemical reactions which take place. The replacement of cement by fly ash, on an equal weight basis, varies from 0 to 30%. If the composition of the Portland-Pozzolan blend is balanced so that the potential stoichiometry of the reaction is satisfied, the engineering performance of the hardened mass may be improved.

Table 1.—Compressive Strength (7 Days).

Blended cement		Compression results (7 days)						Average	
		Specimen 1		Specimen 2		Specimen 3			
Cement	Flyash	PSI	MPa	PSI	MPa	PSI	MPa	PSI	MPa
100	0	2128	15.35	2257	15.55	2310	15.92	2265	15.61
95	5	1650	11.37	1685	11.58	1637	11.28	1657	11.41
90	10	1578	10.87	1575	10.82	1556	10.72	1570	10.82
85	15	1821	12.54	1811	12.48	1890	13.02	1841	12.68
80	20	1785	12.30	1787	12.31	1801	12.41	1791	12.34
75	25	1755	12.09	1767	12.17	1737	11.97	1753	12.08
70	30	1665	11.47	1665	11.47	1670	11.51	1667	11.48

With prospects for higher coal use in the future (due to the recent energy crisis) the use of waste material such as fly ash from coal burning will be extremely important. In the 30 years since the end of World War II, an estimated 350 million tons of fly ash have been produced in the United States alone, with an additional 650 million tons worldwide, of which only about 20% has been utilized. By the year 1980, utility coal consumption will approach 550 million tons, with resulting ash production of over 55 million tons annually in the United States. It is apparent that continued effort is desirable to develop new fly ash outlets and expand existing ones.

Fly ash as an additive in Portland cement concrete has proved satisfactory and gained wide acceptance among engineers. Data on the performance characteristics of fly ash as an additive is enormous (1–15). The data on the optimization and performance characteristics of blended cements (Type 1P) is minimal. Additional data is needed such that blended cements may become as readily acceptable as the Portland cement-fly ash additive types.

In order to provide solutions to these problems, the following areas were studied:

1. The optimization of the Portland-Pozzolan blend (Type 1P) by balancing the stoichiometry of the reaction.
2. The determination of the factors affecting the performance of concretes made from mixtures of the Portland-Pozzolan blend (Type 1P), in relation to the needs of structural concrete. Performance characteristics considered include rate of strength development, workability, resistance to freezing and thawing, and salt scaling.

Table 2.—Compressive Strength (14 Days).

Blended cement		Compression results (14 days)						Average	
		Specimen 1		Specimen 2		Specimen 3			
Cement	Flyash	PSI	MPa	PSI	MPa	PSI	MPa	PSI	MPa
100	0	2710	18.67	2700	18.61	2695	18.60	2702	18.63
95	5	2100	14.47	2098	14.50	2110	14.54	2103	14.50
90	10	1887	13.00	1928	13.30	1875	12.95	1897	13.08
85	15	2690	18.53	2715	18.60	2720	18.74	2708	18.62
80	20	2400	16.54	2395	16.54	2387	16.47	2394	16.52
75	25	2350	16.19	2347	16.19	2370	16.33	2356	16.24
70	30	2057	14.19	2065	14.26	2047	14.12	2056	14.19

Table 3.—Compressive Strength (28 Days).

Blended cement		Compression results (28 days) Specimen 1		Specimen 2		Specimen 3		Average	
Cement	Flyash	PSI	MPa	PSI	MPa	PSI	MPa	PSI	MPa
100	0	3041	20.97	3112	21.43	3041	20.95	3065	21.12
95	5	2300	15.86	2285	15.74	2310	15.92	2298	15.84
90	10	2122	14.63	2192	15.09	2051	14.12	2122	14.61
85	15	3112	21.46	3183	21.91	3147	21.70	3147	21.69
80	20	2678	18.46	2758	19.02	2829	19.50	2765	18.99
75	25	2600	17.91	2758	19.02	2758	19.02	2705	18.65
70	30	2334	16.09	2546	17.57	2546	17.57	2475	17.08

Experimental Design

A total of 168 standard size cylinders (63) and beams (105) was made and cured in accordance with ASTM C 192-69; Making and Curing Test Specimens in the Laboratory. All concrete was approximately 3000 lbs/in.[2] (20 MPa) structural concrete. Except for the Portland cement-fly ash ratio, all other factors remained the same in the concrete mix design. The fly ash (of a type which met ASTM standards) was interground with Type 1 Portland cement and replaced the cement in increments of 5% by weight from zero to 30% for a total of 7 mixtures. A series of 4 tests was performed on the concrete cylinders and beams as follows:

1. ASTM C39: Test for Compressive Strength of Concrete Cylinders
2. ASTM C78: Test for Flexural Strength of Concrete
3. ASTM C290: Test for Resistance of Concrete Specimens to Rapid Freezing and Thawing in Water
4. Resistance to Salt Scaling: Details of this test will be presented further on in the article.

In test series one, 3 concrete cylinders of each mix proportion were tested in compression at 7, 14, and 28 days for a total of 63 specimens. In test series two, 3 concrete beams of each mix proportion were tested in flexure at 7, 14, and 28 days for a total of 63 specimens. Test series three consisted of testing 3 concrete beams of each mix proportion for a total of 21 specimens in a standard freezing and thawing apparatus. The temperature in a 4-hour period will vary from a minus 10°F (−23°C) to a positive 40°F (4.4°C) such that six (6) cycles a day would be accomplished. The final test

Table 4.—Flexural Strength (7 Days).

Blended cement		Flexure (7 days) Specimen 1		Specimen 2		Specimen 3		Average	
Cement	Flyash	PSI	MPa	PSI	MPa	PSI	MPa	PSI	MPa
100	0	584	4.02	587	4.04	593	4.07	588	4.05
95	5	397	2.74	395	2.72	390	2.69	394	2.71
90	10	367	2.53	371	2.56	363	2.50	367	2.53
85	15	395	2.72	400	2.76	408	2.81	401	2.76
80	20	384	2.65	397	2.74	410	2.82	397	2.74
75	25	349	2.40	354	2.44	350	2.41	351	2.42
70	30	300	2.07	301	2.07	302	2.07	301	2.07

Table 5.—Flexural Strength (14 Days).

Blended cement		Flexure (14 days) Specimen 1		Specimen 2		Specimen 3		Average	
Cement	Flyash	PSI	MPa	PSI	MPa	PSI	MPa	PSI	MPa
100	0	698	4.81	699	4.82	676	4.66	691	4.75
95	5	624	4.30	633	4.36	633	4.36	630	4.34
90	10	605	4.17	612	4.22	613	4.22	610	4.20
85	15	694	4.78	671	4.62	699	4.82	688	4.74
80	20	513	3.53	524	3.61	583	4.02	540	3.72
75	25	499	3.44	517	3.56	526	3.62	514	3.54
70	30	487	3.36	503	3.47	489	3.37	493	3.40

series, resistance to salt scaling was performed as follows:

> The top surface of 3 concrete beams for each mix proportion for a total of 21 specimens was covered with ¼ in. (6.4 mm) water in the standard freezing and thawing apparatus. Once the water had frozen and the thawing cycle began, flake calcium chloride was applied to the ice in an amount equivalent to 2.4 pounds/yard^2 (1.3 kg/m^2) of surface area (which simulates actual conditions).

The beams were subjected to this procedure daily. Visual examinations were made at regular periods and numerical ratings assigned.

Results

The results of the above-mentioned 4 tests are shown in tabular and/or graphical form. Tables 1–3 are the results of the Compressive Strength of Concrete Cylinders (ASTM C39: Tests for Compressive Strength of Concrete Cylinders) after curing for 7, 14, and 28 days. Tables 4–6 are the results of the Flexural Strength of Concrete Beams (ASTM C78: Tests for Flexural Strength of Concrete) after curing for 7, 14, and 28 days. Figures 1 and 2 show a graphical result of both the compression and flexural results.

It becomes obvious that, in the early stages of development, concrete made without fly ash (Type 1) surpasses that made with fly ash (Type 1P). However, at 14 days, concrete made with Type 1 cement and Type 1P cement (85% cement and 15% fly ash) showed relatively the same strength. Further, at 28 days, concrete made with Type 1P cement (85% cement and 15% fly ash) surpassed strength-wise concrete made with Type 1 cement.

Similar results were obtained for the Flexural Strength of Concrete Beams tested at 7, 14, and 28 days.

The results of test for Freezing and

Table 6.—Flexural Strength (28 Days).

Blended cement		Flexure (28 days) Specimen 1		Specimen 2		Specimen 3		Average	
Cement	Flyash	PSI	MPa	PSI	MPa	PSI	MPa	PSI	MPa
100	0	797	5.49	804	5.51	850	5.86	817	5.65
95	5	761	5.24	745	5.13	744	5.10	750	5.17
90	10	715	4.93	740	5.10	744	5.10	733	5.05
85	15	834	5.75	823	5.67	812	5.58	823	5.66
80	20	657	4.53	682	4.70	686	4.73	675	4.69
75	25	597	4.11	601	4.13	602	4.13	600	4.13
70	30	529	3.64	538	3.72	532	3.67	533	3.65

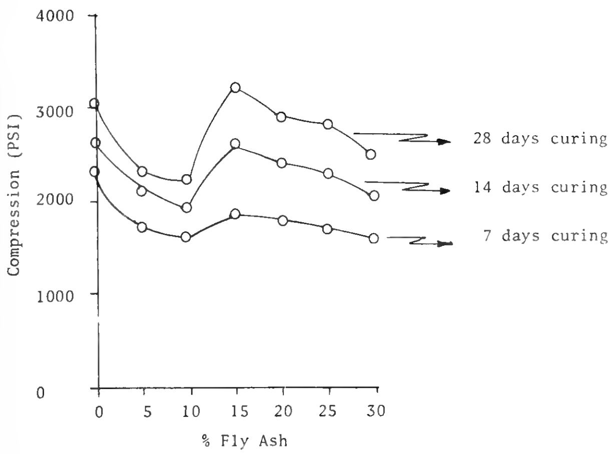

Fig. 1. Comparison of compressive strength results.

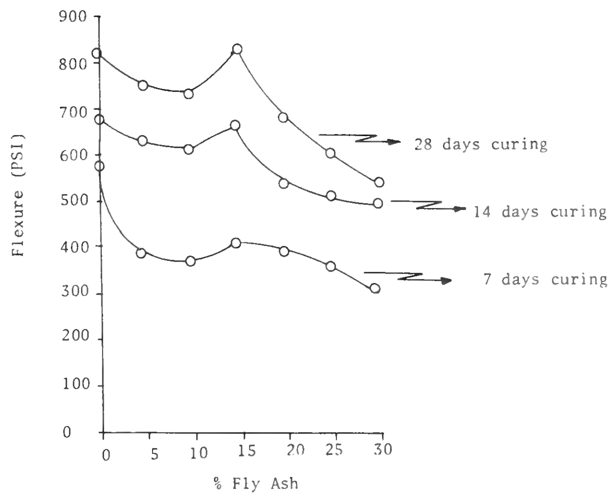

Fig. 2. Comparison of flexural strength results.

Thawing of Concrete Beams (ASTM C290: Test for Resistance of Concrete Specimens to Rapid Freezing and Thawing in Water) are shown in Tables 7, 8, and 9, which show the Young's Modulus of Elasticity in the transverse and longitudinal direction and the dynamic modulus of rigidity. Again in reviewing these results, concrete made with Type 1 cement and Type 1P cement (85% cement and 15% fly ash) showed relatively the same capacity and/or requirements.

In the final test, Resistance to Salt Scaling, the concrete made with Type 1 cement and Type 1P cement (85% cement and 15% fly ash) proved to be of satis-

Table 7.—Dynamic Young's Modulus, Transverse (lbs/in^2 × 10^6).

Blended cement						
Cement	Flyash	Zero cycles	30 cycles	60 cycles	90 cycles	120 cycles
100	0	6.13	2.26	1.59	0.92	—
100	0	6.17	1.27	0.95	0.63	—
100	0	6.69	0.69	0.51	0.42	—
95	5	6.88	0.90	0.68	0.47	—
95	5	6.92	0.46	0.23	0.54	—
95	5	7.02	0.77	0.50	0.51	—
90	10	6.29	1.75	0.88	—	—
90	10	6.85	1.78	0.83	—	—
90	10	6.67	—	—	—	—
85	15	6.41	3.76	2.20	0.64	0.39
85	15	6.71	3.99	2.78	0.67	0.08
85	15	7.10	4.89	2.81	—	—
80	20	6.66	0.96	0.70	0.46	—
80	20	6.56	1.07	0.54	—	—
80	20	6.47	1.09	0.61	—	—
75	25	6.32	0.65	0.39	0.13	—
75	25	5.79	0.65	0.33	—	—
75	25	4.82	0.67	0.39	—	—
70	30	5.82	0.30	0.15	0.14	—
70	30	5.89	0.71	0.43	—	—
70	30	6.03	0.71	0.45	—	—

Table 8.—Dynamic Young's Modulus, Longitudinal (lbs/in^2 × 10^6).

Blended cement						
Cement	Flyash	Zero cycles	30 cycles	60 cycles	90 cycles	120 cycles
100	0	0.94	0.36	0.10	0.12	—
100	0	0.96	0.33	0.11	0.11	—
100	0	0.98	0.20	0.09	0.12	—
95	5	1.01	0.28	0.17	0.05	—
95	5	0.99	0.37	0.23	0.05	—
95	5	1.00	0.63	0.32	0.06	—
90	10	1.00	0.22	0.11	—	—
90	10	0.97	0.40	0.23	—	—
90	10	0.98	—	—	—	—
85	15	0.95	0.58	0.45	0.31	0.62
85	15	0.96	0.64	0.49	0.38	0.61
85	15	0.98	0.77	0.58	—	—
80	20	0.91	0.27	0.32	0.36	—
80	20	0.90	0.22	0.25	—	—
80	20	0.91	0.19	0.10	—	—
75	25	0.86	0.21	0.13	0.05	—
75	25	0.88	0.23	0.12	—	—
75	25	0.93	0.25	0.12	—	—
70	30	0.85	0.11	0.06	0.06	—
70	30	0.86	0.12	0.08	—	—
70	30	0.88	0.13	0.10	—	—

Table 9.—Dynamic Modulus, of Rigidity (lbs/in^2 × 10^6).

Blended cement						
Cement	Flyash	Zero cycles	30 cycles	60 cycles	90 cycles	120 cycles
100	0	2.64	0.47	0.43	0.34	—
100	0	2.64	0.49	0.37	0.21	—
100	0	2.65	0.53	0.44	0.21	—
95	5	2.85	0.16	0.10	0.05	—
95	5	2.86	0.16	0.12	0.03	—
95	5	2.84	0.16	0.13	0.08	—
90	10	2.58	0.32	0.20	—	—
90	10	2.68	0.31	0.14	—	—
90	10	2.78	—	—	—	—
85	15	2.60	0.71	0.47	0.39	0.31
85	15	2.65	0.95	0.49	0.49	0.35
85	15	2.70	0.80	0.48	—	—
80	20	2.65	0.35	0.21	0.07	—
80	20	2.56	0.39	0.20	—	—
80	20	2.61	0.38	0.21	—	—
75	25	2.53	0.16	0.10	0.03	—
75	25	2.55	0.13	0.07	—	—
75	25	2.58	0.13	0.08	—	—
70	30	2.45	0.03	0.02	0.01	—
70	30	2.46	0.05	0.03	—	—
70	30	2.47	0.03	0.01	—	—

Table 10.—Results of Deicer Scaling Tests.

Blended cement		Scale rating						
Cement	Flyash	Zero cycles	30 cycles	60 cycles	90 cycles	120 cycles	150 cycles	200 cycles
100	0	0	1	1	1	1	1	1
100	0	0	1	1	2	2	2	2
100	0	0	1	1	1	1	1	1
95	5	0	1	2	3	4	5	—
95	5	0	2	3	4	5	6	—
95	5	0	1	2	3	3	4	—
90	10	0	2	3	4	5	5	—
90	10	0	2	3	4	5	5	—
90	10	0	2	2	3	4	5	—
85	15	0	1	1	2	2	2	2
85	15	0	1	1	1	1	1	1
85	15	0	1	2	1	1	1	1
80	20	0	2	3	4	5	5	—
80	20	0	1	2	3	4	5	—
80	20	0	1	2	3	4	5	—
75	25	0	2	3	4	5	5	—
75	25	0	2	2	3	4	5	—
75	25	0	2	3	4	5	5	—
70	30	0	2	3	4	5	5	—
70	30	0	2	2	3	4	5	—
70	30	0	1	2	2	3	4	—

Where: 0 = Scaling
1 = Slight Scaling
2 = Slight to Moderate Scaling
3 = Moderate Scaling
4 = Moderate to Severe Scaling
5 = Severe Scaling

factory performance when compared as shown in Table 10.

Conclusions

1. The Pozzolan fly ash proved to be a satisfactory cement replacement as a Type 1P cement (85% cement and 15% fly ash).
2. Type 1P cement (85% cement and 15% fly ash) can be used successfully in place of Type 1 provided that the concrete is allowed to cure at least 14 days.
3. No difference in workability was noticed in a comparison of all batches.
4. Type 1P cement (85% cement and 15% fly ash) was the only mix design portion that proved satisfactory. Any lesser or greater portion of fly ash would have additional results.

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The Status of Rhizoecus amorphophalli *Betram, a Little-Known Oriental Mealybug (Homoptera: Pseudococcidae)*

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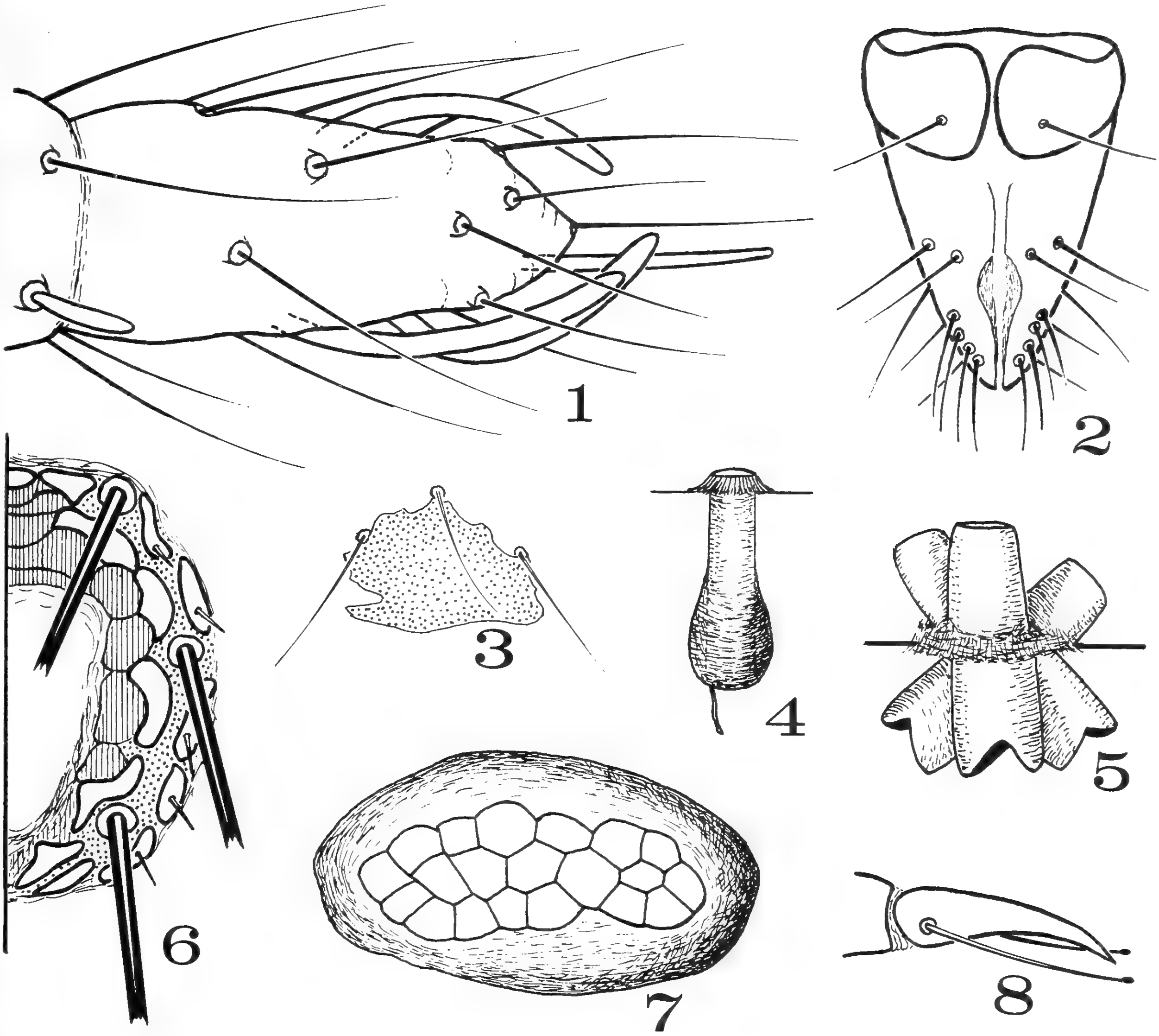
ABSTRACT

Rhizoecus amorphophalli Betram, originally described from Java, is widely distributed in the Pacific area. Comparison of the types with material from Hawaii, India and the Philippines reveals no morphological differences. *Rhizoecus advenus* Beardsley from Hawaii and Micronesia is considered a junior synonym of *Rhizoecus amorphophalli.* The latter is redescribed, illustrated, and a lectotype designated.

Betram (1940) described *Rhizoecus amorphophalli* from Java. In 1946, I transferred the species to *Ripersiella* Tinsley, a genus later synonymized with *Rhizoecus* (Hambleton, 1974). No further mention was made of *R. amorphophalli* until Beardsley (1966) compared it with *Rhizoecus advenus* Beardsley from Hawaii and Micronesia, indicating that they may eventually be synonyms.

A comparison of 5 paratypes of *R. advenus* with the syntypes of *R. amorphophalli* reveals no major diagnostic differences in their morphology. The minor differences in the size of cerores and number of multilocular disk pores that were noted are normal variations in a species. Specimens from India and the Philippines were identical with the syntypes of *R. amorphophalli*, except for size. According to Beardsley (op cit.), *R. advenus* possesses a single circulus on abdominal segment IV and occasionally has a small circulus on segment V. Of 31 specimens examined during this study, 24 possessed 2 circuli. Invariably the circulus on segment V is smaller. For these reasons, *R. advenus* is here considered a junior synonym of *R. amorphophalli.*

This species is widely distributed in the



Figs. 1–8. *Rhizoecus amorphophalli*, female, 1, terminal segments of antenna; 2, rostrum; 3, cephalic plate; 4, tubular duct; 5, tritubular ceroris; 6, anal ring, right half; 7, circulus; 8, hind claw.

Oriental Region and probably was transported by man on roots and tubers of various economically important food plants.

Rhizoecus amorphophalli **Betram**
Figs. 1–8

Rhizoecus amorphophalli Betram, 1940:267.
Ripersiella amorphophalli: Hambleton, 1946:61.
Rhizoecus advenus Beardsley, 1966:468. New **synonymy.**

Adult female: Broadly ovate. Length, 1.48–1.73 mm; width, 0.73–0.93 mm. Antennae 6-segmented, broadly separated, average length of segments in microns: I, 33; II, 23; III, 33; IV, 18; V, 17: VI, 42; apical segment about twice as long as wide, with 3 moderately stout sensory setae and 1 spinelike sensory seta; segment V with 1 short, small sensory seta. Interantennal space equal to combined length of segments IV–VI. Eyes small, pigmented, about 10μ in diameter. Rostrum of medium size, 63μ long, 50μ wide; rostral loop extending to or slightly beyond 2nd coxae. Cephalic plate irregularly triangulate, 20μ long, 30μ wide, with 3 prominent body setae on its periphery. Dorsal ostioles strongly sclerotized.

Legs small, average length of segments of hind pair in microns: Trochanter, 40; femur, 91; tibia, 81; tarsus, 53; claw, 17; claw digitules elongate, dilated at extremities, extending beyond claws.

Normally with 2 stout, truncate, strongly sclerotized circuli, the larger on abdominal segment IV averaging about 20μ long, 30μ wide, one on segment V smaller, sometimes absent, averaging 15μ long, 21μ wide, both prominently reticulated. Anal lobes weakly developed, unsclerotized, with 3 elongate setae, longest about 60μ long, trilocular pores usually crowded at their bases. Anal ring small, 35μ in diameter, its setae 50–58μ long; outer portion of anal ring with 12–14 elongate oval to sinuate cells, with spicules; inner portion of ring with 10 much larger, irregularly shaped cells adjacent to a series of globular, darkened cells. Tritubular cerores of 2 sizes, their ducts short, stout, bifurcate at bases, maximum length about 7μ, evenly distributed, varying between 117–140, larger size more abundant dorsally, smaller size occurring on both surfaces. Multilocular disk pores confined to venter of abdominal segments VII–IX, 13–23 borne transversly along posterior margin of segment VII, 27–42 occurring on VIII and IX. Tubular ducts elongate, with broadly rounded sclerotized bases, length about 6μ, widely distributed on both surfaces over entire body; more common ventrally, 5–7 per segment. Trilocular pores almost circular in outline, more abundant dorsally, sparse around legs and intersegmentally. Body setae variable in size, longest on venter about 25μ, shorter and finer on dorsum, about 15μ long.

Lectotype female—From 3 syntypes on slide No. 1, remounted in 1978, I designate the adult female on the extreme right as lectotype. The slide labeled as follows: "*Amorphophalus* I '38, Bogar. leg. Bot. A. P. L., CCV 1290, *Rhizoecus amorphophalli* det. Betram" is to be deposited in the Agricultural Experiment Station, Bogar. *Paralectotypes*: 10 on 3 slides taken with lectotype, and 8 newly mounted females from original preserved type material, 6 in Rijksmuseum van Natuurlijke Historie, Leiden, Netherlands and 2 in U. S. National Museum, Washington, D. C.

Specimens Examined.—In addition to the type material from Bogar, the following specimens were examined: 5 paratypes of *Rhizoecus advenus* Beardsley, Honolulu, Hawaii, 27-VIII-1959, J. W. Beardsley, 2 ♀♀, intercepted at Washington, D. C. from Java, 6-III-1925, W. V. Reed 9 ♀♀ intercepted at Los Angeles, Calif., 30-V-1973 from the Philippines, J. R. Davidson, 6 ♀♀ intercepted at New York from India, 29-VI-1976, D. Femiano.

Host Plants.–*Amorphophallus variabilis, Colocasia esculenta* (Araceae), *Cordyline terminalis* (Agavaceae), *Curcuma longa, Kaempferia galanga* (Zingiberaceae).

Distribution.—Caroline Island (Truk), Hawaii, India, Java, Philippines.

Acknowledgments

I am very grateful to Dr. P .H. van Doesburg, Rijksmuseum van Natuurlijke Historie, Leiden, and Dr. J. G. Betram, Deventer, Netherlands, for their assistance in securing and making available the type specimens of *Rhizoecus amorphophalli*. I thank Richard Wilkey, Arthropod Slide Mounts, Bluffton, Indiana for remounting the type material.

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Annual Variation in Larval Amphibian Populations Within a Temperate Pond

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ABSTRACT

This study reports the results of a four year monitoring program of larval amphibians from a single pond located in the eastern United States. Striking year to year population variation occurred in terms of (1) population size, (2) larval recruitment, and (3) habitat use. The present data base precludes isolation of cause and effect relationships in the population dynamics of larval populations. Any given kind of larval amphibian population variation is the simultaneous interactive result of several causes.

Basic to an understanding of the functioning and dynamics of amphibian communities is a knowledge of the kinds and intensities of year-to-year variation in larval populations. Surprisingly, little basic information is available for larval amphibian communities. Most studies of variations in amphibian life history patterns have focused on the adult phase, treating the larval phase as a kind of "black box." The number of quantitative studies analyzing larval population dynamics at the community level can be counted on the fingers of one hand. The most important of these studies is from a two-species amphibian community in British Columbia, Canada (Calef, 1973). The present study was undertaken with the purpose of gathering basic information on year-to-year variability in larval populations from a diverse temperate amphibian community.

The results of a four-year monitoring program of larval amphibians from a single pond located in the coastal plains of Maryland are reported herein. The study site is a large pond which rarely dries up completely. Data from the first two years have been analyzed previously with respect to habitat partitioning (Heyer, 1976). The patterns of larval occurrence of growth stages and microhabitat overlap are similar for all years of the study and are not dealt with further (see Heyer, 1976, for first two year's results).

Methods and Materials

Minimum and maximum daily temperatures and daily rainfall were taken from records kept by the Environmental Sciences Program of the Smithsonian Institution at the Chesapeake Bay Center for Environmental Studies, near Edgewater, Anne Arundel County, Maryland. Pond water temperatures were recorded when weekly samples of larval amphibians were taken through the spring, terminating at the end of June for four successive years. Three dipnet sweeps were taken each week during the sampling period: a surface, midwater, and bottom sample. The pond, together with details on how the sweeps were taken and the disposition of the larval samples through identification, are described elsewhere (Heyer, 1976). The basic data set analyzed herein consists of the numbers of larvae of the species taken in each sweep sample each week. The raw data comprise an adjunct appendix which is available from the author on request. This data set is supplemented with field notes recorded each week during the sampling period.

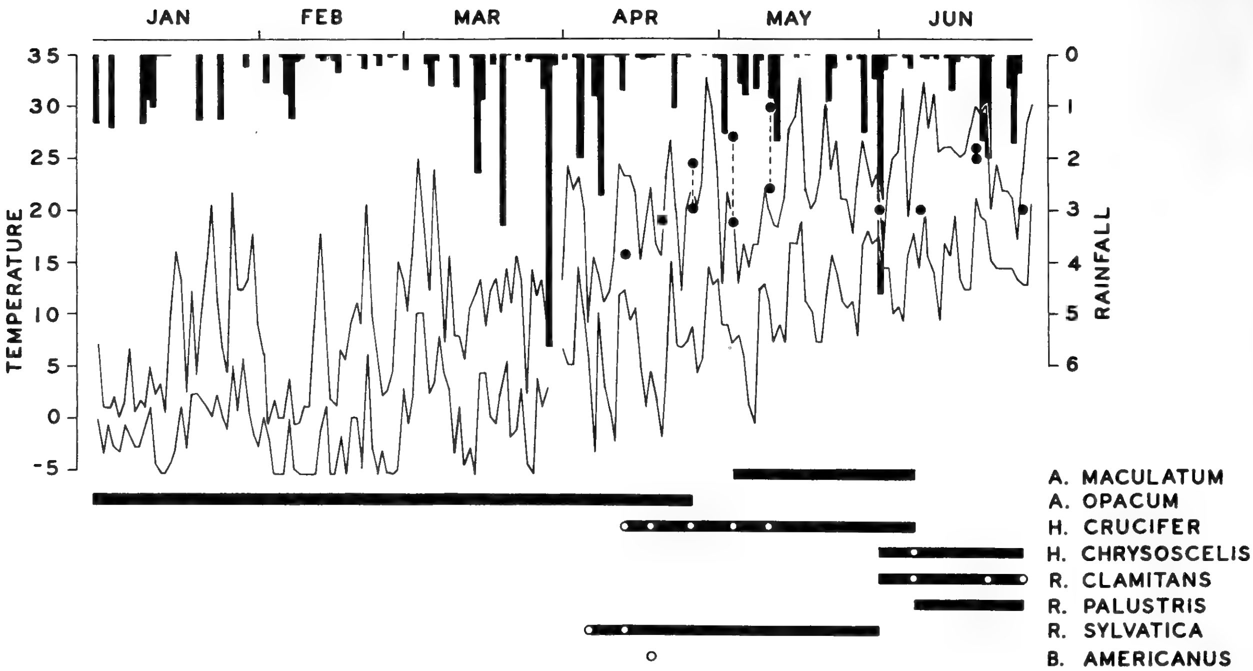

Fig. 1. Climatic and larval occurrence patterns for the first 180 days of 1974. Rainfall in cm, maximum and minimum temperatures in degrees Celsius. Solid circles equal surface water temperatures taken in shade and sun, afternoon readings. If only a single water temperature, sky was overcast. Dark horizontal bars equal presence of free swimming larvae captured in nets. Presence of *A. opacum* assumed from 1 January to first sampling date. Open circles equal presence of eggs, hatchlings, or Gosner (1960) stage 25 or 26 tadpoles and represent larval recruitment (data not gathered for salamanders).

Results of the four-year study differ slightly from results of the previous two-year study (Heyer, 1976) for three reasons. The first is that *Rana palustris* larvae were not identified until the third year's sample was being processed. In the previous report, the *Rana clamitans* samples contained *Rana palustris*. The earlier collections were re-examined and identifications were corrected for the present study. Second, a single sample of 296 *Bufo americanus* larvae which had just hatched from their egg string was included in the previous analysis. These are excluded from this study as they represent data on egg placement rather than larval habitat use. Third, *Acris crepitans* was not analyzed as the species was taken rarely in the pond (data are included in the total numbers of larvae category as used in the niche breadth measures, however).

Results and Analyses

Climate, Larval Occurrence, and Numbers of Individuals.—Figures 1–4 show the relationship of the climate parameters of temperature and rainfall with occurrence of eggs, recently hatched larvae and older larvae. Recently hatched larvae (Gosner, 1960, stages 25–26) are included to provide information on population recruitment.

The numbers of larvae sampled each year are presented in Table 1. Because sampling techniques were the same over the four-year period, the numbers of larvae sampled reflect changes in population size over the four years.

It is clear that several biotic and abiotic factors varied during the four-year study. There was considerable variation in the intensity of winter cold conditions, in the timing and intensity of warming trends in the spring, and in the amount and distribution of rainfall. The time that larval populations were in the pond varied from year to year, as did the length of the larval recruitment period for those species with a long breeding season (e.g., *Hyla crucifer*), and the total larval biomass.

Particular weather patterns unques-

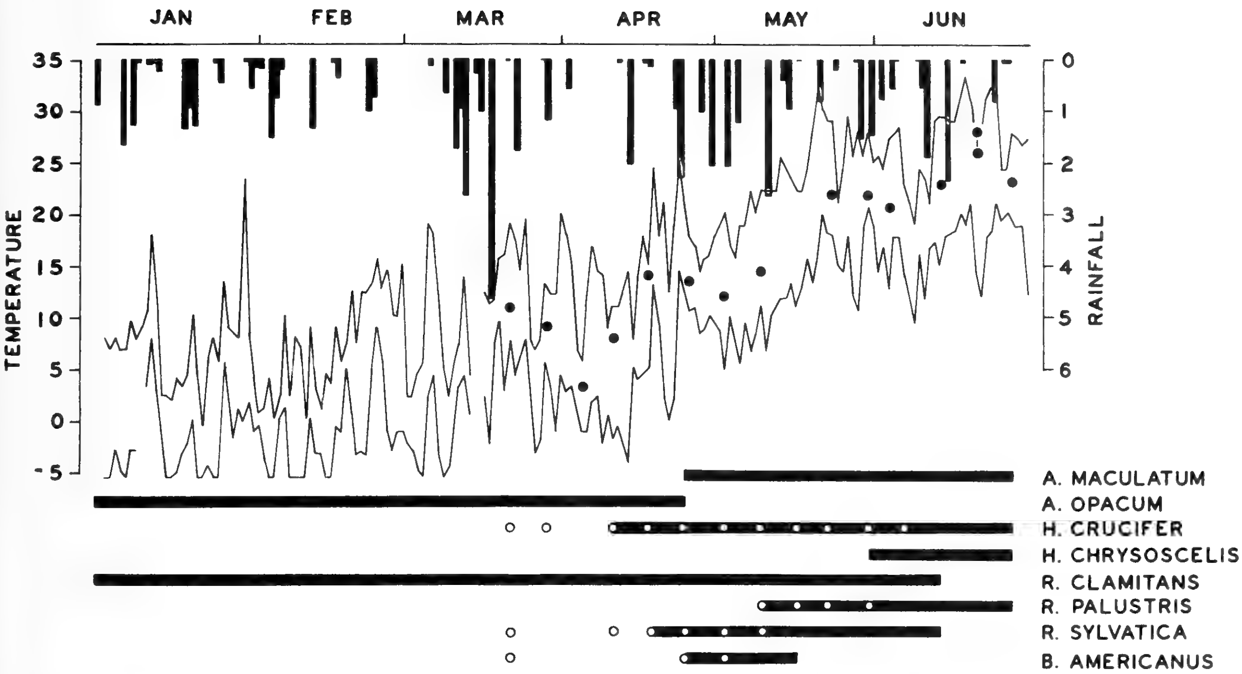

Fig. 2. Climatic and larval occurrence patterns for the first 180 days of 1975. Legend as for Fig. 1 except water temperatures taken in morning; presence of *A. opacum* and *R. clamitans* assumed from 1 January to first sampling period.

tionably account for two instances of larval dynamics. The extremely cold winter of 1977 killed all overwintering *Ambystoma opacum* larvae and greatly reduced the population of overwintering *Rana clamitans* larvae. Keith Berven (pers. comm.) found many *Rana clamitans* larvae trapped in ice on the pond in the early spring of 1977. Other weather patterns may account for variations in other larval populations (e.g., *Rana sylvatica*), but other relationships are not as clear or obvious as those discussed for *Ambystoma opacum* and *Rana clamitans*. Certain other probable cause-and-effect relationships are discussed below.

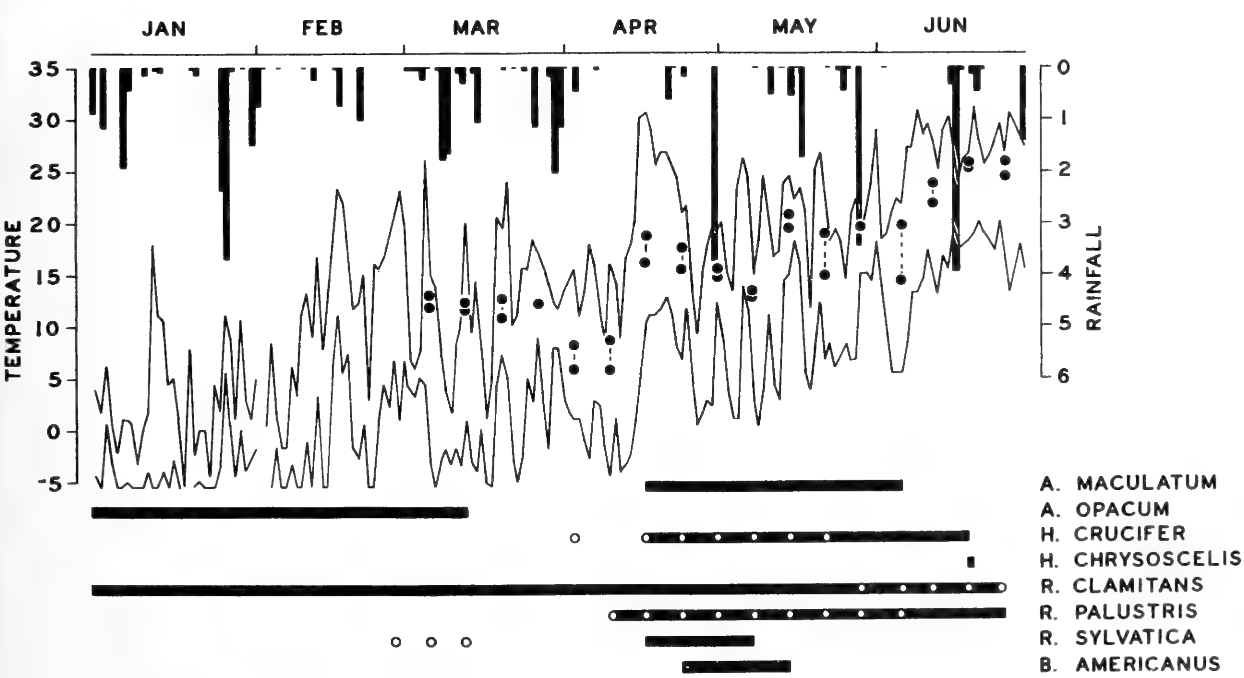

Fig. 3. Climatic and larval occurrence patterns for the first 180 days of 1976. Legend as for Fig. 2.

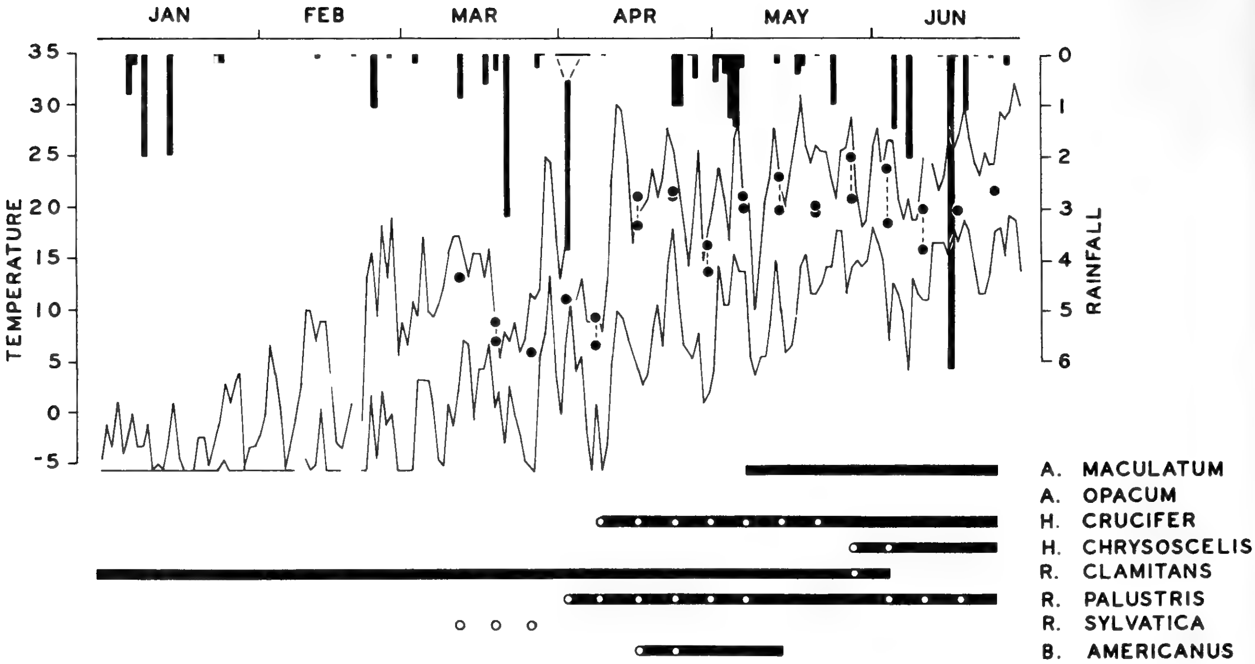

Fig. 4. Climatic and larval occurrence patterns for the first 180 days of 1977. Legend as for Fig. 2 except rainfall for first five days of April combined; presence of *R. clamitans* assumed from 1 January to first sampling date.

