Microbial Selection

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ANY CONSIDERATION OF THE PROBLEM of microbial selection is inevitably linked with both the heterogeneity of microbial populations and the nature of resistance. Selection presupposes differences between cells, arising adaptively or by mutation. Appropriate use of the selective agent will change the average composition of a population, resulting in the establishment of new types, even to the complete exclusion of parent-type cells. Many experiments show that a so-called pure culture descended from a single cell eventually comes to consist of several different kinds of individuals unlike the remainder of the population. If the number of properties studied is large, each cell may be unique. Quantitative studies on variability are greatly simplified if the differences observed are discontinuous and have a genetic origin.

The extraordinary ecological flexibility of microorganisms enables certain of them to survive in the most unfavorable of habitats. Bacteria have been found growing at a pH of less than 1, and at temperatures exceeding 70° C. The list of chemical compounds utilized as sources of energy for biosynthesis continues to surprise the biochemist. Great variability, rapid reproduction, small size, and ease of environmental manipulation combine to make the controlled analysis of populations exceeding 10^{10} individuals a feasible laboratory procedure. Yet obviously we cannot examine 10^{10} cells one by one. It is here that selection enters, based on differences in the level of resistance of individual cells to the selective agent, and allowing in favorable instances the elimination of all but a small fraction of the population. For example, in the presence of certain bacteriophages or antibiotics, only one mutant bacterial cell in a sensitive population of approximately one billion may be able to survive and form a clone.

Sensitivity to toxic agents is one of the properties showing considerable variation within a group of microorganisms related by descent. Most often the different grades of resistance in natural populations are distributed in small steps over a limited concentration range of the agent. By continued selection, however, resistance may be shifted either upward or downward. Experimental methods devised to accomplish microbial selection must be fitted to the nature of the selecting agent. The choice of selective environments is almost limitless. Without detailed reference to a vast literature, attention is directed to such physical agents as radiation, temperature, desiccation, pressure, surface tension, and mechanical agitation. The category of chemical materials available to establish selective pressures includes metallic ions, halogens, acids, alkalis, oxidizing and reducing agents, alcohols, phenols, dyes, and others too numerous to mention. Any chemical substance may belong to more than one group, and the distinction between physical and chemical agents is often arbitrary, with the possibility that common effects may be produced. Selection of x-ray- or ultraviolet-resistant *Escherichia coli* strains results in simultaneous resistance against many chemical agents affecting redox potential, and vice versa (*1*). The concept that related modes of action of toxic agents may be revealed through patterns of cross-resistance has many interesting implications (*2*).

Selective agents may in themselves be entirely or predominantly of biological origin, as exemplified by antibodies, bacteriophages, antibiotics, lysozyme, and the kappa substance in protozoa. Depending on the nature of the selective substance, we may recognize cellular fluctuations in resistance level contingent upon enzymatic differences, modifications in the composition of polysaccharide or other capsular investment layers, alterations in permeability, variations (hypothetical) in the configuration or distribution of virus and antibody receptor sites, and changes in electric charge —to list only a few. The ways in which biological variability may lead to opportunities for microbial selection are evidently vast.

Controversy still exists concerning the mode of origin of microbial resistance, a subject beyond the scope of these introductory comments on microbial selection and often dependent on the particular biological system being studied. A minority of investigators would attribute the increased concentration of drugs required for inhibition of consecutively treated cells to contact-induced resistance, rather than to selection. Obviously, adaptation and selection are not necessarily exclusive. Varied opinions still exist after investigators have attempted to amalgamate their own theories with nuggets of wisdom mined from the writings of Luria and Delbrück (*3*), Demerec (*4*), Hinshelwood (*5*), Sevag and Rosanoff (*6*), and Eagle *et al.* (*7*).

