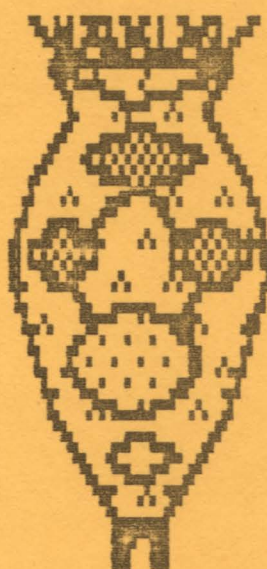
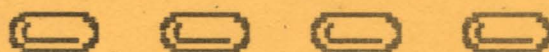


**MIDWEST
BIOSCIENCE**



**MAY 1986
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Opinions expressed are not necessarily those of the AMCBT. Articles published in this journal have not been reviewed by peers.

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NOTES FROM THE EDITOR

This year I have appreciated your interest and participation in your journal. For the first year since I have been Editor, we have been able to publish TWO issues filled with significant and interesting articles. I hope that you will enjoy this issue of Bioscene.

I urge you to join me this summer in setting a personal goal to write one article for Bioscene. You are all interested in learning about laboratory experiments. Why not share your favorite with all of us? This summer, when you are on that special field trip, why not share your experiences with all of us?

If you are using a DEC Rainbow, a Zenith, or an Apple Computer, send us a disk copy and a paper copy of your article. We have these word processing systems: WordPerfect for all systems, Appleworks and Pie Writer. If you are using one of those, simply send us a disk containing the unformatted document. If you are using a different word processor on a compatible computer, send us an ASCII text file. The deadline for the next issue is November 15.

THE APPLE IIe LIVES

I am keyboarding this short story to all of you with two fingers on my Apple IIe. My message is simple - there is life remaining for the Apple II system even in the face of an emerging 16-bit computer world. In this past year, Apple Computer Inc. and other companies have decided to support and upgrade the IIe system. This article is being written on an enhanced IIe equipped with an Applied Engineering Ramworks extended 80 column card (312 K memory), an Applied Engineering Timemaster II clock card, a Street Electronics Alphabits Serial Interface, a Hayes Smartmodem 1200, and an 800K Unidisk 3.5 drive. I am using Apple Computer's Appleworks word processing program which has been modified in two ways: (1) all of the RAM memory is accessible and (2) a set of closed-apple commands have been added with Beagle Bros.'s Macroworks program. An Apple Computer Imagewriter II was used to print the text. All of the additions to the standard IIe are summarized in Figure 1.

Ramworks	212
Clock	99
Appleworks	125
Alphabits	79
Smartmodem	395
SuperSerial	105
Macroworks	35
Unidisk	365
Imagewriter II	450

Total \$1865

You may find a cheaper or more expensive path to the same end. If you subtract the modem and printer, the cost drops to about \$900. I have had quotations of 600 - 700 for a IIe so the entire system is about \$1500. You can purchase a IIc system with 512K RAM for about \$945.

Understand that I am not advocating that all of you rush out and buy such a IIe system. There may be better systems for comparable prices. We had purchased the IIe's and had the software. More importantly, we were comfortable with the software. We wanted more capacity on disks and in RAM.

APPLEWORKS

Much has been written about Appleworks so I am not going to spend time here. If you want to know more, I recommend that you read: Appleworks is a unified interactive working environment consisting of three segments: a word processor, a database, and a spreadsheet. These are linked together by a "clipboard" which enables you to move documents from one environment to the next. Appleworks is not protected and more importantly it has an open architecture. This means that clever people can modify the program to work even better.

The clever people at Beagle Bros. have done just that. Their Macroworks enhances the function of Appleworks by introducing a series of 2-3 key macrocommands that consist of pressing the open-apple key and one other key. For example, to superscript the text you press closed-apple +. With the unmodified program to accomplish this same task, you must press open-apple O+BRTN+ERTNESC<-. Macroworks also enables you to define two temporary macros, each up to 20 characters.

The clever people at Pinpoint Publishing have pushed Appleworks in another direction. With their program Pinpoint they have significantly expanded the capability of the IIE by adding a series of accessories accessible through the Appleworks system, much like the Desktops for the Macintosh and IBM computers.

The Pinpoint System now includes a dialer, communications system, calculator, note pad, appointment calendar, and a speller. To access any of these functions, all you do is press closed apple-P and a menu appears on the screen. With the arrow keys you select the accessory. Then, the screen is saved in a temporary file and the accessory is brought to the screen. When you are finished, the Appleworks screen is reloaded and you can continue. All of this takes seconds if you rely on a disk drive and less time if everything is resident in RAM.