Habitat Use.–Larval Distribution in Sweep Types.—Individual species of larvae are not equally distributed among sweep types (Table 2). The three sweep types sampled different microhabitats within the pond. The unequal distribution of larvae among sweep types reflects habitat partitioning by the larvae (also see Heyer, 1976).

Microhabitat Breadth.—Another mode of habitat utilization concerns distribution across all microhabitants in the pond. The basic information statistic commonly used to compare species use of a habitat is the formula for niche breadth:

$$B_j = \sum_i p_{ij}^2,$$

where B_j is habitat breadth and p_{ij} is the proportion of occurrence of species j in sweep i (modified from Levins, 1968).

The habitat breadths calculated from the summarized sweep data of Table 2 are presented in Table 3. The resultant values (Table 3) give an overview of how the three microhabitats (three sweep types) were used from year to year by the entire species assemblage. Most of the species used little of the sampled habitat, but a few species used much of the sampled habitat. Considerable year to year variation occurs among the three sweep types.

In summary, three kinds of year to year larval populational variation account for the variation discussed and documented above. These, ranked in what are believed to be the decreasing order of importance are:

1) Population size. Variation in the number of larvae of each species from year to year.

Table 1.—Numbers of Larvae Sampled.

	1974	1975	1976	1977
A. maculatum	17	134	80	20
A. opacum	12	4	10	0
H. chrysoscelis	26	26	2	21
H. crucifer	634	1884	1295	754
R. clamitans	12	58	60	20
R. palustris	2	107	488	377
R. sylvatica	191	79	5	0
B. americanus	0	480	345	86
Totals	884	2790	2285	1284

2) Larval recruitment. Variation in the time at which hatchlings are incorporated into the populations, as well as how many times they are incorporated each year.

3) Habitat use. The differential utilization of microhabitats by each species from year to year.

Table 2.—Total Numbers of Larvae Sampled by Sweep Type.

	S	M	B	X^2
A. maculatum				
1974	11	2	4	7.88*
1975	59	28	47	10.94**
1976	48	27	5	34.68***
1977	14	3	7	7.75*
A. opacum				
1974	6	3	3	—
1975	0	1	3	—
1976	2	6	2	—
1977	0	0	0	—
H. crucifer				
1974	530	46	58	721.11***
1975	891	566	427	180.60***
1976	1001	136	158	1126.92***
1977	642	40	72	912.90***
H. chrysoscelis				
1974	6	17	3	12.54***
1975	3	12	11	5.62
1976	1	1	0	—
1977	20	1	0	36.29***
R. clamitans				
1974	3	1	8	—
1975	11	10	37	24.24***
1976	24	12	24	4.80
1977	8	4	8	1.60
R. palustris				
1974	0	1	1	—
1975	0	63	44	58.56***
1976	1	253	234	242.12***
1977	32	151	194	112.08***
R. sylvatica				
1974	7	130	54	121.00***
1975	6	34	39	24.03***
1976	2	2	1	—
1977	0	0	0	—
B. americanus				
1974	0	0	0	—
1975	4	433	43	703.46***
1976	1	207	137	190.82***
1977	6	60	20	54.79***

* = Significant at 5% level, ** at 1% level, *** at 0.1% level. S = surface sweep, M = midwater sweep, B = bottom sweep. X^2 testing hypothesis S:M:B.

Table 3.—Habitat Breadths, Based on Summed Sweep-Type Occurrences.

	1974	1975	1976	1977
A. maculatum	0.01	0.01	0.01	0.01
A. opacum	0.01	0.01	0.01	0
H. chrysoscelis	0.01	0.01	0.01	0.01
H. crucifer	1.14	1.50	0.98	0.87
R. clamitans	0.01	0.01	0.01	0.01
R. palustris	0.01	0.01	0.33	0.76
R. sylvatica	0.64	0.01	0.01	0
B. americanus	0	0.14	0.16	0.06

Interactions among these three kinds of variation produce the results seen in year-to-year variation of habitat breadths (Table 3).

Discussion

Two observations that contributed to the observed variation are difficult to explain. The first is the collection of *Bufo americanus* larvae as they were hatching in 1974, but the lack of subsequent larval captures of this species for 1974. The second is the absence of *Rana sylvatica* larvae in the 1977 samples, despite the fact that *Rana sylvatica* was known to breed that year, the egg masses were as abundant as in previous years, and the eggs hatched. There were no obvious instances of greater egg mortality in 1977 than observed in other years, nor were predators observed at the egg masses. A possible explanation is that the 1977 larvae were killed by heat. The temperature of 30 March was unseasonably warm (Figure 4), and the hatchling larvae have an upper thermal temperature tolerance of about 35°C (Zweifel, 1977). On 30 March, the hatchlings likely were still congregated around the egg masses. The eggs were laid in shallow water exposed to direct sunlight, a situation where water temperature sometimes exceeds the maximum air temperature (as in Figure 1). Unfortunately, no temperature readings of the water were taken at the egg mass site on 30 March nor is the degree of larval dispersal known, so this explanation must remain speculative.

The remainder of this discussion focuses on the year-to-year larval variation, the probable sources of the variation, and the interactions between kind and source of variation. The purpose of the discussion is an attempt to understand what annual variation means in the larval amphibian community studied. Although discussion centers upon the study community itself, much of the interpretation should be valid for larval amphibian communities in general. Data from this study are integrated with results from other studies. In attempting to present a complete discussion, some assumptions are made where no data are available; such assumptions lack literature citations.

Three major modes of year-to-year larval population variation are documented above: population size, recruitment, and habitat use. Larval recruitment reflects the interaction of three components: (1) egg deposition, that is, when and how often the adults deposit egg masses; (2) egg and embryonic mortality; and (3) embryonic development, that is, the amount of time involved from egg deposition to hatching into a free swimming larva. For purposes of discussion, these three components are treated separately. Two other expressions of larval variation not examined in this study, but potentially important are: the time from hatching to metamorphosis, and the size of larvae at metamorphosis. These seven kinds of variation are likely the most important affecting the larval community under study. The relative importance of these kinds of variation are thought to be: (1) population size (egg number), (2) egg deposition, (3) egg and embryonic mortality, (4) embryonic development, (5) size at metamorphosis, (6) time from hatching to metamorphosis, and (7) habitat use.

The major sources of year to year larval population variation are (no ranking order intended):

1) Physical-climatic factors. The interaction of rainfall, temperature, and photoperiod likely are sufficient descriptors.

2) Number and breeding pattern of adults. More variation would be expected in non-territorial species (e.g., *Hyla crucifer*) than in territorial species (e.g., *Rana clamitans*). More variation would be expected in species with a prolonged breeding season (e.g., *Hyla crucifer*) than in species with a single egg deposition pattern (e.g., *Rana sylvatica*).

3) Food resources. The two species of salamanders probably feed on the same kind of food, aquatic invertebrates and tadpoles. The six species of tadpoles are all scraping and chewing feeders and likely feed on detritus, algae, epifauna, and plankton. Previous studies suggest larvae with similar mouthparts would be feeding on these kinds of food (e.g., Heyer, 1973), but no feeding data were gathered in this study.

4) Predators. Potential predators of salamander larvae in the study pond include other salamander larvae and aquatic insects. Tadpole predators include salamander larvae and aquatic insects. No quantitative data on predation were obtained in this study.

5) Intra-specific and 6) inter-specific competition among larvae. No direct data for these interactions were taken in this study.

Neither the expressions of variation nor their sources are independent factors. As one example, habitat use is probably density-dependent, i.e., correlated with population size. Similarly, the number of breeding adults and predators undoubtedly are influenced strongly by physical-climatic factors.

The most important observation to be made is that each causal factor finds expression in more than one kind of variation, and conversely, that each mode of variation, save one, has more than one cause (Table 4). The one exceptional mode is variation in embryonic development. This is largely influenced by physical climatic factors, ignoring genetic variation in developmental time. Genetic

Table 4.—Sources of Variation Affecting Various Parameters in Larval Amphibian Populations.

Parameter	Physical-climatic factors	# & breeding pattern of adults	Food resources	Predators	Intra-specific competition	Inter-specific competition
1. Population size	E	×	(×)	×	(×)	(×)
2. Egg deposition	×	×				
3. Egg and embryonic mortality	×			×		
4. Embryonic development	×					
5. Metamorphic size	×		×		×	×
6. Time from hatching to metamorphosis	×		×		×	×
7. Habitat use	E		×	×	×	×

E = Cause and effect documented in this study, × = cause and effect documented or presumed from other studies, (×) cause and effect presumed to be of minor importance.

variation, while evolutionarily important, should not be an important factor over ecological time as considered in this study. The amount of yolk stores also affects developmental time. Variation in yolk stores within eggs of each of the study pond species is not known, but probably would add only a day or two of variance at most in hatching time as all study pond species have relatively little yolk in each egg. Other possible causes of variation in embryonic development time, such as oxygen concentration, although probably not important for the study pond populations, could be important at other sites. Causal factors are now discussed in terms of the modes of variation they produce, with documentation from this and other studies.

The only source of variation that affects all parameters considered here is the category "physical-climatic" factors. This study documents the apparent effect of a severe winter on populations of *Ambystoma opacum* and *Rana clamitans*. Another common physical-climatic factor affecting population dynamics is the drying up of temporary ponds (Heyer, 1973; Wiest, 1974). Physical-climatic factors are very important in determining when eggs are deposited. The most thorough analysis of this phenomenon is Savage's (1961) study of variation in egg deposition dates in the frog *Rana temporaria*. Savage (1961) found that aspects of temperature, rainfall, photoperiod, altitude, longitude, and latitude could be used to build a multiple correlation coefficient mathematical model that accounted for 50% (r^2) of the total variance of observed spawn dates for *Rana temporaria*. Because of the immense volume of data required to perform an adequate analysis of this sort, it is unlikely that Savage's study will ever be repeated for another amphibian species. Egg mortality due to heavy rains, ponds drying or freezing is well known (e.g., Heyer, 1973), as is the relationship between temperature and variation in embryonic development time (e.g., Lillie and Knowlton, 1897; Moore, 1939). The present study demonstrates that a harsh winter can affect habitat use by removing one species from the habitat. Temperature also is known to affect the time from hatching to metamorphosis as well as size at metamorphosis (e.g., Herreid and Kinney, 1967).

The number of breeding adults determines the maximum number of larvae in the pond. The number of breeding adults also might affect variation in timing of egg deposition, especially in species with extended breeding seasons. If adult population densities are high, eggs should be laid on more days than if adult population densities are low.

Food resources could be so limiting that some individuals actually died from starvation, thereby affecting variation in population size. This is probably a rare situation, as most temporary ponds likely have a flush of energy input with a resultant algal bloom that is cropped by the tadpoles. Distribution of food resources could affect habitat use if the food resources were patchily distributed. Food resources affect the time from hatching to metamorphosis as starved tadpoles continue to live but do not grow (e.g., Calef, 1973). Food resources also affect the size of the larvae at metamorphosis.

Predators have a direct effect on larval population size due to feeding on eggs and free swimming larvae (e.g., Brockelman, 1969; Calef, 1973). Predators also could have an effect on habitat partitioning, if predators occurred more frequently in some microhabitats and not in others. At the study pond odonate naiads were present in the microhabitats sampled by the surface and bottom sweeps, but not in the midwater sweep microhabitat. Inferential support for predators having an effect on larval amphibian habitat use is found in Heyer, McDiarmid, and Weigmann (1975) and Heyer (1976).

Intraspecific competition can have an effect on population size in the case of cannibalism resulting from competition for food, a possible explanation for the documented cases of cannibalism in *Scaphiopus* (Bragg, 1964). The results of intraspecific competition are not usually this drastic, however. Experimental studies have demonstrated the effects of intraspecific competition on time from hatching to metamorphosis (e.g., Brockelman, 1969). As intraspecific competition has been demonstrated in experimental studies, it is reasonable to assume that competition occurring at high densities would result in the utilization of suboptical habitat by some members of the population. Intraspecific interactions can have a positive or negative effect on size at metamorphosis (e.g., Wassersug, 1973).

The role of interspecific competition is much better understood for salamanders (e.g., Wilbur, 1972) than for tadpoles (e.g., DeBenedictus, 1974). Experimental studies have shown the effects of interspecific competition on time from hatching to metamorphosis and size at metamorphosis (e.g., Wilbur, 1972). Interspecific competition, if occurring in nature, would be expected to have an effect on habitat use.

The between-year variability outlined above is similar to the variability observed between ponds within a year (Heyer, 1973). Different ponds in a given geographic area have different physical environmental regimes, numbers of breeding adults, food resources, and predators. Because larval population sizes are different from pond to pond, larval competitive interactions among ponds would be expected to differ. Adults of a given amphibian species may be confronted by a variety of breeding ponds which differ extensively in their suitability for breeding and for larval growth. The results of this study indicate that the same sort of marked variability is observed in a single pond over time: this pattern of extreme between-pond and between-year variability puts certain constraints on life history parameters of the amphibians using the environments. Because the larval habitat is unpredictable, a given adult has a better chance of maintaining its genes in the gene pool if it places its eggs in more than one pond or in the same pond for more than one year. The variability demonstrated in this study contrasts with Calef's (1973) study of a two-species permanent pond system in British Columbia, where he found very little variability over a two year period. I believe the British Columbia system is a special ecological situation and the system examined in this study is more typical of larval population dynamics.

The major point of this discussion is that it is virtually impossible to isolate individual cause-and-effect relationships in the population dynamics of naturally occurring larval amphibian populations. For example, variability in size at metamorphosis may reflect the interaction of physical-climatic factors, food resources, and intra- and interspecific competition. An experimental study isolating any one of these sources of variation could demonstrate variation in size at metamorphosis. Thus, a study which examined competition would demonstrate that competition could explain variation occurring in nature but would not predict whether competition was the only source of larval metamorphic size variation in nature, nor that it was the critical source of variation. A case in point is the attempt to explain the variation seen in larval populations of *Rana palustris* and *R. sylvatica* in the present study. Population sizes of both species were very different from year to year, as was habitat use. Assuming that food resource and predator levels were equivalent over the four years (assumptions needed for simplification to focus on the possible effects of competition, but may in fact not be equivalent), yearly variation in larval populations can be explained in three ways. The first is to invoke interspecific competition. The data in Tables 1 and 3 indicate a trend where the first year is dominated by *R. sylvatica* larvae, the third and fourth years are dominated by *R. palustris* larvae. This could be interpreted as a replacement of one species by the other over time as the result of interspecific competition. However, an equally plausible explanation would be that the variation in population size was due to physical-climatic differences from year to year. Whatever climatic conditions are optimal for *R. sylvatica* larvae are suboptimal for *R. palustris* larvae, and vice versa. Thus, 1974 had climatic conditions optimal for *R. sylvatica* survival and poor for *R. palustris* survival; 1976 and 1977 had climatic conditions optimal for *R. palustris* survival and poor for *R. sylvatica* survival; 1975 had intermediate climatic conditions for both. The fact that about as many *R. sylvatica* eggs were laid and hatched in 1977 as in 1974, lends some support to this explanation. Yet a third plausible explanation would consider the combined effects of climate and competition whereby competitive ability depends on physical conditions. It is impossible to conclusively isolate the factors of cause and effect of larval population variation in this case, given the data available. Similarly, I think it is impossible to isolate the cause and effect of larval population variation in most, if not all, naturally occurring larval populations, given our present data base.

Conclusions

The larval phase is one part of the amphibian life cycle where the effects of natural selection likely are the greatest. Therefore, it is necessary to understand the kinds and sources of larval population variation in naturally occurring situations to fully understand the amphibian life cycle. The kinds of larval population variations encountered in nature cannot be demonstrated to have simple cause-and-effect relationships. Rather, a given kind of variation is the simultaneous interactive result of several causes.

Experimental studies on larval populations that demonstrate the cause and effect of certain kinds of variation cannot be extrapolated convincingly of field conditions. Experimental studies do lead to a greater understanding of larval population dynamics in nature, however. The experimental manipulation of larval amphibians in a field setting introduced by Brockelman (1969) has been followed by a series of studies, several of which are ongoing, examining the effects of food resources, predation, and intra- and interspecific competition on larval population variation. There is much to be learned from these types of studies, but at our present state of knowledge, we already know more about how larval amphibians live in field pens than in naturally occurring ponds. One of the goals of larval amphibian studies should be to gather basic data on densities and occurrences of larvae in naturally occurring ponds, so that experimental results can be interpreted with greater meaning.

Acknowledgments

Elena, Laura, and Miriam Heyer worked with me in the field over the entire study. Miriam Heyer helped process the larvae in the laboratory. Without their willingness to share their Saturdays with me collecting larvae, the project would not have been undertaken.

David L. Correll, James F. Lynch, and Francis Williamson, of the Smithsonian Institution's Chesapeake Bay Center for Environmental Studies, facilitated our work at the study site.

James F. Lynch and Roy W. McDiarmid, National Fish and Wildlife Laboratory, Smithsonian Institution, have helpfully criticized the manuscript.

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THE AWARDS PROGRAM OF THE ACADEMY

Irving Gray

General Chairman

The Annual Awards Dinner meeting of the Academy which commemorated the 100th anniversary of Albert Einstein's birth was held March 15, 1979, at the Kenwood Country Club. Five awards were made for distinctive contributions to research and two joint awards were made for science teaching.

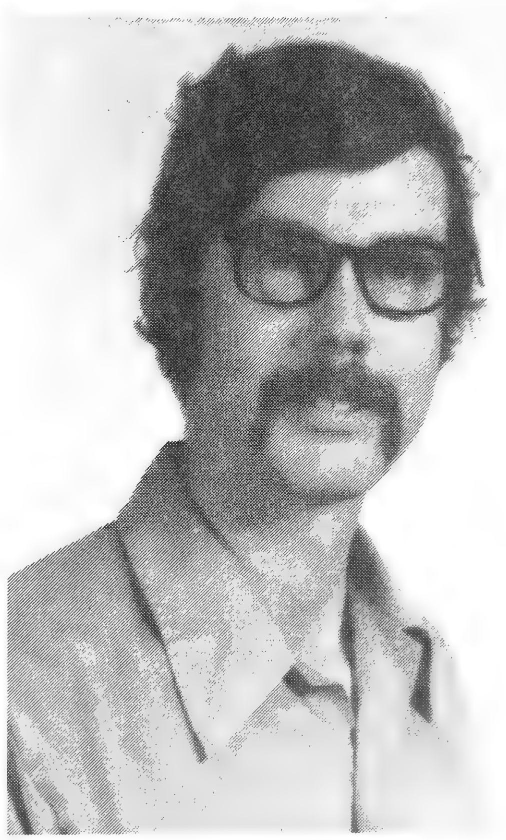
This year the award for Teaching of College Science was named in honor of Dr. Leo Schubert, former Chairman of the Department of Chemistry, American University. Dr. Schubert's untimely death in June, 1978, caused a severe loss both personal and professional to many individuals throughout the nation in the field of chemistry and science education. His work with young people in science was a major contribution to the growth of many scientific careers. His warm personality and his insights into the positive development of science teaching, his guidance, counsel, and friendship will be sorely missed.

The scientists honored in research were: Behavioral Sciences, Stephen M. Kerst, Ph.D., Catholic University of America; Biological Sciences, Alfred D. Steinberg, M.D., National Institutes of Health; Engineering Sciences, Robert E. Berger, Ph.D., National Bureau of Standards; Mathematics and Computer Sciences, Jay P. Boris, Ph.D., Naval Research Laboratory; Physical Sciences, Konstantinos Papadopoulos, Ph.D., Naval Research Laboratory.

The scientists honored in teaching were: Leo Schubert Award in College Teaching, Milton M. Slawsky, Ph.D., and Zaka I. Slawsky, Ph.D. (joint award), University of Maryland; Bernice G. Lamberton Award in High School Teaching, Ronald R. Myers, T. C. Williams High School and Ronald J. Smetanick, Thomas S. Wooton High School (joint award).

Behavioral Sciences

Dr. Stephen M. Kerst is Assistant Professor of Educational Psychology in



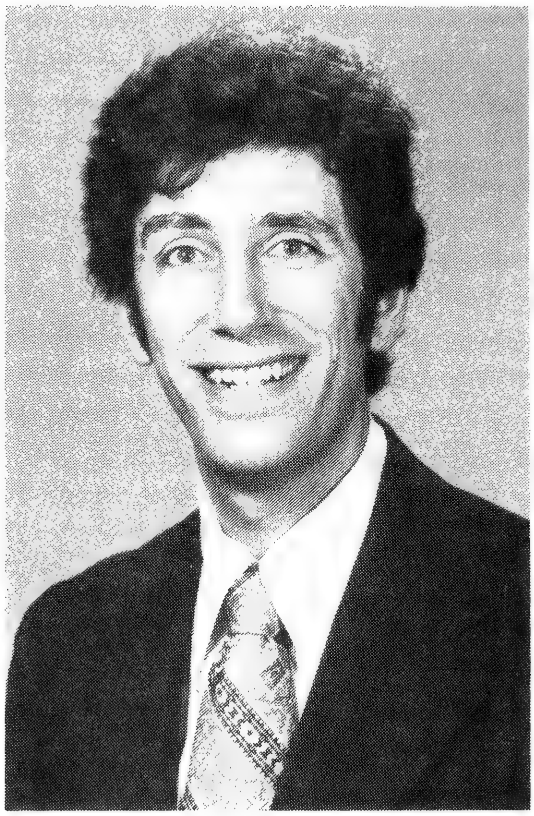
Stephen M. Kerst

Alfred D. Steinberg

the School of Education of The Catholic University of America. Born in Champaign, Illinois, Dr. Kerst had all of his college education at the University of Wisconsin, receiving his Ph.D. in Educational Psychology in 1974. He is a member of several learned societies including The Psychonomic Society, Eastern Psychological Association, American Educational Research Association, American Psychological Association and others. Dr. Kerst was cited for "creative memory."

Biological Sciences

Dr. Alfred D. Steinberg is Senior Investigator, Arthritis and Rheumatism Branch, National Institute of Arthritis, Metabolism and Digestive Disorders of the National Institutes of Health. Born in New York City, Dr. Steinberg received his A.B. from Princeton University in 1962 and his M.D. from Harvard Medical School, *cum laude*. He has membership in several learned societies among which are: American College of Physicians (Fellow), American Society for Clinical Investigation, American Association of Immunologists, and several others. Dr. Steinberg was cited for "concepts of the pathogenesis and treatment of systemic lupus erythromytosis."



Robert E. Berger

Engineering Sciences

Dr. Robert E. Berger is Mechanical Engineer, National Bureau of Standards. Born in Baltimore, Maryland, Dr. Berger received his B.S. in Engineering from Case Western Reserve University in 1968 and his Ph.D. in Fluid Mechanics from Johns Hopkins University in 1973. He is a member of the American Society for Testing Materials, the American Society of Mechanical Engineers, as well as other learned societies. Dr. Berger was cited for "development of improved test methods to reduce head and eye injuries."

Mathematics and Computer Sciences

Dr. Jay P. Boris occupies the Chair of Science in Computational Physics and is Chief Scientist, Laboratory of Computational Physics, National Bureau of Standards. Born in Buffalo, New York, Dr. Boris received his college education at Princeton University, obtaining his Ph.D. in 1968. He is a member of The Applied Physics Society, Sigma Xi, Phi Beta Kappa, and others. He received the Research Publication Award in 1972 and

Jay P. Boris

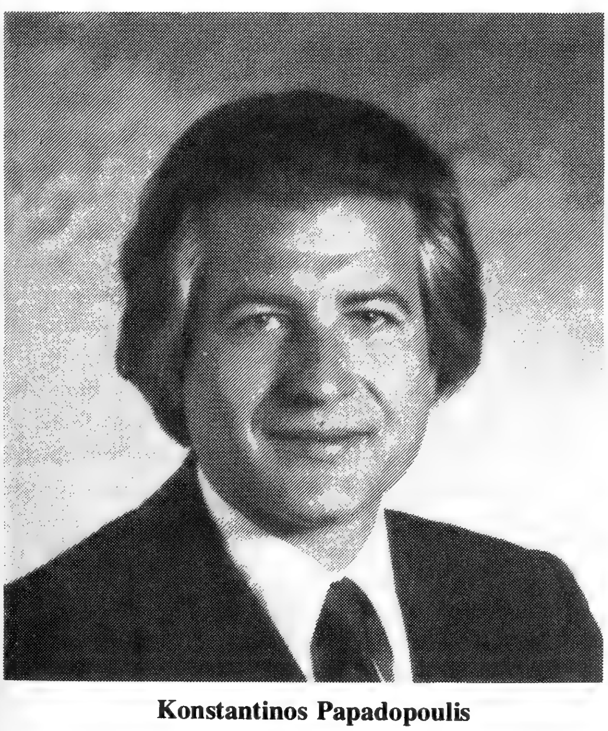
1973, as well as other performance awards including The Arthur S. Fleming Award in 1976. Dr. Boris was cited for "outstanding contributions in computational physics and numerical analysis."

Physical Sciences

Dr. Konstantinos Papadopoulos is Division Consultant and Professor in Physics Department, University of Maryland, and The Naval Research Laboratory. Born in Larissa, Greece, he received his B.Sc. in physics from the University of Athens in 1960, his M.Sc. in nuclear engineering from the Massachusetts Institute of Technology in 1965 and Ph.D. in physics from the University of Maryland. He is a member of several learned societies including: Fellow of American Physical Society, American Geophysical Union, Full Member of Sigma Xi. He was the recipient of the E. O. Hulbert and Navy Meritorious Awards. Dr. Papadopoulos was cited not only for a wide range of contributions to physical and geophysical phenomena, but particularly for his leadership in theoretical and computational plasma physics.

Teaching of College Science– Leo Schubert Award

Dr. Zaka I. Slawsky was Chief of Physics Research at the Naval Ordnance Laboratory and Professor of Physics (P.T.) at the University of Maryland until his retirement in 1975. Born in Brooklyn, New York, Dr. Slawsky received a B.S. degree from Rensselaer Polytechnic Institute in 1933, an M.S.



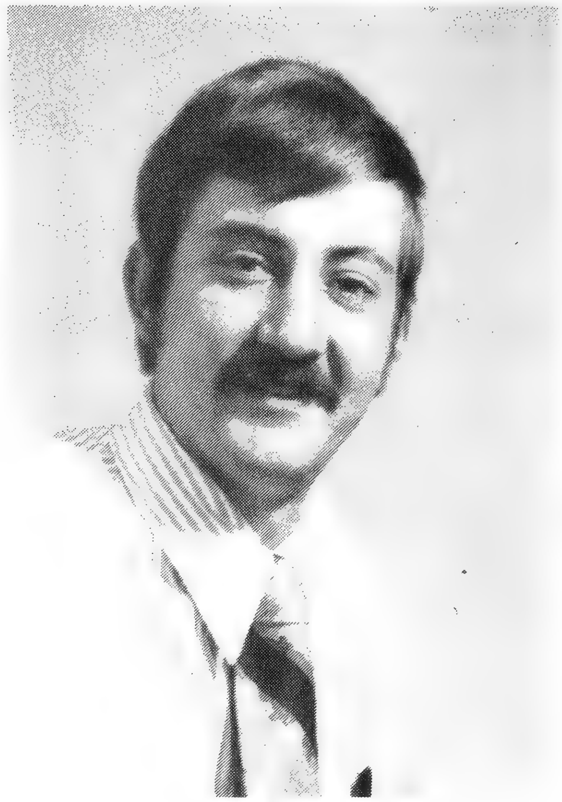
Konstantinos Papadopoulis

Zaka I. Slawsky

from California Institute of Technology in 1935 and Ph.D. from the University of Michigan in 1938, all in Physics. He is a member of many learned societies including The Philosophical Society and a Fellow of the American Physical Society and Washington Academy of Sciences. Dr. Slawsky was cited (with Dr. Milton M. Slawsky) for "Pioneering work in the development of a highly successful physics tutoring program and for demonstrating an innovative approach to the involvement of retired scientists in the teaching of physics."

Dr. Milton M. Slawsky was Director of Physics, Air Force Office of Scientific Research, until his retirement in 1974. He is visiting lecturer in physics at the University of Maryland. Born in Brooklyn, New York, he received a B.S. degree from Rensselaer Polytechnic Institute in 1933, an M.S. from California Institute of Technology in 1935, and Ph.D. from the University of Michigan in 1938, all in physics. Dr. Slawsky is a Fellow of the Washington Academy of Sciences, the American Physical Society, and other learned societies. He was cited (with Dr. Zaka I. Slawsky) for "pioneering work in the development of a highly successful physics tutoring program and for demonstrating an innovative approach to the involvement of retired scientists in the teaching of physics."

Milton M. Slawsky



Ronald R. Myers

Teaching of High School Science

Mr. Ronald R. Myers is teacher of Chemistry at the T. C. Williams High School in Alexandria, Virginia. Born in Fostoria, Ohio, Mr. Myers received his B.S. and M.S. at Bowling Green State University, finishing in 1974. He attended N.S.F. institutes in physics in 1974 and 1975 and is currently a candidate for a Ph.D. at American University. He is a member of several societies including the American Chemical Society and American Association of Physics Teachers. He received a grant from the latter organization for an innovative teaching project and the Merck Award in Chemistry while at Bowling Green State University. Mr. Myers was cited for "excellence in teaching and motivating ordinary students to do extraordinary work in chemistry."

Mr. Ronald J. Smetanick is teacher of Biology at the Thomas S. Wooton High School in Rockville, Maryland. Born in Tarentum, Pa., Smetanick received a

B.S. in Biology from Clarion State University in 1963 and a M.S. in Secondary Education from the University of Maryland in 1970. He has had a distinguished career at both the Junior High and High School levels, making a significant impact in student relations. Mr. Smetanick was cited as being "an outstanding teacher and humanitarian."

The chairmen of the several subcommittees that carried out the difficult job of making the individual selections are acknowledged with sincere thanks:

Dr. Sherman Ross, Behavioral Sciences
Dr. Lewis Affronti, Biological Sciences
Dr. Joan Rosenblatt, Mathematics and Computer Sciences
Dr. Conrad H. Cheek, Physical Sciences
Dr. Joseph B. Morris, Teaching of Science.—*Irving Gray*, Ph.D.

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CONTENTS

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This journal, the official organ of the Washington Academy of Sciences, publishes historical articles, critical reviews, and scholarly scientific articles; proceedings of meetings of the Academy and its Board of Managers; and other items of interest to Academy members. The *Journal* appears four times a year (March, June, September, and December)—the September issue contains a directory of the Academy membership.

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Delegates continue in office until new selections are made by the representative societies.

A BIRTHDAY COMMEMORATION

This issue of the Academy' *Journal* is devoted, in part, to the commemoration of the 100th anniversary of the birth of Albert Einstein.

Three papers bearing upon this commemoration were presented at the 584th meeting of the Academy on March 15, 1979 at the Kenwood Country Club in Bethesda, Maryland. Two of those papers, by Drs. Otto Bergmann and Steven Brush, are among those you will find published in this issue of the *Journal*. The third presentation at that meeting was by Dr. Carroll Alley, ''Experimental General Relativity—1979'', but a manuscript was not received for publication in this collection.

The remaining articles presented here were delivered at a subsequent meeting of the Academy on May 17, 1979, also at Kenwood.

Richard H. Foote
Editor

Theoretical General Relativity–1979

Otto Bergmann

Department of Physics, The George Washington University, Washington, D. C. 20052

The physical idea of the general theory of relativity can perhaps be explained with a story of historical possibilities. We know that *Eratosthenes of Cyrene* determined the radius of the earth in the third century B.C. It is quite possible that a qualitative theory of surfaces could have been developed at that time, a theory which we owe to *C. F. Gauss*. Considering the highly speculative nature of ancient science, one can easily imagine that some philosopher proposed the idea that the curvature at any point of the surface of the earth may not be fixed for all times, but that it may change with the intensity of the sunlight or the temperature of the fire deep underneath the point on the earth. This is an absurd view but it does illustrate the physical idea of general relativity without the need to visualize a four-dimensional space-time continuum.

Einstein's general relativity generalizes the flat space-time continuum, described by the invariant four-distance between neighbouring events

$$(ds)^2 = c^2(dt)^2 - (dx)^2 - (dy)^2 - (dz)^2 = \mathring{g}_{\alpha\beta}dx^\alpha dx^\beta \quad (1)$$

to a curved space-time continuum

$$(ds)^2 = g_{\alpha\beta}dx^\alpha dx^\beta \quad (2)$$

(summation over all indices occurring twice!)

with $x^0 = ct$, $x^1 = x$, $x^2 = y$, $x^3 = z$ and the meaning of $\mathring{g}_{\alpha\beta}$ can be seen from (1). Although (2) cannot be reduced to (1) in general, we may introduce local coordinates which reduce to (1) at one space-time point. In local Riemannian coordinates, (2) can be expanded

$$g_{\alpha\beta} = \mathring{g}_{\alpha\beta} + \tfrac{1}{3}R_{\alpha\kappa\beta\lambda}x^\kappa x^\lambda + \ldots \quad (3)$$

where $R_{\alpha\kappa\beta\lambda}$ is the curvature tensor, which is restricted by the field equations

$$R^\kappa{}_{\alpha\beta\kappa} - \tfrac{1}{2}g_{\alpha\beta}R^{\kappa\lambda}{}_{\kappa\lambda} = -kT_{\alpha\beta} \quad (4)$$

where $T_{\alpha\beta}$ is the energy-momentum tensor, which includes all the contributions in energy and momentum which may be present at the point except gravitational energy. The derivation of (4) does not make use of the flat space-time metric (1), but an alternative derivation of Einstein's equation (4) starts from a field equation in flat space-time

$$\mathring{g}^{\alpha\beta}\frac{\partial^2}{\partial x^\alpha \partial x^\beta}g_{\kappa\lambda} = -kT_{\kappa\lambda} \quad (5)$$

and leads to (4) on the grounds that the energy-momentum tensor in (5) should include the contribution from the gravitational field. The latter is quadratic in the derivatives of $g_{\kappa\lambda}$ and one obtains in fact Einstein's equation (4).[1]

Returning to (2), we make two observations. First, *A. Z. Petrov* in 1954 gave a classification of the curvature tensor

$R_{\alpha\beta\kappa\lambda}$ in empty space, i.e. with $T_{\alpha\beta} = 0$ in (4), which became most valuable in the study of gravitational radiation. Secondly, it is easy to derive from (3) the equation of geodesic deviation which makes the curvature tensor directly measurable. The equation was known to *C. G. J. Jacobi* for surfaces and was generalized by *T. Levi-Civita*.

For many years after the formulation of general relativity, only two exact and physically important solutions were known. The Schwarzschild solution describes a single mass point without internal structure and the theoretical study of the three early experimental tests were made with the help of this solution. The Reissner-Nordström solution includes a net electrical charge with the mass. Since then many new exact solutions have been found, the most important being the Kerr solution.[2] It describes a spinning mass particle and is important because the final state of a collapsing star will in general have a finite angular momentum. Many other exact solutions have been found, but their physical significance is not always transparent. The modern theory of gravitational collapse belongs to astrophysics and depends as much on elementary particle physics as on gravitation. This is true even of cosmology, whose greatest triumph recently has been the experimental support of the big-bang theory on the early universe by the discovery of the black-body radiation corresponding to a temperature of 3°K. It should perhaps be said in this connection that we now have a fairly complete relativistic kinetic theory with a relativistic Boltzmann equation.[3]

The classical theory of general relativity is a theory of gravitation, but the gravitational interaction between elementary particles is rather weak compared to the electric and nuclear interaction, and it is therefore hardly surprising that the unification of gravitation with other interactions has not progressed as much as the study of gravitation for macroscopic bodies. We can have complete confidence in the latter—radical modifications are either not attractive or have no experimental support—but there is still much room for speculations on the atomic level. We will mention here briefly the Yang-Mills formalism, which plays an important role in elementary-particle physics; it could be considered an offspring of the general theory of relativity. According to *W. Heisenberg*, the proton and the neutron should be considered as two members of one family, the nucleon-family. *Yang and Mills* insisted that the mathematical distinction between these two particles should be left to the choice of a local observer and should not be predetermined for the whole universe. If the index A = 1 or 2 distinguishes between proton and neutron, Yang and Mills demanded that a theory involving a field ψ_A should be invariant under transformations

$$\psi_A'(x) = S_A{}^B(x)\psi_B(x) \qquad (6)$$

and this gives rise to covariant derivations with intrinsic affine connections $\Gamma_{A\alpha}{}^B$ and then also to a curvature in the intrinsic space. Similar concepts have appeared even before Yang and Mills in the theory of spinors in curved space-time. It is amusing that these theories are linked, formally at least, to the theory of relativity through the principle of general covariance, which is often considered as the least physical cornerstone of the classical theory of relativity, and sometimes even just as a necessary evil.

The aim of fundamental physics is a unified field theory, which in some way can describe the many particle varieties and their interactions. The only way this can be done at present is by introducing many fields and quantize these fields. The Unified Field theory which Einstein developed in the last years of his life contains too few degrees of freedom and its quantization would be next to impossible. Unfortunately the attempts to unify the general relativity and quantum theory of elementary particles do not take into account the intuitive meaning of the concepts employed by the classical theory of relativity: length and time intervals, curvature and parallel transfer. We may hope for another Albert Einstein to bring clarity and beauty back into physics.

References

1. W. Thirring, Annals of Physics *16,* 96 (1962).
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Einstein's Philosophy of Physics

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"One of the greatest achievements in the history of human thought" was the comment of the physicist Sir Joseph J. Thomson, PRS, when he announced the experimental comfirmation of Einstein's general theory of relativity at a meeting of the Royal Society on Nov. 6, 1919. He added, "I have to confess that no one has yet succeeeded in stating in clear language what the theory of Einstein really is"—a typical remark of that time. Cornelius Lanczos, sometime research assistant of Einstein, claimed in his "Albert Einstein and the Cosmic World Order" (1965), "He [Einstein] considered himself more a philosopher than a professional physicist." Strictly a natural philosopher, truly a genuine amateur! He was, indeed, distinguished by his interest in a broad domain of physics, in contrast with modern theoreticians.

The evolution of philosophical ideas, to be sure, is often guided by the development of physical theories. Einstein, for instance, came into contact with problems formerly regarded as the prerogatives of professional philosophers, namely, the nature of space and time. His own approach, a combination of mathematical insight and observed data, was quite remote from that of the ivory tower philosopher, but it involved more implicit philosophy than many an explicitly philosophical system owing to his own broad view.

The German theoretical physicist Max Planck, a sponsor of Einstein for the Prussian Academy of Science, noted that two conflicting philosophies of science have cited Einstein's writings in their support, namely, the positivistic and the metaphysical. In this connection it is interesting to peruse "Albert Einstein: Philosopher-Scientist" (ed. P. A. Schilpp, 1949). In the article "Einstein, Mach, and Logical Positivism" the theoretical physicist Philipp Frank, who knew Einstein from 1910 and succeeded him two years later at the German University of Prague, concluded that there is not "any essential divergence between Einstein and 20th-century logical empiricism." In his concluding comments Einstein made no remark about this article, whereas he particularly noted with respect to the one on "Einstein's Theory of Knowledge" that "the American physicist Victor Lenzen constructs a synoptic total picture in which what is missing in the utterances is carefully and with delicacy of feeling supplied. Everything said there appears to me convincing and correct." The basis of my own comments here is primarily Einstein's Herbert Spencer Lecture "On the Method of Theoretical Physics" (Oxford, 1933), which Frank has called "the finest formulation of his [Einstein] views on the nature of physical theory." It is truly amazing how Einstein's logical analysis of relativity at age 54 coincided with his interpretation of it at 26.

Einstein always acknowledged his indebtedness to the Austrian physicist Ernst Mach, first rector of the German University of Prague, whom he did not actually meet until the Vienna Congress in 1913. In his 1916 obituary Einstein gratefully stated, "I can say with certainty the study of Mach and Hume has been directly and indirectly a great help in my work." Einstein, I believe, was the true heir of Mach's physical ideas. Let us see in what way.

The 19th-century philosophy of physics was still embroiled in Pilate's perennial question, "What is truth?" Is there scientific truth as opposed to philosophical truth? You may recall Adam's attempt in "Paradise Lost" to learn from the archangel Raphael whether the Copernican planetary system or the Ptolemaic one is true. The politic reply was to leave such matters to God above, an admonition ignored later by the aggressive Galileo. In the 19th century for a physical phenomenon to be scientifically true meant for it to have a satisfactory mechanical analogue as in the case of sound, heat, and light. This view peaked in popularity about 1870. Gustav Kirchhoff, the Heidelberg physicist, asserted in his "Mechanics" (1874) that its purpose was "to describe completely and as simply as possible motions occurring in nature." Two years earlier Mach had prescribed logical economy of thought and simplicity for all science. But a new day was heralded in 1889 by the Bonn professor of Physics Heinrich R. Hertz, who preferred to take Maxwell's equations for directly describing electromagnetic phenomena.

Mach's own attitude went back to the French philosopher Auguste Comte who argued in 1830 that any scientific theory should be judged with respect to its representation of positive experience—subsequently called positivism. In 1883 Mach himself urged that only statements leading to observable phenomena should be used—a positivistic criterion. On this basis he opposed any vacuous notion such as Newton's idea of absolute space. He insisted that terrestrial motions in space should be viewed relative to the "fixed" stars. Einstein saw these material bodies distorting the space about them and thus determining the paths of freely moving objects there, i.e., general relativity—a wholly new idea in the history of thought.

Pursuing the critical outlook of Mach and the Scottish philosopher David Hume, he analyzed the concept of simultaneity, which is simple enough when two events occur at the same place, but not so obvious when they are separated by a great distance accessible only by light travelling with its finite speed. Percy W. Bridgman, the Harvard experimentalist, regarded Einstein's conception of simultaneity as the best illustration of operationalism.

In Mach's phenomenological physics processes were to be described by concepts derived inductively or intuitively from sensory experiences. Einstein, however, did not agree with his view of general laws of physics as mere summaries of experiential results, or simple abstractions from them, such as whiteness from white objects, i.e., in the spirit of Newton's "non fingo hypotheses"—typical of 19th-century scientific doctrine, e.g., the English physicist John Tyndall (Mach himself did allow a small gap).