In common with investigations in microbial genetics elsewhere, research in our laboratory has been directed whenever possible toward the use of selective systems of the streptomycin type (*4*), wherein a relatively constant number of highly resistant cells may be isolated in a single experiment over a wide range in concentration of the drug. Here mutation rates are determined easily and quantitatively, even though the data

may represent a collective estimate of several genetic changes (*8*), particularly at intermediate drug levels. Sensitive cells in the population are simply eliminated. Described as facultative multiple-step resistance, as opposed to obligatory multiple-step resistance (*8*), the streptomycin pattern, to our knowledge, has been observed only in mycobacteria exposed to isoniazid by Szybalski and Bryson (*9*) and in staphylococci treated with micrococcin by Markham *et al.* (*10*). Resistance of the streptomycin pattern is dependent on mutation, and permits selective isolation in the case of isoniazid of fully resistant strains in the complete absence of the drug (*11*) when the replica-plate method of Lederberg and Lederberg (*12*) is used.

Unfortunately for geneticists, but happily for physicians, the facultative multiple-step pattern and the one-step pattern of bacterial resistance are rare. Resistance to most agents, including those used in chemotherapy, follows the obligatory multiple-step pattern, as noted in the isolation of penicillin-resistant strains (*13*). This means that most antibiotics will eliminate all the members of a bacterial population if used initially in high concentration. It also means that special methods for the selection of such resistant strains may be necessary, permitting drug concentrations inhibitory to the general population but allowing multiplication of mutants with small factors of resistance.

Table 1 represents a survey of the principal methods generally applicable for isolating resistant microorganisms, including use of the turbidostatic selector and the gradient plate to be described later.

Only the direct methods are practical for the derivation of resistant strains. Indirect methods have been intended to demonstrate the spontaneous origin of resistant mutants (replica-plate) or have emerged incidentally in studies of the nature of variations in sensitivity. Specialists concerned directly with problems of microbial selection and resistance will be interested in the observation that with more than 50 antibiotics studied in this laboratory it has always been possible to isolate bacterial strains either more sensitive or more resistant than the parent culture. Any strain may have different levels of resistance, depending on the species or variety of organisms. One may, however, anticipate the existence of certain naturally occurring strains that are so close to the potential upper or lower level of resistance that modifications through artificial selection may be made at first in one direction only.

TABLE 1

METHODS OF ISOLATING RESISTANT STRAINS

I. *Direct methods* (in the presence of the toxic drug)

Increase of drug concentration	Medium	
	Liquid	Solid
Stepwise	Serial dilutions (test tubes)	Serial dilutions (agar plates)
Continuous	Turbidostatic selector	
Nonproportional	+ direct feeding system	Reservoir agar-plate
Proportional	+ proportional feeding system	Gradient agar-plate

II. *Indirect methods* (in the absence of the toxic drug)
Examples
Replica-plate method (*12*)
Selection by associated characters (e.g., rate of growth, resistance to other agents related by cross-resistance)
Selection at random

Part I: Gradient Plate Technique for Study of Bacterial Resistance[1]

Waclaw Szybalski

FOR extensive studies of patterns of bacterial cross-resistance (*2*) it has been necessary to devise a simpler and more efficient method of isolating strains resistant to a large variety of antibiotics. Previous methods, based either on serial dilution or on the use of an agar plate in contact with a reservoir of antibiotic, present certain disadvantages.

In serial dilution methods concentration of the chemical agents increases stepwise; and if the concentration steps are not kept close together it is easy to miss the proper dilution range, which is often very narrow. When a scarce antibiotic is used, it is possible only within relatively narrow limits to decrease the volume of nutrient and thus conserve the chemical. In doing so, one also decreases the size of the bacterial population and reduces the chance of isolating resistant mutants. Another shortcoming of these methods is their waste of labor and materials; generally, only one plate or tube of the series is useful, and the rest are discarded.

Continuous increase of the antibiotic concentration is the advantage of methods based on the use of an agar plate in contact with a reservoir of antibiotic solution, such as an assay cylinder, paper disk, or "gutter plate" (*14*). In this case, however, the concentration gradient represents a steep logarithmic function. The areas of appropriate concentration are usually very narrow and may move rather rapidly during the experiment, owing to diffusion.