Also, this system enables you to merge pictures drawn with Borderbund's Dazzle Draw or Beagle Bros.'s Graphics program into your Appleworks files. Many of the accessories are unnecessary but I have found the calendar and communications programs very helpful. This program (Pinpoint & Speller) lists for \$125 but I have seen Pinpoint and Speller selling for \$39 each. Judging from the several additional sub-programs that are now available, I suspect that Pinpoint will be expanding the capabilities of these programs rapidly.

UNIDISK 3.5

I have had this system for less than two weeks, but I am a true believer. On one disk, I have all of my Appleworks primary program, dictionary, and an entire series of sub-directories. With all of this (about 4 full standard disks), I still have about 300 K of space available. The 3.5 disk is much sturdier - I can put it my pocket. While this is configured by Apple only for ProDOS, several other programs are available that turn the drive into two 400K DOS drives.

RAMWORKS

A 500 K Database on an Apple? Impossible? Not if you have a Ramworks II card installed in your Apple. Ramworks II replaces the 80 column card for the IIE with a card that supports an 80 column

also adds considerable resident memory to the computer. With modification, the Appleworks program can be entirely loaded into this RAM significantly speeding up the operation of the program. Only the printer driver program must be accessed from the disk. Also, Appleworks itself is expanded so that you can use the available RAM space. This means that you can have large databases, spreadsheets or documents in RAM. Also, you can rapidly switch between documents.

With the supplied software, you can use the extra RAM as a ramdrive for either the DOS or ProDOS operating system. This software also enables you to configure Appleworks to utilize all of the added RAM space. In addition, you can add a print buffer to the software. With the print buffer installed, I have noted some delay in accepting keyboard input when the program is bank switching. I prefer a buffer either installed on the printer or on the printer interface.

This card has changed the IIE from a memory-limited machine to a 128 - 1000+ K RAM. I have been using the Applied Engineering card for more than a year. While I have been satisfied with its operation and with their technical support, other cards are available. Most reviews seem to favor the Ramworks II card.

ALPHABITS

Alphabits is a serial printer card introduced by Street Electronics Corporation to enable users to fully access the diverse abilities of the Imagewriter II system. With pull-down menus, a resident cropping editor for page 1, page 2, or Hi-res graphics, this system is an ideal card for the IIE operating with an Imagewriter. At \$79 for academic institutions, its a real bargain. From within programs, including Appleworks, you can place star commands that alter the action of the printer. The star commands are easy to remember and do not cause the problems for word processors that are caused by escape or control commands. This card can be equipped with a 64K print buffer so that you can print long documents and still work with other programs.

THE THIRTIETH ANNUAL MEETING
September 26-27

Our Theme
BIOLOGISTS AND PUBLIC POLICY
at
SANGAMON STATE UNIVERSITY

About the Annual Meeting

Program planning is progressing well. We are pleased to announce that our keynote speaker will be Dr. George Kieffer of the Department of Ecology, Ethology, and Evolution at the University of Illinois. Professor Kieffer will speak, following our banquet, on the general topic of the scientific community and its role in society. His lecture is entitled, "What Should Society Expect From Scientists?" He will address, in part, the charge that scientists are unresponsive to the problems that arise from science and technology and examine aspects of our role in the wise use of new knowledge. Dr. Kieffer is the author of a book entitled Bioethics: A Textbook of Issues and he has published numerous papers dealing with bioethics. In addition to the scholarly activities in this area, Dr. Kieffer has worked extensively in the development of materials for biological education, especially biology for non-majors. As part of this endeavor he has written two audio-tutorial texts for use in the non-majors biology at U. of I.

Once again, we are calling for papers for the Annual Meeting. As we noted in the previous BioScene, it seems appropriate to look at the contributions of biologists to public policy. Biologists function in society as consultants, advocates, educators and researchers. Our activities frequently impinge on controversial social issues. Questions regarding our role in the dissemination of new knowledge and new technologies need to be discussed. What are our responsibilities as biologists? We are especially asking for papers that focus on biologists as citizens who because of

their special expertise and skills have much to contribute to the public debate and to public policy issues. Such issues as the nature of science education and the effects of new knowledge and techniques in biology on medical and ethical issues are but two examples of societal issues that we influence. Please consider making a presentation. Don't limit your response to the theme if you wish to share course ideas, laboratories, or other valued experiences with your colleagues.

About the University

Sangamon State University, designated the state's public affairs university, is a liberal arts institution educating students for careers in the private and public sectors. It is an upper-division university, beginning at the junior year and continuing through graduate studies. Sangamon State began classes in 1970, offers 22 undergraduate and 23 graduate programs and is accredited by the North Central Accrediting Association. University enrollment is approximately 3,200 with about 180 faculty, providing the atmosphere of a small private institution at attractive state tuition rates.