Einstein was indebted also to the French mathematical physicist Henri Poincaré, whom he did not actually meet until the 1911 Solvay Conference in Brussels. In this connection let us glance back at 18th-century rationalism. In 1748

Hume questioned causality being necessarily inherent in successive events. Immanuel Kant, the German philosopher, argued in 1781 that phenomena per se are insufficient for describing phenomena; some reason has to be injected into the description, but not without limit—creativity is bounded by certain necessary thought conditions. Such was Euclidean geometry, a thought mold, an *a priori* requisite. The production, however, of consistent non-Euclidean geometries independently by the Russian mathematician Nicholaus I. Lobachevski and the Hungarian mathematician Wolfgang Bolyai soon liberated the human mind in this regard.

In 1912 Poincaré insisted that "the general properties of science are not statements about reality, but arbitrary statements how words such as straight lines, force, energy are to be employed in properties of geometry, mechanics, and physics;" they are "free creations of the mind," agreements among people for expediency, mere conventions, hence the designation of this as conventionalism. Einstein, for instance, considered integers to be an invention of man for simplifying his experience. He regarded the approximate success of both Newton's law of gravitation and his own as indicative of their fictitious character. In the Spencer lecture he confessed, "I am convinced that we can discover by means of purely mathematical constructions the concepts and the laws connecting them with each other, which furnish the key to the understanding of natural phenomena." General relativity, in his opinion, illustrates the incorrectness of the proposition that scientific concepts are necessarily derived from experience.

These two points of view, Mach's and Poincaré's, represent opposite extremes of the positivism movement—Mach emphasising the empirical foundation and Poincaré the logical consistency of the superstructure. In the late 1920's the Vienna circle (Morris Schick, Rudolf Carnap, Otto Neurath, *et al.*) combined them to form logical positivism—happily renamed logical empiricism by the American philosopher Charles Morris. Inasmuch as Hume is sometimes regarded as its father and Poincaré as its godfather, let us examine Einstein's own relation to this doctrine.

Einstein considered it an oversimplification that every statement of physical science should be translatable word for word into observable facts. He preferred to replace this positivistic criterion with a much broader one, viz., that one can use "any symbols or words possible in the formulation of the principles, provided that statements about observable quantities can be equally derived from them." In the Spencer lecture he stated, "The structure of the world of reason, the empirical contents, and their relations must find their representation in the conclusions of the theory." (Einstein himself had a remarkable faculty of deducing all possible logical consequences from his own fundamental principles.) Einstein did not at all agree with the French philosopher René Descartes' dictum that thinking *per se* can reveal a knowledge of the world of experiences, he felt that the latter itself serves as a necessary boundary condition, that physical content is a prerequisite to any mathematical formulation. In his 1921 lecture at Princeton University he warned that "the universe of ideas is just as little independent of the nature of our experience as clothes are of the form of the human body."

Einstein placed emphasis not only on testing observation but also on simplifying theory, (Simplicity itself, to be sure, is not a simple concept.) In 1902 he had simplified the Boltzmann theory for random motion (Gibbs' method being unknown to him at the time); he applied it three years later to explain quantitatively Brownian motions. In his Oxford lecture he concluded, "It is the grand object of all theory to make these irreducible elements simple and as few in number as possible without having to renounce the adequate representation of any empirical content whatever." A long chain of mathematical and linguistic arguments may result; the length, I believe is usually proportional to the simplicity of the structure. Nevertheless, one is always amazed at the power of abstract thinking.

These two major emphases of Einstein, particularly after 1920, appear to be in keeping with Frank's own conclusion (1947) that "Einstein speaks almost in line with logical empiricism in his 'Remarks on Bertrand Russell's Theory of Knowledge' [1944]"

But not quite! Einstein's passionate quest for reality, I believe, led him far beyond logical empiricism.

Einstein, you see, believed in nature. In the first place, he looked upon nature as real. In 1931 he said, "The belief in an external world independent of the percipient subject is the foundation of all science." "I cannot conceive of a genuine scientist without that profound faith." Secondly, he considered nature rational. In his 1936 lecture "On Physical Reality" he confessed, "The most incomprehensible thing about the world is that it is comprehensible." The freedom of thought (within limits) he regarded as one of Kant's great discoveries in approaching nature, that it is "possible to get away from the individual observer and sublimate it into something universal, 'public,' and 'real.' " For Einstein, the primacy was neither theory nor experiment, but rather the all-embodying lawfulness which manifests itself in the universe—hence his own humility. (It seems to me that Robert Berks' large figure of Einstein looking down casually at the small constellations at his feet is hardly in keeping with his character; a humble Einstein would have been gazing up in rapturous admiration at the overpowering, wonder-full universe.)

Nature, in the third place, is a riddle that man can solve to some extent. Einstein had a passion to understand it; he would not be content merely to describe it somehow, with his deep artistic feeling (cf. his love of music) he sought the underlying harmony of the universe, the luring music of the spheres. Walter Nernst, the German chemist, saw in the young Einstein the model for the young Kepler in "The Redemption of Tycho Brahe" by Max Brod, a Prague associate of Einstein. He believed profoundly that "behind the tireless effort of the investigator lurks a stronger, more mysterious drive; it is existence and reality that one wishes to comprehend." In 1929 he combined the gravitational field with the electromagnetic field to form a unified field theory—unfortunately inaccessible to experimental check in its four-dimensional expression.

The starting point for any pilgrim's progress toward understanding the universe must be reality itself, i.e., physical reality in Einstein's view, which exists only with respect to those characters manifest in observable experimental results. Geometry, for example, is a description of physical reality. Einstein regarded a physical field as the most profound and fruitful conception of reality since Newton; he had pictures of the English Michael Faraday and Clerk Maxwell hanging in his study both in Berlin and in Princeton. (Relativity, indeed, reveals connections between descriptions of one and the same reality; it by no means implies an abandonment of truth, i.e., relativism.)

The struggling pilgrim, however, is not without a road guide. Einstein was convinced that "since sense perception informs us only indirectly of the world of physical reality, it is only by speculation that it can become comprehensible to us." His intuition, he believed, would lead him to penetrate the depth of reality by means of mathematical ideals. Einstein's law of gravitation, for instance, resulted from his search for the simplest covariant law for a space-time Riemannian matrix. (The very intensity, indeed, of his investigation gave an impression of a somewhat metaphysical quest.) Some specially illuminated road, he believed, would lead ultimately to the real explanation; there would be revealed the magic words "Open Sesame" to uncover the universe's secret. At Oxford he insisted, "In my opinion there is the *correct* path, and . . . it is in our power to find it. Our experience to date justifies us in feeling sure that in nature is centralized the idea of mathematical simplicity. . . . In a certain sense I hold it to be true that pure thought is competent to comprehend the real as the ancients dreamed." Elsewhere he noted, "The function is not that of a novelist [fancy free—in Coleridge's sense], but that of a person who solves a crossword puzzle. Any word can be proposed in the solution, but there is only one that fits the puzzle in all its parts." There *is* an answer to the riddle. In the mathematics common room of Fine Hall, Princeton University, above the fireplace, is an inscription ascribed to Einstein: "Raffiniert ist der Herr Gott, aber boschaft ist Er nicht." (God is cunning, but He is not mischievous.)

About all his physics appears an aura of religion. At Oxford Einstein admitted to "something ineffable about the real, something occasionally described as mysterious and awe-inspiring." He saw in "the fact that the method turns out to be true in the empirical sense" "a property of our world, an empirical fact, a hard fact." He had a mystical feeling toward the harmony of universal law. As Frank observed, "The possibility of mathematical physics, if we put it perfunctorily, is almost identical with religion." In his opinion Einstein's self-designated cosmic religion was essentially a "belief in the possibility of a symbolic system of great beauty and conceptual simplicity from which all facts can be logically derived."

Einstein and Indeterminism

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The current celebrations of Albert Einstein's 100th birthday have now reached a level of intensity which is high enough to bring back from the grave, if not Einstein himself, at least a couple of his colleagues, if you believe the report which appeared in the March 12, 1979 issue of the *Chronicle of Higher Education*:

> They were all gathered back at Albert Einstein's old stomping grounds at the Institute for Advanced Study last week. J. Robert Oppenheimer, the "father of the atomic bomb." John Wheeler, the man who coined the name "black hole." John von Neumann, formulator of the game theory.[1]

Although Wheeler was certainly alive and well when he lectured at the Smithsonian recently, I don't think anyone has seen Oppenheimer or von Neumann for at least a decade.[2]

Tonight I want to talk about another ghost: the philosophical position which Einstein defended throughout most of his life, but which is now generally thought to be dead. I realize that a successful revival of this position would be almost as great a miracle as reviving Oppenheimer and von Neumann, but I think it is appropriate when we celebrate a great man like Einstein to discuss his defeats as well as his victories. Others will tell you all you want to know about the theory of relativity and the other discoveries which constitute Einstein's permanent contribution to modern physical science. But you may occasionally hear them mention, somewhat apologetically, the embarrassing fact that Einstein would not accept the fundamental validity of quantum mechanics as a complete description of nature on the atomic level. As Max Born wrote in 1949, many physicists regarded this fact "as a tragedy—for him, as he gropes his way in loneliness, and for us who miss our leader and standard-bearer."[3]

What was Einstein's objection to quantum mechanics? First of all I must emphasize that it was much more than the well-known statement, "God does not play dice." Indeed the announced title of my talk is perhaps a little misleading in this respect. Several months ago I agreed that I would speak to this group in Washington on March 14, on the topic "Einstein and Indeterminism." If you believe in the principle of indeterminism you should not be surprised to find that I am now speaking in a slightly different place at a slightly different time on a slightly different topic. But the deviation itself, in accordance with the indeterminacy principle, is based on the quantum. What Einstein disliked about quantum theory was not simply that it postulated an inherent randomness in nature, but that it *denied the existence of a real world independent of our observations of it*. He felt that Niels Bohr and Werner Heisenberg had gone too far along the road of positivism and idealism, by denying reality not only to entities that *can't* be observed, but also to those that *aren't* observed in a particular experiment. He could not accept the proposition that the existence of a particular property of the electron, such as its position or momentum, depends on the fact that we choose to measure it; or, as Bohr expressed it, that reality belongs to the observation, not to the property.

Einstein is often regarded as the founder of theories which provide no comprehensible explanation of reality but which must nevertheless be accepted since they have been confirmed by experiment. A prime example of this "Einstein mystique" is the statement that only 12 people in the world can understand the theory of relativity. As an historian of science I am sometimes asked by colleagues, and even by complete strangers, to verify or give the source of Einstein quotations and anecdotes. Usually I am unable to do so, but in this case I think I have found something very close to the original source. In an article in the *New York Times*, November 10, 1919, after stating that Einstein is "about 50 years of age" (exaggerating only by 10 years) the reporter says:

> When he offered his last important work to the publishers he warned them there were not more than twelve persons in the whole world who would understand it, but the publishers took the risk.[4]

So apparently we must blame Einstein himself for starting this myth. But it was eagerly accepted and popularized by the press, and provides a convenient excuse for anyone who doesn't want to make the effort to understand relativity theory.

But Einstein suffered from a more insidious form of mystification. For many years his example was invoked in support of logical positivism or empiricism; it was claimed that relativity theory had been invented in order to explain the failure to observe any motion of the earth through "absolute space" or "ether" as in the Michelson-Morley experiment. Einstein was depicted as a follower of Ernst Mach, and he was praised for having abstained from using any theoretical concepts that could not be defined by measurements. The logical positivists used Einstein as an ally in their efforts to show that science should not attempt to find out what the world is really like, but must be content with systematizing and predicting the results of experiments. Einstein's friend and biographer Philipp Frank, one of those responsible for promoting this view of Einstein, was at least honest enough to record his own surprise when he learned, in 1929, that Einstein was opposed to positivism.[5]

Another colleague who was surprised to learn that he had misunderstood Einstein's attitude was Werner Heisenberg. When Einstein in 1926 questioned the notion that "none but observable magnitudes must go into a physical theory," Heisenberg replied: "Isn't that precisely what you have done with relativity. . . . After all, you did stress the fact that it is impermissible to speak of absolute time, simply because absolute time cannot be observed; that only clock readings, be it in the moving reference system or the system at rest, are relevant to the determination of time." Heisenberg reports Einstein's unsettling rejoinder: "Possibly I did use this kind of reasoning," Einstein admitted, "but it is nonsense all the same . . . on principle it is quite wrong to try founding a theory on observable magnitudes alone. In reality the very opposite happens. It is the theory which decides what we can observe."[6]

Recent historical work, especially by Gerald Holton, has shown that Einstein turned away from Mach's empiricist philosophy toward a realist view of nature, and that his earliest work on relativity was *not* undertaken in response to the Michelson-Morley experiment.[7] Hence the positivists should not be allowed to cite Einstein in support of their doctrines. But my primary concern here is with the much more direct attack which Einstein launched against positivism in the realm of atomic physics.

In the great trilogy of 1905, Einstein's paper on Brownian movement is generally considered the least revolutionary. It acquires significance only if one realizes that at the end of the 19th century it was fashionable among the more philosophically sophisticated scientists to deny the existence of atoms, or rather to proclaim that the atomic hypothesis was useless and even harmful because atoms had not been directly observed. Ernst Mach, Wilhelm Ostwald and their followers were the precursors of the 20th-century logical positivists, insisting that scientific theories only describe rather than explain the phenomena of nature, and that concepts not directly based on observation are meaningless. I do not mean to imply that a majority of scientists actually accepted this view, but it was certainly quite influential and led some of the atomists, such as Ludwig Boltzmann, to feel that their approach was in danger of being abandoned.[8]

At this point, around 1902, Einstein entered the picture. Here is his own account:

> Not acquainted with the earlier investigations of Boltzmann and Gibbs, which had appeared earlier and actually exhausted the subject, I developed the statistical mechanics and the molecular-kinetic theory of thermodynamics which was based on the former. My major aim in this was to find facts which would guarantee as much as possible the existence of atoms of definite finite size. In the midst of this I discovered that, according to atomistic theory, there would have to be a movement of suspended microscopic particles open to observation, without knowing that observations concerning the Brownian motion were already long familiar. . . . The agreement of these considerations with experience together with Planck's determination of the true molecular size from the law of radiation (for high temperatures) convinced the sceptics, who were quite numerous at that time (Ostwald, Mach) of the reality of atoms. The antipathy of these scholars towards atomic theory can indubitably be traced back to their positivistic philosophical attitude. This is an interesting example of the fact that even scholars of audacious spirit and fine instinct can be obstructed in the interpretation of facts by philosophical prejudices. The prejudice—which has by no means died out in the meantime—consists in the faith that facts by themselves can and should yield scientific knowledge without free conceptual construction. Such a misconception is possible only because one does not easily become aware of the free choice of such concepts, which, through verification and long usage, appear to be immediately connected with the empirical material.[9]

It was the French physical chemist Jean Perrin (1870–1942) who accomplished the experimental confirmation of Einstein's formulae for Brownian motion, and with the help of these and other results finally established the atomic structure of matter.[10] While no one doubted the reality of *atoms* after Mach's death in 1916, positivism reared its head again in the 1920s with the development of quantum mechanics; the question now became: do instantaneous properties of subatomic particles (e.g. the position and momentum of the electron) have a real existence?

Before examining Einstein's answer to that question, I must make two remarks about Einstein's role in the development of quantum theory.

First, while it is generally acknowledged that Einstein's 1905 paper on the photoelectric effect was a major advance beyond Planck's formulation of quantum theory, the importance of Einstein's work has been enhanced by Thomas Kuhn's recent arguments that Planck did not actually propose a quantum hypothesis in 1900. Kuhn claims that Planck used his constant *h* only to define intervals of energy for the purpose of combinatorial calculations, and that the notion of a *discontinuity* in allowed values of energy originated with Einstein (reinforced by Paul Ehrenfest).[11] Thus a case can be made that Einstein is the founder of both relativity and quantum theory.

Second, the idea of indeterminism did not suddenly enter atomic physics with the quantum formulations of Heisenberg and Born in 1926–27, but emerged gradually from debates on irreversibility going back to the 19th century.[12] Einstein himself was largely responsible for promoting indeterminism in the first quarter of the 20th century. Brownian movement, thanks to Einstein's successful theoretical explanation of it, could be cited as visible evidence of the effects of random atomic motions. Relativity theory challenged Newtonian ideas of space and time, and Heisenberg himself, in his 1927 announcement of the Indeterminacy Principle, compared the impossibility of talking about the simultaneity of distant events with the impossibility of talking about the precise position and momentum of a particle. But it was Einstein's quantum theory which, according to Max Born and others, showed that atomic radiation must be treated as a random process, although Einstein himself considered it a "weakness of the theory . . . that it leaves the duration and direction of the elementary processes to 'chance'."[13]

The first evidence of Einstein's strong opposition to indeterminism (aside from his remark in the 1916 paper quoted above) is found in a letter to Max Born, 29 April 1924, about the Bohr-Kramers-Slater paper in which strict energy conservation in atomic processes was replaced by a probabilistic hypothesis:

> Bohr's opinion about radiation is of great interest. But I should not want to be forced into abandoning strict causality without defending it more strongly than I have so far. I find the idea quite intolerable that an electron exposed to radiation should choose *of its own free will*, not only its moment to jump off, but also its direction. In that case, I would rather be a cobbler, or even an employee in a gaming-house, than a physicist.[15]

Einstein's verdict on the work of Heisenberg and Schrödinger was expressed in another letter to Born, 4 December 1926:

> Quantum mechanics is certainly imposing. But an inner voice tells me that it is not yet the real thing. The theory says a lot, but does not really bring us any closer to the secret of the 'old one.' I, at any rate, am convinced that *He* is not playing at dice.[15]

In October 1927, at the Solvay Congress in Brussels, Bohr presented his theory of complementarity, the nucleus of the "Copenhagen Interpretation of Quantum Mechanics." The famous Bohr-Einstein debate began at this meeting. Einstein attempted to disprove the Indeterminacy Principle with a series of thought-experiments, but Bohr was able to refute each one, in some cases by invoking relativity theory. As a result of these discussions Einstein was forced to accept the Heisenberg principle, but he still rejected Bohr's claim that quantum mechanics tells us all we can expect to know about nature. Bohr succeeded in showing that the Copenhagen interpretation is logically selfconsistent and that quantum mechanics accounts for the experimental facts—but only at the cost of abandoning the idea that a particle has definite properties independent of our observations. For Einstein that was clearly unsatisfactory and so he concentrated on showing that quantum mechanics is an "incomplete theory" that fails to account for every element of reality.

Einstein's objection that quantum mechanics is incomplete was most sharply articulated in a 1935 paper published with two younger physicists, Boris Podolsky and Nathan Rosen. They began by defining reality (perhaps the first time this had ever been done in a scientific journal?):

> *If, without in any way disturbing a system, we can predict with certainty . . . the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity.*[16]

Note that Einstein is not disputing the 19th-century positivist claim that reality must not be attributed to a quantity which cannot be determined by observation. But he refused to follow Bohr in his claim that reality may not be attributed to a quantity unless it actually *is* determined by observation.

Einstein, Podolsky and Rosen considered two systems (which might be simply two electrons) which interact for a short time and then remain completely separated so that neither one can possibly influence the other. One can then measure the momentum of system I and, since the total momentum is assumed to be known, one has thereby determined by subtraction the momentum of system II—with complete certainty. Alternatively one could have chosen to measure the position of I and, by a similar line of argument, the position of II would be exactly determined. By hypothesis neither measurement could have any direct effect on II. Thus, they argue, II must actually have had those particular values of position and momentum, whether or not the measurements were made on system I. But this conclusion contradicts the Indeterminacy Principle, and there is no solution of the Schrödinger wave equation corresponding to definite values of both position and momentum. Hence quantum mechanics fails to give a complete description of reality.

In his reply Bohr protested that the Einstein-Podolsky-Rosen criterion for reality is "ambiguous." By this he meant that one cannot talk about the "reality" of system II apart from the experiment on system I; even though there is no direct interaction by which the measurement on I might influence the state of II, they are bound together by the very fact that one is trying to get information about II by observing I. Thus the Einstein-Podolsky-Rosen argument only illustrates a characteristic feature of quantum mechanics, and in particular shows how it involves a new conception of physical reality—a conception which, Bohr claimed, had already been introduced by Einstein's general theory of relativity.[17]

Bohr and Einstein agreed that their disagreement was essentially philosophical. Einstein had maintained the realist position but had stripped it of all reference to unobservable quantities, in deference to the acknowledged success of quantum mechanics; he insisted only that if a quantity can be measured with certainty, then it must be real. Bohr chose to defend an extreme instrumentalist position: a quantity is not real just because it *can* be measured, it is also necessary that it *is* measured. Or rather, reality cannot be attributed to the quantity itself in any case, but only to the measurement of the quantity.

Erwin Schrödinger then entered the debate on the side of Einstein, with his famous "cat paradox." A cat is placed in a chamber with a radioactive sample and a Geiger counter connected to an electrical device that will kill the cat with probability ½ in a certain time interval. At the end of the experiment the cat is represented, according to quantum mechanics, by a wave function which is the sum of functions corresponding to the cat alive and dead. According to the Copenhagen interpretation (if one is willing to apply it to macroscopic objects as well as to atomic particles) the cat is neither alive nor dead but in some intermediate state—until we open the chamber and look at it. At the instant when we *observe* the cat, its wave function "collapses" and it becomes either alive or dead.[18]

The cat paradox makes rather more vividly the same point that Einstein had been pressing against Bohr since 1927: however accurate quantum mechanics may be in predicting the results of experiments, it fails to give an acceptable description of reality, i.e. of the external world independent of the observer. Bohr's reply boiled down to the claim that one simply cannot expect quantum mechanics to give such a description because there is none. The tragedy of Einstein was that he failed to find a replacement for quantum mechanics that would satisfy his personal criteria. By general agreement he "lost" the debate with Bohr; yet anyone who believes that the physical world exists independently of his or her own observation of it must hesitate just a bit before applauding the victor.[19]

Notes

1. Anne C. Roark, "Notes on . . . Einstein," *Chronicle of Higher Education*, March 12, 1979, p. 2.
2. J. Robert Oppenheimer died 18 February 1967; John von Neumann died 8 February 1957.
3. Max Born, "Einstein's Statistical Theories," in *Albert Einstein Philosopher-Scientist*, ed. P. A. Schilpp (New York: Library of Living Philosophers, 1949), pp. 163–177 (quotation from pp. 163–64).
4. "Lights all askew in the heavens," *New York Times*, November 10, 1919, reprinted in *Science in the Twentieth Century*, ed. Walter Sullivan (New York: Arno Press, 1976), p. 8.
5. Philipp Frank, Einstein, *His Life and Times* (New York: Knopf, 1947), p. 215. Cf. his *Modern Science and its Philosophy* (Cambridge, Mass.: Harvard University Press, 1941), pp. 30–57.
6. Werner Heisenberg, *Physics and Beyond* (New York: Harper & Row, 1971), p. 63.
7. Gerald Holton, *Thematic Origins of Scientific Thought, Kepler to Einstein* (Cambridge, Mass.: Harvard University Press, 1973). See also E. Zahar, "Mach, Einstein and the Rise of Modern Science," *British Journal for the Philosophy of Science*, 28 (1977): 195–213.
8. See e.g. Boltzmann's foreword to Part II (1898) of his *Lectures on Gas Theory*, trans. S. G. Brush, (Berkeley: University of California Press, 1964) pp. 215–216.
9. Albert Einstein, "Autobiographical Notes," in *Albert Einstein Philosopher-Scientist*, ed. P. A. Schilpp (New York: Library of Living Philosophers, 1949), pp. 1–95 (quotation from pp. 47, 49). For the history of Brownian motion and details of Einstein's theory, see S. G. Brush, *The Kind of Motion We Call Heat* (New York: American Elsevier, 1976), Chapter XV.
10. See Mary Jo Nye, *Molecular Reality: A Perspective on the Scientific Work of Jean Perrin* (New York: American Elsevier, 1972).
11. Thomas S. Kuhn, *Black-Body Theory and the Quantum Discontinuity, 1894–1912* (New York: Oxford University Press, 1978).
12. S. G. Brush, "Irreversibility and Indeterminism: Fourier to Heisenberg," *Journal of the History of Ideas*, 37 (1976): 603–630.
13. Quoted from the translation of Einstein's 1916 paper in B. L. van der Waerden, *Source of Quantum Mechanics* (Amsterdam: North-Holland, 1967), p. 76. For additional references see Brush, *op. cit.* (note 12).
14. *The Born-Einstein letters*, trans. Irene Born (New York: Walker, 1971), p. 82.
15. *Ibid.*, p. 91.
16. A. Einstein, B. Podolsky, and N. Rosen, "Can Quantum-Mechanical Description of Reality be considered complete?" *Physical Review*, series 2, 47 (1935): 777–780.
17. Bohr's reply is reprinted with the Einstein-Podolsky-Rosen paper in *Physical Reality*, ed. S. Toulmin (New York: Harper & Row, 1970). See also Bohr's article "Discussion with Einstein on epistemological problems in atomic physics," pp. 199–241 in the Schilpp book cited in note 3.
18. E. Schrödinger, "Die gegenwärtige Situation in der Quantenmechanik," *Naturwissenschaften* 23 (1935): 807–812.
19. For a survey of recent developments see B. d'Espagnat, "The Quantum Theory and Reality," *Scientific American*, 241, no. 5 (November 1979): 158–181 and references on page 206; A. Shimony, "Metaphysical Problems in the Foundations of Quantum Mechanics," *International Philosophical Quarterly*, 18 (1878): 3–17.

Einstein and Religion

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When I mentioned to some of my colleagues that I was planning to give a talk about Einstein's views on religion, I was greeted with considerable skepticism and many a raised eyebrow. "Einstein was a great scientist, but he was not a theologian—of what significance are his opinions about religion?" "He did not concern himself with theological questions." "He did not write or publish much about his religious views." These were some of the comments I received from my more outspoken friends. Some considered a discussion on my part about Einstein and Religion as a trivial or even frivolous undertaking.

In answer to these doubts, I would like to point out two well known facts. First, Moses did not complete a full four-year course at an accredited theological seminary—nor did Buddha or Mohammed or Jesus Christ. Secondly, in his book, Ideas and Opinions, Einstein devotes 18 full pages to the subject of religion. His famous paper on the special theory of relativity, published in 1905 in the Annalen der Physik, which shook the foundations of classical physics and ushered in a new era in modern science, was only a few pages longer. It could be safely assumed that Einstein did not devote 18 pages of his writings to a subject of this importance without giving this matter prolonged and serious study.

Before discussing Einstein's ideas on religion, we will briefly review what is known about his religious background and upbringing. As is well known, Einstein was born of Jewish parents at Ulm, a medium size city in Bavaria. His Jewish ancestors, both maternal and paternal, lived for many generations in south-western Germany in a region known as Swabia. Although his parents generally adhered to Jewish traditions, they were in Einstein's own words, "entirely irreligious." In spite of his parents' attitude toward religion, Einstein states in his autobiographical remarks (Albert Einstein: Philosopher, Scientist; Edited by Paul Arthur Schilpp, 1970, p. 3) that he was deeply religious until he reached the age of twelve.

Here we should insert the following information concerning Einstein's early schooling. At the time of Einstein's childhood, the elementary schools in Germany were run under religious auspices. However, instead of sending young Einstein to a Jewish religious school, his parents sent him to a Catholic school. The reasons for that decision are not known, but Philipp Frank, who knew Einstein intimately since the year 1910, states in his book Einstein, His Life and Times (p. 9), that his parents "were not sufficiently interested in a Jewish education to send their children to a Jewish school since there was none near their home and it would have been expensive. His parents may even have felt that by sending their boy to a Catholic school he would come into more intimate contact with non-Jewish children." Einstein was the only Jewish child in his class, but according to Frank, Einstein had no recollection of having any objection to his participation as a Jewish pupil in a Catholic religious school. On the contrary, he seems to have derived a great deal of pleasure from this experience. Einstein left elementary school at the age of ten to enter Luitpold Gymnasium in Munich.

When he turned twelve, a drastic change took place in young Einstein's attitude toward traditional religion. Just as he had acquired strong religious feelings as a child on his own—his parents being entirely indifferent to religion—he also developed a strong contrary opinion when he reached the age of twelve. He recalls (Schilpp, p. 3):

"Through reading of popular scientific books, I soon reached the conviction that much in the stories of the Bible could not be true. The consequence was a positively fanatic (orgy of) freethinking coupled with the impression that youth is intentionally being deceived by the state through lies; it was a crushing impression. . . ."

Through most of his formative years Einstein was largely oblivious to religion, being much too preoccupied with other activities such as his scientific studies, his problems connected with making it through the school system, and later with earning a livelihood.

An interesting incident occurred during the process of Einstein's appointment to the German University in Prague in the fall of 1910, which sheds some light on his attitude toward religion during his earlier adult years. It pertains to Einstein's religious affiliation. At that time appointments to the German University were made by the emperor of Austria upon recommendation from the university faculty. Franz Josef, who was then emperor of Austria, held strong religious convictions and would not appoint anyone to teach at the university who did not belong to a recognized church. During that period Einstein did not consider himself as affiliated with any religious denomination, and if required to state his religion in connection with an application for office would normally have given the response: none, to any question about his religious affiliation. It should be noted that Einstein was at that time married to Mileva Maritsch, a classmate of his at the Swiss Federal Polytechnic School in Zurich, who was of the Greek Orthodox religion. He had no qualms about marrying outside his faith, or having his children, whom he loved dearly, brought up by their mother in the Greek Orthodox faith. When Einstein learned about Emperor Franz Josef's requirement he simply stated his religion in his application for appointment as "Mosaic," which was the customary nomenclature then used in Austria to designate a member of the Jewish faith.

I would like to recount one more incident bearing on Einstein's religious views, which took place about 20 years later.

On April 7, 1929, Einstein's theory of relativity was mercilessly denounced by Cardinal O'Connell of Boston as atheistic. Delivering a major address in Boston to the members of the Catholic Clubs of America of the New England area, he warned his audience against professor Einstein's theory of relativity as "befogged speculation producing universal doubt about God and His creation" and as "cloaking the ghastly apparition of atheism" (New York Times, 25 April, 1929, p. 60).

When he read about this vehement and, what he believed to be, unjustified attack upon Albert Einstein and his theories by a fellow clergyman, Rabbi Herbert S. Goldstein of the Institutional Synagogue at 37 W. 116th Street in New York City was outraged. He immediately sat down and dispatched a telegram—not to Cardinal O'Connell in Boston, but to Professor Einstein, who was at that time in Dusseldorf, Germany. The telegram contained five little words; namely, "Do you believe in God?" This was rather a demeaning question to pose to any self-respecting individual in a telegram, but especially to a world renowned scientist of Einstein's stature.

Einstein had several options open. He could have just ignored so disrespectful and foolhardy a question emanating from a recognized religious leader in America. Or better still, he could have replied with five little words of his own—rather four little words and a blank, viz: "Mind your own———business."

Einstein chose neither of these two approaches. He was apparently not at all offended by the boldness of the Rabbi's question—and within a few days Rabbi Goldstein received a substantive reply in a telegram from Albert Einstein at his home in New York. Einstein's telegram read:

"Ich glaube an Spinozas Gott der Sich in gesetzlicher Harmonie des seienden offenbart, nicht an Gott der Sich mit Schicksalen und Handlungen der Menschen abgibt."

Which translated from good emperor's German to good king's English means:

"I believe in Spinoza's God who reveals Himself in the orderly harmony of what exists, not in a God who concerns Himself with the fates and actions of human beings."

Einstein's reply to Rabbi Goldstein summarizes in one sentence one of the basic tenets which forms the foundation of his religious doctrine. He describes these views in greater detail in several articles which he published and in talks to religious groups which he delivered during his lifetime.

Einstein was awed and enthralled by the majesty and harmony of the universe and the laws of nature which govern the cosmos. "The most incomprehensible thing about the world is that it is comprehensible," he used to say (Albert Einstein and the Cosmic World Order, Cornelius Lanczos, 1965, p. 112). On the one hand, we look at the great complexity of the world we live in, beginning with elementary particles and fundamental forces, progressing through the simple atomic and molecular structures of matter to the more complex molecules, the amino acids, DNA (deoxyribonucleic acid) and organic materials, then to living self-reproducing organisms, plants and animals, and finally to the development of thinking, intelligent and cultured human beings. On the other hand, we witness the discovery of universal, comprehensive, all-embracing, yet simple laws which precisely govern the behavior of natural phenomena at all levels of magnitude and complexity, from the minutest elementary particles to the largest galaxies; from the simplest elementary forces to the most complex forms of human behavior. It is this superior universal power which governs the cosmos and which may be entirely beyond the feeble grasp of the human mind which Einstein calls God. This God, as Einstein conceives Him, is the God of all existence, who governs all phenomena and actions in the universe. But he is not a personal God, who punishes and rewards human actions or who concerns himself with the daily lives of human beings.

We quote a few representative statements from Einstein's writings or public discussions on this subject. Einstein writes (Universal Jewish Encyclopedia, Vol. IV, 1941, pp. 32–33):

"My religion consists of a humble admiration of the inimitable superior spirit who reveals himself in the slight details we are able to perceive with our frail and feeble mind. Ethics are a more important matter for us, not God. That deeply emotional conviction of the presence of a superior reasoning power, which is revealed in the incomprehensible universe, forms my idea of God; in the conventional manner of expression it could therefore be designated as pantheistic."

In "The World As I See It" (1929, p. 242) Einstein expresses these thoughts in the following words:

"The most beautiful thing we can experience is the mysterious. It is the fundamental emotion which stands at the source of true art and true science. He to whom this emotion is a stranger, who can no longer pause to wonder and stand rapt in awe, is as good as dead: his eyes are closed. This insight into the mystery of life, coupled though it be with fear, has also given rise to religion. To know that what is impenetrable to us really exists, manifests itself as the highest wisdom and the most radiant beauty which our dull faculties can comprehend only in their most primitive forms—this knowledge, this feeling, is at the center of true religiousness. In this sense, and in this sense alone, I belong in the ranks of devoutly religious men."

And again, on page 267 (Ibid.):

"But the scientist is possessed by the sense of universal causation. The future to him is every whit as necessary and determined as the past. There is nothing divine about morality, it is purely a human affair. His religious feeling takes the form of rapturous amazement at the harmony of natural law, which reveals an intelligence of such superiority that, compared with it, all the systematic thinking and acting of human beings is an utterly insignificant reflection."

Einstein was a humanitarian. He was, as a person, kind, gentle and humble. He was a leader in the movement for pacifism and disarmament. Insofar as time allowed, he aided many charitable endeavors. He despised authoritarianism and militarism. He fought for the underdog and the oppressed. He decried the innate human desires for wealth, honor and power. Among the ethical virtues upon which Einstein placed an especially high value was the goal to achieve individual freedom. He stressed this on many occasions. On the other hand, we have already noted in two of Einstein's quotations his belief that morality or ethics is not a standard of conduct which is established by a divine being, but in his words is "purely a human affair." In view of this belief, how then does Einstein justify the necessity for human beings to conduct themselves in accordance with a code of ethics and morality?

His justification is based on two premises: 1) that none of us have achieved the high level of culture and material well-being we now enjoy on our own, but are indebted to others now living, or to past generations for this progress, and 2) that by providing freedom to individuals to conduct their lives in accordance with their own inclinations, society stands to gain greatly from the important advances which some of these individuals will achieve, which they would not have been able to accomplish if forced to exist in a regimented environment.

Let us read the basis for the first of these justifications as expressed in Einstein's words (Forum and Century, Vol. 84, pp. 193–194; reprinted in Einstein, Ideas and Opinions, 1954, p. 8):

"How strange is the lot of us mortals! Each of us is here for a brief sojourn; for what purpose he knows not, though he sometimes thinks he senses it. But without deeper reflection one knows from daily life that one exists for other people —first of all for those upon whose smiles and well-being our own happiness is wholly dependent, and then for the many, unknown to us, to whose destinies we are bound by the ties of sympathy. A hundred times every day I remind myself that my inner and outer life are based on the labors of other men, living and dead, and that I must exert myself in order to give in the same measure as I have received and am still receiving."

Einstein expressed opinions on a number of other questions pertaining to religion. In the remaining time I would like to touch upon some of these. The most important subject among these is, no doubt, the perennial strife which existed throughout the centuries between science and religion. Einstein addressed this subject on a number of occasions. On November 9, 1930 the New York Times featured an article in its Sunday Magazine section, written expressly for the newspaper by Albert Einstein and entitled "Religion and Science." On May 19, 1939 Einstein gave an address at the Princeton Theological Seminary on "Science and Religion" and in 1940 he participated in a symposium entitled "The Conference on Science, Philosophy and Religion in Their Relation to the Democratic Way of Life" (published in New York, 1941).

Einstein attempted to reconcile the conflict between science and religion. His main thesis was that there is no valid reason for this conflict to exist between these two important fields of human endeavor, since their purposes and methods do not overlap but are separate and complementary. In his view knowledge or science can teach us only what *is* or how facts are related to each other. The purpose of religion, on the other hand, is to determine what *should be*, especially what should be the goal of human aspirations.

In his address to the Conference on

Science, Philosophy and Religion in Their Relation to the Democratic Way of Life (reprinted, Einstein, Ideas and Opinions, p. 45) Einstein states these views very clearly:

"For science can only ascertain what *is*, but not what *should be*, and outside of its domain value judgements of all kinds remain necessary. Religion, on the other hand, deals only with evaluations of human thought and action: it cannot justifiably speak of facts and relationships between facts. According to this interpretation the well-known conflicts between religion and science in the past must all be ascribed to a misapprehension of the situation which has been ascribed."

Of special interest is also Einstein's views on the theological and philosophical question of free will. Einstein did not believe that a human being is endowed with the capacity to exercise free will. He quoted Schopenhauer in this regard who said, "a man can do what he wants, but he cannot want what he wants."

Einstein also showed a religious-like devotion for such human goals and endeavors as Goodness, Truth, Beauty, Fellowship, Art, Research and Music. He writes (Einstein, The World As I See It, p. 239):

"The ideals which have lighted me on my way and time after time given me new courage to face life cheerfully have been Truth, Goodness and Beauty. Without the sense of fellowship with men of like mind, of preoccupation with the objective, the eternally unattainable in the field of art and scientific research, life would have seemed to me empty. The ordinary objects of human endeavor—property, outward success, luxury—have always seemed to me contemptible."

Finally, I would like to describe Einstein's attitude toward the traditional religions. As we have noted, he did not believe in a God who punishes the wicked or rewards the righteous; nor did he believe in a God who concerns himself with the daily activities of men. He definitely did not believe the bible stories and at one time, at age twelve, he castigated them as intentional lies and deceptions. What, then, were his views concerning the older religions in adult life?

Einstein actually showed a high regard for the contributions made by the major religions. In his writings he tended to emphasize the positive contributions made by these religions and to overlook the grief, misery, torture and deaths which have resulted from the great conflicts that have occurred due to religious rivalry. Although he certainly was opposed to the practice of religious rituals and customs, he believed that there was a useful purpose in some of these in the educational processes. He gave high praise to the part played by the traditional religions and their leaders in bringing to the human race the ideals of morality and ethical behavior. We quote from his address at the Princeton Theological Seminary (reprinted, Einstein, Ideas and Opinions, p. 43):

"The highest principles for our aspirations and judgements are given to us in the Jewish-Christian religious tradition. It is a very high goal which, with our weak powers, we can reach only very inadequately, but which gives a sure foundation to our aspirations and valuations."

In the New York Times article he states (reprinted, Einstein, Ideas and Opinions, p. 37):

"The Jewish scriptures admirably illustrate the development from the religion of fear to moral religion, a development continued in the New Testament. The religions of all civilized peoples, especially the peoples of the Orient, are primarily moral religions."

Now, what more precisely were Einstein's views concerning the contributions of the Jews to morality? He states these most succinctly in his Credo as a Jew, republished in the Universal Jewish Encyclopedia, Vol. IV, 1941, pp. 32–33: (See also Einstein, the World As I See It, 1933, p. 143.)

"The striving after knowledge for its own sake, the love of justice verging on fanaticism, and the quest for personal independence—these are the motivating traditions of the Jewish people which cause me to regard my adherence thereto as a gift of destiny. Those who rage today against the ideals of reason and of individual freedom, and seek to impose an insensate state slavery by means of brutal force, rightly see in us their irreconcilable opponents. History has imposed upon us a severe struggle. But as long as we remain devoted servants of truth, justice and freedom, we shall not only continue to exist as the oldest of all living peoples, but we shall also, as hitherto, create, through productive effort, values which shall contribute to the ennobling of mankind."

One of my former schoolmates, Rabbi Morris Gordon (Congregation Har Shalom), has recently told me an interesting private story about Einstein, which sheds additional light on his sentimental attachment to traditional Jewish customs. It was told to him by a young woman he knows very well, who lived, when she was a child, with her family in Princeton in close proximity to Einstein's residence. This young woman, by the way, is now a prominent mathematician in her own right and teaches mathematics at the University of California.

Occasionally, on Saturdays, the Jewish Sabbath, Einstein used to invite all the children in the neighborhood to his house for an Oneg Shabbat (Sabbath celebration). He used to given them refreshments, play his violin and tell them stories, often about the children in Israel (then Palestine) whom he visited, and who were working hard helping their parents to build a new homeland for the Jews. He used to tell them that on the Sabbath he did not like to do everyday work, even research in mathematics or physics, but he liked to engage in more pleasant activities such as playing the violin.

On Passover eve he would sometimes gather the children in his house for a Passover mini-Seder. Einstein was a lover of freedom, and Passover is the holiday of freedom, which commemorates the deliverance of the Israelites from slavery to freedom. Einstein would talk to the children about freedom, and he would point out to them that freedom cannot be won once and for all (as by the exodus of the Israelites from Egypt), but must be regained over and over again by every generation. He drew an analogy with a beautiful statue which was erected long long ago in the desert, and he would ask the children what would happen to the statue after a number of years. They would reply that it would be covered with sand before too long and would lose its beauty. And he would point out that in order to regain its original beauty the sand would have to be carefully and painstakingly removed every ten or twenty years, and the statue would have to be refurbished so that it could glisten again in its full beauty. The same principle applies to the attainment of freedom.

Albert Einstein—A Moral Visionary in a Distraught World

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Toward the end of January 1933, after an indecisive election that gave no clear majority to any of the numerous contending political parties, Hindenburg, President of the embattled German Republic, turned over the office of Chancellor to Adolph Hitler. This limited transfer of power was quickly followed by a fire of suspicious origin in the Reichstag Building. It provided the excuse for the arrest of members of the opposition parties, and opened the door for the absolute rule of the German Nazi party.

Within six years these events led to World War II and to convulsions that even today remain to be resolved. They also, at the time, confronted many people, especially those of Jewish ancestry with decisions of crucial importance. Among those affected were thousands of scientists.