For these reasons we have tried to develop a method (*15*) that will allow the preparation of an agar plate with a very gradual proportional increase of the antibiotic concentration along one horizonal axis—the gradient axis. Plates are poured with two layers of agar (Fig. 1). The bottom layer consists of 20 ml plain nutrient agar, allowed to harden with the plate slanted sufficiently so that the entire bottom is just covered. With the dish in the normal horizontal position, another 20 ml of agar is added, containing the

[1] Aided by a research grant from the National Tuberculosis Association.

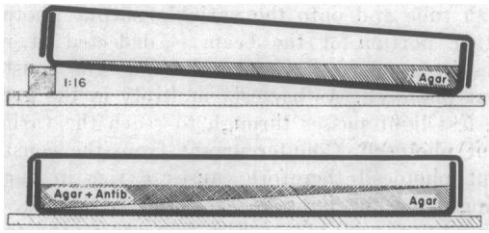

FIG. 1. Method of preparing a gradient plate.

appropriate concentration of toxic agent. Downward diffusion of the drug, which in this way becomes diluted in proportion to the ratio of the thicknesses of the agar layers, establishes a uniform, linear concentration gradient during subsequent incubation. The drug may also be incorporated in the bottom layer, and by changing the ratio of its concentrations in both layers it is possible to adjust the range and the slope of the gradient, which remains surprisingly stable for several days after the preparation of the plate. When heavy bacterial suspensions are incorporated in the top layer, or else streaked or spread over the agar surface, only the resistant cells are able to form colonies beyond the boundary of confluent growth; and if the resistant colonies are streaked out on the same plate, the resistance may be verified and further increased (Fig. 2). In this way one plate may be substituted for several series of dilutions, increasing resistance over more than one step. Resuspension of the resistant colonies in broth, with or without subsequent incubation, and further plating on gradient plates with a higher concentration of the toxic agent, have been used to develop strains of *E. coli, M. pyogenes* var. *aureus,* and *Mycobacterium ranae* that are resistant to over fifty chemotherapeutic agents.

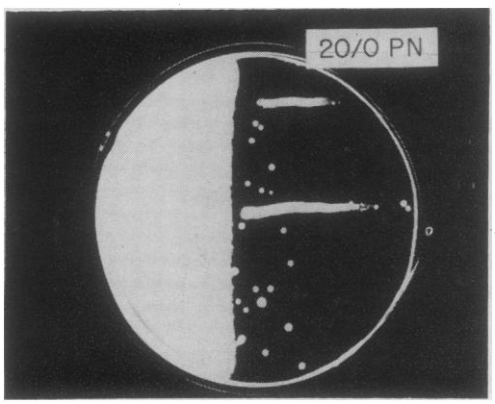

FIG. 2. Gradient plate. Bottom layer—nutrient agar; top layer—nutrient agar + penicillin (20 μg/ml). Surface seeded with a suspension of *E. coli,* strain B/r. Only resistant cells develop colonies beyond the boundary of confluent growth. Two of these resistant colonies are streaked out. Note the formation of second-step resistant colonies at the end of the streaks.

With the use of small, autoclaved artist's brushes or glass capillaries, as many as ten streaks of the standardized bacterial suspensions can be placed parallel to the concentration-gradient axis on one gradient plate. The same method allows easy comparison of the sensitivities of various strains to a given drug, since the length of the growing streaks is a direct measure of the inhibitory concentration of the drug (*2*) (Fig. 3). The shape of the streaks permits visual distinction of different patterns of inhibition (Fig. 4). Gradual inhibition may indicate that the toxic agent interferes with a simple chemical reaction of a low kinetic order. Abrupt inhibition suggests interference with a mathematically high-order reaction, represented, for instance, by a chain of consecutive reactions. It seems to be important, in describing an antibacterial agent, to consider not only the inhibitory concentration, but also the pattern of inhibition.

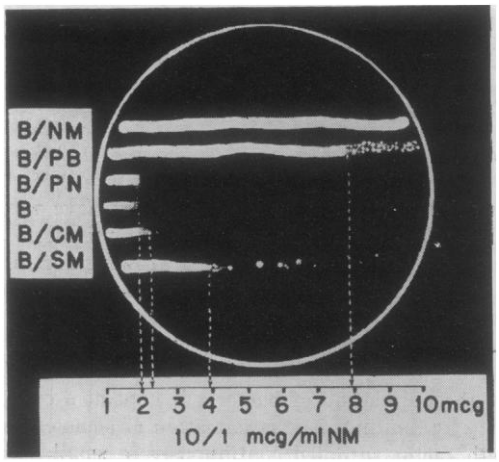

FIG. 3. Measurement of bacterial sensitivity. Neomycin is incorporated in both agar layers—10 μg/ml in the top, and 1 μg/ml in the bottom layer. Suspensions of *E. coli* consisting of the parent strain B and strains resistant to neomycin B/NM, polymyxin B B/PB, penicillin B/PN, chloromycetin B/CM, and streptomycin B/SM are streaked over the surface of the gradient plate. In the example the approximate inhibitory concentrations in μg/ml are: 2 (B and B/PN); 2.3 (B/CM); 4 (B/SM); 8 (B/PB); 10 (B/NM).

Among the potential applications of the gradient-plate method we may mention the simple assay of antibacterial drugs and the study of microbial growth factors.

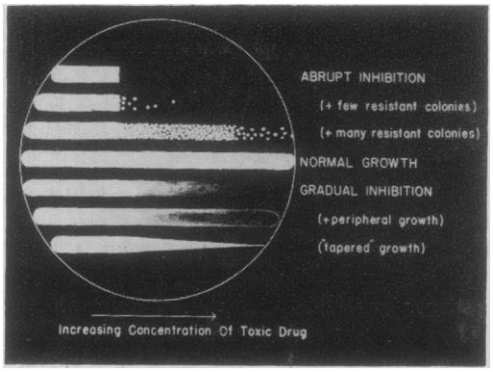

FIG. 4. Examples of inhibition patterns.

Another approach to the problem of providing a proportionately increasing concentration of toxic agent using *liquid* media has been made by Bryson in this laboratory by means of a mechanical device (the turbidostatic selector), to be described in Part II.

Part II: The Turbidostatic Selector—A Device for Automatic Isolation of Bacterial Variants

Vernon Bryson

IN RECENT years several investigators have worked on the problem of continuous bacterial cultivation. Apparatus designed to keep bacteria growing for indefinite periods has been described by Sims and Jordon (*16*), Levin (*17*), Savage and Florey (*18*), Kautsky and Kautsky (*19*), Gerhardt (*20*), and others. In the device of Monod (*21*) and that of Novick and Szilard (*22*), the population of bacteria is kept at a constant density by limiting the concentration of some essential growth factor supplied continuously in small quantities to the culture. This results in the attainment of a dynamic steady state at less than the normal growth rate, with culture volume maintained by a self-leveling overflow. In most of the equipment designed up to the present time, including the chemostat of Novick and Szilard, emphasis has been directed to supporting the bacterial population by continuous addition of a chemical environment of constant composition.

For some time we have been interested in making an apparatus for the cultivation of bacteria in a continuously or intermittently changing environment (*23*). The device has been named the turbidostatic selector (Fig. 5). The two essential components are a simple electronic circuit controlling periodic addition of nutrient to microorganisms whenever the culture reaches a fixed turbidity; and a proportional-feed system for increasing the concentration of some toxic substance, at a geometric rate, in the nutrient delivered automatically to the growth tube in response to reproduction of the cells.

Bacteria in the growth tube are kept at constant temperature. Culture turbidity is continuously measured by a standard system of two photovoltaic cells, balanced against each other in a potentiometer circuit, as in a conventional colorimeter. Every time turbidity exceeds the preset value, the galvanometric relay system opens a solenoid-operated pinch clamp, and fresh nutrient is added to the culture, decreasing its turbidity until the circuit is again balanced. Culture volume is kept constant by a self-leveling overflow.