By April of 1933, many extreme Nazi policies were put into effect, such as the abrupt retirement or removal from office of all Jewish state employees. When the likely consequences of this decision were brought to the attention of Hitler, he said:

> Our national policies will not be revoked or modified, even for scientists. If the dismissal of Jewish scientists means the annihilation of contemporary German science, then we shall do without science for a few years.[1]

> dann arbeiten wir eben einmal 100 Jahre ohne Physik und Chemie[2] (Then we shall do without physics and chemistry for 100 years).

A person's response to cataclysmic events uncovers the deepest wellsprings of beliefs and attitudes. Three well-known German-Jewish scientists were among the thousands who were trapped by events into formulating their responses. They were born less than ten years and less than a few hundred miles apart. All three had received Nobel awards for their outstanding contributions within a few years of each other. They were neighbors in Berlin just prior to and during World War I. Each was the head of newly established Kaiser-Wilhelm Institutes for Chemistry, Physical Chemistry and for Physics. They knew each other well. They were Fritz Haber, the brilliant physical chemist and creator of the synthetic ammonia industry; Richard Willstätter, the most creative organic chemist of his day; and Albert Einstein.

With such similar backgrounds one would surmise that their responses to the threats of 1933 would have been similar. But no. Haber, whose most deep-seated passion was a fanatical attachment to his country, was dead of a broken heart in less than a year.[3] Willstätter remained a virtual prisoner in Germany for five tortured years. At last, on reaching Switzerland and safety, he said:

> I hear that many, who after overcoming much fear and many hazards, on leaving Germany and crossing the frontier, would wave their hats with joy. I want to weep.[4]

What a contrast with Einstein! He was, in the winter of 1932, visiting the California Institute of Technology where he had been spending half a year for the past two years with R. A. Millikan and E. D. Hubbell. He was about to return to his Institute in Berlin in late March. But before leaving Pasadena he gave an interview to a reporter of the New York World Telegram and said, in tones ringing clear to this day:

> As long as I have any choice in the matter I shall live only in a country where civil liberties, tolerance and equality of all citizens before the law prevail. Civil liberty implies

freedom to express one's political convictions in speech and in writing: tolerance implies respect for the convictions of others: whatever they may be. These conditions do not exist in Germany at the present time.[5] (1933)

and added a statement that, even today, has few adherents:

For an internationally minded man, citizenship of a specific country is not important. Humanity is more important than national citizenship.[6] (1933)

Citizenship As A Political Statement

How can one summarize the social views of this extraordinary person which molded his entire personality and formed his most fundamental beliefs? I will make this attempt with a few happenings that, like well-matched pearls, form a beautiful strand. The veritable flood of books and of reminiscences, the collections of letters and the massive archival material of speeches, statements and interviewing help to explain apparent paradoxes and curious twists that were difficult to comprehend when viewed in isolation.

Although Einstein never wrote an autobiography that touched on much more than his love for physics,[7] he frequently and with great candor expressed his thoughts about matters that affected him deeply:

My passionate sense of social justice and social responsibility has always contrasted oddly with my pronounced lack of need for direct contact with other human beings and human communities. I am truly a 'lone traveler' and have never belonged to my country, my home, my friends or even my immediate family with my whole heart. In the face of all these ties I have never lost a sense of distance and a need for solitude—feelings that increase with the years.[8]

He craved solitude and yet became the most public of men; he disliked war and yet rallied the world in a war against Nazi tyranny; he wanted world rule and threw his efforts into the creation of Israel; he was appalled by the misuse of science and yet had a share in the unleashing of the most destructive weapons that technological man was able to design.

His most characteristic pattern was that of a stubborn fighter. Once involved in a struggle that touched his sense of values, he would pursue the matter doggedly, privately in days when no one yet listened, or before the world when the tools of public discourse became available to him.

Let us survey the unusual events connected with his citizenship. As a young student in Munich he chafed under the strict German school system:

The teachers in the elementary school appeared to me like sergeants and the gymnasium teachers like lieutenants.

His parents, having moved to Italy to recoup a foundering business, had left Albert in Munich to complete his precollege studies. After suffering for half a year in solitude disliking the drill-field atmosphere of learning by rote while all the time teaching himself calculus and geometry, he so upset the teaching staff that he had no difficulty being released prematurely from school at the age of fifteen, with a physician's certificate that a nervous condition made a trip to Italy to rejoin his parents desirable both for him and the school's staff.

Ronald W. Clark, with the help of a German historian of science, spent much effort to document the subsequent events.[9] The sixteen-year old Albert pleaded with his father that he should help him to renounce his German citizenship. These laborious efforts bore fruit and in 1896 the Württenberg authorities formally ended his German citizenship. He was left without nationality papers as he moved to Switzerland to continue with his studies of Physics at the Eidgenoessische Technische Hochschule in Zurich and was granted Swiss citizenship in 1901. By then, he had completed his academic studies, in less than brilliant fashion, as far as the outside world could see. Eligible for Swiss military service, he was promptly rejected because of flat feet and varicose veins.

In a peaceful and seemingly stable Europe this unusual political statement and change of national allegiance would have served for a lifetime. Eleven years of intense and productive scholarship followed. To be sure, family problems had to be overcome but the world seemed at peace. Only the controversies that swirled about fundamental issues in Physics needed his attention.

Then came the year 1912. The most prestigious offer to accept the Directorship of the new Kaiser-Wilhelm Institute für Physik in Berlin and, as an additional honor, membership in the Preussische Akademie der Wissenschaften, brought with it an automatic conferral of Prussian (and, therefore, German) citizenship. Since a Kaiser-Wilhelm Institute director was a German civil servant (even though most of the funds for the setting up of the organization and paying for the building of the structures came from private donors, many of them Jewish) there was some doubt whether that position, indeed, required German citizenship. This issue was never formally resolved. Einstein continued as a Swiss citizen and retained his Swiss passport. The German authorities were apparently satisfied that the automatic acquisition of Prussian citizenship satisfied their needs.

Within a year World War I broke out. Belgium was invaded. Belgian citizens were apprehended, accused of sabotage and shot, often as hostages. The world was appalled. To counteract this wave of condemnation, a Manifesto was published and signed by nearly one hundred of Germany's best known intellectuals.[10] Einstein refused to sign.

When the war ended in defeat for the Germans, with the monarchy overthrown and a republic based on democratic principles established in Weimar for the first time in Germany's history, Einstein formally threw in his lot with the new government. He requested the civil rights of a German citizen as a symbolic act of support for the new regime. Luckily, it was not necessary to relinquish his Swiss citizenship or passport, acquired 20 years earlier.

He said later that this act of solidarity was one of the big mistakes of his life, comparable only to the introduction of an unnecessary constant into his cosmological equation which led to the conclusion that the universe was "stationary" rather than "expanding"; and the writing of two letters to President Franklin D. Roosevelt in 1939 and 1940, urging the development of nuclear weapons against the Germans and Japanese.

At first only one small diplomatic incident arose. When in 1922 he was awarded the Nobel prize for his work on the Photo-electric Effect and was unable to attend the Stockholm ceremonies, a question arose as to which ambassador, the German or the Swiss, should stand in for him to receive the award. It was finally resolved that the German ambassador was to receive the medal in Sweden and that the Swiss ambassador in Berlin was to hand it to Einstein. In the records of the Nobel Foundation Einstein is listed as a German.

In 1933 this tortuous citizenship problem was finally resolved. When the consequences of Hitler's access to power became clear, a break with everything that tied Einstein to Germany was inevitable. Having said publicly that "I am not going home"[11] the decision was made to return from the USA on the planned date but to disembark in Antwerp, go to Brussels, hand over the German passport, therewith surrendering his German civil rights and, after leaving the German embassy, never to set foot on German soil again.

The break with the country that had disappointed him twice, as a youth and, again, in middle age, was irreparable. Until his death, some twenty years later, he would not join any German society or accept any German awards. He replied to an inquiry from Otto Hahn whether he would accept a Foreign Membership of the Max Planck Gesellschaft, the descendent of the Kaiser Wilhelm Gesellschaft:

> It pains me that I must say "No" to you, one of the few men who remained decent and did what they could during those evil years: but I

cannot do otherwise. The crime of the Germans is truly the most abominable ever to be recorded in the history of the so-called civilized nations.[12] (1949)

Arguments for Peace and World Government

There was in Einstein a stubborness about fundamental moral issues that served him as a compass throughout his life. He hated killing. He found wars abhorrent. While his Kaiser Wilhelm Institute colleagues Haber and Willstätter eagerly signed up for war service, Einstein, in the very center of Prussianism, helped to prepare an antiwar Manifesto.[13] Forty years later, one week before his death, he joined Lord Russell in a ringing declaration to contain the nuclear arms race with the Soviet Union, to rethink once again the horrors of a nuclear war and to lay down a foundation on which to build peace. And three days later, working on a statement to celebrate the anniversary of Israel's independence, he said:

> And the big problem of our time is the division of mankind into two camps. . . . a power conflict between East and West, although the world being round, it is not clear what precisely is meant by the term 'East' and 'West'. . . . political passions, once they have been fanned into flame, exact their victims. . . .[14] (1955)

But he was confounded by events where absolute and extreme moral or political judgments cannot stand inviolate forever. When he saw that a country like Germany, by a deliberate policy of violence and war, might overwhelm all the values that were dear to him and to subjugate anyone standing in its way, he cast aside his pacifism and his refusal for self-defense and protection:

> Were I a Belgian, I should not, in the present circumstances, refuse military service: rather, I should enter such service cheerfully in the belief that I would thereby be helping to save European civilization.[15] (1933)

He was pleading for a political system in which the anarchy among nation states would be replaced by a world order of new institutions with sufficient powers so that disputes could be settled by a superior authority:

> I believe the condition in which the world finds itself today makes it not only a matter of idealism but one of direct necessity to create unity and intellectual co-operation among nations. Those of us who are alive to these needs must stop thinking in terms of "What should be done for our country?". Rather, we should ask: "What must our country do to lay the groundwork for a larger world community?" For without that greater community no single country will long endure.[16] (1922)

The destructive tools made available by technology gave added urgency to his pleas:

> In my opinion the only salvation for civilization and the human race lies in the creation of a world government, with security of nations founded upon law. As long as sovereign states continue to have separate armaments and armament secrets, new world wars will be inevitable.[17] (1945)

> There can be no doubt that world law is bound to come soon, whether by coercion or peaceful agreement. No other defense exists against the modern methods of mass destruction. Should man misuse science and engineering in the service of selfish passions, our civilization is doomed. The nation-state is no longer capable of adequately protecting its citizens: to increase the military strength of a nation no longer guarantees its security.[18] (1947)

The Chain of Events to Popular Fame

What made it possible for Einstein, whose deepest instincts were to be left alone, to command so much public recognition? How could a man, whose professional contributions required insights that few people can put forth, become a household word as a symbol of scientific wisdom, an oracle of man's future? There were no passionate public debates about his work as there were with Darwin about the *Descent of Man* that threatened the comfortable belief of man's special place in the universe. There was no public taking of sides as with Freud's reappraisal of dimly recognized dark and threatening forces behind man's behavior that challenged long-held views of morals and standards. What special circumstances prevailed to direct the flash of public recognition onto this man?

The clues to this extraordinary development were buried in the silver grains of half a dozen photographic plates that were brought back in May 1919 from a solar eclipse that swept across northern Brazil and the small island of Principe off the coast of Africa. By a freak of accident, this eclipse occurred against a stellar background in which an unusually large number of bright stars were positioned near the sun's rim. Einstein had predicted three years earlier that the image of the stars whose light needed to pass near the sun's rim would be displaced by a small amount (1.76″ of arc, or less depending on the distance), less than 1/1000 of an inch for the closest encounters, as compared to their normal position in the sky when there was no massive body interacting with the path of the light.

Late in 1915 and early in 1916, in the middle of the war, Einstein had published his climatic paper that linked gravity with the space-time relations that he had examined 10 years earlier in his Special Relativity Theory. His new General Relativity Theory led him to make three predictions. It gave a new value to the already well-known abnormality in the motion of Mercury around the sun, a value in much closer agreement than anything calculable from Newtonian assumptions. He predicted a small change in the frequency of light due to gravitational effects, a prediction that proved difficult to detect but was finally observed by watching a companion star of Sirius.

The third prediction of the bending of light, however, was more easily measured[19] and, in fact, could have been seen at previous solar eclipses if someone had gone to the trouble of setting up an experiment that would have concentrated on this effect. However, in the absence of a compelling theoretical guide, the determination of such a small deflection would have been an effort beyond anything an astronomer would be expected to perform.

Einstein's predictions were the result of a conceptual picture that looked for scientific truths in the opposite way—a deductive way—from the more common inductive way where many observations are combined to give rise to a general law which, in turn, may predict further unexpected events. Mendele'ev did it with his Periodic Table of chemical elements which, when properly arranged in a systematic way, pointed out where to look for missing structures.[20] Not so with Einstein's approach. His constructs owed nothing to specific observations. Rather, he began with general propositions from which particular measurable results might be deduced.

How was the prediction of the bending of light confirmed? The events culminating in the momentous joint meeting of the British Royal Society, meeting with the Royal Astronomical Society in November 1919, read as if they had been thought up by a skilled dramatist. Imagine the setting for the announcement—Burlington House, the home of the Royal Society of which Newton was a founding member more than 200 years ago and whose portrait hung prominently in the auditorium. The devastating war between England and Germany had ended less than a year before and while there was no peace as yet, the terrible carnage of World War I was, at last, over.

The meeting had no intentions of renewing contacts broken by the war, or to reestablish the severed threads between the separated scientific communities. The sole objective of the meeting was to present and to discuss a formal report by the Astronomer Royal and his associates on:

> "A determination of the deflection of light by the sun's gravitational field from observations made at the total solar eclipse of May 29, 1919"[21]

a venture that had been jointly organized by the two societies two years earlier.

Sir J. J. Thompson, President of the Royal Society, known for his work on the electron, was in the chair. Frank Dyson, the Astronomer Royal, who had pointed out the unusually favorable circumstances of this particular eclipse,[22] and Sir Arthur Eddington of Cambridge University, the leader of one of the two expeditions, spoke to a hushed audience. As Alfred North Whitehead recalled later:

> It was my good fortune to be present at the meeting of the Royal Society in London when the Astronomer Royal for England announced that the photographic plates of the famous eclipse, as measured by his colleagues in Greenwich Observatory, had verified the prediction of Einstein that rays of light are bent as they pass in the neighborhood of the sun.
>
> The whole atmosphere of tense interest was exactly that of the Greek drama: we were the chorus commenting on the decree of destiny as disclosed in the development of a supreme incident. There was dramatic quality in the very staging: the traditional ceremonial, and in the background the picture of Newton to remind us that the greatest of scientific generalizations was now, after more than two centuries, to receive its first modification. Nor was the personal interest wanting: a great adventure in thought had at length come safe to shore.[23]

The two expeditions had nearly failed. Eddington's expeditions to the island of Principe came back with 18 photographs of the eclipse. Sixteen of them were useless because of a thin cloud cover and only two showed images of the very brightest stars nearest to the sun. At Sobral in Brazil the clouds lifted one minute prior to totality but all 18 pictures taken with an astrographic telescope that depended on a mirror to deflect light into the instrument, were hopelessly blurred. Luckily, a second telescope, borrowed from an Irish astronomer-priest, provided seven acceptable pictures.

Despite these near disasters the measurements could leave no doubt. Dyson's report said that the greatest weight should be attached to the results from Sobral (1.94″). The Principe observations gave deflections of 1.61″, but with a large probable error. Both pointed clearly toward the predicted 1.75″ of Einstein's theory.

At the meeting Dyson and Eddington stated most emphatically that the crucial test of Einstein's theory had been a success. Thompson, calling for a general discussion added:

> If it is sustained that Einstein's reasoning holds good then it is the result of one of the highest achievements of human thought.[24]

There was a spirited debate. Could other explanations suffice? One speaker, pointing to Newton's portrait said: "We owe it to that great man to proceed very carefully" But there was no holding back now, no waiting for the next eclipse in 1922 in Australia which confirmed the results without doubt.[25] The next day, the *London Times* carried a banner headline story and an editorial

REVOLUTION IN SCIENCE
NEW THEORY OF THE UNIVERSE
NEWTONIAN IDEAS OVERTHROWN
The Fabric of the Universe[26]

The unsigned author of this beautifully and accurately presented story quotes Thompson as saying:

> "They had just listened to 'one of the most momentous, if not the most momentous pronouncement of human thought.' "[27]

With such a send-off the press had no need to invent more drama than was there in fact. An English expedition, making its preparations in the middle of a terrible war, had confirmed predictions of an individual living in the land of the enemy, and formulating a view of space, time and gravitation that differed from the common sense view of Newton.

Like a spark in a room filled with combustibles the news story burned a spot in men's minds at a time when despair with man's behavior had all but triumphed. Einstein's prediction, skillfully confirmed by the British astronomers, dramatically presented to the scientific world, and so responsibly reported to the world at large, came at a time when its emotional impact was profoundly moving. It uncovered a person who, through the strength of his character and the messages of his humane outlook, would sustain this attention throughout his life.

"This I Believe"

Just prior to his journey to Pasadena in 1932, without knowing that the political developments would forestall a return to his home and to the country of his birth forever, Einstein made a radio recording for the German public of his most deeply held views. It came too late to influence the events that were about to descend on the world. But as the beliefs of a thoughtful person, it will be read after the rantings of those then in power have long been forgotten:

It is a special gift of grace to join those who have the opportunity and who are able to dedicate their best efforts to the study and exploration of objective, timeless topics. I am happy and grateful that I shared in this gift. It made me independent of the personal fate and actions of my fellow men, even though this independence should not blind one to the obligations that bind us irrevocably to the past, the present and future of humanity.

Our situation on this earth is a curious one. Each one of us arrives here for a short stay, involuntarily and unbidden, not knowing for what reason and for what purpose. In our daily lives we feel that we are here for the sake of others, those whom we love and many others whose fate is intertwined with ours.

I am often saddened by the thought of how much of my life is based on the labor of others and I know how much I owe them.

I do not believe in free will. Schopenhauer's saying that "A man can *do* what he wants, but he cannot *will* what he wants" accompany me in all situations. It excuses the behavior of people even when they hurt me. This recognition of the absence of free will protects me from taking myself and my fellow men too seriously as acting and as judging individuals, and it keeps me from losing my sense of humor.

I never sought wealth and luxury and have, in fact, a good deal of contempt for them. My passion for social justice has brought me into conflict with people, as has my antipathy to any bonds and dependencies that are not absolutely essential. I admire the individual and inexpressibly dislike force and discrimination. These feelings have made me a dedicated pacifist and an opponent of militarism. I reject nationalism even in the guise of patriotism.

Privileges based on position or property appear to me unjust and corrupting, as is an excessive personality cult. I acknowledge the ideal of democracy, even as I recognize the disadvantages of democratic governments. Social equality and economic protection of the individual appear to me important goals of the social compact.

In daily life I am a 'loner' but the awareness of being part of the invisible company who strive for beauty and justice leaves me no time to feel lonely.

The most beautiful and profound thrill that man can experience is the feeling of mystery. It forms the basis of religions and provides the deepest nourishment for art and for science. He who does not experience it appears to me not dead but blind. To be aware that beyond the accessible there is hidden an unreachable experience whose beauty and majesty touches us only indirectly and in pale reflection—that is true religion. In *this* sense I am a believer. It is enough for me to approach these secrets with wonder and to attempt to formulate a concise picture in my mind of the majestic structure of the universe.[28] (1932)

Acknowledgments

I am grateful to Ms. Brenda G. Corbin who made the splendid collection of the Naval Observatory Library available for research and study.

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Einstein in the U. S. Navy

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The figure of Albert Einstein has fascinated his contemporaries; he was not only the greatest scientist of our age, but also the best-loved and most admired man among all scientists. Because of his stupendous contributions to science, one of which resulted in the atomic age, his name became known, through newspapers, magazines, radio and television, not only to the educated laymen, but also to those who had less education than the present audience; and even those who know the name of no other scientist know the name of Einstein.

Several biographies of Einstein were published, which dealt with almost every aspect of his life, but one aspect of his life—in my opinion an important aspect—was not discussed in any of them but one, and in that only very briefly and to some extent misleadingly. This aspect is the story of how Einstein, a lifelong pacifist, helped during World War II to fight the Nazis through his work for the U. S. Navy.

The best and most complete biography of Einstein was written by Ronald W. Clark, with the title *Einstein, the Life and Times*, and it was published by the World Publishing Company in 1971. Clark devoted less than two pages in his 631-page book to Einstein's work for the Navy Bureau of Ordnance, and even that is partly erroneous, based on George Gamow's book *My World Line*. This is not Clark's fault; he wrote what scant information he received, and apparently no one referred him to the person who could have given him both more and more accurate information, namely, to me. At the time Mr. Clark wrote his book, I was a professor in the Department of Chemistry at Clarkson College of Technology.

First I have to tell you the background of how Einstein and I became acquainted. At the time of Pearl Harbor, I was a research chemist in the U. S. Department of Agriculture. Soon after that, I applied for a commission in the Navy. After a long drawn-out fight with the Navy, which included one rejection, I won the fight, and received my commission as a full lieutenant (equivalent to a captain in the Army) on September 2, 1942. After that it took more than a month until I located a billet in the Bureau of Ordnance and was called in for active duty.

Mr. Clark, following Gamow's book, wrote about the "Division of High Explosives" in the Bureau of Ordnance, but there was no such thing. The Bureau had a "Research and Development Division (Re)," the division had a section called "Ammunition and Explosives (Re2)", and the section had a subsection called "High Explosives and Propellants (Re2c)." I was assigned to Re2c. It had two other reserve officers in it when I joined, and we divided the work among ourselves. One became head of propellant research, I became head of high explosives research, and the third, who was a lieutenant j.g., became my assistant and deputy. I was, on the basis of my broad experience in the field, excellently qualified for my assignment. I knew the names of two high explosives: TNT and dynamite. With that knowledge, I became head of high explosives research and development for the world's largest Navy!

But I was young and learned fast; furthermore, the staff kept on growing as the war progressed. I acquired two groups of civilian scientists; one headed by one of the speakers at this meeting, Raymond J. Seeger; another of tonight's speakers, Harry Polachek, was in this group; the other group was headed by Gregory Hartmann, who eventually became Technical Director of the post-war Naval Ordnance Laboratory at White Oak. I also had a few officers. Besides the people directly under me, I had very many other scientists working for us indirectly. The great majority of the civilian scientists doing war research was organized into the National Defense Research Committee (NDRC), which had two divisions doing research on high explosives: Division 2, headed by Professor E. Bright Wilson of Harvard University, which worked on underwater explosives in Woods Hole, Massachusetts, and Division 8, headed by Professor George Kistiakovsky, also of Harvard, which worked on explosives in air in Bruceton, Pennsylvania. This is a long introduction to my meeting Einstein, but I believe it was necessary to see the set-up to understand better what I will say from this point on.

The top people of the Army, Navy and the two civilian divisions had occasional joint conferences to discuss their research on high explosives. At one such conference, the name of Einstein was mentioned by somebody. That gave me an idea. I asked the Army people whether Einstein was working for them. The answer was no. Then I asked the civilians whether Einstein was working for them, and the answer again was no. Why? "Oh, he is a pacifist," was the answer, "furthermore, he is not interested in anything practical. He is only interested in working on his unified field theory." I was not satisfied with these answers. Like those who gave the answers, I was ignorant of the fact that Einstein had changed his pacifist views publicly since Hitler's ascension to power; nor did I know that Einstein *was* interested in practical things. The first biography of Einstein, that of Philipp Frank, was to appear only four years later. Nevertheless, I felt that Einstein could not be a pacifist in a war with Hitler, nor did I believe that he would be unwilling to contribute his efforts to this war. So I decided that I would try to get Einstein for the Navy.

In the second week of May, 1943, I wrote a letter to Einstein, asking his permission to visit him in Princeton. The gracious consent came by return mail. The visit took place on May 16. After the pleasant preliminaries, I asked Einstein whether he would be willing to become a consultant for the Navy in general, and for me, in the field of high explosives research, in particular. Einstein was tremendously pleased about the offer, and very happily gave his consent. He felt very bad about being neglected. He had not been approached by anyone to do any war work since the United States entered the war. He said to me, "People think that I am interested only in theory, and not in anything practical. This is not true. I was working in the Patent Office in Zurich, and I participated in the development of many inventions. The gyroscope too." I said, "That's fine. You are hired." We both laughed, and agreed that Einstein would talk the details over with Dr. Frank Aydelotte, the Director of the Institute for Advanced Study, where Einstein was employed.

Already on the next day, both Einstein and Aydelotte wrote separate letters to me, and it is worth quoting both letters in full. Both letters came on the stationery of the Institute. The following was Einstein's letter:

May 17, 1943

Dear Lieutenant Brunauer:

I have your kind letter of May 13 and have discussed with Dr. Aydelotte, Director of the Institute for Advanced Study, the matter of my cooperation with the Research and Development Division of the Navy. Dr. Aydelotte approved heartily of my participating in your research operations. He and I both feel that the individual contract would be most suitable, and I agree fully with the arrangements outlined in the enclosed letter from Dr. Aydelotte.

I very much enjoyed your visit and look forward with great satisfaction to this association with you in research on Navy problems. I shall expect to receive from you in due course the contract and information about the work which you wish me to undertake, and I hope that I shall be able to make some useful contribution.

In this connection, I should like to raise one question: Would it in any way interfere with my usefulness to the Navy if I should spend a part of the summer in a cottage at Lake Saranac? I do not know whether it will be possible for me to take a holiday away from Princeton in any case, and certainly if my usefulness to the Navy would be increased by remaining in Princeton I should be most happy to do so. If, however, it would be equally convenient for you, I think I could probably work to better advantage in the more agreeable climate of Lake Saranac during the hot months of summer.

Yours very sincerely,
(signed) A. Einstein

How clear from this letter is Einstein's joy over the fact that he was finally drawn into the war research! "I very much enjoyed your visit and look forward with great satisfaction to this association with you in research on Navy problems." I think it is obvious that I enjoyed the visit at least as much as he. This was my first opportunity to meet the man whom I considered one of the two greatest scientists of all times (the other was Newton). And how clearly the letter shows Einstein's humility, asking the permission of a simple Navy lieutenant to spend the summer at Lake Saranac. I am sure that Einstein couldn't know at that time that I was a scientist, my field being very far from Einstein's interests. He could have written simply that during the summer he may be reached at Lake Saranac, but no—he asked the permission of the Navy lieutenant. Naturally he received it from me, but he didn't use it. He stayed at Princeton. The letter of Dr. Aydelotte is also interesting and I quote that also in full.

May 17, 1943

Dear Lieutenant Brunauer:

Professor Einstein has told me of his conversation with you and showed me your gracious letter of May 13th suggesting arrangements under which he may be of assistance to the Navy for theoretical research on explosives and explosions.

In talking over the matter with Professor Einstein he and I have both come to the conclusion that probably the best arrangement would be for the Navy to make an individual contract with him on the basis of $25 per day, Professor Einstein to let you know at intervals the amount of time he has actually spent on Navy problems. I think it is important to leave in the arrangements for an assistant in case a great deal of routine work should be necessary, although Professor Einstein cannot tell at this time whether or not he will need the services of an assistant.

I take the liberty of writing to you simply to say that the Institute for Advanced Study cordially approves of this arrangement with Professor Einstein and looks forward with pride to having him undertake this service for the Navy.

Believe me,

Yours very sincerely,
(signed) Frank Aydelotte, Director

This gracious letter shows that Dr. Aydelotte was doubly happy about my offer: for the sake of Einstein and for the sake of himself and the Institute. The most amusing part of the letter for us today is the consultant fee of $25 per day for the world's greatest scientist. It was a ridiculously small fee even at that time. As to the assistant mentioned in the letter, it was never needed because no routine work was ever assigned to Professor Einstein.

The originals of the two letters are in the Navy or in the Archives, but I had photocopies made of them, and had them framed. This is the only thing I had on a wall of my office, wherever I worked, and one of the greatest joys in my life has been that I was able to make Einstein happy. And so I became, using some exaggeration suggested by a friend, Einstein's "boss" for three years.

The news of my successful visit spread like wildfire in the Bureau of Ordnance. Officers, from ensigns to admirals, came to me with the question, "Is it true that Professor Einstein is working for us?" When they found out that it was true, it settled the matter of the outcome of the war in their minds. The U. S. Navy and Einstein were an unbeatable combination.

Einstein's security clearance was obtained very quickly, and the contract was signed on May 31. Soon after that, I made my second trip to Einstein, taking to him for consideration one of the toughest problems that puzzled us at that time. The problem was whether the detonation of a torpedo should be initiated in the front or in the rear. The three most important characteristics of the shock wave produced in a detonation are the peak pressure, the impulse or momentum of the shock wave, which includes the duration of the shock, and the energy released in the explosion. If in a torpedo the detonation of the high explosive is initiated at the forward end, one obtains the highest peak pressure. If the detonation is initiated in the rear end, one obtains the highest momentum. The energy developed is the same, regardless where the explosion is initiated. So the question was which of the three main characteristics causes the most damage. If it is the peak pressure, the explosion should be initiated at the front end of the torpedo; if it is momentum, it should be initiated at the rear end, and if it is the energy, the location of the initiation does not make any difference.

Einstein was thinking about the problem for about ten minutes, and finally chose momentum and gave the reasons. But a few days later I received a letter from him telling me that he gave much further thought to the matter, and changed his conclusion. He decided that the energy developed in the explosion was the most important factor, and gave his reasons. Very expensive experiments performed much later showed that he was right. Of course this subject was highly confidential during the war, but I hope that now—thirty-five years later—it is declassified.

This is a good example of the problems we took to Einstein, and this one example should suffice. He always gave very careful thought to the problems we took to him and always came up with a reasonable answer. I alluded to some misleading statements in Clark's excellent book. These he took from George Gamow. Gamow, a brilliant theoretical physicist, was also one of my consultants during the Second World War. According to Gamow's story, he was the Navy's liaison man with Einstein; he took the research we did to Einstein, who listened with interest and praised the work. The implication is that Einstein only "listened,'' but made no contribution, and this is false. Less important is the implication that he was the only contact with Einstein. He claimed that he visited Einstein every two weeks, which is not true; I visited Einstein about once in two months and that was more frequent than Gamow's visits. Raymond Seeger and many others also utilized Einstein's services.

I mention here two men. A young man, who worked on torpedoes in the old Naval Ordnance Laboratory, asked my permission to consult Einstein about his research. Naturally, I gave my permission. My co-workers and I considered this young man very brilliant, but we did not suspect that he would be the first man, and to date the only one, to receive two Nobel Prizes *in the same subject*, physics. His name is John Bardeen. Another man was Henry Eyring, who is one of the greatest physical chemists of the country and the world. Eyring was then a professor at Princeton University, but he had never met Einstein. He and his brilliant group of young coworkers worked on a high explosives project for us. I introduced Henry to Einstein, and our walk in Einstein's garden became one of the great experiences of Eyring's life.

If I were asked to state what *specific* contributions were made by Einstein to our high explosives research, I would have to say this. New and more effective high explosives were developed during the war, and they were used by the Navy and the Army (which then included the Air Force) against Germany, Japan and their allies. (I found out later that at least the underwater explosives, possibly others, were also used in the Korean and the Vietnam War.) But these developments were the results of the efforts of large groups of people, including Einstein. It is impossible to assess the contributions of the individuals within the groups. The new developments resulted from team work, and Einstein was a member of the team—three of tonight's speakers were members of the team. But it is easy to assess the value of a different type of contribution of Einstein—his contribution to morale. It was uplifting to know that ''Einstein was one of us.''

I learned from Clark's book that in July 1943, i.e., soon after Einstein joined the Navy, he wrote to his friend Bucky, ''So long as the war lasts and I work for the Navy, I do not wish to begin anything else.'' But we were unable to supply him with enough work to occupy him full time. Whenever I visited him, I found that the tall and long blackboard in his study was filled from the left to right end, and from top to bottom, with long, complicated equations, written with neat, small-sized symbols—obviously work on the unified field theory. Nor were my bimonthly or more or less frequent visits spent on business alone. After the business came the conversation. We talked about the progress of the war, about interesting items in the news, about history, philosophy, about personal experiences, and about a great variety of other things. Einstein had a wonderful sense of humor; he loved to make witty remarks and tell humorous anecdotes. He laughed heartily at his own jokes and also at mine. His well-known wisecrack, ''I am in the Navy, but I was not required to get a Navy haircut,'' was born in one of our conversations. I am very sorry now that I did not make detailed notes after each trip to Einstein. But that was the busiest time of my life; I worked seven days a week and twelve hours or more every day, as did many others. During three and a half years, we had three days off, the three Christmas days.

The great mathematician G. H. Hardy called Einstein ''good, gentle, and wise,'' and it would be difficult to find better adjectives for him than these. But I would add one more, ''humble.'' You could see that in his letter to me, which I read to you, but that is only one example. In all my visits, I received the impression of a genuinely humble person. On one occasion, he gave me one of his books as a present. It was *The Meaning of Rela-*

tivity. On the empty page under the cover he wrote in his beautiful, small, clear letters only this much: A. Einstein, and under it the year, 1945. I was disappointed that he did not write more, but I attribute it to his humility, to his great modesty.

C. P. Snow visited Einstein only once in his life, in the summer of 1937. He wrote a long essay about his visit. He found Einstein a sad man and a pessimist. During the eight hours they spent together, he heard Einstein's famous laughter only once. Einstein had good reasons to be pessimistic then; that was the time of the rapid rise of Hitler, and the western powers did nothing about it. But since Snow's essay appeared twelve years after Einstein's death, it created the impression that Einstein was always like that. This is not so. During my visits, while the war lasted, Einstein was gay and ebullient; in those visits he laughed heartily and often. He had good reasons for that too; we were on the way to eradicating Hitler and his Nazi system, and Eintein was—by his work in the Navy—one of the eradicators.

Although Einstein's third and last contract as "Consultant for Research on Explosives" ran from July 1, 1945 (before the end of the war) to June 30, 1946 (nine months after the end of the war), there was no need to consult him after the end of the war. Hiroshima shook up many people, and Einstein more than anyone else. I visited him twice after the war; last time in April 1946. Einstein's mood changed—he was worried about the fate of mankind. I expressed the deep gratitude of the Navy, the Bureau of Ordnance, and especially of my own for the privilege of working with him, and he in turn thanked me for getting him into the war research, which gave him great satisfaction. When we said goodbye to each other, I was deeply moved, and perhaps he was moved too.

That was the last time I saw him. Our paths diverged after that. Our aim was the same: the prevention of a third world war, but our paths were different. I stayed in the Navy for four and a half more years to build up a new organization for high explosives research and development. Einstein's path was complete disarmament and the establishment of a world government, and he exerted all his energy, all his effort, and all his influence to achieve those ideals. As we know, he failed. I believe that Einstein knew that his efforts were doomed to failure; he was a prophet way ahead of his time. But the "conscience of the world," as Einstein was called, could not but fight to the end for what he believed, however hopeless the fight was.

This is the story of Einstein in the Navy in a nutshell. It is incomplete for two reasons: I myself could have said more if the time allotted to my talk had been longer. What is more important, doubtless others could add their experiences to mine. Some day a more complete story will emerge about this important part of Einstein's life. But even this short history is far more complete than anything you can find in print to date. Thank you for your attention.

THE DIRECTORY OF THE ACADEMY FOR 1979

Foreword

The present, 54th issue of the Academy's directory is again this year issued as part of the September number of the Journal. As in previous years, the alphabetical listing is based on a postcard questionnaire sent to the Academy membership. Members were asked to update the data concerning address and membership in affiliated societies by June 30, 1979. In cases in which cards were not received by that date, the address appears as it was used during 1979, and the remaining data were taken from the directory for 1978. Corrections should be called to the attention of the Academy office.

Code for Affiliated Societies, and Society Officers

1 The Philosophical Society of Washington (1898)

President:	George T. Armstrong, 1401 Dale Dr., Silver Spring, MD 20910
Vice-President:	William G. Maisch, 205 Yockum Parkway, Alexandria, VA 22034
Secretary:	Lowell D. Ballard, 722 S. Colonial, Sterling, VA 22170
Delegate:	James F. Goff, 3405 34th Pl., N.W., Washington, D.C. 20016

2 Anthropological Society of Washington (1898)

President:	Marie J. Bourgeois, Rsch. Trng. Sec., Div. Nursing, BHM, HSA, HEW, 3700 East West Hwy., Hyattsville, MD 20782
President-elect:	Michael Kenny, Dept. of Anthro., Catholic University, Washington, D.C. 20017
Secretary:	John L. Landgraf, 2423 Eye St., N.W., Washington, D.C. 20037
Delegate:	Jean K. Boek, National Graduate Univ., 1101 N. Highland St., Arlington, VA 22201

3 Biological Society of Washington (1898)

President:	Oliver S. Flint, Jr., Curator, Dept. of Entomology, Smithsonian Institution, Washington, D.C. 20560
Vice-President:	Richard Banks, U.S. Dept. of Interior, Fish & Wildlife Div., Bird & Mammal Labs., Washington, D.C. 20240
Secretary:	Michael A. Bogan, U.S. Dept. of Interior, Fish & Wildlife Div., Bird & Mammal Labs., Washington, D.C. 20240
Treasurer:	David L. Pawson, Curator, Dept. of Invertebrate Zoology, Smithsonian Institution, Washington, D.C. 20560
Delegate:	William R. Heyer, Amphibian & Reptiles, Nat. History Bldg., Smithsonian Institution, Washington, D.C. 20560

4 Chemical Society of Washington (1898)

President:	Dr. Walter Benson, FDA, HFD 420, 200 C St. S.W., Washington, D.C. 20204
President-elect:	Dr. George Mushrush, Chem. Dept. George Mason Univ., 4400 University Dr., Fairfax, VA 22030
Secretary:	Dr. Jo-Anne Jackson, Natl. Bureau of Stds., Bg. 223, Rm. A329, Washington, D.C. 20234
Delegate:	Dr. Barbara Howell, Natl. Bureau of Stds., Bg. 222, Rm. A367, Washington, D.C. 20234

5 **Entomological Society of Washington (1898)**

President: Donald R. Davis, Dept. of Entomology, NHB 105, Smithsonian Institution, Washington, D.C. 20560
Vice-President: T. J. Spilman, Dept. of Entomology, NHB 169, Smithsonian Institution, Washington, D.C. 20560
Secretary: Wayne N. Mathis, Dept. of Entomology, NHB 169, Smithsonian Institution, Washington, D.C. 20560
Delegate: Donald R. Davis, see above

6 **National Geographic Society (1898)**

President: Robert E. Doyle, National Geographic Society, Washington, D.C. 20036
Chairman: Melvin M. Payne, National Geographic Society, Washington, D.C. 20036
Secretary: Owen R. Anderson, National Geographic Society, Washington, D.C. 20036
Delegate: T. Dale Stewart, Smithsonian Institution, Museum of Natural History, Washington, D.C. 20560

7 **Geological Society of Washington (1898)**

President: Francis R. Boyd, Jr., Carnegie Institution of Washington, Geophysical Lab., 2801 Upton St., N.W., Washington, D.C. 20008
Vice-President: J. Thomas Dutro, U.S. Geological Survey, Branch of Paleontology and Stratigraphy, U.S. National Museum, Washington, D.C. 20560
Secretary: William E. Davies, U.S. Geological Survey, Reston, VA 22092, Mail Stop 973
Delegate: Not appointed

8 **Medical Society of the District of Columbia (1898)**

President: William S. McCune
President-elect: Frank S. Bacon
Secretary: Thomas Sadler
Delegate: Not appointed

9 **Columbia Historical Society (1899)**

President: Wilcomb E. Washburn, Amer. Studies, S.I., Washington, D.C. 20560
Vice-President: William H. Press, 1511 K St., N.W., Washington, D.C. 20005
Secretary: Marcellina Hummer, 2006 Columbia Rd., N.W., Washington, D.C. 20009
Delegate: Paul H. Oehser, National Geographic Society, Washington, D.C. 20036

10 **Botanical Society of Washington (1902)**

President: Dr. Kittie Parker, Dept. of Biology, George Washington University, 2029 G N.W., Washington, D.C. 20052
Vice-President: Dr. Ted Bradley, Dept. of Botany, George Mason University, 4400 University Drive, Fairfax, VA 22030
Secretary: Mrs. Antoinette Frederic, Dept. of Botany, Howard University, 2401 6th St. N.W., Washington, D.C. 20059
Delegate: Conrad B. Link, Univ. of Md., Dept. of Horticulture, College Park, MD 20742

11 **Society of American Foresters, Washington, Section (1904)**

Chairman: Dr. Richard T. Marks, Rt. 2, Box 29, Warrenton, VA 22186
Chairman-elect: Jay McConnel, 4324 Ashford La., Fairfax, VA 22032
Secretary: Charles Newlon, 13106 Poplar Tree Rd., Fairfax, VA 22030
Delegate: Boyd Post

12 **Washington Society of Engineers (1907)**

President: Jeffrey H. Rumbaugh, Potomac Electric Power Co., 1900 Pennsylvania Ave., N.W., Washington, D.C. 20068
Vice-President: Guy H. Hammer, Washington Hospital Dr., Washington, D.C. 20010
Secretary: Charles E. Remington, 2005 Columbia Pike, Arlington, VA 22204
Delegate: George Abraham, 3107 Westover Dr., S.E., Washington, D.C. 20020

13 **Institute of Electrical & Electronics Engineers, Washington Section (1912)**

Chairman: C. David Crandall, 12214 Old Colony Drive, Upper Marlboro, MD 20870
Vice-Chairman: Dr. Sajjad H. Durrani, 17513 Lafayette Dr., Olney, MD 20832
Secretary: Dr. Gideon Kantor, 10702 Kenilworth Ave., Garrett Park, MD 20766
Delegate: George Abraham, 3107 Westover Dr., S.E., Washington, D.C. 20020

14 American Society of Mechanical Engineers, Washington Section (1923)

Chairman:	John Ritzmann, Washington Gas Light Co., 6801 Industrial Dr., Springfield, VA 22151
Vice-Chairman:	Markley Au, Nuclear Regulatory Commission, Fuel Cycle Division, Washington, D.C. 20555
Secretary:	John Fairbanks, Naval Ship Engineering Center, Crystal Plaza, Arlington, VA 22207
Delegate:	Michael Chi, 2721 N. 24th St., Arlington, VA 22207

15 Helminthological Society of Washington (1923)

President:	J. Ralph Lichtenfels, Animal Parasitology Inst., SEA, BARC-East, Beltsville, MD 20705
Vice-President:	Nancy Pacheco, Naval Medical Research Inst., Bethesda, MD 20014
Corresponding Secretary/ Treasurer:	Sherman Hendricks, Gettysburg College, Dept. of Biology, Gettysburg, PA 17325
Recording Secretary:	Milford Lunde, Lab. of Parasitic Diseases, NIH, Bethesda, MD 20014
Delegate:	Robert S. Isenstein, FSQS, USDA, BARC-East, Beltsville, MD 20705

16 American Society for Microbiology, Washington Branch (1923)

President:	Frank Hetrick, Dept. of Microbiology, Univ. of Md., College Park, MD 20742
Vice-President:	Dr. George Royal, Dept. of Microbiology, Howard Univ., Washington, D.C. 20059
Secretary:	Dr. Thomas Elliott, 126 Moore Ave., Vienna, VA 22180
Delegate:	None Appointed

17 Society of American Military Engineers, Washington Post (1927)

President:	Col. Edwin P. Geesey, DAEN-FEZ-B, Washington, D.C. 20314
Vice-President:	R.Adm. H. R. Lippold, NOAA, Washington, D.C. 20233
Secretary:	William I. Jacob, DAEN-FER-P, Washington, D.C. 20314
Delegate:	Hal P. Demuth, 4025 Pine Brook Rd., Alexandria, VA 22310

18 American Society of Civil Engineers, National Capital Section (1942)

President:	James W. Harland, 1511 K St., N.W., Suite 337, Washington, D.C. 20005
Vice-President:	Norman L. Cooper, Dept. of Transportation, 400 7th St., Rm. 9422, Washington, D.C. 20590
Secretary:	Robert Efimba, Dept. of Civil Engineering, Howard University, Washington, D.C. 20059
Delegate:	Robert Sorenson, Coastal Engineering Research Ctr., Kingman Bldg., Ft. Belvoir, VA 22060

19 Society for Experimental Biology & Medicine, D.C. Section (1952)

President:	Elise A. Brown, USDA, Washington, D.C. 20750
Vice-President:	Ariel Hollinshead, G. W. Univ., Warwick Cancer Clinic, Washington, D.C. 20052
Recording Secretary:	Jocelyn Stewart, Food & Drug Adm., Rockville, MD 20204
Corresponding Secretary:	William Von Arsdel, Food & Drug Adm., Bureau of Drugs, Rockville, MD 20204
Treasurer:	Margaret Davison, Dept. of Defense, Defense Fuel Supplies, Washington, D.C.
President Emeritus:	Arthur Wykes, Natl. Library of Medicine, Bethesda, MD 20014
Delegate:	Cyrus R. Creveling, NIAID, Washington, D.C.

20 American Society for Metals, Washington Chapter (1953)

Chairman:	Charles N. Scott, Southern Railway System, P.O. Box 233, Alexandria, VA 22313
Vice-Chairman:	Dr. Anna C. Fraker, B118 Materials Bldg. (564), Natl. Bureau of Stds., Washington, D.C. 20234
Secretary:	Joseph R. Crisci, David Taylor NSRDC, Code 282, Annapolis, MD 21402
Treasurer:	James R. Ward, V-S-E, Inc., 2550 Huntington Avenue, Alexandria, VA 22303
Delegate:	Dr. Charles G. Interrante, B120 Materials Bldg. (562), Natl. Bureau of Stds., Washington, D.C. 20234

21 American Association for Dental Research, Washington Section (1953)

President:	John D. Termine, Natl. Institute of Dental Research, Bethesda, MD 20014
Vice-President:	William R. Cotton, Naval Medical Research Institute, Bethesda, MD 20014
Secretary:	Stanley Vermilyea, Walter Reed Army Inst. of Res., Washington, D.C. 20012
Delegate:	William V. Loebenstein, National Bureau of Standards, Washington, D.C. 20234

22 American Institute of Aeronautics and Astronautics, National Capital Section (1953)

Chairman:	George J. Vila, General Dynamics, 1745 Jefferson Davis Hwy., Suite 1000, Arlington, VA 22202
Vice-Chairman:	Dr. Richard Hallion, Smithsonian Institution, National Air & Space Mus., 7th & Independence Ave., Washington, D.C. 20560
Secretary:	Dr. Frederick L. Schuyler, Department of Energy, MS C-448, Washington, D.C. 20545
Delegate:	George J. Vila, General Dynamics, 1743 Jefferson Davis Hwy., Arlington, VA

23 American Meteorological Society, D.C. Chapter (1954)

Chairman:	Dr. John A. Leese, NOAA/NESS, Room 3308 FB 4 S1X1, Washington, D.C. 20233
Vice-Chairman:	Mr. Edward M. Carlstead, NOAA/NWS/NMC, Room 410 WWB W33, Washington, D.C. 20233
Corresponding Secretary:	Capt. Donald G. Buchanan, DOD Weather Liaison Officer, DET 1, AFGWC, Washington, D.C. 20330
Delegate:	Mr. A. James Wagner, NOAA/NWS/NMC, Room 604 WWB W35, Washington, D.C. 20233

24 Insecticide Society of Washington (1959)

Chairman:	William E. Bickley, American Mosquito Control Association, P.O. Box 75, Riverdale, MD 20840
Chairman-elect:	William Hollis, National Agricultural Chemicals Association, 1155 15th St., N.W., Washington, D.C. 20005
Secretary:	Judd O. Nelson, Dept. of Entomology, University of Maryland, College Park, MD 20742
Delegate:	Jack R. Plimmer, USDA, SEA, Beltsville Agricultural Research Center, Beltsville, MD 20705

25 Acoustical Society of America (1959)

Chairman:	John A. Molino, Sound Section, NBS, Washington, D.C. 20234
Vice-Chairman:	Charles T. Molloy, 2400 Claremont Dr., Falls Church, VA 22043
Secretary:	William K. Blake, Naval Ship R & D Ctr., Bethesda, MD 20034
Delegate:	None appointed

26 American Nuclear Society, Washington Section (1960)

President:	Arthur Randal, Am. Nuclear Energy Council, 1750 K St., N.W., Washington, D.C. 20006
Vice-President:	S. Bassett, NUS Corp., Rockville, MD 20852
Secretary:	Ray Durante, Westinghouse Electric, 1801 K St., N.W., Washington, D.C. 20006
Delegate:	Dick Duffy, Nuclear Engineering, Univ. of Md., College Park, MD 20742

27 Institute of Food Technologists, Washington Section (1961)

President:	Mahlon Burnette III, Grocery Manufacturers of America, 1010 Wisconsin Ave. N.W., Washington, D.C. 20007
Secretary:	Allen Matthys, National Assn. of Food Processors
Treasurer:	Katherine Albert
Delegate:	William Sulzbacher, 8527 Clarkson Dr., Fulton, MD 20759

28 American Ceramic Society, Baltimore-Washington Section (1962)

Chairman:	W. T. Bakker, General Refractories Co., P.O. Box 1673, MD 21203
Chairman-elect:	L. Biller, Glidden-Dirkee Div., SCM Corp., 3901 Hawkins Point Rd., Baltimore, MD 21226
Secretary:	Edwin E. Childs, J. E. Baker Co., 232 E. Market St., York, PA 17405
Delegate:	None appointed

29 Electrochemical Society, National Capital Section (1963)

Chairman:	David R. Flinn, Bureau of Mines, College Park Research Center, College Park, MD 20740
Vice-Chairman:	John R. Ambrose, National Bureau of Standards, Bldg. 223, Rm. B254, Washington, D.C. 20234
Secretary:	George Marinenko, National Bureau of Standards, Bldg. 222, Rm. A217, Washington, D.C. 20234
Delegate:	David R. Flinn, see above

30 Washington History of Science Club (1965)

Chairman:	Richard G. Hewlett, Atomic Energy Comm.
Vice-Chairman:	Deborah Warner, Smithsonian Institution
Secretary:	Dean C. Allard
Delegate:	None appointed

31 American Association of Physics Teachers, Chesapeake Section (1965)

President:	Morton Rubin, University of Maryland, Baltimore County
Vice-President:	Eugenie V. Mielczarek, George Mason Univ., 4400 University Dr., Fairfax, VA 22030
Secretary:	Roberta Stoney, Langley High School
Delegate:	Peggy A. Dixon, Montgomery College, Takoma Park Campus

32 Optical Society of America, National Capital Section (1966)

President:	George J. Simonis, Harry Diamond Laboratory, Code 320, 2800 Powder Mill Road, Adelphi, MD 20783
Vice-President:	Carl H. Mikeman, Night Vision and Electro-Optics Lab., DELNV-VI, Ft. Belvoir, VA 22060
Secretary:	Martin J. Koomen, NRL Code 7171, Washington, D.C. 20375
Delegate:	Dr. George Simonis

33 American Society of Plant Physiologists, Washington Section (1966)

Chairman:	Werner J. Meudt, USDA, ARS Bldg. 50, Beltsville, MD 20705
Vice-Chairman:	Charles F. Cleland, Radiation Biology Lab., 12441 Parklawn Dr., Rockville, MD 20852
Secretary:	William VanDerWoude, Beltsville Agricultural Research Center, Seed Research Lab., Bldg. 049, Beltsville, MD 20705
Delegate:	W. Shropshire, Jr., Smithsonian Inst., 12441 Parklawn Drive, Rockville, MD 20852

34 Washington Operations Research Council (1966)

President:	G. Thomas Sicilia, Office of the Assistant Secretary of Defense (MRA & L) (RR) Pentagon, Washington, D.C. 20301
Vice-President:	Gary Sorrell, Management Consulting and Research Inc., 5203 Leesburg Pike, #608 Falls Church, VA 22041
Secretary:	Donald J. Gantzer, Department of Energy, Washington, D.C. 20545
Treasurer:	James Dwyer, Office of the Secretary of Defense (MRA & L)
Delegate:	John G. Honig, 7701 Glenmore Spring Way, Bethesda, MD 20034

35 Instrument Society of America, Washington Section (1967)

President:	Francis C. Quinn
President-elect:	John I. Peterson
Secretary:	Frank L. Carou
Delegate:	None appointed

36 American Institute of Mining, Metallurgical & Petroleum Engineers (1968)

Chairman:	Garrett R. Hyde, 6027 Springhill Dr., Greenbelt, MD 20770
Vice-Chairman:	John A. Patterson, 7705 Hamilton Spring Rd., Bethesda, MD 20034
Secretary:	John H. DeYoung, Jr., 12677 Magna Carta Rd., Herndon, VA 22070
Delegate:	Gus H. Goudarzi, 658 Pemberton Court, Herndon, VA 22070

37 National Capital Astronomers (1969)

President:	Mary Ellen Simon, 8704 Royal Ridge Lane, Laurel, MD 20811
Vice-President:	Wolfgang Schubert, 7906 Gosport Lane, Springfield, VA 22151
Secretary:	Sharon Edmonds, 11322 Cherry Hill Road, Beltsville, MD 20705
Delegate:	Benson J. Simon, 8704 Royal Ridge Lane, Laurel, MD 20811

38 Maryland-District of Columbia and Virginia Section of Mathematical Assoc. of America (1971)

Chairman:	John Smith, 1837 Negel Ct., Vienna, VA 22180
Vice-Chairman:	Howard Penn, U.S. Naval Academy, Annapolis, MD 21402
Secretary:	John Hanson, James Madison Univ., Harrisonburg, VA 22801
Vice Chairman/ Delegate:	Patrick Hayes, 950 25th St., N.W., Washington, D.C. 20037

39 D.C. Institute of Chemists (1973)

President:	Dr. Nina M. Roscher, American University, Dept. of Chemistry, Washington, D.C. 20016
President-elect:	Dr. Robert L. Patrick, Gillette Research Inst., 1413 Research Blvd., Rockville, MD 20850
Secretary/ Treasurer:	Ms. Carolyn E. Damon, 3100 S. Manchester St., Apt. 540, Falls Church, VA 22044
Delegate:	Dr. Miloslav Rechcigl, Agency for International Development, Washington, D.C. 20523
Alternate Delegate:	Edmund M. Buras, Jr., Gillette Research Institute, 1413 Research Blvd., Rockville, MD 20850

40 The D.C. Psychological Association (1975)

President:	John F. Borriello, St. Elizabeth's Hospital, Overholser Division, Washington, D.C. 20032
President-elect:	Eugene Stammeyer, St. Elizabeth's Hospital, Overholser Division, Washington, D.C. 20032
Secretary:	Sylvia M. Tetrault, Howard Univ. College of Medicine, Washington, D.C. 20059
Delegate:	John J. O'Hare, Office of Naval Research, 800 N. Quincy St., Arlington, VA 22217

41 The Washington Paint Technical Group (1976)

President:	Robert F. Brady, Jr., GSA
Vice-President:	Mildred A. Post, National Bureau of Standards, Bldg. 226, Rm. B-348, Washington, D.C. 20234
Secretary:	William Allanach, International Paint, Harve de Grace, MD
Delegate:	Paul G. Campbell, National Bureau of Standards, B-348, Br., Washington, D.C. 20234

42 Potomac Division, American Phytopathological Society (1977)

President:	J. R. Stavely, Tobacco Laboratory, USDA, Agric. Research Center, Beltsville, MD 20705
Vice-President:	C. R. Curtis, Dept. of Plant Pathology, Va. Polytechnic Inst., Blacksburg, VA 24061
Secretary/ Treasurer:	L. D. Moore, Dept. of Plant Pathology, Va. Polytechnic Inst., Blacksburg, VA 24061
Delegate:	T. van der Zwet, Fruit Laboratory, USDA, Agric. Research Center, Beltsville, MD 20705

43 Metropolitan Washington Chapter of the Society for General Systems Research (1977)

Chairman:	Ronald W. Manderscheid, 6 Monument Ct., Rockville, MD 20850
Secretary:	Helen G. Tibbitts, 4105 Montpelier Rd., Rockville, MD 20853
Delegate:	Ronald W. Manderscheid, 6 Monument Ct., Rockville, MD 20850

44 Potomac Chapter, Human Factors Society (1977)

President:	Dr. Michael L. Fineberg, BDM Corp. 7915 Jones Branch Road, McLean, VA 22101
Vice-President:	Dr. E. Ralph Dusek, Army Research Institute, 5001 Eisenhower Ave., Alexandria, VA 22333
Secretary:	Mr. Gerald S. Malecki, Office of Naval Research, 800 N. Quincy St., Arlington, VA 22217
Delegate:	Dr. H. McIlvaine Parsons, Institute for Behavioral Research, 2429 Linden Lane, Silver Spring, MD 20910

45 **Potomac Chapter, American Fisheries Society (1978)**

President:	Galen Buterbaugh, 8708 Higdon Drive, Vienna, VA 22180
President-elect:	Norville Prosser, 511 Shaw Drive, Spotsylvania, VA 22553
Secretary:	Stephanie Story, 6538 Lee Valley Drive, #101, Springfield, VA 22150
Delegate:	Irwin Alperin, ASMFC, 1717 Massachusetts Ave., N.W., Washington, D.C. 20236

Alphabetical List of Members

M = Member; F = Fellow; E = Emeritus member; L = Life Fellow. Numbers in parentheses refer to numerical code in foregoing list of affiliated societies.

A

ABDULNUR, SUHEIL F., Ph.D., Chemistry Dept. The American University, Washington, D.C. 20016 (F-4)

ABELSON, PHILIP H., Ph.D., Editor *SCIENCE* Magazine, American Association for the Advancement of Science, 1550 Mass. Ave., N.W., Washington, D.C. 20005 (F-1, 4, 7, 16)

ABRAHAM, GEORGE, M.S., Ph.D., 3107 Westover Dr., S.E., Washington, D.C. 20020 (F-1, 6, 12, 13, 31, 32)

ACHTER, M. R., 417 5th St., S.E., Washington, D.C. 20003 (F-20, 36)

ADAMS, ALAYNE A., Ph.D., 8206 Lake Park Dr., Alexandria, Va. 22309 (F)

ADAMS, CAROLINE L., 242 North Granada St., Arlington, Va. 22203 (E-10)

ADLER, SANFORD C., 14238 Briarwood Terr., Rockville, Md. 20853 (F-1)

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AYENSU, EDWARD, Ph.D., 9200 Wilmett Ct., Bethesda, Md. 20034 (F-3, 10)

B

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BAKER, LOUIS C.W., Ph.D., Dept of Chemistry, Georgetown University, N.W., Washington, D.C. 20057 (F-4)

BALLARD, LOWELL D., 722 So. Colonial, Sterling, Va. 22170 (F-1, 13, 32)

BARBOUR, LARRY L., 19309 Poinsetta Court, Gaithersburg, Md. 20760 (M)

BARBROW, LOUIS E., Natl. Bureau of Standards, Washington, D.C. 20234 (F-1, 13, 32)

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BECKER, EDWIN D., Ph.D., Inst. Arthritis & Metabolic Dis., Bldg. 2 Rm. 122, National Institutes of Health, Bethesda, Md. 20014 (F-4)
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BECKMANN, ROBERT B., Ph.D., Dept. of Chem. Engineering, Univ. of Md., College Park, Md. 20742 (F-4)
BEIJ, K. H., 69 Morningside Dr., Laconia, N.H. 03246 (L-1)
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BENESCH, WILLIAM, Inst. for Molecular Physics, Univ. of Maryland, College Park, Md. 20742 (F-1, 32)
BENJAMIN, C. R., Ph.D., IPD/SEA, USDA, Rm. 459, Federal Bg., Hyattsville, Md. 20782 (F-6, 10)
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BENNETT, MARTIN TOSCAN, Ch.E., 3700 Mt. Vernon Ave., Rm. 605, Alexandria, Va. 22305 (F-4, 6)
BENNETT, WILLARD H., Box 5342, North Carolina State Univ., Raleigh, N.C. 27607 (E)
BENSON, WILLIAM, Ph.D., 618 Constitution Ave., N.E., Washington, D.C. 20002 (M-34, 40, 44)
BERGER, ROBERT E., Ph.D., 10313 Twinedew Pl., Columbia, Md. 21044 (F)
BERGMANN, OTTO, Ph.D., Dept. Physics, George Washington Univ., Washington, D.C. 20052 (F-1)
BERMAN, ALAN, Ph.D., 9304 Maybrook Pl., Alexandria, Va. 22309 (F-25)
BERNETT, MARIANNE K., Code 6170, Naval Res. Lab., Washington, D.C. 20375 (M-4)
BERNSTEIN, BERNARD, M.S., 7420 Westlake Terr., #608, Bethesda, Md. 20034 (M-25)
BERNTON, HARRY S., 4000 Cathedral Ave., N.W., Washington, D.C. 20016 (F 3-8)
BESTUL, ALDEN B., 9400 Overlea Ave., Rockville, Md. 20850 (F-1, 6)
BICKLEY, WILLIAM E., Ph.D., P.O. Box 20840, Riverdale, Md. 20840 (F-5, 24)
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BYLAWS

Washington Academy of Sciences

Last Revised in September, 1974

Article I. OBJECTIVES

Section 1. The purposes of the Washington Academy of Sciences shall be: (a) to stimulate interest in the sciences, both pure and applied, and (b) to promote their advancement and the development of their philosophical aspects by the Academy membership and through cooperative action by the affiliated societies

Section 2. These objectives may be attained by, but are not limited to:

(a) Publication of a periodical and of occasional scientific monographs and such other publications as may be deemed desirable.
(b) Public lectures of broad scope and interest in the fields of science.
(c) Sponsoring a Washington Junior Academy of Sciences.
(d) Promoting science education and a professional interest in science among people of high school and college age.
(e) Accepting or making grants of funds to aid special research projects.
(f) Symposia, both formal and small informal, on any aspects of science.
(g) Scientific conferences.
(h) Organization of, or assistance in, scientific expeditions.
(i) Cooperation with other Academies and scientific organizations.
(j) Awards of prizes and citations for special merit in science.
(k) Maintaining an office and staff to aid in carrying out the purposes of the Academy.

Article II. MEMBERSHIP

Section 1. The membership shall consist of three general classes: members, fellows and patrons.

Section 2. Members shall be persons who are interested in and will support the objectives of the Academy and who are otherwise acceptable to at least two-thirds of the Committee on Membership. A letter or application form requesting membership and signed by the applicant may suffice for action by the Committee; approval by the Committee constitutes election to membership.

Section 3. Fellows shall be persons who by reason of original research or other outstanding service to the sciences, mathematics, or engineering are deemed worthy of the honor of election to Academy fellowship.

Section 4. Nominations of fellows shall be presented to the Committee on Membership as a form approved by the Committee. The form shall be signed by the sponsor, a fellow who has knowledge of the nominee's field, and shall be endorsed by at least one other fellow. An explanatory letter from the sponsor and a bibliography of the nominee's publications shall accompany the completed nomination form.

Section 5. Election to fellowship shall be by vote of the Board of Managers upon recommendation of the Committee on Membership. Final action on nominations shall be deferred at least one week after presentation to the Board, and two-thirds of the vote cast shall be necessary to elect.

Section 6. Each individual (not already a fellow) who has been chosen to be the recipient of an Academy Award for Scientific Achievement shall be considered nominated for immediate election to fellowship by the Board of Managers without the necessity for compliance with the provisions of Sections 4 and 5.

Section 7. An individual of unquestioned eminence may be recommended by vote of the Committee on Membership Promotion for immediate election to fellowship by the Board of Managers, without the necessity for compliance with the provisions of Sections 4 and 5.

Section 8. Persons who have given to the Academy not less than one thousand (1,000) dollars or its equivalent in property shall be eligible for election by the Board of Managers as patrons (for life) of the Academy.

Section 9. Life members or fellows shall be those individuals who have made a single payment in accordance with Article III, Section 2, in lieu of annual dues.

Section 10. Members or fellows in good standing who are retired and are no longer engaged in regular gainful employment may be placed in emeritus status. Upon request to the treasurer for transfer to this status, they shall be relieved of the further payment of dues, beginning with the following January first; shall receive notices of meetings without charge; and at their request, shall be entitled to receive the Academy periodical at cost.

Section 11. Members or fellows living more than 50 miles from the White House, Washington, D. C., shall be classed as nonresident members or fellows.

Section 12. An election to any dues-paying class of membership shall be void if the candidate does not within three months thereafter pay his dues or satisfactorily explain his failure to do so.

Section 13. Former members or fellows who resigned in good standing may be reinstated upon application to the Secretary and approval by the Board of Managers. No reconsideration of the applicant's qualifications need be made by the Membership Committee in these cases.

Article III. DUES

Section 1. The annual dues of each class shall be fixed by the Board of Managers. No dues shall be paid by emeritus members and fellows, life members and fellows, and patrons.

Section 2. Members and fellows in good standing may be relieved of further payment of dues by making a single payment to provide an annuity equal to their annual dues. (See Article II, Section 9.) The amount of the single payment shall be computed on the basis of an interest rate to be determined by the Board of Managers.

Section 3. Members or fellows whose dues are in arrears for one year shall not be entitled to receive Academy publications.

Section 4. Members or fellows whose dues are in arrears for more than two years shall be dropped from the rolls of the Academy, upon notice to the Board of Managers, unless the Board shall otherwise direct. Persons who have been dropped from membership for nonpayment of dues may be reinstated upon approval of the Board and upon payment of back dues for two years together with dues for the year of reinstatement.

Article IV. OFFICERS

Section 1. The officers of the Academy shall be a President, a President-elect, a Secretary, and a Treasurer. All shall be chosen from resident fellows of the Academy.

Section 2. The President shall appoint all committees and such non-elective officers as are needed unless otherwise directed by the Board of Managers or provided in the Bylaws. He (or his substitute—the President-elect, the Secretary, or the Treasurer, in that order), shall preside at all meetings of the Academy and of the Board of Managers.

Section 3. The Secretary shall act as secretary to the Board of Managers and to the Academy at large. He shall conduct all correspondence relating thereto, except as otherwise provided, and shall be the custodian of the corporate seal of the Academy. He shall arrange for the publication in the Academy periodical of the names and professional connections of new members, and also of such proceedings of the Academy, including meetings of the Board of Managers, as may appropriately be of interest to the membership. He shall be responsible for keeping a register of the membership, showing such information as qualifications, elections, acceptances, changes of residence, lapses of membership, resignations and deaths, and for informing the Treasurer of changes affecting the status of members. He shall act as secretary to the Nominating Committee (see Art. IV, Sect. 9).

Section 4. The Treasurer shall be responsible for keeping an accurate account of all receipts and disbursements, shall select a suitable depository for current funds which shall be approved by the Executive Committee, and shall invest the permanent funds of the Academy as directed by that Committee. He shall prepare a budget at the beginning of each year which shall be reviewed by the Executive Committee for presentation to and acceptance by the Board of Managers. He shall notify the Secretary of the date when each new member qualifies by payment of dues. He shall act as business advisor to the Editor and shall keep necessary records pertaining to the subscription list. In view of his position as Treasurer, however, he shall not be required to sign contracts. He shall pay no bill until it has been approved in writing by the chairman of the committee or other persons authorized to incur it. The fiscal year of the Academy shall be the same as the calendar year.

Section 5. The President and the Treasurer, as directed by the Board of Managers, shall jointly assign securities belonging to the Academy and indorse financial and legal papers necessary for the uses of the Academy, except those relating to current expenditures authorized by the Board. In case of disability or absence of the President or Treasurer, the Board of Managers may designate the President-elect or a qualified Delegate as Acting President or an officer of the Academy as Acting Treasurer, who shall perform the duties of these officers during such disability or absence.

Section 6. An Editor shall be in charge of all activities connected with the Academy's publications. He shall be nominated by the Executive Committee and appointed by the President for an indefinite term subject to annual review by the Board of Managers. The Editor shall serve as a member of the Board.

Section 7. An Archivist may be appointed by the President. If appointed, he shall maintain the permanent records of the Academy, including important records which are no longer in current use by the Secretary, Treasurer, or other officer, and such other documents and material as the Board of Managers may direct.

Section 8. All officers and chairmen of standing committees shall submit annual reports at the May meeting of the Board of Managers.

Section 9. The Nominating Committee (Article IV, Section 2) shall prepare a slate listing two or more persons for each of the offices of President-elect, of Secretary and of Treasurer, and four or more persons for the two Managers-at-large whose terms expire each year and at least two persons to fill each vacant unexpired term of manager-at-large. The slate shall be presented for approval to the Board of Managers at its first meeting in October. Not later than November 15, the Secretary shall forward to each Academy Member and Fellow an announcement of the election, the committee's nomination for the offices to be filled, and a list of incumbents. Additional candidates for such offices may be proposed by any Member or Fellow in good standing by letter received by the Secretary not later than Dec. 1. The name of any eligible candidate so proposed by ten Members or Fellows shall be entered on the ballot.

Section 10. Not later than December 15, the Secretary shall prepare and mail ballots to members and fellows. Independent nominations shall be included on the ballot, and the names of the nominees shall be arranged in alphabetical order. When more than two candidates are nominated for the same office the voting shall be by preferential ballot in the manner prescribed by the Board of Managers. The ballot shall contain also a notice to the effect that votes not received by the Secretary before the first Thursday of January, and votes of individuals whose dues are in arrears for one year or more, will not be counted. The Committee of Tellers shall count the votes and report the results at the annual meeting of the Academy.

Section 11. The newly elected officers shall take office at the close of the annual meeting, the President-elect of the previous year automatically becoming President.

Article V. BOARD OF MANAGERS

Section 1. The activities of the Academy shall be guided by the Board of Managers, consisting of the President, the President-elect, the immediate past President, one Delegate from each of the affiliated societies, the Secretary, the Treasurer, six elected Managers-at-Large, and the Editor. The elected officers of the Academy shall hold like offices on the Board of Managers.

Section 2. One Delegate shall be selected by each affiliated society. He shall serve until replaced by his society. Each Delegate is expected to participate in the meetings of the Board of Managers and vote on behalf of his society.

Section 3. The Board of Managers shall transact all business of the Academy not otherwise provided for. A quorum of the Board shall be nine of its members.

Section 4. The Board of Managers may provide for such standing and special committees as it deems necessary.

Section 5. The Board shall have power to fill vacancies in its own membership until the next annual election. This does not apply to the offices of President and Treasurer (see Art. IV, Sect. 5), nor to Delegates (see Art. V, Sect. 2).

Article VI. COMMITTEES

Section 1. An Executive Committee shall have general supervision of Academy finances, approve the selection of a depository for the current funds, and direct the investment of the permanent funds. At the beginning of the year it shall present to the Board of Managers an itemized statement of receipts and expenditures of the preceding year and a budget based on the estimated receipts and disbursements of the coming year, with such recommendations as may seem desirable. It shall be charged with the duty of considering all activities of the Academy which may tend to maintain and promote relations with the affiliated societies, and with any other business which may be assigned to it by the Board. The Executive Committee shall consist of the President, the President-elect, the Secretary and the Treasurer (or Acting Treasurer) ex officio, as well as two members appointed annually by the President from the membership of the Board.

Section 2. The President, with the approval of the Board of Managers, shall appoint a Nominating Committee of six Fellows of the Academy, at least one of whom shall be a past President of the Academy, and at least three of whom shall have served as Delegates for at least one year. The Chairman shall be a past President. (See Article IV, Section 9.)

Section 3. The President shall appoint in advance of the annual meeting an Auditing Committee consisting of three persons, none of whom is an officer, to audit the accounts of the Treasurer (Art. VII, Sect. 1).

Section 4. On or before the last Thursday of each year the President shall appoint a committee of three Tellers whose duty it shall be to canvass the ballots (Art. IV, Sect. 10, Art. VII, Sect. 1).

Section 5. The President shall appoint from the Academy membership such committees as are authorized by the Board of Managers and such special committees as necessary to carry out his functions. Committee appointments shall be staggered as to term whenever it is determined by the Board to be in the interest of continuity of committee affairs.

Article VII. MEETINGS

Section 1. The annual meeting shall be held each year in May. It shall be held on the third Thursday of the month unless otherwise directed by the Board of Managers. At this meeting the reports of the Secretary, Treasurer, Auditing Committee (see Article VI, Sect. 3), and Committee of Tellers shall be presented.

Section 2. Other meetings may be held at such time and place as the Board of Managers may determine.

Section 3. The rules contained in "Robert's Rules of Order Revised" shall govern the Academy in all cases to which they are applicable, and in which they are not inconsistent with the bylaws or special rules of order of the Academy.

Article VIII. COOPERATION

Section 1. The term "affiliated societies" in their order of seniority (see Art. VI, Sect. 2) shall be held to cover the:

Philosophical Society of Washington
Anthropological Society of Washington
Biological Society of Washington
Chemical Society of Washington
Entomological Society of Washington
National Geographic Society
Geological Society of Washington
Medical Society of the District of Columbia
Columbia Historical Society
Botanical Society of Washington
Washington Section of Society of American Foresters
Washington Society of Engineers
Washington Section of Institute of Electrical and Electronics Engineers
Washington Section of American Society of Mechanical Engineers
Helminthological Society of Washington
Washington Branch of American Society for Microbiology
Washington Post of Society of American Military Engineers
National Capital Section of American Society of Civil Engineers
District of Columbia Section of Society for Experimental Biology and Medicine
Washington Chapter of American Society for Metals
Washington Section of the International Association for Dental Research
Washington Section of American Institute of Aeronautics and Astronautics
D. C. Branch of American Meteorological Society
Insecticide Society of Washington
Washington Chapter of the Acoustical Society of America
Washington Section of the American Nuclear Society
Washington Section of Institute of Food Technologists

Baltimore-Washington Section of the American Ceramic Society
Washington-Baltimore Section of the Electrochemical Society
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D. C. Psychological Association
Washington Paint Technical Group
American Phytopathological Society
Society for General Systems Research
Human Factors Society
American Fisheries Society

and such others as may be hereafter recommended by the Board and elected by two-thirds of the members of the Academy voting, the vote being taken by correspondence. A society may be released from affiliation on recommendation of the Board of Managers, and the concurrence of two-thirds of the members of the Academy voting.

Section 2. The Academy may assist the affiliated scientific societies of Washington in any matter of common interest, as in joint meetings, or in the publication of a joint directory: Provided, it shall not have power to incur for or in the name of one or more of these societies any expense or liability not previously authorized by said society and societies, nor shall it without action of the Board of Managers be responsible for any expenses incurred by one or more of the affiliated societies.

Section 3. No affiliated society shall be committed by the Academy to any action in conflict with the charter, constitution, or bylaws of said society, or of its parent society.

Section 4. The Academy may establish and assist a Washington Junior Academy of Sciences for the encouragement of interest in science among students in the Washington area of high school and college age.

Article IX. AWARDS AND GRANTS-IN-AID

Section 1. The Academy may award medals and prizes, or otherwise express its recognition and commendation of scientific work of high merit and distinction in the Washington area. Such recognition shall be given only on approval by the Board of Managers of a recommendation by a committee on awards for scientific achievement.

Section 2. The Academy may receive or make grants to aid scientific research in the Washington area. Grants shall be received or made only on approval by the Board of Managers of a recommendation by a committee on grants-in-aid for scientific research.

Article X. AMENDMENTS

Section 1. Amendments to these bylaws shall be proposed by the Board of Managers and submitted to the members of the Academy in the form of a mail ballot accompanied by a statement of the reasons for the proposed amendment. A two-thirds majority of those members voting is required for adoption. At least two weeks shall be allowed for the ballots to be returned.

Section 2. Any affiliated society or any group of ten or more members may propose an amendment to the Board of Managers in writing. The action of the Board in accepting or rejecting this proposal to amend the bylaws shall be by a vote on roll call, and the complete roll call shall be entered in the minutes of the meeting.

ACT OF INCORPORATION OF THE WASHINGTON ACADEMY OF SCIENCES

We, the undersigned, persons of full age and citizens of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 545 to 552, inclusive, of the Revised Statutes of the United States relating to the District of Columbia, as amended by an Act of Congress entitled "An Act to amend the Revised Statutes of the United States relating to the District of Columbia and for other purposes," approved April 23, 1884, hereby associate ourselves together as a society or body corporate and certify in writing:

1. That the name of the society is the Washington Academy of Sciences.
2. That the term for which the Corporation is organized shall be perpetual.
3. That the Corporation is organized and shall be operated exclusively for charitable, educational and scientific purposes and in furtherance of these purposes and for no other purpose shall have, but not be limited to, the following specific powers and purposes:
   a. To encourage in the broadest and most liberal manner the advancement and promotion of science.
   b. To acquire, hold, and convey real estate and other property and to establish general and special funds.
   c. To hold meetings.
   d. To publish and distribute documents.
   e. To conduct lectures.
   f. To conduct, endow, or assist investigation in any department of science.
   g. To acquire and maintain a library.
   h. And, in general, to transact any business pertinent to an academy of sciences.

Provided, however, that notwithstanding the foregoing enumerated powers, the Corporation shall not engage in activities, other than as an insubstantial part thereof, which are not in themselves in furtherance of its charitable, educational and scientific purposes.

4. That the affairs, funds, and property of the Corporation shall be in general charge of a Board of Managers, the number of whose members for the first year shall be nineteen, all of whom shall be chosen from among the members of the Academy.
5. That in the event of dissolution or termination of the Corporation, title to and possession of all the property of the Corporation shall pass to such organization, or organizations, as may be designated by the Board of Managers; provided, however, that in no event shall any property of the Corporation be transmitted to or vested in any organization other than an organization which is then in existence and then qualified for exemption as a charitable, educational or scientific organization under the Internal Revenue Code of 1954, as amended.

Editor's Note: This Act of Incorporation is shown as amended in 1964 by Francois N. Frenkiel, President, and George W. Irving, Jr., Secretary, acting for the Washington Academy of Sciences, in a Certificate of Amendment notarized on September 16, 1964. A copy of the original Act of Incorporation dated February 18, 1898, appears in the Journal for November 1963, page 212.

JOURNAL OF THE WASHINGTON ACADEMY OF SCIENCES

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CONTENTS

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This journal, the official organ of the Washington Academy of Sciences, publishes historical articles, critical reviews, and scholarly scientific articles; proceedings of meetings of the Academy and its Board of Managers; and other items of interest to Academy members. The *Journal* appears four times a year (March, June, September, and December)—the September issue contains a directory of the Academy membership.

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Risk Assessment in Dam Safety Analysis

Richard H. McCuen

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ABSTRACT

While those involved in the design and construction of dams have an excellent safety record, the fact that dam failures have occurred requires the engineering profession to re-examine current design practices. A design system that permits the assessment of risk for all design factors that involve uncertainty and relates the relative risks to the overall risk of failure would be a major improvement over the factor of safety approach to design. This can be accomplished using Bayesian decision theory. The Bayesian approach was demonstrated for the design of a small earth dam used to control flooding in construction areas, and its use was discussed as a means of selecting the optimum design hydrograph.

Risk: Definition and Interpretation

All of the words, danger, peril, hazard, and risk, refer to an exposure to harm or loss. Because it stresses uncertainty, risk distinguishes itself from the others and is especially significant with respect to dam safety. Furthermore, the uncertainty of harm or loss is often weighed against possible gain, and quite often the exposure to the harm or loss is made voluntarily (1).

While the idea of risk is rarely misunderstood, there is some confusion about how it is measured. In some cases, risk is represented by the probability of occurrence or non-occurrence of an event, while often risk is converted to an expected value of monetary benefits or loss. For consistency, risk should be limited to a probability statement and used only as a component of expected benefits or losses. The latter can be referred to as risk cost or risk loss.

With respect to dam safety, the probability of failure of the structure is the event of interest. The risk involved may be assessed either subjectively or with an analytical model. For comparing benefits to be derived from an inspection program, risk can be assessed on an annual basis and the benefits of inspection measured using the decrease in the probability of a failure. The annual risk, which is the probability that a dam will fail during one year, can be separated into component parts called relative risks, which are conditional probabilities that reflect the possible causes of failure (2).

In order to accurately assess the annual risk and the benefits of an inspection program, it will be necessary to quantify the relative risks. Uncertainty arises because of both the complexity of the physical system and the natural forces that affect the system. That is, relative risks reflect different sources of uncertainty. To accurately assess the annual risk, it is, therefore, important to have a means of combining the benefits and losses associated with the relative risks. The method selected to assess the most profitable action should be systematic and capable of weighing all of the relative risks involved.

Those involved in the design and construction of dams recognize the uncertainty that exists. Primary components of the total risk include extreme hydrologic events and variation in geologic characteristics. To account for sources of uncertainty, design includes factors of safety. Unfortunately, the relationship between design safety factors and the risk of failure are not adequately defined. Without such a relationship it is difficult to minimize the costs. Only by assessing the relative risks and the associated costs can the risk cost to society be optimized.

A Decision Theory Approach to Risk Assessment

Bayesian statistical decision theory (3), which has been called the statistical method of the 21st century, provides a more rational and effective methodology for assessing risk than classical statistics. Specifically, it provides for decision making that involves a combination of empirical analysis, professional experience, and engineering judgment.

In Bayesian analysis the decision process is assumed to consist of a set of alternative actions, a set of possible outcome events that are associated with each action, and a utility function that describes the value of each outcome. While the expected value theorem is used as the decision mode of classical analysis, the action/outcome sequence is expressed in probabilistic terms and the expected value of a utility function is used in Bayesian analysis to select the preferred action; the preferred action is the one that provides the optimal (i.e., either the maximum or minimum) value of the utility function.

The decision process is a systematic process that is conveniently represented by a decision diagram. The decision maker begins with a certain amount of information I. This information is used to identify n courses of action A_i. Associated with each course of action are a set of possible outcomes, where O_J indicates the j[th] outcome and $P(O_j)$ is the probability of outcome O_j. Associated with each decision process is a utility function that describes the utility of each outcome; the utility that corresponds to outcome O_j is denoted as U_{ij}. The decision maker should select the action A_i that provides the optimum value of the expected utility EU_i, which is given by

$$EU_i = \sum_{j=1}^{m} U_{ij}P(O_j) \qquad (1)$$

When the decision process is executed in a sequential mode, collateral information is collected and used to modify the prior probabilities $P(O_j)$. The collateral information will yield an estimate of the most likely outcome, which will be represented by a set of conditional probabilities. Specifically, past experience has indicated that when outcome O_j occurred, the collateral information indicated outcome event E_k; the likelihood of this is represented by the probability $P(E_k | O_j)$. For a future prediction of an outcome, the prior probability $P(O_j)$ is then modified to yield the posterior probability $P(O_j|E_k)$, which is the probability of outcome O_j. Given that the collateral information indicates outcome E_k, the posterior probabilities are computed using Bayes Theorem:

$$P(O_j | E_k) = \frac{P(E_k | O_j)P(O_j)}{\sum_{\text{all } j} P(E_k | O_j)P(O_j)} \qquad (2)$$

The posterior probabilities can then be used to compute revised estimates of the expected utility:

$$EU(A_i) = \sum_{\text{all } j} U_{ij}P(O_j | E_k) \qquad (3)$$

The action A_i with the optimal utility is then selected.

Quite often the collection of collateral information involves a probabilistic analysis (4). In such cases a preposterior analysis can be used to decide whether or not the collection of collateral information

Table 1.—Outcomes and utility function for dam design example.

Action	Outcome O_1	O_2	O_3
A_1	S(−1200)	F(1200−10000)	F(−1200−10000)
A_2	S(−4000)	S(−4000)	F(−4000−10000)

S = Survival; F = Failure

will be worthwhile. The preposterior analysis examines the terminal decision for each possible outcome. If a preposterior analysis indicates that the experiment should be conducted or collateral information collected, then the posterior analysis estimates the set of posterior probabilities according to the outcome of the experiment. When the experiment has been conducted, the expected benefits are computed using the posterior analysis.

A Decision Theory Approach to Design of Earth Dams

The decision theory approach can be illustrated using a typical design problem. An earth dam is required to protect a construction site during construction. There are two possible designs, with the more expensive design providing a higher level of protection. The costs of the dams are \$1200 and \$4000. Failure of either dam will cause \$10,000 worth of damage. An analysis indicates that the hydrologic states of nature can be represented by three outcomes: $Q_1 = 400$ cfs, $Q_2 = 500$ cfs, and $Q_3 = 600$ cfs. Table 1 shows both the outcome and utility for the two actions and three outcomes, with F and S indicating failure and survival, respectively. The utility function consists of either the cost of the structure when the dam survives or the sum of the cost and damage when the state of nature causes failure. The outcome probabilities are made from a hydrologic analysis of past data and for the example the following probabilities were determined: $P(O_1) = 0.3$, $P(O_2) = 0.5$, $P(O_3) = 0.2$; these are called the prior probabilities. The decision diagram is shown in Fig. 1. Using the outcome probabilities and the utility function, the following expected utilities were determined:

$$EU(A_1) = 0.3(-1200) + 0.5(-11200) + 0.2(-11200) = -\$8200$$

$$EU(A_2) = 0.3(-4000) + 0.5(-4000) + 0.2(-14000) = -\$6000$$

Since the objective is to minimize the expected utility, action A_2 is selected. Note that while the expected utility is −\$6000 that this payoff will never occur; there will be either a cost of \$4000 for the dam or \$14000 for cost and damage.