The operation of the electronic circuit is controlled by current from a light box supported above a magnetic stirrer by metal legs, and containing the growth tube (Fig. 5, *B*). A light beam, entering this box from the lamp (Fig. 5, *A*), is split with a mirror. One portion of the entering beam passes directly through the growth tube and onto the variable output photocell. Another portion of the beam is deflected at right angles by a mirror and is directed to the constant-output photocell. As bacteria multiply in the growth tube, less light passes through to reach the variable-output photocell. Countercurrent from the constant-output photocell therefore causes a rise in current passing from the light box to the control box. The latter unit, not visible in Fig. 5, contains the transformers, relays, and galvanometer required to operate the pinch clamp solenoid and regulate the temperature of the culture. Construction details are cited elsewhere (*24*). Current entering the control box passes directly

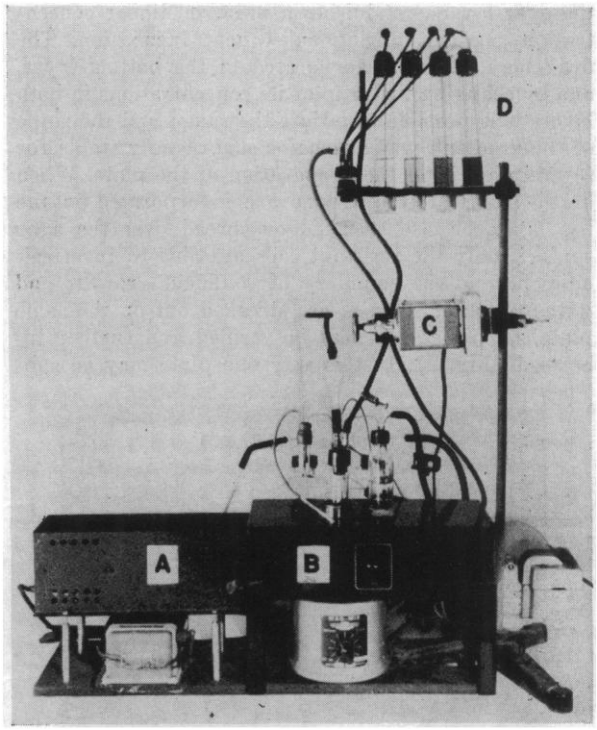

FIG. 5. The turbidostatic selector. (*A*) lamp; (*B*) light box containing growth tube and photovoltaic cells; (*C*) solenoid-operated hosecock; (*D*) proportional-feed system.

to an enclosed lamp-type galvanometer, shunted to give a sensitivity of about 20 mm/μa, and with the ground-glass scale removed. As bacteria grow in the light box, the rise in current reaching the galvanometer causes its beam to move horizontally and to leave the galvanometer through the aperture made by removing the ground-glass scale. At an optical density corresponding to an arbitrary cell titer, the galvanometer beam enters a photorelay.[2]

Closure of an a-c circuit by the photorelay activates a cumulative counter and the solenoid-operated hosecock (Fig. 5, *C*). Rubber tubes passing *under* the baseplate of the hosecock are thus opened, allowing sterile air to bubble into the proportional feed (Fig.

[2] Model 904185 BX, Photobell Co., New York City.

5, *D*), mixing the liquid and preventing entrance of contaminating microorganisms with the fall of fluid level. Nutrient siphons downward from the proportional feed into the growth tube, and excess culture passes through a constant-level siphon leading from the growth tube into a waste bottle. The resulting dilution of cells and decrease in optical density of about 2 per cent move the beam off the photorelay, and the cycle is repeated only if and when adapted or mutant elements of the population are able to grow within the increasingly rigorous selective environment. The upper limit of turbidity may be set with the potentiometer. Evolutionary change is automatically controlled by the increases in selective pressure, dependent on the genetic or adaptive potential of the microbial population, expressed as continued growth in the presence of a changing environment.