To improve the reliability of the decision, a meteorologist is hired to make a long-range weather forecast for the design life of the temporary dam. Past experience has indicated that when the outcome proved to be O_j, the forecast predicted outcome E_k with the conditional probability $P(E_k|O_j)$. For the example, the conditional probabilities are given in Table 2. Specifically, when the outcome proved to be O_2, the forecaster had predicted O_3 in 3 of 10 cases and O_1 in 2 of 10 cases. The prior probabilities can be revised using Bayes Theorem (Eq. 2). For example, if the collateral information indicated that outcome O_3 was most likely, then revision of the prior probabilities would yield the posterior probabilities: $P(O_1) = 0.1$, $P(O_2) = 0.5$, and $P(O_3) = 0.4$. While the posterior probability indicates that outcome O_2 is still the most likely outcome, the posterior probability of O_3 increased and that of O_1 decreased. The expected utilities are then revised as:

$$EU(A_1) = 0.1(-1200) + 0.5(-11200) + 0.4(-11200) = -\$10,200$$

$$EU(A_2) = 0.1(-4000) + 0.5(-4000) + 0.4(-14000) = -\$8,000$$

The collateral information did not change the decision that should be made (i.e., A_2 should still be selected). However, the expected utility of the optimum decision increased because the collateral information indicated that the high discharge associated with outcome O_3 was most

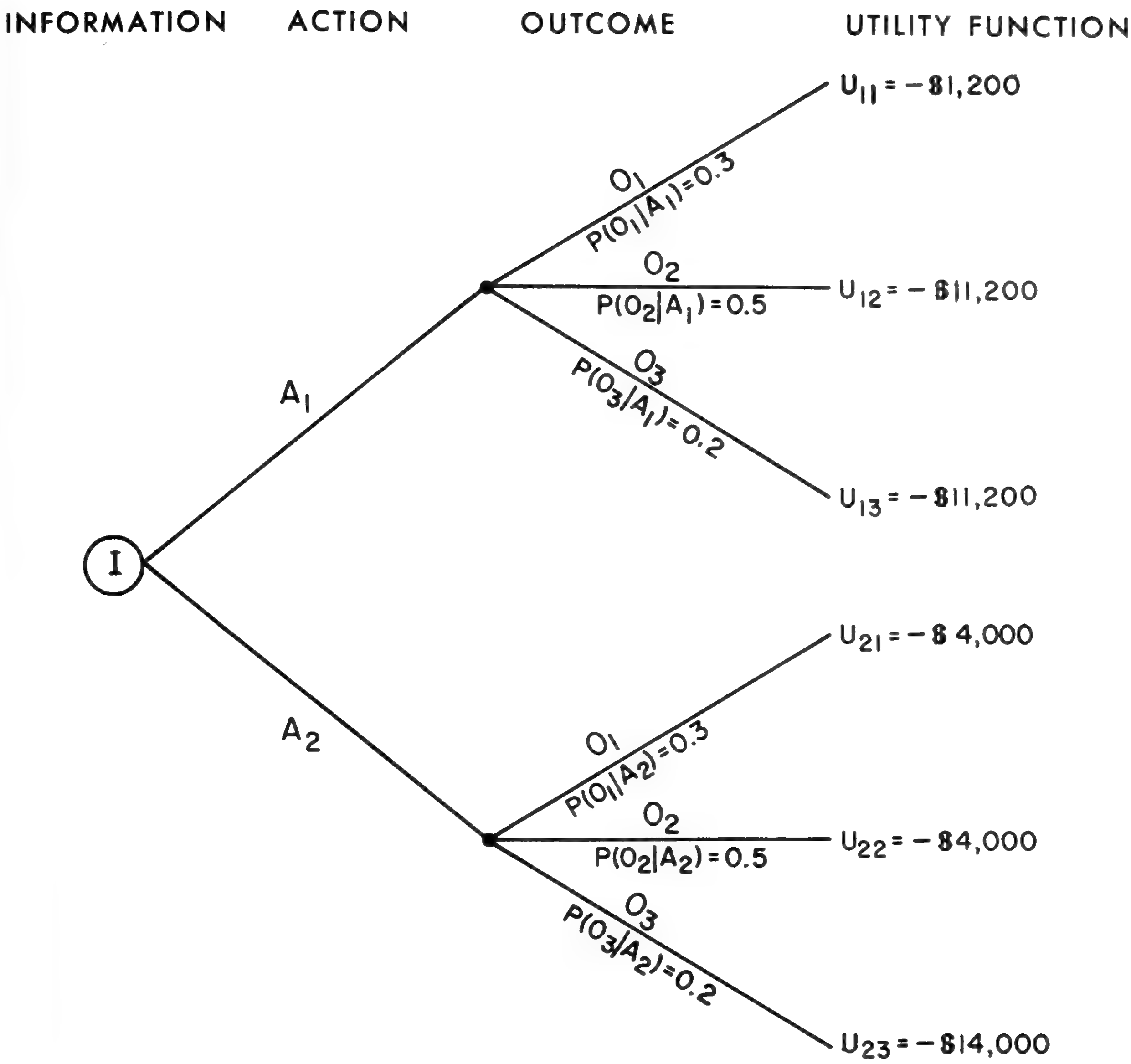

Fig. 1. Decision tree for earth dam design problem.

likely to occur. Note that while the collateral information indicates that O_3 is the most likely outcome, there is still considerable uncertainty and O_2 is the most likely outcome when both sources of information are considered.

A Decision Theory Approach to Design Flood Selection

An important element in the design of a dam is the selection of the design hydrograph. If the exceedence probability of the peak discharge is used as the design characteristic of the design hydrograph, then the decision theory approach can consider flood hydrographs for several alternative exceedence probabilities and the design hydrograph that minimizes the expected utility selected for the final design. Note that this process does not reduce the overall safety of the structure and, in fact, it optimizes the social cost of the structure. Furthermore, the decision theory approach has the advantage that the exceedence probability is not being selected arbitrarily but, instead, is selected in a way that reflects the risk of failure.

Table 2.—Conditional probability matrix $P(E_k IO_j)$ for dam design example.

	O_j		
E_k	1	2	3
1	0.8	0.2	0.0
2	0.2	0.7	0.1
3	0.1	0.3	0.6

The procedure for finding the optimum design hydrograph follows the procedure outlined for the dam design case. In this example, the magnitude of floods may be determined using any of the available methods for estimating peak discharges at ungaged locations. The prior probabilities could be evaluated and used in the computation of the expected utility. To improve the reliability of the decision, a decision may be made to collect collateral information prior to the design and construction of the facility. Specifically, it is worthwhile examining the possibility of installing a gage at the site and collecting streamflow data for a period of time. A preposterior analysis can be used to identify the optimum record length. If the preposterior analysis indicates that streamflow should be monitored at the site, then a Bayesian analysis can be used to compute the posterior probabilities. The expected utility evaluated using the posterior probabilities can be used to select the optimum design hydrograph.

Conclusions

At the present time, factors of safety are used to account for the uncertainty involved in the design and construction of dams. While this approach has resulted in an excellent safety record, the fact that dam failures have occurred requires the engineering profession to re-examine current practices in the design and construction of dams. A major step forward would be to adopt a design system that permits the assessment of risk for all design factors that involve uncertainty and enables the overall risk of failure to be related to the relative risks involved. Bayesian decision theory provides a framework for directly evaluating both the economics and engineering risk involved in the design and construction of dams. While the decision theory approach has numerous advantages over the traditional factor of safety method of design, it requires an assessment of the probability distribution function for all design factors that involve uncertainty. This assessment may be the result of both theoretical and empirical analyses. However, after these analyses have been made, the decision theory approach should lead to safer dams at less cost. The decision theory approach was discussed for two factors that involve uncertainty.

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Plasticity in Nesting Behavior of a Renting Wasp, and Its Evolutionary Implications. Studies on Eumenine Wasps, VIII (Hymenoptera, Aculeata)

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ABSTRACT

Ancistrocerus tuberculocephalus sutterianus (Saussure), previously known as a "renting" wasp (namely, a wasp that nests within preexisting cavities), is shown to be a facultative rather than an obligate renter. The wasp mined and masoned nests within a block of pith-like plastic, and it did so inside of a dark enclosure ($\leq$0.8 lux = maximum illumination). Thus it can (and does) excavate nests of a strikingly different sort than those it commonly rents. Significantly, the excavated nests are quite similar to the supposedly primitive nests of certain ground-nesting *Euodynerus*.

Occupancy of a darkened enclosure is related to *A. t. sutterianus'* association with *Sceliphron*. Evolutionary aspects are discussed, and it is shown that current, favored methods for studying twig-dwelling wasps must tend to bias results. Contrary to common belief, facultative renters are very likely a numerous class among eumenids, obligate renters comprising a small or empty one.

The striking behavior and nests of *Ancistrocerus tuberculocephalus sutterianus* (Sauss.) to be described have no parallel in what has been recorded for this species or, as far as I am aware, for any other of the many nearctic eumenid wasps known to occupy trap nests. Both *A. tuberculocephalus tuberculocephalus* (Sauss.) and *A. t. sutterianus* are "renting" wasps; that is, they are known to construct nests in small preformed cavities and in open burrows in wood, whether natural or artificial (Rau 1940, Bequaert 1944, Bohart [in Muesebeck *et al.* 1951], Barr [in Ferguson 1962], Parker 1962, Parker and Bohart 1968, Krombein 1967, Goodpasture 1974). Is "renting" obligatory for *A. tuberculocephalus*—is that the limit of its nesting behavior and capability?

As neither subspecies is known to mine in the ground, to burrow in plant stems, or to construct free nests of mud, each a regular but different mode of nest construction employed by particular eumenines, it may seem idle to wonder what sorts of nest *A. t. sutterianus* would or could construct were it not to "rent." The eleven nests to be described give ten direct, surprising answers to that question.

The behavior that led to construction of the nests of *A. t. sutterianus* (Riverside, California) is unusual in two main respects: (1) the nests were made within a dark, nearly completely enclosed space of approximately 0.02 m^3 (0.68 ft^3), namely within a box with tight walls, and (2) they were made in a solid block of plastic having a pith-like consistency.

The box, mounted on a masonry wall 112 cm (3′8″) above the ground, was open only on the underside by an irregular hole roughly 5 $\times$ 2 cm (1.6 in^2). Illumination within the box was by reflection through the hole from the earth below, reduced by an internal baffle to a level at the nesting site at midday of only 0.5–0.6 lux, reaching a peak of 0.8 lux in the early afternoon. Subjectively 0.5–0.6 lux corresponds with summer dusk about one-half hour after sunset and is near the absolute threshold (0.26 lux) of the completely dark-adapted honey bee (Autrum and Seibt 1965). The exposed soil below the box, regularly dampened by a slight seepage each evening, apparently served as source of mortar used by the nesting wasp.

The Nesting Substrate

The nests were constructed in a 20 cm × 18 cm × 25 mm-thick block of white styrofoam® placed furthest from the entrance, against the left inner wall of the box. The block served to hold unused control pins (of a timing device), the pins being inserted in a horizontal row near its upper edge. One pin, however, had fallen from the plastic, leaving an irregular hole. On August 18, that hole was found to have been covered with a dab of mud; elsewhere on the formerly unbroken vertical surface of the styrofoam, well below the line of inserted pins, there were ten other scattered pats of mud.

The Nests

The dabs of mud marked the closure of a nest of *Ancistrocerus t. sutterianus* in each case. Burrows of ten of the eleven nests had necessarily been initiated and excavated by a female wasp, for they were constructed where no pins had pierced a passage into the styrofoam. The control pin that had fallen from its hole must have left a broken surface and an only partially open, horizontal passage about 17–20 mm long × 0–2 mm wide, irregularly compressed into the styrofoam (to judge from those perforations left by the other pins when removed). That narrow, ill-shaped hole had been greatly widened and modified by the founding wasp to form a single-celled nest (fig. A). The construction of that nest differed in no obvious way from those of the five other one-celled nests (figs. B–F), even though it alone had been excavated along the line of a preformed passage. The wasp that emerged from that nest had done so before the nests were discovered in mid-August, 1976. To judge from the dimensions of its provisioned cell (table 1, A), the occupant almost certainly had been a male.

The eleven nests had in common (1) a covering cap, somewhat ellipsoidal or circular in shape, rough on its surface and generally but not always (e.g. figs. B, D) somewhat convex, (2) an entrant passage, largely filled with the mud of the cap but in no case partitioned by a special wall to form a vestibular cell, and (3) one or two cells, dug with the major axes very roughly normal to the entrant passage. In only two cases (cells I-1 and K-1) was the bottom of a cell not veneered with mud to form a smooth, concave floor; in neither of these had that cell been provisioned by the wasp, nor had an egg been attached to its wall. Each of the five two-celled nests (G-K) had a complete mud partition separating the two provisioned cells. The outer surface of the partition that faced the upper cell was smooth and concave, the inner surface (forming the roof of the bottom cell) was rough and convex, as usual in eumenine nests and so important for the survival of individuals and species (Cooper 1956, 1957; Tsuneki and Moriyama 1973).

The cocooning larvae, having thrust the remains of the caterpillar prey and their fecal pellets below, had coated the surfaces of their cells with "varnish" and silk. The cocoon of the parasitic wasp *Chrysis* (*Tetrachrysis*) *coerulans* Fabr. in nest D was free, nevertheless the walls of that cell also had been lightly "varnished" and very loosely webbed.

Measurements, ratios, and estimates (as areas and volumes) of components of the nests are given in Table 1. There is little quantitative fidelity in either one-celled or two-celled nests, a fact well reflected in the very large coefficients of variation of the linear measurements that range from 13 to 79 for rank-1 nests, 15 to 66 for rank-2 nests. Nor do features of individual nests, such as attributes of the cap, length of passage, size of cell, depth of nest or cell correlate in any obvious way with dates of emergences from the nests. The only clear relation is that the necessarily younger wasp of each fully-provisioned two-celled nest had emerged before its elder, the older wasp in each case having developed in the larger bottom cell.

Such structural regularities as do occur are all familiar architectural features

Table 1.—Nests of *Ancistrocerus tuberculocephalus sutterianus* (Sauss.) excavated in a styrofoam block, ranked in order of cell number and date of emergence and lettered to correspond with figures. One-celled nests = A through F, 2-celled = G through K (lower cell = 1, upper = 2). Linear measurements and thickness (θ) in mm, areas in mm^2, volumes in mm^3 (all decimals rounded). Cap asymmetry = length: width; masonry at base of cell = maximum thickness of mud liner of single and bottom cells, and cross wall of 2-celled nests. Nest depth is the greatest vertical distance excavated from the surface of the styrofoam. CV = coefficient of variation for linear dimensions.

	Emerged		Cap			Passage			Cell		Masonry			
Fig.	Sex	Date	Area	Asym	θ	L	W	Nest depth	Vol	L:W	base cell-1	cross wall	Exit hole Dia.	Ratio V wasp: V cell
A	?[1]	8/18	79	1.4	6.2	5.2	4.3	11.4	181	1.1	0.8	—	3.6	?
B	♂	11/20	37	1.2	1.0	1.0	4.8	9.0	123	1.9	1.5	—	2.8	0.2
D	?	3/18	30	1.0	3.0	4.6	4.5	11.5	231	1.4	1.5	—	?	—
F	♂	3/19	35	2.0	2.8	2.0	3.5	9.5	105	1.6	0.1	—	?	0.3
E	♂	3/23	23	1.5	5.5	5.0	3.5	11.0	170	1.5	1.0	—	?	0.3
C	♂	3/23	87	1.4	3.0+	6.0	4.0	14.0	170	1.5	0.1	—	?	0.5
		CV			53.4	50.1	13.0	16.0			78.8			
H			37	1.0	1.3	1.0	5.0	12.5					4.4	
2	♂	11/13							179	1.4		1.0		0.3
1	♂	11/16							188	1.7	1.8			0.4
G			34	1.2	2.7	3.0	3.5	18.5					3.6	
2	♂	11/13							204	1.4		1.0		0.2
1	♂	11/18							230	2.3	0.8			0.4
J			49	1.1	3.7	3.0	4.5	16.0					4.0	
2	♂	11/20							198	1.8		4.0		0.3
1	?								247	2.4	0.5			?
K			91	1.1	5.5	3.5	5.0	18.0					3.5	
2	♀	<12/30							466	1.2		1.6		0.2
1	O[2]								118	1.8	0			—
I			37	1.2	3.5	1.5	4.0	11.5					—	
2	O[2]	—							28	2.0		2.0		
1	O[2]	—							59	1.8	0			
		CV			46.4	45.2	14.8	19.2[3]			65.9[3]	64.5		

[1] The wasp had emerged before the suite of nests was discovered.

[2] Unprovisioned cells; those of I-2, I-1 are clearly too small for rearing, the nest is abnormal and its bottom cell contained the shriveled remains of a walled-in spider.

[3] CV for nest depth estimated for cells of H, G and J only, known to be those of males—or probably so (cell J-1).

regularly found in linear nests of eumenids constructed in hollow twigs or in trap nests of which the outer walls limit cell shapes: (1) the first provisioned cell is larger than any subsequent provisioned cell; (2) the base of the first cell is smoothed with mud into a regular concavity if otherwise it would be irregular, and if that cell is a provisioned one (compare the unprovisioned basal cells of nests I and K with all other basal cells); and (3) cross walls are smooth and concave where facing the exit of the nest, rough and convex on the reverse side. Finally, the sole cell from which a female wasp emerged is by far larger than any of the nine cells from which males emerged.

The Sex Ratio

The observed sex ratio is 9 males to 1 female. Two of the original brood died as larvae and were not sexed, so the probable primary sex ratio for this family cannot be less than 9 males to 4 females or more than 12 males to 1 female (for the sex is unknown of the wasp that emerged prior to discovery of the nests), namely from 69 to 92% males. Possibly these nests were made by a female with

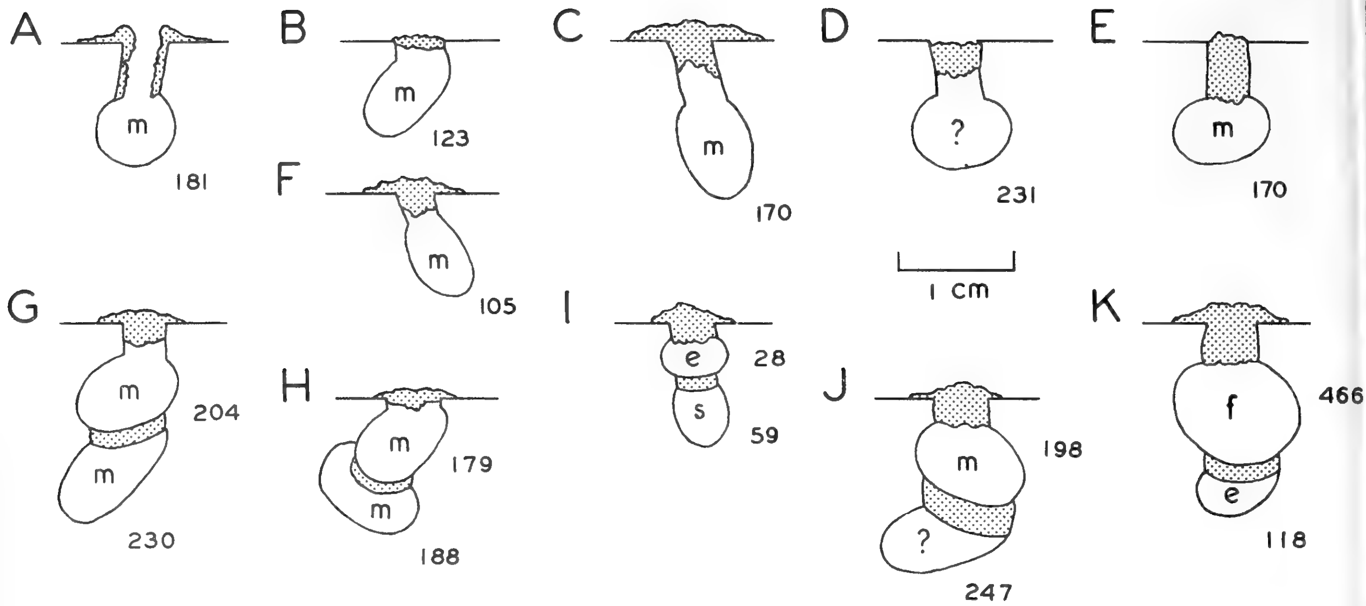

Fig. 1. A–K, diagrams of nests excavated by *Ancistrocerus tuberculocephalus sutterianus* (Saussure) in styrofoam. All nests were dug normal to the vertical surface of the plastic; mud closures and cross-walls hatched (see text and table for details); volume, in mm^3, noted to lower right of each cell; sex of occupant of each cell indicated where known; *Chrysis coerulans* Fabr. emerged from D; pharate pupa accidentally destroyed in J–1; e = empty cell, f = female, m = male, s = dead spider; scale = 1 cm.

a nearly exhausted supply of sperm, for available records from rearings of *A. t. sutterianus* suggest a less skewed ratio, thus 9 males, 0 females (Bequaert 1944), 37 males, 43 females (Parker 1962), 6 males, 3 females (Goodpasture 1974), and 3 males, 1 female (Cooper, unpublished), for a total of 55 males to 47 females, or 54% males. Nevertheless, it cannot be guessed whether that ratio is close to the primary one or not, for only Bequaert and I have recorded the total number of provisioned cells involved.

Krombein (1967) reports that 86 stored cells of *A. t. tuberculocephalus* gave 43 males, 5 females, with 38 cells failing to produce adults, of which *most* were judged by Krombein to have been those of males on the basis of cell dimensions and position in the linear nests. Krombein's observations gave lower (43 males, 43 females) and upper (81 males, 5 females) bounds for the sex ratio of 50% and 98% males, with 50% very probably far too low. In any case the range for the nominate species includes the estimates for my eleven nests of *A. t. sutterianus*. The strongly skewed sex ratio observed is thus not likely to be attributable to limitations placed on cell size or on nidification by pecularities of the nesting-substrate. It may, however, prove a function of the particular portion of the nesting period during which the nests were made; for example, Krombein's nests and those made in styrofoam probably represent samples from near (or at) the close of the nesting period.

Discussion

Excavation of the nests was not seen, so it cannot be proven that the eleven nests were all constructed by a single female (although believed to be so). Indeed it is known only that the nests were built not later than the close of July. Emergences were not clustered, but scattered over a period of at least seven months (Table 1). Such irregular emergence does not require the progeny to be that of more than one nesting female. Krombein (1967) records a nest of *Ancistrocerus t. tuberculocephalus* that took more than a year for the emergence of all occupants, and I have observed occasional nests of *A. antilope* (Panzer) with mixtures of diapausing and not diapausing individuals (see Nielsen 1932 for similar records). But either way, whether nests of one female or more than one, the observations bear importantly on the adaptive plasticity of this eumenine wasp, and probably on that of many others.

It is striking that a founding female of *A. t. sutterianus* explored a darkened, spacious enclosure as a possible nesting site, an enclosure in which the maximum illumination attained was only 0.8 lux (at about 1300 hours Standard Time). That behavior is quite unlike what has commonly been recorded for other eumenids, but it assuredly must prove adaptive if finding old nests of *Sceliphron*, suitable for renovation, is now a significant feature of this eumenid's ecology as it seems to be (Bequaert 1944, Bohart [in Muesebeck *et al.* 1951], Goodpasture 1974, Parker [*in litt.*]). Species of *Sceliphron*, including *S. caementarium* (Drury) (Shafer 1949), frequently make their mud nests in shaded, or even dimly lit situations. For example, *Sceliphron* have been recorded by Fabre (1891) as having constructed nests within a narrow-mouthed gourd on the mantlepiece of a farmhouse, as well as within the depths of stone piles; Ferton (1908) took a nest from beneath a large stone; Dutt (1913) and Williams (1945) found nests in hollow trees, and indeed Iwata (1976) holds *Sceliphron deforme* Smith may at times ". . . prefer dark wall corners within closets" of houses. Thus search of a darkened space probably does not represent a behavioral quirk of the female (or females) that made the nests in styrofoam; it is viewed as one behavioral component involved in the common association of *A. t. sutterianus* with abandoned nests of *S. caementarium*.

A second striking fact is that *A. t. sutterianus* does not have a strongly stereotyped nesting routine. Maindron (1882) classified eumenids into three categories of nesting types: (1) constructors of masonry enclosed cells, (2) burrowers (mainly into soil), and (3) occupiers and renovators of preexistent burrows or cavities, namely "renters" as Iwata (1942, 1976) and others call them. Renting ordinarily minimizes the effort of nest construction, thus providing a reduction in the wasp's energy budget (as Roubaud 1916 and Malyshev 1917 pointed out) even though the preexistent burrow may require modification to its needs as in Rau's (1928) record of *Ancistrocerus antilope* (Panzer) enlarging a burrow of *Ceratina* in sumach pith. When modification requires cutting out pith, as in that case, the renting wasp demonstrates a capacity that should permit it to construct in entirety its own nest in suitable, unworked pithy stems. Were renting long established, with available preformed burrows regularly exceeding demand and now the exclusive abode of a species, selection would be expected to favour maintenance of those abilities required for renovating hollowed stem nests or modifying available mud nests (since widening or reworking may often be required). There would be no such pressure, however, to maintain any genetic basis for instinctive construction of an entire nest in the absence of an available preformed burrow or cavity. An expected evolutionary result would be species of wasp that have become obligate renters.

Before the large number of observations now on record had been obtained, it was quite generally believed that the eumenids include many species which regularly mine soft wood and pith, constructing nests in their entirety, in contrast to others, also nesting in burrows, that habitually rent. There are, however, few cases (if any) on record where this may now be taken to be so, for all established burrowers in pith and wood known to me appear in fact to be facultative renters that readily accept suitable, preformed cavities as nesting sites. Among eumenines they include at least the African *Rygchium marginellus* (Fabr.) (Roubaud 1916), the Formosan *Nortonia kankauensis* Schult. (Iwata 1939, see Iwata 1976), and the European *Gymnomerus laevipes* (Schuckard) (Blüthgen 1961, Danks 1971b), *Pseudomicrodynerus parvulus* (Herrich-Schaeffer) (Blüthgen 1961), *Microdynerus helvetius* Sauss. (Enslin, 1922), *M. exilis* (Herrich-Schaeffer) (Blüthgen 1961; Danks 1961b) and *Ancistrocerus parietinus*

(Linn.) (Maindron 1882; Blüthgen 1961). Among rhaphiglossines certain species of *Rhaphiglossa* (see p. 250, Iwata 1976) and *Psiloglossa algeriensis* Saunders (Ferton 1920) have also been shown to be facultative renters. Indeed facultative renters may be a much larger class among eumenids than now suspected, including fabricators of masonry-enclosed cells as well as species that burrow in soil, in plant stems, etc. Except perhaps for very common species, however, facultative renting will not often be recognized as such for two principal reasons: (1) the very useful hollow trap-nest technique, as now so widely employed, permits only a test of the faculty for renting and, in some cases, for modifying existing burrows; (2) when a naturally occurring nest is found within an earlier abandoned masonry nest, or in a burrow within which there are unmistakable signs of prior occupancy, it is quite correctly concluded that a prefabrication has been used, namely that the nest is in fact a "rented" one. However, in the latter case all or most other natural nests of that species thereafter automatically become suspect as a rented nest even in the absence of clear evidence of earlier occupancy. For example, Krombein (1959) obtained a series of seven natural twig nests of *Leptochilus republicanus* (Dalla Torre). One among them had clearly been rented, for a dead *Ectemnius* (a crabronid) was found at the bottom of that nest; the origins of all six others therefore come into doubt! Is *L. republicanus* a facultative renter, or an obligate one as Parker (1966) believes to be the case for all twig-dwelling *Leptochilus*? With luck, traps of blueberry stems, rose stems, sumach and elder twigs, etc., having an intact central pith and set out where wasps abound, as Danks (1971a) appears first to have done in a systematic way, might give an answer in this and other cases.

In any case the evidence presented proves *A. t. sutterianus* to be a facultative renter. Furthermore the nests it constructed in the soft plastic have a special significance. All eleven are less like nests of a typical stem nesting eumenine than they are similar to nests of a primitively ground burrowing eumenine, *Euodynerus crypticus* (Say), described by Isely (1914), Rau and Rau (1918), Turner (1922) and Vest (1936) under the name *Odynerus dorsalis* Fabr. (see Bohart and Menke 1974). The encircling hard outer wall of a plant stem of course limits to a cylindrical hollow the shape that can be given to a cell by a wasp whose body's cross-section is but slightly less than the diameter of the pith cavity. The nests in styrofoam, however, had no lateral limitations placed upon their construction, although the depth to which they could be constructed could not exceed 25 mm unless the wasp curved its entrant burrow from the horizontal plane (as many aculeates that burrow into clay banks do, but which it did not do). Unlike the described nests of *E. crypticus*, that were dug more or less vertically into hard soil (first moistened and softened by the wasp), and which frequently had a vestibular space, those of *A. t. sutterianus* were tunnelled horizontally, and no vestibule was made. In all else, however, though made in substrates of markedly different textures, hardnesses and necessarily modes of working, the nests of the two species are closely similar in design. Thus entrances are normal to the surface, or nearly so; ovoid cells are wider than the entrant burrows, with long axes not in line with the entrant burrows, and in tandem when there is more than one per nest for there are no lateral offshoots; separations of cells are by mud partitions, with the bottom provisioned cell of multicelled nests the larger. What is more, the nesting *A. t. sutterianus* removed the excavated pellets of plastic from the interior of the box, just as *E. crypticus* scatters its earthen pellets remote from its burrow's entrance. All of which gives emphasis to Evan's (1977) observation that in Eumenidae certain aspects of nesting behavior, location and type of nest "are not closely correlated with generic divisions based on structure."

Thus *A. t. sutterianus* is not an obligate renter, even though heretofore it has been known exclusively as an occupant of empty nests of other aculeates, preformed burrows and trap nests. It is fully capable of constructing a nest in entirety in the absence of a suitable cavity and, when it does so, it surprisingly may exhibit what is widely considered to be a primitive nesting behavior and nest pattern (*e.g.*, Evans and Eberhard 1970, Iwata 1976). It seems likely that available free or abandoned cavities suitable for occupancy do not regularly exceed demand, that on average both intra- and extraspecific competition for them must occur and, therefore, that selection still favors retention of primary nesting capability and behavior. Very likely *A. t. sutterianus* is not unusual among renting eumenids as a facultative renter (consider the cases cited above). Indeed the class of *obligate* renters, now regarded as largest of all, may prove to be a small or empty one, literally an artifact of the common current use of hollow trap nests. As with *A. t. sutterianus*, nesting routines of many species are probably less rigid than now believed to be the case, at least among eumenids that rent. Seemingly "atavistic" patterns may be expressed adaptatively under circumstances departing from those provided by hollow trap-nests and other preformed cavities, hence from what is now believed to be customary. Interestingly, Tsuneki and Moriyama (1973) point out a similar persistence of atavistic attributes as explanation of the appropriate responses by *Discoelius japonicus* Perez (a *leaf-cutting* eumenid) to cues that are included in the mud walls of nests made by wasps of other, widely different species, for orientation of pupae toward a nest's exit.

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The Weight of Cicada Killer Wasps, Sphecius speciosus, *and the Weight of their Prey*

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ABSTRACT

Contrary to the distinct weights and lengths between male and female cocoons previously found by other workers, a slight overlap in the weights of adult cicada killers was found in the present study. Wasps preyed on 3 species of *Tibicen*. Two of these, *T. resh* and *T. figurata*, have never previously been reported as prey. Of the 10 specimens of prey, 8 were the larger *T. resh*. As reported previously by several workers, female cicada prey considerably outnumbered males taken. Six *T. resh* were female, 2 were male. The remaining *T. figurata* and *T. lyricen* were both females. Two of 5 cicadas weighed more than twice as much as the wasps carrying them, and the remaining 3 cicadas weighed less than twice as much as the wasps. Previous claims of cicadas weighing 4 to 6 times as much as the wasps carrying them appear to be greatly exaggerated.

Female cicada killer wasp eggs are typically provisioned with 2 cicadas and male eggs with 1 cicada (Dow 1942). Dow found that cocoons were of 2 different classes in respect to size. Measurements of their lengths and weights showed that male and female cocoons were quite distinct and separated by intervals of 5.0 mm and 1.0 g. According to Dambach and Good (1943), 47 cells containing small or medium-sized cocoons were found to be provisioned with but 1 cicada. In the same set of observations, cells containing large cocoons were found to have been provisioned with 2 cicadas in 19 cells and with 3 cicadas in 5 cells. Only 2 large cocoons were found with single cicadas, and each of these had a large female, *Tibicen lyricen*. Dow (1942) excavated 42 cells, 3 of which contained 3 cicadas; none of the 3 contained cocoons. Of the 18 cocoons Dow reared to adults, 2 of the adult males came from cells containing 2 cicadas each. Both contained a male and a female of the lighter *Tibicen canicularis*. Of the 6 adult females reared, all came from cells which contained 2 female cicadas, 2 of them 2 females of *T. lyricen*, 2 a *T. canicularis* and a *T. lyricen*, and 2 *T. canicularis*. Dow reared 12 adult males and 6 adult females and found the weight of the males to range from 0.13 g to 0.44 g and the weight of the females to range from 0.61 g to 1.09 g.

The present study will show that although female wasps tend to be considerably larger and heavier than male wasps, this is occasionally not the case. This was first suspected as a result of years of data gathering from Brooklyn populations in which the sex of wasps could be determined from their emergence holes. Males came from holes 5 to 10 mm, 5- and 6-mm holes were rare, and females came from emergence holes 12 mm to 19 mm, 17- to 19-mm holes being quite rare. However, roughly one-half of 11 mm emergence holes were made by males, and roughly one-half were made by females. A further assumption supported by numerous observations of emerging wasps is the width of the emergence hole provides a good index of the width and size of the wasp. Dambach and Good (1943) found the average length of 135 cocoons was 32 mm, and the average width at the widest point was 11 mm. The smallest cocoon found measured 21 mm in length and 7 mm in diameter. The largest

Table 1.—Weight of the Various Male and Female Cicada Killers in Present Study.

Adult Males

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Weight (g)	0.30	0.41	0.46	0.47	0.50	0.51	0.54	0.55	0.57	0.62	0.64	0.64	0.64	0.69	0.69	0.70	0.71

Adult Females

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Weight (g)	0.61	0.82	0.92	1.06	1.12	1.18	1.18	1.20	1.20	1.21	1.22	1.24	1.25	1.28	1.37	1.38	1.40	1.41	1.50	1.52	1.57	1.58	1.74

specimen found was 47 mm in length and 16 mm in diameter. Dambach and Good's (1943) cocoon widths are almost identical with adult emergence hole widths used by the observer in sexing the Brooklyn populations. There is little doubt that the relationship is not one of chance. The mean width of 111 emergence holes in population 1 in Brooklyn in 1958 was 10 mm. The smallest hole measured 6 mm in diameter. The largest hole was 16 mm in diameter. These figures closely approximate Dambach and Good's (1943) figures for cocoon widths.

Dow (1942) obtained his cicada killer cocoons from Berkley, Massachusetts. The following study of a cicada killer population was made on a sandy tract surrounding the main building of the U. S. Department of Agriculture, Southern Forest Experiment Station in Pineville, Louisiana in July, August, and September of 1977. A total of 40 adult *Sphecius*, 17 males and 23 females, was captured and weighed while alive. A total of 10 paralyzed cicadas was taken from females and weighed. Three live cicadas from the area were weighed which were not captured by wasps. The Pineville cicadas belonged to 3 species. In order of decreasing size, they were *Tibicen resh*, *T. figurata*, and *T. lyricen*. There were 10 *T. resh* (8 ♀♀ and 2 ♂♂), 2 *T. figurata* (1 ♀ and 1 ♂), and 1 ♀ *T. lyricen*. The use of *T. resh* and *T. figurata* as prey by *Sphecius* had not been previously reported. Assuming that the 3 prey species and sexes are equally easy to capture, the relative number of the different cicadas caught might reflect the relative abundance of the different species and sexes in the area, or the wasps might have been selecting their prey species as well as the sex of their prey. This latter hypothesis appears to be true of *Sphecius* in general (Lin, in press).

In 5 of the previous cases, the weight of the female wasp as well as the weight of her prey was obtained.

In 4 cases, the female was weighed immediately after her emergence, having

Table 2.—Weight of Living Cicada Prey (1) Taken from *Sphecius* and (2) Captured by Observer.

No.	1	2	3*	4	5	6	7*	8	9	10	11	12	13*
Wt. of Cicada (g)	1.61	1.79	1.86	2.11	2.24	2.35	2.59	2.66	2.70	2.70	2.78	2.81	2.84
Species	T.l.	T.f.	T.f.	T.r.	T.r.	T.r.	T.r.	T.r.	T.r.	T.r.	T.r.	T.r.	T.r.
Sex	♀	♀	♂	♂	♀	♀	♀	♀	♀	♂	♀	♀	♀

* Captured by observer.
T.l. = *T. lyricen lyricen*.
T.f. = *T. figurata*.
T.r. = *T. resh*.

been caught while still in copula. In 2 of these cases, the male in copula with the female was also subsequently weighed. All wasps and cicadas were weighed on a Mettler H64 scale which is accurate to ±0.1 mg.

The weight of adult males ranged from .30 g to .71 g with a mean of .57 g. The weight of adult females ranged from .61 g to 1.58 g with a mean of 1.26 g. See Table 1 for the weights of the various males and females in the present study. The mean weight of Dow's males was .35 g and considerably less than the mean weight of males in the following study. The mean weight of Dow's females was .82 g and also considerably less than the mean weight of females of the study. Only 2 of the 17 males in the present study were lighter than 1 or more males in Dow's sample.

Four females of the total of 23 in the following study were lighter than 1 or more females in Dow's sample.

The lightest female in the present study (.61 g) was lighter than 8 of the 17 males in the present sample (see Table 1). This female also weighed the same as Dow's lightest female.

The range in weight of the 10 prey specimens taken from female wasps was 1.61 g to 2.81 g $\bar{X}$ 2.33 g. Table 2 gives the weight and sex of these specimens including the three not captured by *Sphecius*. Dow (1942) did not have any freshly paralyzed prey, so he captured a few cicadas of the 2 species (*Tibicen canicularis* and *T. lyricen*) used by *Sphecius* in his sample and took the weight of these specimens as estimates of the weight of the actual prey. The male *T. canicularis* weighed .93 g, and the female 1.12 g. The male *T. lyricen* weighed 1.39 g and the female 1.94 g. All of the specimens in the present study weighed more than the male and female of *T. canicularis* and the male of *T. lyricen*. Only 2 of the 10 specimens weighed less than Dow's female *T. lyricen* (see Table 2). The heavier wasps in the present study might be a consequence of the heavier prey species used by the Pineville wasps. Dow (1942), however, presents several reasons why his weight data should be subject to criticism. The most serious of these is that his specimens were weighed both alive and dead in varying periods of time after reaching full development.

Table 3 gives the weight of the 5 female *Sphecius* and the weight of each female's prey. Though the sample is small, there is no correlation between the weight of the female *Sphecius* and the weight of her prey. The lightest of the 5 females carried the heaviest prey specimen. Balduf (1941) claimed to have weighed freshly killed wasps and their cicada prey and found the cicadas to weigh 4–6 times as much as the wasps. Table 3 reveals that 2 of the 5 cicadas weighed more than twice as much as the wasps but con-

Table 3.—Weight of Female *Sphecius* and Weight of Her Prey.

No.	1	2	3	4	5
Wt. of Cicada (g)	2.66	2.70	2.70	2.78	2.81
Wt. of Wasp (g)	1.37	1.20	1.38	1.58	1.06
Weight ratio	1.94	2.25	1.95	1.76	2.65

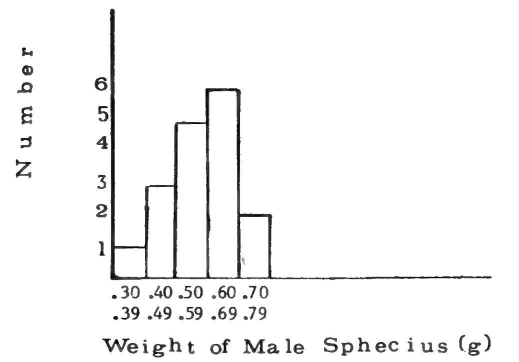

Fig. 1. Weight of male *Sphecius* in grams.

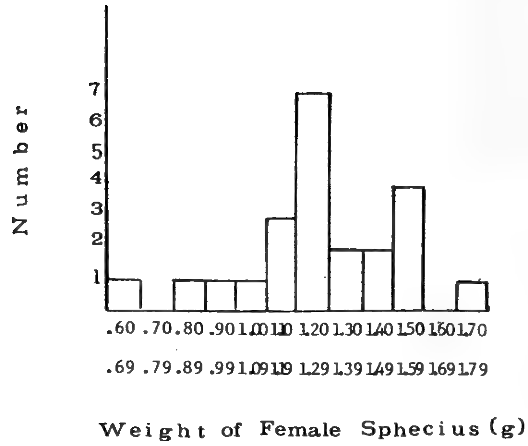

Fig. 3. Weight of female *Sphecius* in grams.

siderably less than 3 times as much, and the remaining 3 cicadas weighed less than twice as much as the wasps. Only by comparing the lightest of the female wasps (.61 g) and the heaviest cicada captured by *Sphecius* (2.81 g) do we come to a figure approximating Balduf's, where the cicada weighed more than 4 times the wasp. However, we are seemingly dealing with a rare extreme because this female weighed less than 8 males in the sample of 17. In the case of the second lightest female (.82 g), the cicada weighed less than 4 times the wasp (2.81 g). Dow's data support a similar conclusion; his heaviest cicada (1.94 g) weighs 3 times his 2 lightest female wasps (.61 g, .63 g) and 2 times his third and fourth lightest female and less than 2 times his 2 heaviest wasps. The Pineville cicadas are all larger species than the Brooklyn cicadas which were *T. linnei*, and sometimes these Brooklyn females abandoned the cicadas in unsuccessful attempts to climb objects tall enough to take flight from and reach the nest. Thus, cicadas typically double or less than double the weight of wasps were too heavy for some wasps to return with. Balduf's (1941) claims of prey weighing 4–6 times as much as the wasps carrying them seems to be greatly exaggerated.