The proportional feed (Fig. 6) consists of four

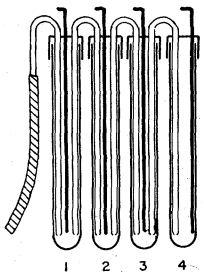

FIG. 6. Detail of proportional feed. Heavy lines represent stainless steel aeration tubes. Toxic agent and nutrient are withdrawn from rubber tubing connected to tube #1.

screw-cap test tubes connected by siphon bridges. Nutrient in each tube contains a dilution of toxic substance present in the tube to its right. The usual difference in concentration between adjacent tubes is tenfold, illustrated for graphic purposes by dye in Fig. 5. In actual use, the proportional-feed tubes must be optically identical and more trauslucent than the cell suspension in the growth tube.

The toxic agent and added nutrient are not titrated directly into the growth tube from a single vessel, because the concentration gradient available by titration results in an unduly steep rise of selective pressure in the growth tube. As a comparative example of concentration gradients obtainable by different methods, we may first consider the result of titration or direct-feed (Fig. 7). The data represent dye samples taken from a receiving vessel acting as the growth tube and containing 30 ml of phosphate buffer at pH 6.7. A solution of buffer containing neutral red reading 55.1 in the Fisher colorimeter (525 filter) was added to the receiving vessel in 20-ml quantities. After each addition, the contents of the receiving vessel were again reduced to 30 ml, and the withdrawn 20-ml sample was measured colorimetrically. Nine consecutive samples gave the titration curve shown in Fig. 7. As more samples were taken, the final concentration approached a value of 55.1. In the chemostat of Novick and Szilard, a chemically constant concentra-

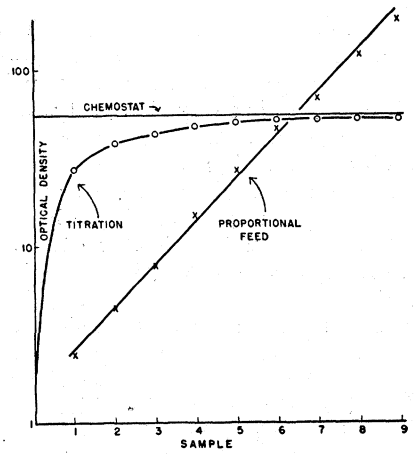

FIG. 7. Density measurements of dye samples, indicating concentration gradients obtainable by methods described in the text.

tion of limiting nutrilite is added to the growth tube. For purposes of comparison, the chemostat curve is represented in Fig. 7 as equivalent to the original concentration of dye added in the titration experiment. With continued sampling, the chemostat and titration curves should become experimentally indistinguishable.

In modifying the bacterial environment by increasing the concentration of a toxic substance, the titration curve is not as useful as a geometric increase of the type $y = a \cdot b^x$. The geometric increase observed in Fig. 7 may be considered as an approximate calibration of the proportional-feed system. In obtaining the data, a 0.5 per cent tincture of neutral red in 50 per cent alcohol was distributed in the four proportional-feed tubes as follows: The tube farthest from the siphon outlet (Fig. 6, #4) received 0.7 ml of dye solution, and each adjacent tube received one tenth the concentration of the tube distal to it with respect to tube #1. Each tube contained approximately 50 ml of buffer (pH 6.7), with 30 ml in the growth tube. Consecutive 20-ml samples were drawn from the terminal proportional-feed tube into the growth tube, again withdrawn after mixing, and then measured with a green filter in the colorimeter. In other experiments it is seen that, if the factor increase between proportional-feed tubes is decreased to 5 or less, the curve tends to become sigmoid.

A single vessel may be substituted for the proportional feed when a *decreasing* concentration gradient is required—for example, in the isolation of prototrophs by diluting out the required nutrilite supporting growth of an auxotroph. In such an experiment complete medium in the growth tube would be periodically diluted by direct feed of minimal media. The selector may also be operated as a chemostat without the restriction of a limiting growth factor.

As auxiliary equipment, the selector is provided with a rescue system that will deliver pure nutrient to the culture at timed intervals, independent of the rate of growth. Nutrient from the rescue system is

not sufficient to provide entirely for growth at a rate exceeding 20 per cent of the normal growth rate. Therefore, unless the reproducing cell population is very small or is growing very slowly, it will continue to activate the proportional feed. The rescue system serves to dilute out toxic agent introduced from the proportional feed to provide repeated opportunities for selection. Its use may be required when the toxic agent produces a bacteriostasis that effectively prevents selective growth, resulting in a complete cessation of activity. The culture is aerated by humidified air blown over the surface and maintained at 37° C by a heating element inserted in the centrifuge carrier holding the growth tube. Cells are mixed by a magnetic stirrer, and samples may be withdrawn at will by aspiration into an attached vial.[3]

To understand the process of automatic evolution it is necessary to recall that many toxic agents are not equally harmful to all the individuals of a bacterial population. As more toxic chemical is added in nutrient from the proportional feed, bacterial growth is reduced and a process of artificial selection is begun. A point is reached when the general level of population can no longer increase. If resistant mutants or variants are present in the general population, and can grow, they alone will contribute to added population density and an increasingly rigorous environment will result. The exponential nature of the concentration gradient results in a continued selective process, with the increase of selection pressure always proportional to the concentration of toxic agent already attained. A gradual increase in the toxicity of the environment is of relatively great significance in attainment of the penicillin pattern, as opposed to the streptomycin pattern of resistance (*25*).

Several types of experiments may be performed by the selector without more than occasional attention from the operator. The present design does not permit the use of toxic agents that reduce light transmission; and the rate of flow from both proportional-feed and rescue systems tends to diminish if unadjusted during the progress of an experiment. Some of these difficulties can be overcome by modified design. To facilitate the derivation of quantitative information from the instrument, it is being equipped with a recording time stamp in place of the cumulative counter, to indicate the exact moments of operation of the hosecock. Another timer will hold the hosecock open for one minute at each operation.

Our present efforts are directed toward the isolation of bacteria resistant to antibiotics and germicidal agents. It is at once seen that some agents are more suitable for use in the selector than others. With *E. coli* (strain B), penicillin resistance has been increased two- to fourfold, whereas over a seventyfold increase is possible. Increased resistance by a factor of 16 was obtained by employing neomycin in one ten-day run of the instrument. Without use of the rescue system, a zephiran-resistant strain of *E. coli* (B/ZS) was isolated by the selector in three days. It proved to be no more sensitive to this quaternary ammonium compound than the stock laboratory strain (B/Z #10) obtained by ten consecutive isolations from broth containing the highest tolerable concentration of drug (Table 2). Cells were grown for 48 hours at 37° C.

[3] Acknowledgment is due to Waclaw Szybalski for several useful suggestions.

TABLE 2

PERCENTAGE OF VIABLE *E. coli* AFTER GROWTH IN NUTRIENT BROTH CONTAINING ZEPHIRAN, AS COMPARED WITH CONTROL

	Zephiran concentration				
	1/ 64,000	1/ 128,000	1/ 256,000	1/ 512,000	Control
Strain B	0	0.00006	14	103	100
Strain B/ZS	0	1.4	51	67	100
Strain B/Z #10	0	0.01	25	33	100

Certain toxic substances may prove to be unsuited for use in the selector because, at the exact level of bacteriostasis, the metabolic activity of the majority of cells is able to exhaust essential substrate materials and effectively suppress the emergence of clonal mutants or adapted populations better fitted for survival. Obviously, where growth depends on the presence of bacterial mutants, the population size should exceed the reciprocal of the mutation rate. Since the number of cell divisions per unit increase in toxic concentration may affect the pressure of selection, experiments are now being initiated in which an aspirator bottle containing 3 liters of nutrient is placed between the proportional feed and the culture. The aspirator bottle and proportional feed are placed at the same height, and connected by siphons so that their fluid levels drop simultaneously. A more gradual increase of toxic agent is thus attainable. Present experience indicates that for the empirical isolation of antibiotic-resistant mutants, the instrument is not as effective as the gradient plate method (*2, 26*).