The weight of 4 newly emerged females caught in copula was .61 g, .82 g, 1.21 g, and 1.28 g. The males involved in the second and third cases were also weighed, being .69 g and .54 g. In the copulatory flight, the female pulls the male behind her (Lin, 1966, 1967). The data for females indicate there is no large change of weight between emergence and later in the season. The 2 lightest females were caught at emergence (.61 g, .82 g). However, 2 relatively heavy females were also caught on emergence—the 10th heaviest female (1.21 g) and the 14th heaviest female (1.29 g) of the total of 23 females (Table 1). After emergence and copulation, females leave the arena-nesting society for approximately 8 days.

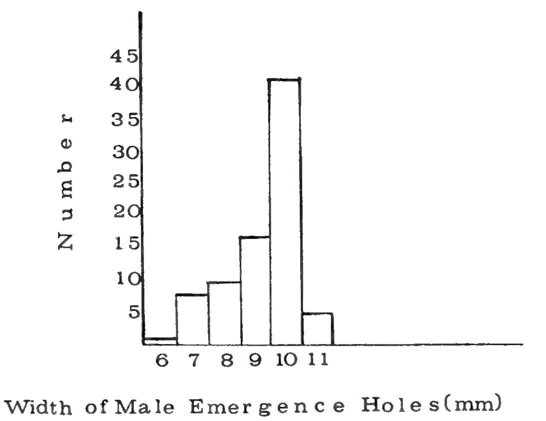

Fig. 2. Width of male emergence holes in mm.

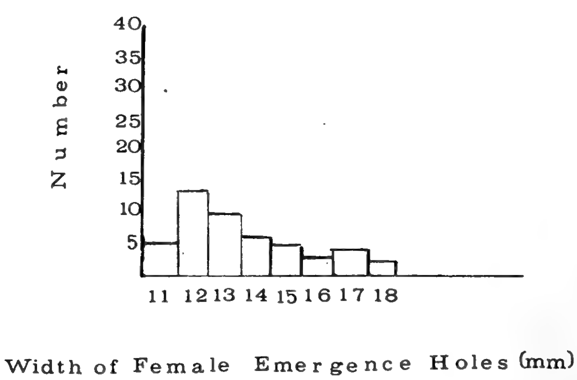

Fig. 4. Width of female emergence holes in mm.

The remaining females in Table 1 were probably at least 8 days old or older.

Emergence holes and their widths were marked, counted, and measured from July 12 to July 31. These holes were not counted daily but sporadically on 9 different dates. Most holes were probably accounted for, since the soil was hard clay and relatively inaccessible to destructive forces. Emergence continued after July 31 and up to August 25, when Dr. John Moser saw a copulating pair; thus, the female had just emerged. Males live a maximum of about 15 days and females about 30 to 33 days (Lin in Evans, 1966). I suspect I counted and measured one-half to three quarters of all the emergence holes in the population. Wasps were weighed from July 15 to September 7. A very large proportion of weighed wasps probably had their emergence holes measured, especially since after mating, the newly emerged female leaves the arena-nesting society for about 8 days, and males spend long periods in their territories, approximately after 5 days following their emergence. In Fig. 1, male-weight categories were plotted by number of wasps. Weight and width of wasps are likely to be correlated. Thus, in Fig. 2, male emergence holes (6 to 10 mm and one-half 11 mm holes—because about one-half of 11 mm holes produce males) were plotted as to number, and there is a very similar pattern between numbers in male-weight categories and size categories of male emergence holes. The same was done for females in Figs. 3 and 4. In the females, there is no distinct pattern.

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The Afrotropical Species Assigned to Terellia *R.D.* *(Diptera: Tephritidae)*

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ABSTRACT

None of the Afrotropical species assigned to *Terellia* Robineau-Desvoidy belongs to that genus. The following new combinations are made: *Terellia nigrofemorata* Munro and *Terellia taeniaptera* Bezzi are transferred to *Stephanotrypeta* Hendel; *Terellia complanata* Munro and *Trypeta planiscutellata* Becker are transferred to *Hyalotephritis* n. gen., the latter as the type-species; *Terellia planiscutellata* Becker var. *australis* Bezzi (=*Terellia australis* Bezzi) is transferred to *Tephritites* n. gen., as type- and only included species; *Terellia xanthochaeta* Munro is transferred to *Trupanea* Schrank. *Stephanotrypeta vittata* n. sp. is described, and a key to the four known species of the genus is given. *Terpnodesma* Munro becomes a junior synonym of *Stephanotrypeta* (n. syn.). A lectotype is designated for *S. taeniaptera*.

Terellia was proposed by Robineau-Desvoidy (1830) for *palpata* Robineau-Desvoidy and *luteola* Robineau-Desvoidy. Both of these species were later found to be conspecific with *serratulae* Linnaeus, an older name (Becker, 1905; Hendel, 1927). While revising the Terelliinae of the world, I have confirmed that the Palaearctic species assigned to *Terellia* (e.g. Hendel, 1927) form a monophyletic group (evidence to be elaborated in greater detail elsewhere) and belong to this genus or to the closely related *Orellia*. Among other features, specimens of these species are characterized by the inclinate posterior upper fronto-orbital bristle.

None of the Afrotropical species assigned to *Terellia* is congeneric with its type-species or even belongs to the subfamily Terelliinae. This is easily revealed by their reclinate posterior upper fronto-orbital bristles. Munro (1967) mentioned the incorrect placement of the Afrotropical species in *Terellia*; however, in the Afrotropical catalog (Cogan and Munro, in press) the same species are still being listed under *Terellia*. Munro (1929) presented a key to the six Afrotropical species assigned to *Terellia: australis, complanata, hysia, nigrofemorata, taeniaptera* and *xanthochaeta*. Of these, *Trypeta hysia* Walker was later stated by Munro (in litt.) to belong to the Otitidae, and *Terellia taeniaptera* Bezzi was transferred to, and designated as, the type-species of *Terpnodesma* Munro (1956). The latter species as well as the other four species are treated herein and are assigned to the proper genera (two are here described as new) and subfamilies.

Subfamily **Aciurinae**

Stephanotrypeta Hendel

Stephanotrypeta Hendel, 1931: 8. Type-species: *Stephanotrypeta brevicosta* Hendel, by monotypy. —Munro, 1947: 88, 219 (key, discussion).
Terpnodesma Munro, 1956: 469. [**New synonym.**]

Hendel (1931) erected *Stephanotrypeta* and placed it in the subfamily Trypetinae because of the relatively short 6th abdominal tergum of the female (as compared with the 5th) and the banded wing pattern. Munro (1947) transferred *Stephanotrypeta* to the Aciurinae, a subfamily that he revised for the Afrotropical Region.

Munro (1956) proposed *Terpnodesma* for *Terellia taeniaptera* Bezzi, and placed it in the subfamily Tephritinae. He stated, however, that the correct placement of *Terpnodesma* must await further study. Munro (1929: 7) described *Terellia nigrofemorata*, which has never been recorded since. After studying specimens of these species, as well as of a related, undescribed species, I have concluded that all four species are congeneric. The unusual character of *S. brevicosta*, the costa reaching r_{4+5}, is shared also by *S. nigrofemorata* and is not considered to be of generic significance.

The generic characterization given by Hendel (1931) and Munro (1956) is sufficient and will not be repeated. However, the subfamilial placement of *Stephanotrypeta* requires a comment. While some Aciurinae have whitish, lanceolate, postorbital bristles, a character of Tephritinae, very rarely do they have the posterior upper orbital bristle lanceolate. *Stephanotrypeta* has lanceolate postorbitals and 2 dark and acuminate upper orbitals; and therefore can hardly be included in the Tephritinae. The wing pattern is neither typical of the Tephritinae nor of the Aciurinae. The absence of distinct scapular bristles in this genus makes its inclusion in the Trypetinae unwarranted. The relative length of the 6th tergum of the female was found to be somewhat variable inter- and intraspecifically. Even if the 6th tergum were only half the length of the 5th, as stated by Hendel (1931), this character cannot be considered a conclusive factor in subfamilial assignment of this or other genera. Although females of most trypetines have the 6th tergum shorter than the 5th, and most tephritines have it as long or longer, there are many exceptions in both subfamilies. In the Aciurinae the length of the 6th tergum varies from less than to greater than the length of the 5th.

The best-known character to define an aciurine is probably a biological one. All known hosts of Aciurinae are either Labiatae, Acanthaceae or Verbenaceae (*Trirhithromyia marshali* Bezzi (Schistopterinae) is the only known example of a non-aciurine species breeding in plants of one of these families (Acanthaceae)). The record of specimens of *S. brevicosta* from *Lantana* (Verbenaceae), although not being a rearing record, is significant, therefore, in supporting the inclusion of *Stephanotrypeta* in the Aciurinae. Within the Aciurinae *Stephanotrypeta* may fall within the platensina group (Munro, 1947) or, if the hosts are indeed Verbenaceae, it could perhaps be placed in Munro's "Group IV", together with *Munroella* and other genera, which have a similar tendency for banded wing patterns.

The Aciurinae are restricted to the Old World, where they are abundant in the tropics, mainly in the Afrotropical Region.

Key to the species of *Stephanotrypeta*

1. Costa reaching end of r_{4+5}; last section of m attenuated toward apex; r_{4+5} and m divergent toward apex; apex of cell R_5 hyaline 2
   Costa reaching end of m; last section of m not attenuated; r_{4+5} and m parallel or convergent apically; apex of cell R_5 brown 3
2. Mesonotum with distinct but pale, partly fused, brown, dorsocentral vittae; femora mostly yellow, hind femur, except base and apex, black; 2 longest bands of wing convergent posteriorly; stigma about 3 times as long as wide, mainly yellow, except for brown base and apex; aedeagus with apical funnel-like structure, without cornuti (fig. 4); 'oviscape with coarse whitish hairs' .... *S. brevicosta* Hendel
   Mesonotum uniformly gray, without brown vittae; femora, except base and apex, mainly black; 2 longest bands of wing parallel; stigma about 2 times as long as wide, mainly brown; aedeagus not known; oviscape mainly with fine brown hairs, with slight whitish hairs at base .... *S. nigrofemorata* (Munro)
3. Mesonotum with two distinct, brown, dorsocentral vittae; aristal hairs shorter than basal width of arista (fig. 6); surstylus distinctly produced into curved, posterior flaps (fig. 3); aedeagus more sclerotized (fig. 5); oviscape with white pubescence on basal ½–⅔ .... *S. vittata* Freidberg, n. sp.
   Mesonotum uniformly gray; aristal hairs as long as, or slightly longer than, basal

width of arista (fig. 7); surstylus not produced into distinct posterior flaps (fig. 2); aedeagus less sclerotized; dorsal side of oviscape at most with slight white pubescence at base .... *S. taeniaptera* (Bezzi)

Stephanotrypeta brevicosta Hendel

Stephanotrypeta brevicosta Hendel, 1931: 8, Pl. 1, figs. 4, 5.—Munro, 1947: 219.

This species was originally described from Egypt (a male and female), and has not been recorded since. Three males from Kenya—two caught on *Lantana*, Nairobi, VI.37, Van S. (?=Van Sommern), and the other from Kajiado, 6.I.1972, A. Freidberg—extend the range of this species to east Africa and provide the only indication for the hosts of species of *Stephanotrypeta*. The preapical spot in the wing of the male from Kajiado is not connected to the transverse band, but this is only intraspecific variation. The 9th tergum is similar to that of *S. vittata* in posterior view but differs in lateral view, being narrower and almost equally wide throughout its height (fig. 1). The aedeagus has an apical funnel-like structure (fig. 4), but no cornuti. Females were not available for study.

Stephanotrypeta nigrofemorata (Munro), new combination

Terellia nigrofemorata Munro, 1929: 9, Pl. 1, fig. 2.
"*Terellia*" *nigrofemorata*, Munro, 1967: 16.

This species was described and is thus far known from a single female that I have seen from South West Africa. The femora are mainly black, and the wing pattern is distinctive too (see Munro's figure and the above key). The costa reaches r_{4+5}, not m as shown in Munro's figure.

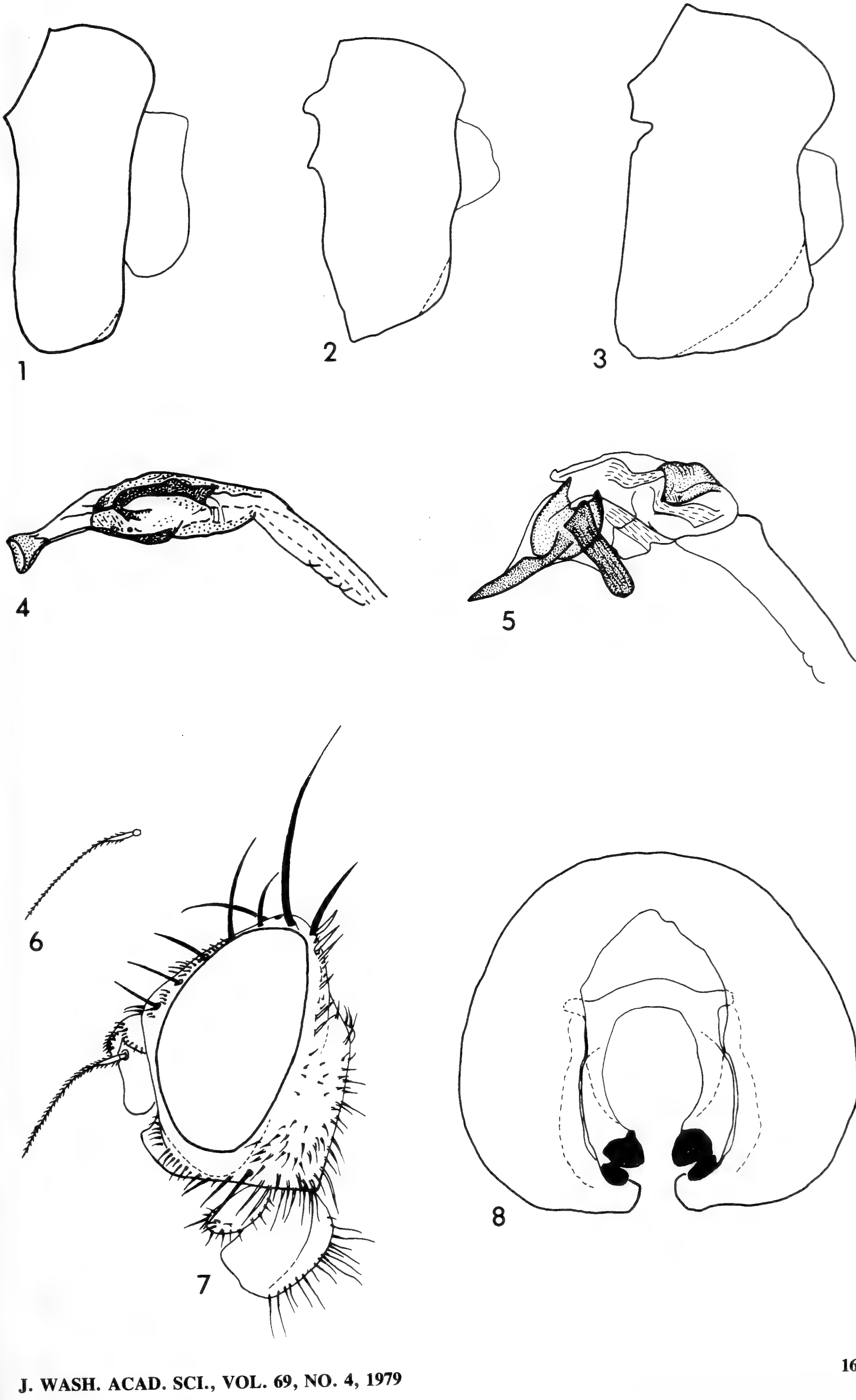
Stephanotrypeta taeniaptera (Bezzi), new combination

Terellia taeniaptera Bezzi, 1923; 581; 1924a; 506, Pl. 13, fig. 52; 1924b: 118.—Munro, 1929: 7.
Terpnodesma taeniaptera (Bezzi): Munro, 1956: 469, figs. 2, 3; 1966: 3.

This was the first Afrotropical species to be assigned to *Terellia*, and later it was designated as the type-species of *Terpnodesma*. Bezzi (1923) recorded a female from Madagascar and compared it to a male from Transvaal, on which he based his (1924a) more detailed description. However, the species dates from 1923, not 1924 (as cited by Munro, 1956), despite the heading "*Terellia taeniaptera* sp. nov." for the 1924a description. Bezzi (1924a) stated: "One specimen from Pretoria, August 1916 (H. K. Munro); but the species is known also from East Africa and even from Madagascar". Munro (1956) said: "The type, a male, in the South African National Collection of Insects, Pretoria, is from Barberton, August 1913, L. S. Hulley (not from Pretoria)". I have seen a male which is labeled: "Barberton, Aug 1913, LSH [?=L. S. Hulley], H. K. Munro/*Terellia taeniaptera* n. sp., t [?=type] ♂", and also the female recorded by Bezzi (1923) from Madagascar. The female is labeled: "*Terellia taeniaptera* Bezzi, Type ♀", but it is a different species than the male (see also record under *S. vittata* n. sp.).

Although Bezzi (1923) referred to a male and female in the original description (the female is deposited in the Museum Civico Storia Naturale, Milan), he did not designate a type specimen, and both specimens referred to must be considered as syntypes. In a recent letter from Munro (23 October 1979) he confirms: "There is only the single type of *T. taeniaptera* the only specimen of the species that *Bezzi ever had from me*. It is from Barberton, 1913." Based on this statement, I can only conclude that Bezzi errored in citing the label data for the type specimen. The correct data were given above. Munro stated that this specimen is the "type", but as he did not formally designate this specimen as the lectotype, I am doing so here. The

Figs. 1–8, *Stephanotrypeta* spp.: 1, *S. brevicosta*, male, 9th tergum, lateral view; 2, *S. taeniaptera*, male, 9th tergum, lateral view; 3, *S. vittata*, male, 9th tergum, lateral view; 4, *S. brevicosta*, aedeagus; 5, *S. vittata*, aedeagus; 6, *S. vittata*, arista; 7, *S. taeniaptera*, head, lateral view; 8; *S. vittata*, male, 9th tergum, posterior view.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lectotype is deposited in the Plant Protection Research Institute, Pretoria, South Africa.

I have studied specimens from South Africa, Rhodesia, Kenya and Uganda. The species is distinguished from the other congeners by the characters given in the key. Additional descriptive remarks are: The arista is not bare, as stated by Bezzi, but pubescent, as in fig. 7. Furthermore, there are 2 mesopleural bristles, not one, as stated by Bezzi (sockets of 3 missing bristles are visible in the lectotype). The legs are usually completely yellow; in one specimen the middle and hind femora are somewhat blackish. The wing and aedeagus were illustrated by Munro (1956). Vein r_{4+5} often with several setulae along distal section, in addition to setulae at node. The 9th tergum of the male is illustrated in fig. 2. The 6th tergum of the female is half to about as long as the 5th. Oviscape somewhat shorter than combined length of last three terga, with pubescence entirely or mainly fine and brown, coarser and whitish only ventrally at base, rarely with some whitish pubescence dorsally at base.

Material examined: *Uganda*: Mnkole, Mbarara, 22.IV.1968, P. J. Spangler (1♂,1♀). *Kenya*: Tsavo, 11–12.I.1972, A. Freidberg (1♂). *Rhodesia*: S. Rhodesia, Shangani, De Beer's Ranch, V.1932, Miss A. Mackie (1♀). *South Africa*: Pretoria, 12.III.1926, H. K. Munro (1♂), 13.II.1972, A. Freidberg (3♂); Pretoria, Roodeplaat, XI.1960, J. Bot (1♂); Kaalfontein, Pretoria Dist., 19.IV.1950, A. L. Capener (1♀); Irene, Transvaal, 24.II.1952, H. K. Munro (1♀), 2.III.1952, H. K. Munro (1♂,1♀).

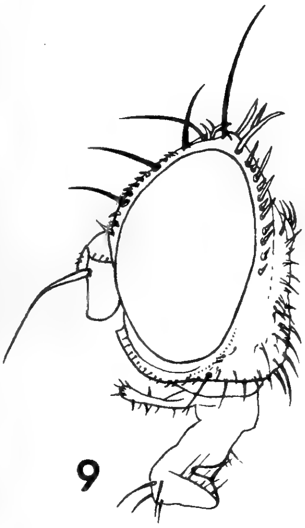
I have not verified records from Zaire, Burundi and Tanzania. Tanzanian specimens, determined as this species (Munro, 1966), belong to *S. vittata* n. sp.

Stephanotrypeta vittata Freidberg, new species

This species is similar to *S. taeniaptera* but differs in the following characters: Arista with shorter pubescence (fig. 6). Mesonotum with two brown vittae that start at the anterior border, extend over the insertion of the dorsocentral bristles, converging slightly, and terminate a little behind the insertion of the prescutellar bristles; a faint and shorter median vitta is more or less distinct at the anterior part of mesonotum. No such vittae are present on mesonotum of *S. taeniaptera*. The dark spots at the insertion of the scutellar bristles are smaller. Legs mainly yellow, forefemur posterodorsally with a blackish longitudinal stripe, middle and hind femora with more or less distinct blackish basal and preapical annuli. Wing: r_{4+5} with setulae only at node; the pattern and venation are very similar in the two species but may show small significant differences if large enough series of specimens are studied. The 9th tergum (fig. 8) differs in having the surstyli distinctly produced into flattened, curved posterior processes, thus it broadens ventrally in side view (fig. 3), while in *S. taeniaptera* it tapers ventrally (fig. 2). The aedeagus (fig. 5) is somewhat more sclerotized but otherwise is very similar to that of *S. taeniaptera* (compare Munro, 1956, fig. 3). The pubescence of the oviscape is coarse and white on the basal ½–⅔, fine and brown otherwise, whereas it is entirely or almost entirely brown in *S. taeniaptera*. Length of body: ♂: 4.3–4.6 mm, ♀: 4.5–6.0 mm, of wing: 3.7–4.3 mm, of oviscape (dorsal side): 0.8–1.3 mm.

Material examined: Holotype, ♂, allotype, ♀, and 4♂ paratypes, *Kenya*, Tsavo, 11–12.I.1972, A. Freidberg. Additional paratypes: Kenya, Ukunda, 25.I.1968, K. V. Krombein (1♂); 20 mi S. Mombasa, 23–25.I.1968, Malaise trap, Krombein & Spangler (1♂). *Tanzania*: Makoa, 10.IV.1959, E. Lindner (1♂,2♀), determined as *Terpnodesma taeniaptera* (Bezzi) by H. K. Munro in 1966. *Aden*: Aden Prot., Wadi Natid, Kirsh, ca 2300 ft, 8.XII.1937, H. Scott & E. B. Britton (1♀); West Aden Prot., Jebel Jihaf, ca 7000 ft, X.1937, H. Scott & E. B. Britton (1♀). *Saudi Arabia*: 18.30N 41.45E, Nr. Muhail, and 18.18N 41.50E, 22.XII.71 (4♂). *Madagascar*: Andrabomana, 1901, Ch. Alluaud (1♀), determined: "*Terellia taeniaptera* Bezzi/type ♀" (Bezzi's handwriting on red paper). The Madagascan specimen, which was described by Bezzi in 1923, was misidentified (see also remark in this paper under *S. taeniaptera*). The holotype and some paratypes are

Figs. 9–15, *Hyalotephritis* spp.: 9, *H. planiscutellata*, head, lateral view; 10, *H. complanata*, male, 9th tergum, posterior view; 11, *H. complanata*, head, lateral view; 12, *H. planiscutellata*, aedeagus; 13, *H. complanata*, aedeagus; 14; *H. planiscutellata*: a, aculeus, b, enlarged tip of aculeus; 15, *H. complanata*: a, aculeus, b, enlarged tip of aculeus.



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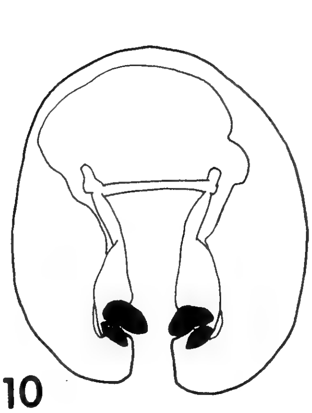

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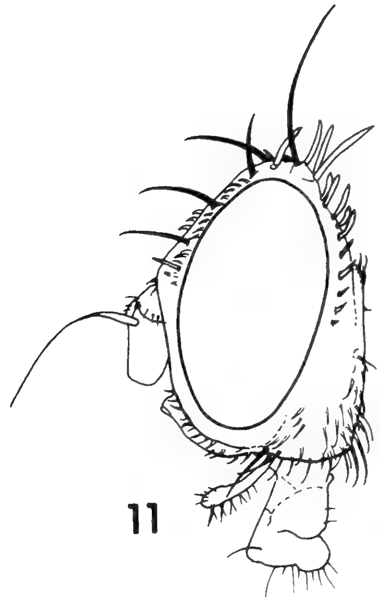

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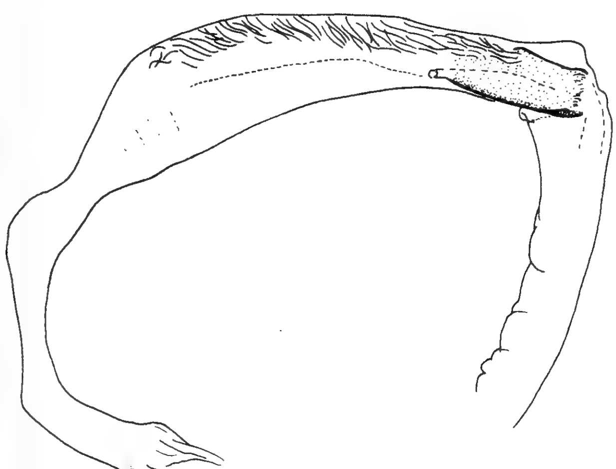

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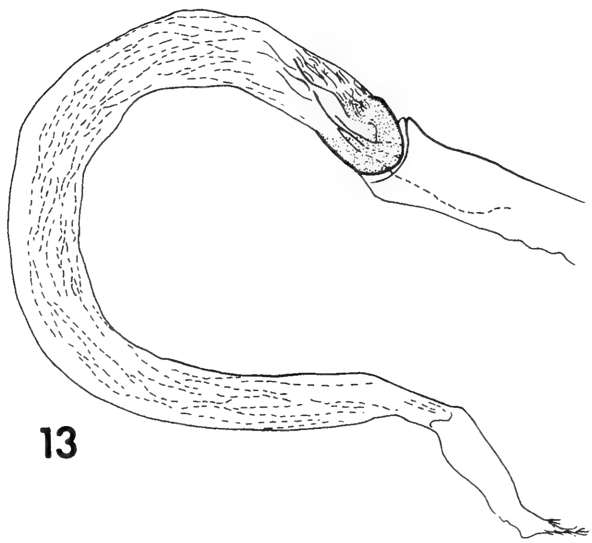

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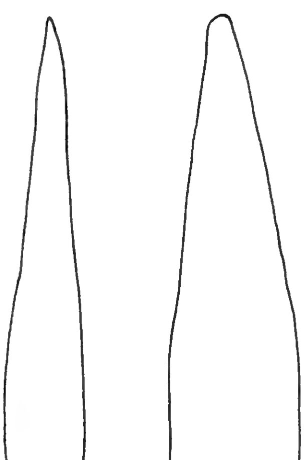

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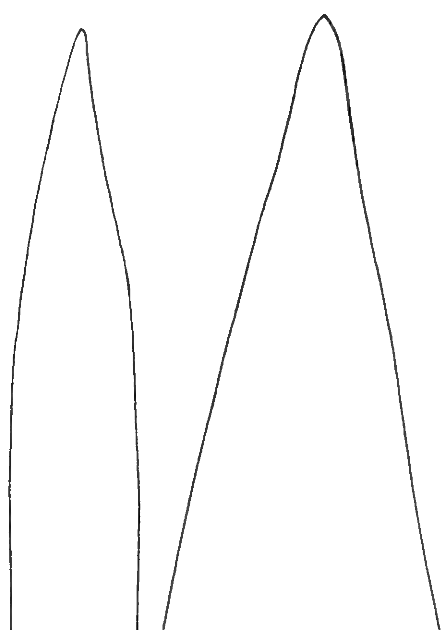

a b

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deposited in the Department of Zoology, Tel Aviv University, Israel. Paratypes are also deposited in the British Museum (Natural History), London; National Museum of Natural History, Washington, D. C.; Museum Civico Storia Naturale, Milan; and Staatliches Museum für Naturkunde, Ludwigsburg.

Etymology: The specific epithet *vittata* is derived from the Latin noun, *vitta*, meaning bands or stripes, referring to the banded mesonotum.

Subfamily **Tephritinae**

Hyalotephritis Freidberg, new genus

Type-species: *Trypeta planiscutellata* Becker, by present designation.

Diagnosis: Head distinctly higher than long, oval; frontal stripe pubescent; fronto-facial angle 125°–135°, usually rounded, occasionally somewhat angular; arista bare or almost bare; proboscis capitate; 2 upper, 3 lower fronto-orbital bristles, posterior upper and anterior lower bristles white and lanceolate, the latter bristle sometimes difficult to detect or missing; apical scutellars 0.5–0.6 as long as basals; wing entirely hyaline, with stigma sometimes yellowish, with pale veins; vein r_{4+5} bare; oviscape tapering, almost triangular; 9th tergum of male oval, with broad surstyli; aedeagus elongate, with slight sclerotization at base, followed by what appears to be pubescence.

The type-species, *planiscutellata*, has been included in *Tephritis* (e.g. Hendel, 1927). In *Tephritis*, however, the head is relatively longer and lower, more angular, fronto-facial angle usually about 100°, only 2 lower fronto-orbital bristles, wing pattern present and the aedeagus less attenuated, more sclerotized and lacking pubescence.

Key to species of *Hyalotephritis*

1. Head height–length ratio averaging 1.30; aedeagus relatively shorter, sclerotization and pubescence occupying greater part (fig. 12) ...... *H. planiscutellata* (Becker)
   Head height–length ratio averaging 1.47; aedeagus relatively longer, sclerotization and pubescence occupying smaller part (fig. 13) .... *H. complanata* (Munro)

Hyalotephritis planiscutellata (Becker), new combination

Trypeta planiscutellata Becker, 1903: 136.
Terellia planiscutellata (Becker), Efflatoun, 1924: 80, Pl. 3, fig. 4.
Tephritis planiscutellata (Becker), Hendel, 1927: 193.—Munro, 1955: 425.—Kugler and Freidberg, 1975: 66.

This species was described from Egypt and recorded also from Israel and Ethiopia. I have studied numerous specimens from Israel (deposited in the Department of Zoology, Tel Aviv University), as well as 2♂ from Egypt, Al Fayyun, 24.X.1966, J. G. Rozen (deposited in National Museum of Natural History, Washington). The head, aedeagus and aculeus are illustrated in figs. 9, 12, and 14 respectively. The only known host plant of this species is *Conyza dioscoridis* (L.) Desf. (Compositae). Efflatoun (1925, 1927) described the immature stages.

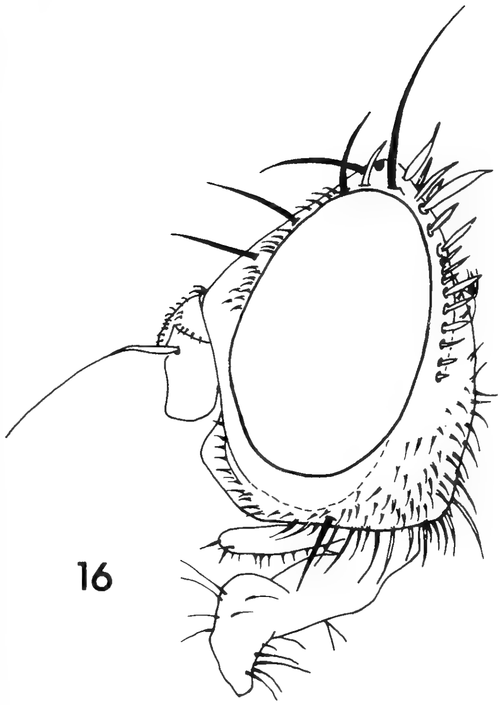
Hyalotephritis complanata (Munro), new combination

Terellia complanata Munro, 1929: 9, Pl. 1, fig. 4.
"Terellia" complanata, Munro, 1967: 16.

This species is known from South- and South West Africa only, and I have examined 1♂ paratype from Hoarlisib Otshu, S. W. A., III.1926, Mus. Exp., as well as 13♂♀ from Njelele R., N. Tvl., Farm "Joan", IX.1939, H. K. Munro (deposited in Plant Protection Research Institute, Pretoria). It differs from the previous species by the characters given in the key. In addition, the aculeus is longer and shaped differently (fig. 15). The head, 9th tergum and aedeagus are illustrated in figs. 11, 10, and 13 respectively.

According to Munro (person. commun.) the species was bred from flower heads of *Conyza dioscoridis*. A puparium,

Figs. 16–22, *Tephritites australis* and *Trupanea xanthochaeta*: 16, *T. australis*, head, lateral view; 17, *T. xanthochaeta*, head, lateral view; 18, *T. australis*, wing; 19, *T. australis*, male, 9th tergum, posterior view; 20, *T. xanthochaeta*, male, 9th tergum, posterior view; 21, *T. australis*, aedeagus; 22, *T. xanthochaeta*, aedeagus.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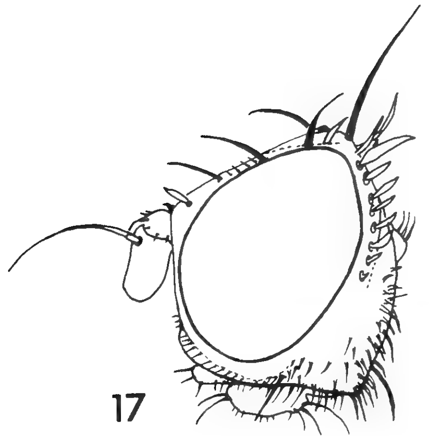
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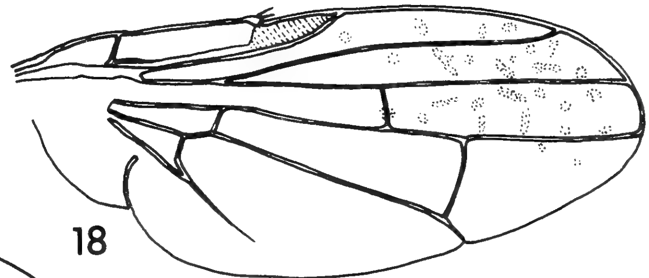
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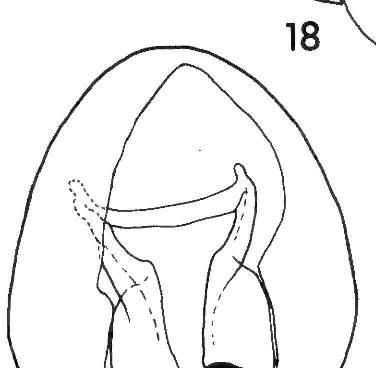
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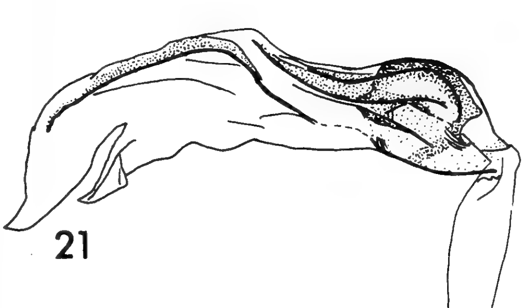
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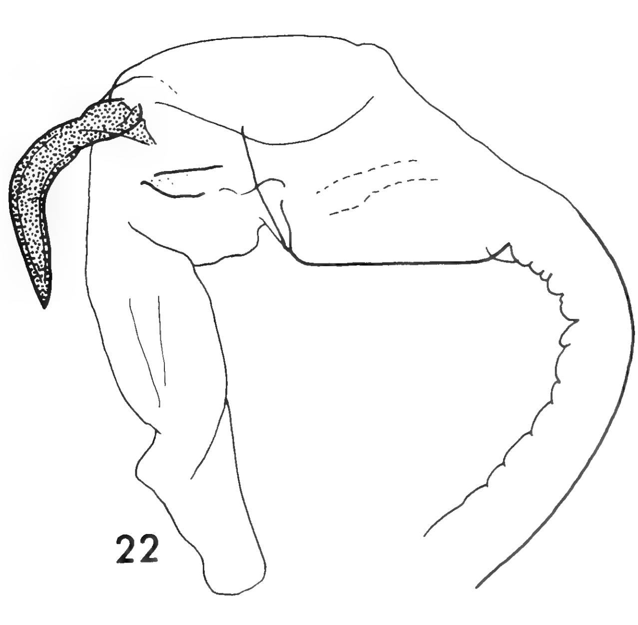
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associated with a female (Shewasaulu, N. Tvl., May 1953, H. K. Munro) was studied. This puparium fits Efflatoun's descriptions and figures (1925 and 1927) for *planiscutellata*, except for the segmentation, which is less demarcated. The surface is distinctly punctate. The distance between the posterior spiracles is 6 times longer than smallest spiracular diameter.

Tephritites Freidberg, new genus

Type-species: *Terellia planiscutellata* var. *australis* Bezzi (=*Terellia australis* Bezzi).

Diagnosis: The genus is distinguished from other tephritine genera by the following combination of character states: Head as in fig. 16; frons slightly longer than wide; frontal stripe bare; fronto-facial angle about 120°–130°; arista bare; proboscis capitate; 2 upper, 2 lower fronto-orbital bristles, the posterior upper bristle white and lanceolate; apical scutellar bristles considerably shorter than half length of basal scutellars; legs: forefemur ventrally at apical ⅓ or ½ with a row of brown or blackish setulae, in addition to the usual paler bristles; wing as in fig. 18: distance between crossveins as long or longer than dm-cu; wing almost entirely hyaline, with small, pale brown, almost indistinct spots, mainly in cells R_1, R_3, and R_5; terminalia as described for the type-species.

Tephritites is similar and possibly related to *Tephritis*. In *Tephritis*, however, the fronto-facial angle is usually smaller, often about 90°–100°, the apical scutellars are usually more than half as long as basals, the forefemur lacks the row of dark setulae, the distance between the crossveins is usually much shorter than dm-cu and the wing pattern is more extensive. *Tephritis*, well represented in most temperate zones, has been recorded from the Afrotropical Region from only two species, of which one is endemic.

Tephritites australis (Bezzi), new combination

Terellia planiscutellata Becker var. *australis* Bezzi, 1924a: 508, Pl. 14, fig. 55.
Terellia australis Bezzi, 1924b: 118; Munro, 1929: 8.
"*Terellia*" *australis*, Munro, 1967: 16.

This species is known from South- and South West Africa only. It was described from several females collected in Pretoria and Barberton. Among other specimens I examined 1♀ in poor condition (Barberton, 17.V.13, H. K. Munro), labeled: "*Terellia planiscutellata* Beck." (Bezzi's handwriting on red paper). This specimen agrees with Bezzi's original description and fixes my concept of the name *australis*. According to Munro (in litt.) it is a syntype, but owing to its poor condition, I am not designating it as a lectotype.

The small spots on the wing are sometimes difficult to detect (compare with Bezzi's figure and description); 9th tergum of male egg-shaped (fig. 19), with the surstyli strongly bent inwardly; aedeagus as in fig. 21; 6th tergum of female with a large shiny black spot, without (or almost without) pollinosity, but often obscured by the dense and coarse pubescence; oviscape as long as combined length of the last 3–4 terga, with a large black spot dorsally at base.

According to Munro (in litt.) the species was bred by W. H. Ghent from *Geigeria passerinoides* (Compositae) (1♂,1♀, Vryburg, Nov. 1947). I have also studied 1♀ and an associated puparium, reared by Munro from *Geigeria* sp. (Kraalkop, Tvl., 20.III.1928). The puparium is shiny black, finely punctate and striated, and with distinct segmentation; anterior spiracle with 3 or 4 papillae; posterior spiracles closer together than diameter of a spiracle.

Other material studied: *South Africa*: Johannesburg, 10.XII.1927, H. K. Munro (1♂); Pretoria, 11.XI.1917, H. K. Munro (1♂♀), 12.XI.1928, H. K. Munro (1♀), 16.XII.1925, H. K. Munro (2♂), I.1926, H. K. Munro (1♂), 13.II.1972, A. Freidberg (1♀); Witdraai BP., X.1925, C. W. Mally (3♂2♀); Bapsfontein TP, 7.XII.1933, H. K. Munro (1♀); E. Transvaal, Vaalhoek, 6.II.1972, A. Freidberg (1♂). *South West Africa*: Kalahari Gamsbok Natnl. Park, S. Afr. Exp., 16–24.V.1956, Twee Rivieren, H. K. Munro, sweeping *Gaigeria* and *Pituranthos* (1♂♀); 9 mi S. Rehoboth, 24.X.1968, J. G. Rozen & E. Martinez (2♂); Gobabeb, Kuiseb River Bed, 26.I.1978, O. Lomholdt (1♀). The specimens are deposited in the Plant Protection Research Institute, Pretoria; Department of Zoology, Tel Aviv University; National

Museum of Natural History, Washington; and Zoologisk Museum, Copenhagen.

Trupanea Schrank

Trupanea Schrank, 1795: 147. Type-species: *Trupanea radiata* Schrank = *Musca stellata* (Fuessly).

The Afrotropical species of this genus were revised by Munro (1964), but the following species was not included.

Trupanea xanthochaeta (Munro), new combination

Terellia xanthochaeta Munro, 1929: 8, Pl. 1, fig. 3.
"Terellia" xanthochaeta, Munro, 1967: 16.

I have examined several of the paratypes and a few other specimens from South West Africa, the only country from which this species is known. From the original description the species can easily be placed in *Trupanea* (note the presence of only two scutellar bristles). However, the anterior lower fronto-orbital bristle is whitish and lanceolate, usually differing from the remaining darker and acuminate lower orbitals. In typical *Trupanea* the lower fronto-orbital bristles are concolorous. The shape of the head (fig. 17) and of the 9th tergum of male (fig. 20) are also somewhat different from those of other species. In all other respects, including the aedeagus and its spine (fig. 22), the species fits the concept of *Trupanea*.

Among the studied material were 2♂2♀ plus associated flower head and puparia, collected by H. K. Munro (Kachikau, Bechuanaland, 25.V.1954). According to Munro (in litt.) these flies were swarming on the plant, *Pluchea leubniziae* (Compositae). The flower head contains 5 empty puparia, which are shiny black and with distinct stripes of spicules. Each of the anterior spiracles has 3 papillae. Other material studied: Kamanyab and Kaross, S.W.A. (4♂♀ paratypes); Letaba KNP. S. Afr., 31.X.1950, H. K. Munro (4♂♀) (deposited in Plant Protection Research Institute, Pretoria).

Acknowledgments

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A Review of the Neotropical Genus Neotaracia *Foote (Diptera: Tephritidae)*

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ABSTRACT

The neotropical tephritid genus *Neotaracia* Foote is reviewed. Two previously described species, *Neotaracia imox* (Bates) and *N. plaumanni* (Hering) (n. comb.), are redescribed, and their taxonomic characters are compared with a third species, *unimacula*, which is described as new. A key to species, a review of the literature, and illustrations of the critical taxonomic characters are included. No information is available concerning the biology of the 3 species belonging to this genus.

Among specimens of Tephritidae currently present in the U. S. National Museum, two closely related but distinctive species of Tephritinae, originally described in the genus *Acrotaenia* Loew, are represented. Earlier (Foote 1978) I designated one of these species, *imox* Bates, the type-species of a new genus *Neotaracia*, which closely resembles *Acrotaenia* in many respects but differs from that genus mainly in wing pattern. The other species represented in the collection is *plaumanni* Hering, collected mostly at Nova Teutonia from 1950 to 1977 by F. Plaumann, which is transferred to *Neotaracia* in the present paper. The discovery of a third species from Mexico and San Salvador, described here as new, prompted me to undertake the present review.

Genus **Neotaracia** Foote

Neotaracia Foote 1978: 31. Type-species, *Acrotaenia imox* Bates.

Diagnosis.—Frons bare, 3 pairs lower fronto-orbitals, 2 pairs upper fronto-orbitals, the posterior pair light colored; all setae in postocular row light colored; broad, rounded facial carina present; 1 pair dorsocentrals, situated on or directly behind transverse suture; notopleurals unicolorous; 2 pairs scutellars, posterior pair less than 0.5 times as long as anterior pair; wing broad, disk dark with hyaline spots in most of the cells; an inverted hyaline triangle usually at apex of subcostal cell and always at apex of vein R2 + 3, and 2 or 3 narrow hyaline incisions into disk from posterior margins of cells R5 and AM.

Discussion.—*Neotaracia* belongs to the tephritine tribe Platensinini, which is characterized by having a long-oval head and a relatively broad wing. In profile the frons meets the face at an obtuse angle or is rounded into it at the antennal bases without a perceptible angle, and the anterior half or third of the wing disk is usually marked darker than the remainder of the disk; the costa usually is bowed prominently between the apices of veins R1 and R2 + 3.

The tribe contains 4 other neotropical genera—*Acrotaenia* Loew, *Caenoriata* Foote, *Acrotaeniacantha* Hering, and *Pseudacrotaenia* Hendel. Foote (1978) discusses means for distinguishing *Neotaracia* from *Acrotaenia* and *Caeniorata*, both of which it closely resembles: the presence in *Neotaracia* of unicolorous postoculars, a facial carina, a bare frons, light colored posterior upper fronto-orbitals, a single pair of dorsocentrals, a straight rather than sinuate vein R2 + 3, relatively short posterior scutellars, and the central position of vein r-m relative to the discal cell. In *Neotaracia* the posterior pair of lower fronto-orbitals and the anterior pair of upper fronto-orbitals are well separated, whereas in *Acrotaeniacantha* and *Pseudacrotaenia* these bristle pairs are situated very close together, and in some species the anterior upper fronto-orbitals are placed anterior to and between the posterior lower fronto-orbitals. The wing disk of *Acrotaeniacantha* is filled with numerous, very small light or hyaline spots, while the discal spots of *Pseudacrotaenia* are larger, less numerous, and have distinct brown borders.

Virtually nothing is known about the ecology or host relationships of the three species discussed herein.

Key to the Species of *Neotaracia* Foote

1. Inverted hyaline triangle immediately apicad of apex of vein R1 absent, replaced by a diagonal, irregular-shaped hyaline spot in the disk of cell R1 (Fig. 8); 2 hyaline incisions from posterior margins of cells R5 and AM .... **unimacula** Foote, n. sp.

   Inverted hyaline triangle immediately apicad of apex of vein R1 present and about the same size and shape at that at apex of vein R2 + 3; 3 hyaline incisions from posterior margins of cells R5 and AM 2

2. Hyaline triangle apicad of apex of vein R1 rarely extending posteriorly across vein R2 + 3; cell R3 and discal cell each with at most 1 very small hyaline spot; apical half of vein M and basal half of vein CuA bordered with brown concolorous with remainder of disk (Fig. 7).................. **imox** (Bates)

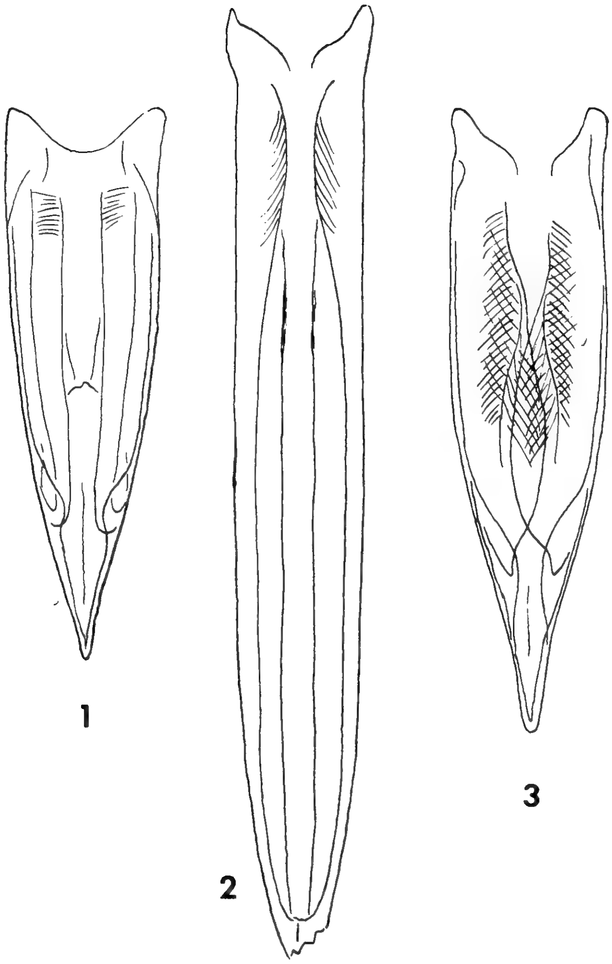
   This hyaline triangle usually extending posteriorly across vein R2 + 3; cell R3 and discal cell each with 2 or 3 hyaline spots; apical half of vein M and basal half of vein CuA bordered with yellow (Fig. 9) .... **plaumanni** (Hering)

Neotaracia imox (Bates)

Acrotaenia imox Bates 1934: 11; fig. 2 (wing). Type-locality, Higuito, San Mateo, Costa Rica.—Aczél 1949: 268 (in neotropical catalog).—Foote 1967: 57.5 (in neotropical catalog).

Neotaracia imox (Bates): Foote 1978: 31; fig. 7 (wing) (taxonomic discussion).

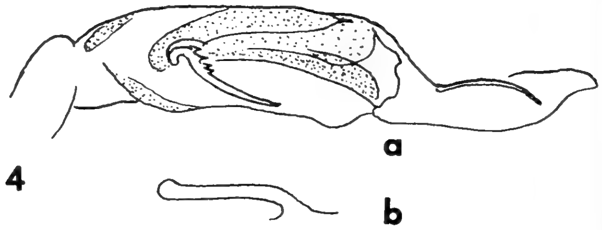
Description.—Similar in size and color to *unimacula* with yellow head and body, abdomen brown or marked with a brown pattern dorsally. Frons from posterior margin of ocellar triangle to ptilinal suture 1.1 times as long as width between eyes at vertex; head and thoracic bristles yellow, nearly concolorous with adjacent integument; dorsocentrals arising very close to or actually upon transverse suture; scutum unmarked except for the presence of an indistinct medial scutoscutellar spot; postscutellum and metanotum entirely yellow or darkened somewhat laterally, the latter without a silvery pollinose central area; hyaline incision at apex of vein R1 rarely crossing vein R2 + 3; cell R3 completely dark centrally (Fig. 7); hyaline spot in base of cell R5 small in both sexes; hyaline spot in base of cell AM small, rounded; brown areas contiguous with apical half of vein M and basal half of vein CuA concolorous with rest of disk;

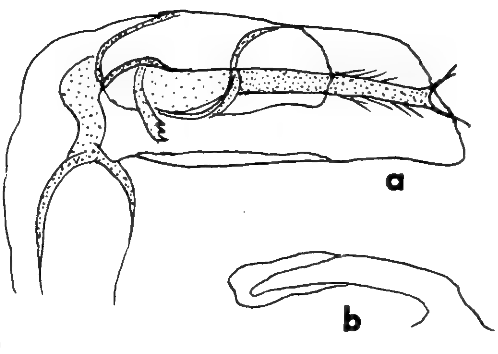


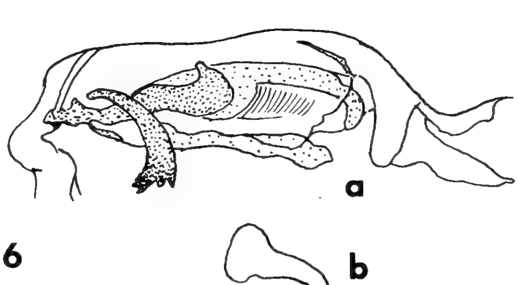
Figs. 1–3, ovipositors, *Neotaracia* spp.: 1, *N. imox* (Bates); 2, *N. unimacula* Foote, n.sp. (tip broken); 3, *N. plaumanni* (Hering).

extension of basal cubital cell 2.3–2.5 times as long as its width at base; abdominal tergites usually completely brown or with yellow areas anterolaterally on each segment; aeaeagus and apodeme of fultella as in Fig. 1; ovipositor (Fig. 4) 0.68–0.77 times as long as sheath.

Specimens examined.—Holotype, ♀, Higuito, San Mateo, Costa Rica, Pablo Schild, col. Additional material. MEXICO: 1 ♀, 1 ♂, Cacahoatan, Chiapas, 30.VIII.1961, H. Sanchez R., Steiner trap in orange tree (USNM). COSTA RICA: 9 ♀♀, 3 ♂♂, 6 ??, Higuito, San Mateo, Pablo Schild (USNM); 1 ♀, 1 ♂, Pedregoso, D.L. Rounds (USNM); 2 ♀♀, Turrialba, 15–19.VII.1965, P. J. Spangler (USNM). PANAMA (all USNM): 1 ♂, La Campana, Muñoz Grove, 10.I.1939, glass traps, J. Zetek No. 4317; 2 ♀♀, 1 ♂, La Campana, I–III.1938, J. Zetek No. 4104; 3 ♂♂, El Cermeno, X.1939, I.1940, fly trap, J. Zetek No. 4621; 1 ♀, Colon, 1.VIII.1946, N. L. H. Krauss No. 823; 5 ♀♀, 3 ♂♂, David, X.1959, N. L. H. Krauss, 3 ♀♀, 1 ♂, XII.1946, N. L. H. Krauss No. 999. CANAL ZONE: 1 ♀, Ancon, 30.XII.1932, J. Zetek; Barro Colorado I., 1 ♀, X.1942, J. Zetek No. 5030, 2 ♂♂, 4.V.1942, J. Zetek No. 4952. COLOMBIA: 2 ♀♀, 1 ♂, Villavicencio, VI.1976, O. Jiminez, McPhail trap (USNM). ECUADOR: 1 ♀, Napo, Limoncocha, 11.VI.1977, D. L. Vincent (USNM). "WEST INDIES": 1 ♀, E. F. Becher, 1907–173 (BMNH). TRINIDAD: 2 ??, St. Augustine, X.1958, F. D. Bennett, CIE Coll. No. 16930,







Figs. 4–6, aedeagi (a) and apodemes of fultella (b) of *Neotaracia* spp.: 4, *N. imox* (Bates); 5, *N. unimacula* Foote, n. sp.; 6, *N. plaumanni* (Hering).

ex inflorescence *Synedvella* nod. fluva [sic] (BMNH); St. Augustine, 5 ♀♀, 3 ♂♂, 8–12.I.1959 (CNC); 4 ♀♀, 1 ♂, I.1959 (CNC); 1 ?, X.1959 (CNC); 1 ♂, XI.1959 (CNC); 1 ♀, 5 mi. s. San Fernando, 24.X.1931, Kisliuk and Cooley No. 231, on leaf sapodilla (USNM); 1 ♂, Port of Spain, nr. Imperial College, 12.XI.1956, fruit fly trap (USNM). VENEZUELA: 1 ??, Carabobo, Valle Seco, I.1940, P. Anduze (USNM); 3 ♀♀, 1 ♂, Guanare, est. Portuguesa, 10–13.IX.1957, Borys Malkin (CNC); 1 ♀, San Esteban, XI.939, P. Anduze (USNM).

Discussion.—The wing patterns of both *imox* and *unimacula* contrast with that of *plaumanni* in having fewer and smaller hyaline markings, causing them to appear somewhat darker. In contrast to *unimacula*, which *imox* resembles closely, the wing of *imox* possesses 2 distinct inverted hyaline triangles, one immediately apicad of the apex of vein R1 and another about the same size and shape at the apex of vein R2 + 3 (see description and discussion of *unimacula*).

N. imox is the most widely spread of the 3 species discussed here, occurring from Chiapas, Mexico south to Colombia and Ecuador and east to Trinidad and Venezuela. It has been collected from McPhail traps on a number of occasions in Panama, the Canal Zone, and Trinidad. Two specimens from Trinidad seen in this study were reared from the inflorescence of the composite *Syndrella nodiflora*, and the species has been found resting on sapodilla and citrus leaves.

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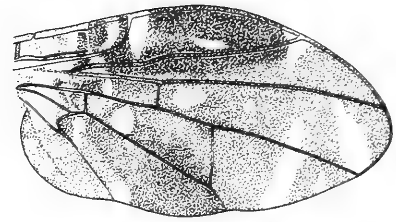

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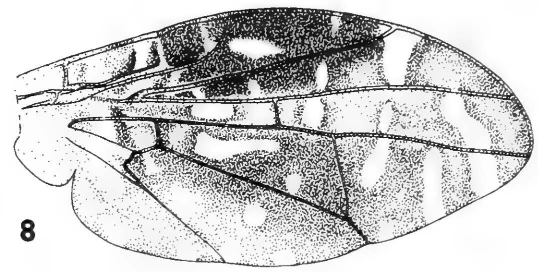

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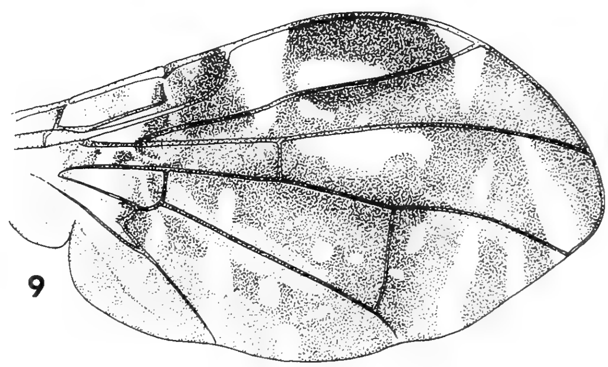

Figs. 7–9, right wings of *Neotaracia* spp.: 7, *N. imox* (Bates); 8, *N. unimacula* Foote, n. sp.; 9, *N. plaumanni* (Hering).

Neotaracia unimacula Foote, new species

Description.—Similar to *imox* with yellow head and thorax but with nearly unmarked yellow abdomen; frons from posterior margin of ocellar triangle to ptilinal suture equal to width between eyes at vertex; head and thoracic bristles yellow, very nearly concolorous with adjacent integument; dorsocentrals arising immediately posterior to transverse suture; scutum anterior to acrostichals with 3 very faint yellow longitudinal fasciae visible only when viewed from behind; no dark scutoscutellar mark present; postscutellum with a pair of very light brown triangular marks ventrolaterally; metanotum somewhat darker yellow than scutellum and postscutellum, otherwise unmarked; triangular hyaline mark at apex of vein R1 absent, replaced in disk of cell R1 by a small, irregularly shaped diagonal hyaline spot not touching costa or veins R1 or R2 + 3 (Fig. 8); cell R3 with 2 or 3 very small rounded hyaline spots; hyaline spot at base of cell R5 small, all the hyaline areas in cells R and R5 with brown borders darker than in adjacent wing disk; hyaline spot in base of cell AM transversely elongate, sometimes nearly contiguous across vein R5 with a transverse spot in cell R3; brown areas contiguous with apical half of vein M and basal half of vein CuA concolorous with rest of disk; extension of basal cubital cell about 2.0 times as long as wide; abdominal tergites of both sexes yellow, concolorous with metanotum, unmarked with darker brown but darker apically and basally than centrally; ovipositor (Fig. 2) about as long as ovipositor sheath (tip broken); aedeagus and apodeme of fultella as in Fig. 5a, b.

Specimens examined.—Holotype, ♀, San Salvador, El Salvador, 19.V.1958,

O. L. Cartwright (USNM Type No. 76061). Paratypes: 1 ♂, same data as holotype (USNM); 1 ♀, Fortín de las Flores, Sumidero, Vera Cruz, Mexico, planta de la cerveceria, D. Rábago Res., 2–3,000 ft., H. V. Weems, Jr. (UF).

Discussion.—The wing pattern of *unimacula* resembles that of *imox* in having fewer and smaller hyaline markings than that of *plaumanni* (cf. Figs. 7–9). The new species may be immediately recognized among the 3 species of *Neotaracia* by the absence of a distinct inverted hyaline triangle immediately apicad of the apex of vein R1. This triangle is replaced by a small irregularly shaped hyaline spot in the middle of the field of cell R1 posterior to the apex of the subcostal cell. Unlike *imox* and *plaumanni*, a very small yellowish or hyaline incision is usually present subapically on the costa in cell R1, and there are only 2 hyaline incisions in the posterior apical quarter of the wing disk. See the description of each species for additional differentiating characters.

N. unimacula has been found only in the Mexican state of Vera Cruz and in San Salvador, El Salvador, Central America. No information is available concerning the habits, life history, or host relationships of this species.

Etymology.—The name *unimacula* signifies the presence of only one prominent inverted hyaline triangle on the anterior costal margin of the wing pattern.

Neotaracia plaumanni (Hering), new combination

Acrotaenia plaumanni Hering 1938: 188, fig. 2 (wing). Type-locality, Nova Teutonia, Santa Catarina, Brazil.—Aczél 1949: 269 (in neotropical catalog).—Foote 1967: 57.6 (in neotropical catalog).

Description.—Frons from posterior margin of ocellar triangle to ptilinal suture 0.9 times as long as width between eyes at vertex; head and thoracic bristles distinctly browner than adjacent yellowish integument; dorsocentral arising close to, but distinctly posterior to, transverse suture; scutum with a narrow, indistinctly margined median vitta; no scutoscutellar mark present; central third of postscutellum silvery pollinose, this segment darkened laterally; metanotum entirely dark; inverted hyaline triangle immediately apicad of apex of vein R1 often extending posteriorly across vein R2 + 3 into cell R3, latter with at least 3 small spots centrally (Fig. 3); hyaline spot in basal half of cell R5 small in females but occupying more than half the length of cell in males; hyaline spot in base of cell AM more or less elongate in parallel with vein dm-cu; apical half of vein M and basal half of vein CuA bordered narrowly with yellow in contrast to surrounding brown color of disk; extension of basal cubital cell 3.5–4.0 times as long as its width at base; abdominal tergites 3–6 brown or brown and yellow, with a distinct yellow transverse band at apex of each tergite; aedeagus and apodeme of fultella as in Fig. 6a, b; ovipositor (Fig. 3) about 0.77–0.82 times as long as sheath.

Specimens examined.—ARGENTINA: 2 ♂♂, 3 ♀♀, 2 ??, Misiones Terr., F. & M. Edwards, BM 1927–63, Bompland, 13–14.I. 1927 (BMNH). BRAZIL: Barueri, K. Lenko, 1 ♀, 19.IX.1965, 1 ♂, XII, 1962 (MZSP); 1 ♀, Iguaçu Falls, 11.XI.1970, J. Sedlacek (Bish); Nova Teutonia (some of following specimens labeled 27°11′, 52°23′, 2–300 m., F. Plaumann): 1 ♂, 1 ♀, 4.IX.1950; 1 ♀, 19.V.1957; 3 ♂♂, 6.I.1959; 1 ♀, 6.II.1959; 1 ♀, 10.II.1959; 1 ♂, 9.IX.1959; 1 ♀, 22.X.1959; 1 ♂, 14.XI.1959; 1 ♀, 23.-XII.1959; 1 ♂, 5.IV.1960; 1 ♀, 26.IV.-1960; 1 ♂, 20.XII.1961; 1 ♂, 19.X.1962; 1 ♀, 25.X.1962; 1 ♂, 30.X.1962; 3 ♀♀, 1 ♂, V.1963; 2 ♀♀, IX.1963; 1 ♀, X.1963; 1 ♀, IX.1964; 1 ♂, X.1963; 1 ♂, XI.1963; 2 ♀♀, I.1965; 1 ♂, II.1965; 1 ♀, IV.1965; 3 ♀♀, 1 ♂, X.1965; 1 ♀, XII.1965; 2 ♀♀, I.1966; 1 ♀, IX.1966; 1 ♀, X.1966; 3 ♀♀, 1 ♂, 1 ??, X.1970; 1 ♀, 1 ♂, 1 ?, XI.1970; 2 ♀♀, I.1971; 2 ♀♀, II.1971; 1 ♀, VII.1971; 3 ♀♀, 2 ♂♂, X.1971; 3 ♀♀, 2 ♂♂, XI.1971; 1 ♀, I.1972; 1 ♀, IV.1975; 1 ♂, VII.1975; 1 ♀, I.1977 (CNC, FNMH, MZSP, UCR, USNM).

Discussion.—In comparison with the 2 foregoing species, *plaumanni* is distinctive in that the hyaline spots in the wing disk are larger and more numerous (cf. Figs. 7–9), a feature especially evident when seen with the naked eye. Although this species resembles *imox* in having 2 inverted hyaline triangles on the anterior margin of the costa as described, it may be distinguished easily from both *imox* and *unimacula* by the narrow yellow margins along the apical half of vein M and the basal half of vein CuA which contrasts with the widespread brown color of the wing disk. Other differences are set forth in the descriptions of the 3 species.

N. plaumanni is apparently restricted to those parts of Brazil and extreme eastern Argentina that lie between 23 and 28° S. Lat. Most of the specimens seen in this study were collected from Nova Teutonia in the state of Santa Catarina, Brazil, where the species must be extremely common. However, no information is available concerning its life history or host associations.

Acknowledgments

I hereby extend my appreciation to G. C. Steyskal, F. L. Blanc, and R. E. White, who read and made valuable comments on this manuscript. Brian Cogan, British Museum (Natural History), corrected some host data associated with specimens. Ms. Laurine Van Wie mounted genitalia and made extensive basic measurements to facilitate the research. The wing figures were drawn by Linda H. Lawrence. The following individuals made study material available to me (initials of institutions indicate depositories to which specimens have been returned): Paul H. Arnaud, Jr., California Academy of Sciences, San Francisco (CAS); Brian Cogan, British Museum (Natural History), London, England (BMNH); Henry S. Dybas, Field Museum of Natural History, Chicago, Illinois (FMNH); Saul Frommer, University of California, Riverside (UCR); J. F. McAlpine, Agriculture Canada, Ottawa (CNC); Nelson Papavero, Museum of Zoology, University of Sao Paulo, Brazil (MZSP); Jose Tenorio, Bishop Museum, Honolulu, Hawaii (Bish); and Howard V. Weems, Jr., University of Florida, Gainesville (UF). Specimens deposited in the U. S. National Museum, Washington, D. C. are designated (USNM).

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Foote, R. H. 1967. 57. Family Tephritidae, pp. 57.1–57.91. *In* Vanzolini, M., and Papavero, N. (eds.), A catalog of the Diptera of the Americas south of the United States. Dep. Zool., Secr. Agric., Sao Paulo, Brazil.

———. 1978. New genera and species of neotropical Tephritidae (Diptera). J. Washington Acad. Sci. 68: 27–32, figs. 1–7.

Hering, M. 1938. Neue Bohrfliegen aus Brasilien (Dipt.). Rev. Entomol. 8: 187–196, figs. 1–8.

MEETING NOTES—BOARD OF MANAGERS

638th Meeting—May 22, 1979

The 638th Meeting of the Board of Managers of the Washington Academy of Sciences was called to order by the President, Alfred Weissler at 8:05 P.M.

1. *Minutes of Last Meeting*: The following corrections were made to the minutes: a. The minutes of the 636th meeting should read that our securities consist of the Bond Fund of America and the Massachusetts Investors Trusts Bond Fund. b. It was noted that the Treasurer's Report is not correct. This report will be discussed under *Treasurer's Report*. The minutes were accepted with this correction and comment.

2. *Announcements*: G. Vila will be the Meetings Chairman for the 1979–1980 season. Committee chairmen were designated for the 1979–1980 season. The list of committees and chairmen are given in Attachment 1.

3. *Report of the Treasurer*: The report of the Auditing Committee was presented. The books of the Treasurer were found to be in good order.

A statement of capital assets and projected cash flow and expense flow was submitted. There was considerable discussion about the uncertainties in the last two items that would arise as a result of our changing our secretarial operations. This discussion culminated in a motion by Cook (seconded by Aldridge).

The Executive Committee is to be empowered to survey our financial situation through the summer and to decide whether we should sell our securities or borrow as needed up to $3000 to meet expenses.

The motion carried with only one opposing vote.

There were two suggestions to improve our cash flow:

1. Request remission of dues during the summer rather than fall, and
2. Solicit Life Memberships. There was no action on these suggestions.

4. *Standing Committees*:

V. Meetings (Vila):

The planning for the Fall program will begin in August. Help would be appreciated.

There was a discussion of the possibility of reinstituting the Christmas lectures. However, it was felt that such a program would interfere with Junior Academy programs before and after Christmas.

VII. Grants-in-aid for Research:

Betty Jane Long will be contacted to determine how money is obtained from AAAS for these grants.

VIII. Encouragement on Science Talent:

192 attended the banquet on 21 May 1979. The bulletin contained errors which were very embarrassing. Obviously, there had been inadequate proofreading.

IX. Public Information:

H. M. Parsons was appointed the new chairman.

5. *Report of the Joint Board on Science Education*: James W. Harr will be the new chairman.

6. *Unfinished Business*: Letters from and to the National Graduate University are attached. It was noted that the 5-year period mentioned in Attachment 3-1 should end 31 May 1984.

No furniture may be sold.

7. *New Business*: O'Hare will establish a committee to reexamine our publications policies. Sherlin will review and clarify our policies on Life Members.

The meeting was adjourned at 10:21 P.M.

Respectfully submitted,
James F. Goff, Secretary

Attachment 1:

Committee Chairmen
1979–1980

Executive:	Dr. Alfred Weissler
Meetings:	Mr. George J. Vila
Nominating:	Dr. Mary H. Aldridge
Encouragement of Science Talent:	Mrs. Elaine F. Shafrin
Science Education (JBSEE):	Mr. Grover C. Sherlin
Tellers:	Mr. Charles Rader
Science, Engineering, & Society:	Mr. George Abraham
Special Committee on Journal and Publications Policies:	Dr. John J. O'Hare

Attachment 2:

May 4, 1979
Dr. Mary Aldridge
President
Washington Academy of Sciences
608 H Street, S.W.
Washington, D. C. 20024

Dear Dr. Aldridge:

In response to the request for use of space at National Graduate University for its offices, I am pleased to inform you that National Graduate University is willing to permit the Washington Academy of Sciences to utilize Suite 321 consisting of three offices, and a secretarial area on the third floor of its Old Dominion Building at 1101 North Highland Street, Arlington, Virginia. In addition, the Academy is permitted to use a conference room for its monthly Board or other meetings by arrangement. This space consists of three offices with outside windows with approximately 648 square feet. The building is about 100 yards from the Clarendon-National Graduate University Metro station which is scheduled to open in November of this year. Thus, it will soon be just a few minutes from downtown Washington by Metro. Keys to the front door of the building and to Suite 321 will be provided authorized representatives of the Academy.

This agreement is for the five-year period beginning June 1, 1979 through May 31, 1983 with its conditions subject to mutual review at the end of two years.

The Washington Academy of Sciences hereby agrees the University is not responsible for Academy property or persons and will therefore carry its own insurance for fire, theft, vandalism, damage and liability.

For information of persons who will be using the space, the phone number of the resident caretaker is 243-3769.

Sincerely yours,

(signed) Walter E. Boek, Ph.D.
President, National Graduate University

639th Meeting—Sept. 18, 1979

The 639th Meeting of the Board of Managers of the Washington Academy of Sciences was called to order by the President, Alfred Weissler at 8:00 pm.

1. *Minutes of Last Meeting*: The minutes were accepted as corrected.

2. *Announcements*: There was a good response to the request for early payment of dues.

The Nominating committee has been appointed (Attachment 1).

R. Foote has resigned as Editor. The Ad Hoc committee on Publications has been asked to consider successors.

Additional Committee Chairmanships are listed in Attachment 2. These chairmen were accepted by the Board.

3. *Report of the Secretary*: The secretarial service is not functioning well. It was suggested that a representative of the service attend future Board meetings for instructional purposes.

4. *Report of the Treasurer*: The Treasurer's report was presented. The total indebtedness of the Academy is approximately $16,000. Therefore Mr. Rupp moved:

"The Board-of-Managers approves the sale of sufficient bonds to raise $16,000 for the retirement of this debt as soon as possible".

Seconded and approved.

The Treasurer's report was accepted subject to audit.

5. *Report of the Standing Committees*:

a. EXECUTIVE

The committee met 28 August 1979. The two orders of business were the program for this season and discussion of finances.

b. MEMBERSHIP (Buras)

Applications for two Members and nominations for six Fellows have been received. There have been problems in processing these forms because of the change in the secretarial service. These problems will be solved shortly.

c. MEETINGS (Vila)

The tentative program was presented.

d. ENCOURAGEMENT OF SCIENCE TALENT (Shafrin)

The membership of the Jr. Academy declined several years ago as a result of elimination of science fairs in several jurisdictions, and bussing which prevents afterschool clubs. There are now only 200 members.

It was moved that the programs of awards banquet be reprinted without errors for the distribution to the attendees. Motion accepted.

On Friday, 9 May 1980 at 0830 hours, the American Institute of Aeronautics and Astronautics will give the Jr. Academy a special tour of its displays at the New Convention Center in Baltimore. At 1100 hours Saturday and Sunday the displays will be open to the public for a small fee.

e. PUBLIC INFORMATION (Parsons)

Plans are being made to publicize meetings through delegate newsletters.

6. *Report of Special Committees*: a. POLICY FOR ACADEMY PUBLICATIONS (O'Hare)

The committee consists of:

Dr. John J. O'Hare, Chairman
Dr. Rita R. Colwell
Dr. William M. Benson
Mr. LaVerne S. Birks
Dr. James H. Howard, Jr.

There was no further report.

7. *Report of the Editor* (Foote): Lancaster Press will publish the last three issues for this year.

At Your Service is to coordinate with the Press to bring out the Membership issue.

The future of the journal (beginning 1980) should be considered because it causes financial problems. The Editor should be in close contact with the budget.

8. *Report from Joint Board on Science Education* (Sherlin): The Joint Board will be recruiting people to serve on it in the future. The composition of the JBSEE is given in Attachment 5.

9. *Unfinished Business* (Honig): We need standing operative procedures for each committee and officer. The Action Policy Planning Committee (Honig) will prepare them.

10. *New Business*:

Moved that:

a. Standing Rules be reprinted in the annual organizational guide.

b. By-laws (with revisions) be reprinted in the directory issue of the Journal.

Accepted.

Policy Planning Committee (Honig)

should consider effect of amending the By-laws so that a former member could join without penalty under certain conditions.

The next Board meeting will be Thursday, October 11, 1979 at 1630 hours before the program. At Your Service should attend.

The meeting was adjourned at 2234 hours.

Respectfully submitted,
James F. Goff, Secretary

Attachment 1:

Nominating Committee:
- Dr. Mary H. Aldridge (Chairman), Immediate Past-President
- Dr. Richard H. Foote, Past-President
- Dr. Alphonse F. Forziati, Past-President
- Mr. Grover Sherlin, Past-President
- Dr. Kurt Stern, Past-President
- Mrs. Marjorie Townsend, President-Elect
- Secretary, Dr. James F. Goff (By-laws, Art. 4, Sec. 3)

Attachment 2:

Additional Committee Chairmanships

Membership	Mr. Edward M. Buras, Jr.
Policy Planning	Dr. John Honig
Ways and Means	Dr. Kurt Stern
Awards for Scientific Achievement	Dr. Irving Gray
Grants-in-Aid	Mrs. Betty Jane Long
Public Information	Dr. Henry M. Parsons
By-laws and Board Rules	Dr. Lawrence A. Wood
Auditing	Dr. Rita R. Colwell

640th Meeting—October 11, 1979

The 640th Meeting of the Board of Managers of the Washington Academy of Sciences was called to order by the President Alfred Weissler at 4:40 P.M.

The minutes were accepted as corrected.

1. *Minutes of the Last Meeting*: Correction: L. Wood should read as C. Wood.

2. *Announcements*: The National Academy of Sciences has published a brochure which lists the addresses and officers of the Academies of Science of the United States. This brochure is on file.

The Academy organization brochure is still being compiled.

3. *Report of the Treasurer*: The Treasurer was absent. However, it was reported by the President that authorization has been sent to the Bond Fund of America authorizing them to sell $16,000 of our bonds.

It was requested that there be compiled a list of those who have paid their dues and that there be a second mailing.

4. *Report of the Standing Committees*:

a. MEMBERSHIP (Buras)

The following were accepted as new members: Ms. Marcia S. Smith, Dr. Steven Barry Berger, Ms. Lani Hummel Raleigh, and Mr. James G. Moore.

It was suggested that letters of welcome be sent to all new members.

b. WAYS AND MEANS (Stern)

The committee will be composed of: K. Stern (Chairman), N. Rupp, and R. Foote.

The committee's preliminary report follows:

- The new secretarial operation should be given a full year trial period.
- A computer service should be found which is located in D. C.
- The fiscal year should be changed to correspond to the terms of the officers; that is, from summer to summer.
- The proper investment of the Academy funds is being considered.

c. MEETINGS (Vila)

- The annual announcement card is being planned.
- Joint meetings are favored.
- Charges for dinners should continue to be collected in advance.

d. ENCOURAGEMENT OF SCIENCE TALENT (Shafrin)

- 27 October 1979 at 1000 hours there will be a program at Georgetown University on Radiological Health.
- 16–17 November 1979 there will be an overnight at the Schmidt Science Center (Prince Georges County).
- 15 December 1979 there will be the Christmas colloquium.
- 11–12 January 1980 there will be a symposium.
- February 1980 there will be a Smithsonian Mall Day.
- March 1980. Date held open for possible snow conflicts in January and February programs.
- 19 April 1980 University of D. C. meeting proposed.
- May Elections.

The report was accepted.

e. PUBLIC INFORMATION (Parsons)

A canvas of affiliates indicates that eight have newsletters, eleven do not.

5. *Report of Special Committees*:

a. NOMINATIONS COMMITTEE

- The committee presented a slate of officers (Attachment 1). Foote moved (Shafrin seconded) that the slate be accepted. The motion was accepted.
- It was moved that ballots be rated by 1, 2, 3 order and that the low rates be allocated to the higher ones. The motion was accepted.

The next meeting of the Board of Managers will be held at the Gillette Research Institute.

The meeting was adjourned at 1013 hours.

Respectfully submitted,
James F. Goff, Secretary

Attachment 1:

Report of Nominating Committee

Slate of Candidates for 1979–80

President
Dr. John Honig
Mr. George Vila
Dr. John O'Hare

Treasurer
Mr. A. James Wagner
Mr. LaVerne S. Birks

Secretary
Dr. Jean Boek
Mr. Charles Rader

Managers-at-Large
Mr. Grover C. Sherlin
Mr. Alvin Reiner
Dr. Joel Fisher
Dr. Joanne Jackson
Dr. Zaka I. Slawsky

641st Meeting—November 29, 1979

The 641st Meeting of the Board of Managers of the Washington Academy of Sciences was called to order by the President, Alfred Weissler at 8:00 P.M.

1. *Minutes of Last Meeting*: In the minutes of the 639th meeting, C. Wood should read as L. Wood.

In the minutes of the 640th meeting, under announcements, the "National Academy of Sciences" should read "National Association of Academies of Sciences."

The minutes were accepted as corrected.

2. *Announcements*: The mailing list is not complete; the following should be checked:

Nina Roscher, Provost
American University

Jean Boek, Director
Division of Special Studies
National Graduate University
1101 North Highland Street
Arlington, Virginia 22201

James F. Goff
3405 34th Place, N.W.
Washington, D. C. 20016

The election ballot is being mailed with the announcement of the next two meetings: 3 January 1980 and 29 January 1980.

The Washington Academy of Sciences organization brochure is still not out. Our affiliates here have not been notified.

3. *Report of the Secretary*: The National Association of Academies of Science has requested display material for the AAAS meeting in San Francisco. The secretarial service should supply.

The Cosmos Club has been reserved for our 15 May meeting.

4. *Report of the Treasurer*: The report of the Treasurer was given. The second dues notice has been mailed. All debts are paid.

The Treasurer's report was received as read.

5. *Report of the Standing Committees*:

a. EXECUTIVE

There was no report.

b. MEMBERSHIP (Buras)

The following new members were accepted:

Christos A. Kapetanakos
John Dennis McCurdy
Dorothy K. Wyatt
Rosilind L. Gross

The following new fellows were accepted:

Marlene Cook Morris
Pearl G. Weissler
James Stanley Murday
Guy Saint Clair Hammer, II
George Julian Vila

The papers are to be forwarded to the Secretarial service. Copies are on file with the secretary. Mr. Weissler will send a letter to each of those people.

c. WAYS AND MEANS (Stern)

The report of the Committee was presented. It was decided to consider these recommendations in the Executive Committee. In particular, concerning Item 6, it was suggested that there should be a check as to why only about one-half the dues are being collected. The report was accepted with deferral of action.

d. MEETINGS (Vila)

The program schedule was presented. The time and place of the 25 January 1980 meeting has not been decided. The 20 March 1980 meeting will be held in the Copley Lounge of Georgetown University at 6:30 P.M. The May meeting will be 15 May 1980 at the Cosmos Club.

e. AWARDS FOR SCIENTIFIC ACHIEVEMENT (Gray)

Mr. Gray has transmitted a set of letters to the Chairman of the six scientific panels.

f. PUBLIC INFORMATION (Parsons)

There are 20 newsletters. A notice will be promulgated to encourage membership in the Academy.

6. *Report of Special Committees*:

a. POLICY FOR ACADEMY PUBLICATIONS (O'Hare)

There are five candidates for the Editor of the Journal. The Board decided that the editor should be a local resident.

b. SCIENCE, ENGINEERING, AND SOCIETY (Abraham)

It was suggested that tape talks for Public Broadcasting might be a means of furthering public understanding. It was commented that NSF may have an interest since it sponsors programs like NOVA. Such talks should not be pedantic but should be definitive.

c. NOMINATING COMMITTEE (Aldridge)

The ballot has been mailed.

d. AUDITING COMMITTEE (Colwell)

There was no report. Secretary should be contacted during January.

Sherlin and Boek will go through files at At-Your-Service to check for unknown obligations.

7. *Report from Joint Board on Science Education* (Sherlin): The logistics of transporting children to the May meeting in Baltimore are being planned.

It was proposed that each affiliate have a delegate on the Joint Board. However, no one saw much point.

8. *New Business*: A motion was proposed that a committee be appointed to prepare at an early date, an information sheet or brochure for Presidents and Chairmen of affiliated organizations which will summarize rules of organization applicable to said affiliates and their members. This would specifically include action points relating to their responsibilities and benefits as affiliates, and the procedures for individual membership and elevation to fellowship.

The motion, proposed by Ed Buras and seconded by Grover Sherlin, was passed unanimously.

The next Board Meeting will be at 7:30 P.M., January 17, 1980 at the Gillette Research Institute.

The meeting was adjourned at 11:13 P.M.

Respectfully submitted,
James F. Goff, Secretary

OBITUARY

John A. Stevenson

John A. Stevenson, 89, a research scientist for the Agriculture Department for more than 50 years, died Tuesday, Oct. 30, 1979, in the Sleepy Manor Nursing Home in Annandale. He lived on Brandy Court in Falls Church.

Mr. Stevenson retired in 1960 and was appointed a collaborator in the Agriculture Department and for 15 years continued his scientific work. For about 35 years he headed the division of mycology and disease survey in Washington and later in Beltsville, where he was in charge of research on the identification of fungi that cause plant diseases.

Mr. Stevenson wrote more than 100 scientific articles, including many on fungi and plant diseases of the American tropics. His scientific and personal merits were recognized by other members of his profession, who named more than a dozen newly discovered fungi in his honor.

He was a charter member and former president of the Mycological Society of America and was president of the Botanical Society of Washington in 1957. He also served in executive positions of the Washington Academy of Sciences and in the American Phytopathological Society and was a member of numerous other scientific societies in the United States and abroad.

An honorary curator of fungi for the Smithsonian Institution, Mr. Stevenson presented his mycological library of more than 6,000 volumes to the Smithsonian in 1976, with the understanding that it would remain with the herbarium of fungus specimens at Beltsville as part of the National Fungus Collection.

Mr. Stevenson was a Past Master of the William R. Singleton Masonic Lodge in the District.

He was born in Woonsocket, S. D., and attended high schools in Wisconsin and Iowa. In 1912 he received a forestry degree from the University of Minnesota. He also was trained in plant pathology and in ecology and was a naturalist in addition to his specialization as a mycologist.

After graduation, Mr. Stevenson was a plant pathologist in Puerto Rico for several years and founded The Journal of Agriculture, a technical publication still issued by the University of Puerto Rico.

Mr. Stevenson became a pathology inspector for the Federal Horticultural Board in Washington, D. C., in 1918. Later, he was in charge of foreign agricultural explorations until he began working as a mycologist in 1927.

Mr. Stevenson developed the reference fungus collections and mycological library for the Agriculture Department at Beltsville. He also wrote two technical books and maintained his interest in stamp collecting.

He leaves his wife of 63 years, Katherine T.; three sons, John Jr., Robert and Donald; a sister; eight grandchildren; and four greatgrandchildren.

JOURNAL OF THE WASHINGTON ACADEMY OF SCIENCES

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