Some potential applications of the turbidostatic selector involve the graphing of cyclical activity of the proportional feed to aid in distinguishing the relative importance of adaptation and mutation-selection as factors in adjustment to a toxic environment. Other possibilities include basic studies of mutation rate; the determination of modified resistance in bacterial populations undergoing little or no multiplication; the analysis of cell physiology at the exact level of bacteriostasis; studies of the comparative resistance of mixed bacterial populations to inhibitory or stimulating chemicals and metabolites; isolation of strains metabolizing foreign substrates by gradual substitution of materials in the proportional feed; and the derivation of partial or multiple-step reverse mutants.

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News and Notes

American Documentation Institute

THE AMERICAN DOCUMENTATION INSTITUTE (of which the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE is a nominating agency) held a two-day annual meeting in the Coolidge Auditorium of the Library of Congress Feb. 26–27. The principal elements of the program were symposia on microfacsimile reproduction and on the rationalization of subject controls, and a discussion of current issues in documentation. There was also a comprehensive exhibit of apparatus applicable to documentary reproduction, projection, transmission, and other techniques of documentation.

The live issue before the meeting was whether the institute, the membership of which had up to then been composed exclusively of delegates nominated by 69 institutions and professional societies, should throw its rolls open to personal and other institutional memberships, and whether it should at the same time become a dues-paying organization.

For some time there has been growing evidence of the need for an organization in which members of different professions who are engaged in documentation, including information officers for scientific and technical organizations, archivists, and librarians, can find a common meeting place for discussion and collaboration. The need is evident in recent communications to this journal by William F. Hewitt, Jr., and Samuel A. Miles (SCIENCE, **114**, 134, 554 [1951]), as well as in the program at the Philadelphia meeting of the AAAS, sponsored by several of its sections under the title "Operation Knowledge" (*ibid.,* **115**, 178 [1952]).

On all points the issue was resolved in favor of liberalizing the membership requirements for ADI. Personal and institutional members will be admitted on equal terms with present and future organizational delegates. As soon as 100 persons and institutions have signified their intention of seeking membership on the new terms, a meeting will be called to consider constitutional changes.

The new officers elected include Luther H. Evans (Librarian of Congress), president; Milton O. Lee (Federation of American Societies for Experimental Biology), vice president; Watson Davis (Science Service), treasurer; and G. Miles Conrad (Library of Congress), secretary.

VERNER W. CLAPP

Library of Congress
Washington, D. C.

Scientists in the News

Frank W. Abrams, chairman of the board of the Standard Oil Company (New Jersey), has been elected to the Ford Foundation's Board of Trustees. Mr. Abrams will continue to serve as chairman of the Fund for the Advancement of Education for the next six to eight months. **Henry Ford II** is serving as acting president of the Foundation while **Paul G. Hoffman,** president, is on temporary leave of absence.

Andrew W. Anderson, chief of the Fish and Wildlife Service's Branch of Commercial Fisheries, has been designated deputy administrator of the Defense Fisheries Administration. Mr. Anderson will assume his new duties in addition to his present assignment for the duration of the DFA program. **Milton C. James,** who retired as assistant director of the service on Mar. 31, served as DFA deputy administrator from its formation until his retirement. Under a reorganization of DFA effected in December 1951, Mr. Anderson took on additional duties as chief of the Office of Operations.

Eugene C. Bovee has been appointed associate professor and acting head of the Department of Zoology and Physiology at North Dakota Agricultural College. Dr. Bovee has been on the staff of the California State Polytechnic College of San Luis Obispo.

Ralph C. Bryant, of Fort Collins, Colo., has been appointed professor of forest economics in the North