Sangamon State is open at the undergraduate level to graduates of accredited junior and community colleges who hold the associate in science or associate in arts degrees. Graduate study is available to students with a bachelor's degree from an accredited institution.

The campus is located on a 740-acre site near Lake Springfield, six miles southeast of downtown Springfield. The

campus includes a 380,000-volume library, Public Affairs Center with excellent conference and performing arts facilities including the 1,951-seat university auditorium, student housing and a physical recreation facility.

The Biology Program has a faculty of four biologists with curricular contributions also coming from biologists in related programs. The Program is currently housed in Building K, one of the temporary buildings constructed on the site of the permanent campus. The Board of Higher Education has recommended a Fiscal Year 1987 budget approval of \$466,700 to plan a new health sciences building. Biology has been well funded historically and we are pleased to be able to teach our students with equipment that is of research quality. Consequently, our students have the opportunity to master marketable skills such as a working knowledge of the transmission electron microscope, a wide variety of other microscopy and microtechniques, and a variety of analytical chemical instruments.

Students earning a B.A. in biology enter a variety of professions, including environmental protection specialists, secondary science education teachers, and medical laboratory analysts. Additionally, a number of our B.A. graduates have continued their education entering various graduate schools in biology. Still others have been successful in entering professional schools in medicine, dentistry, veterinary medicine and other health related professions. Graduates with an M.A. in biology have also been very successful in career advancement. Several have obtained the Ph.D. and are presently actively engaged in research and teaching at the university level. Other M.A. graduates entered professional schools and are now practicing doctors, dentists, and veterinarians.

The Biology Program Faculty and the University Administration look forward to the presence of AMCBT and its membership on the campus for the annual meeting in September.

HOW BIOLOGISTS ARE PERCEIVED

Jim Holler, University of Wisconsin-Platteville

The following article is a summary of some of the author's ideas and those of his colleagues attending the 1985 meeting at Augustana.

The problem of how biologists are perceived can be divided into two categories, how the educational community perceives biologists and how the non-educational community perceives biologists.

The educational community is composed of many facets but this article will concentrate on the views of fellow scientists, non-scientific colleagues and those of administrators.

Among fellow scientists biology is often considered to be a "soft science" or pseudoscience. It is considered to be a field for those who are not intelligent enough to major in mathematics, chemistry or physics. Apparently part of the problem stems from the fact that physical scientists usually take very little biology as opposed to biologists who are usually required to have some background in chemistry and physics. Perhaps the situation can best be summarized by a remark made by a person attending the session. A colleague (a physical scientist) was showing a group of visitors around campus and announced, "This is where we teach science and biology."

The conception of what biology is as viewed by colleagues in non-scientific disciplines is even farther afield. Most have no understanding of what is involved in teaching laboratories. Most perceive the teaching of laboratories as less work than teaching lecture. Some of this may come from the fact that in most institutions less credit is given for teaching laboratories than lecture.

Another perception is that courses in the sciences are viewed as being of a vocational-technical nature and are more

suited to a community college or trade school. Often the proponents of this view consider themselves to be liberally educated! Even in interdisciplinary courses, the scientific works chosen for study tend toward evolution or socio-biology.

It appears that the conception of most administrators of what biologists do is even more distorted. Field studies are usually considered a type of recreation! They have no idea of the time requirements for laboratory preparation and development. Administrators often fail to appreciate the type of physical facilities needed to teach some specialties.

The state of affairs may be best summarized by the view of two deans of Arts and Sciences. One believed that biology was a physical science! The other held the view that there is a hierarchy in science and the reader can draw his own conclusion as to what was thought of biology.

The perception that the layman has concerning biology is different from that of educators in some respects; and in other ways it is not so different. Too often both groups view biologists as bug chasers, animal butchers, and mad scientists. Perhaps this is because the physical sciences are more easily defined. Biology is a synthesis of other sciences. This is a concept that is difficult for the lay person to grasp.

The laypersons often perceive biologists as being nothing but naturalists. In the past the type of training biologists received may have contributed to this concept. Today programs such as "Wild Kingdom", "National Geographic", "Jacques Costeau", and "Nature" still too often promote this idea.

The public often thinks of biologists as resource people. But, as a colleague said, "Why is it, if they have a sick plant they bring it to a biologist but if they have a sick dog, they take it to a veterinarian."

What can be done about the distorted view that all too many people have about biology?

It is fine that the public thinks of us as resource people. I believe that many of us welcome that concept. But it is up to us to exploit that idea by informing people not only about our specialties, but also about other contributions biology has made to society. We are still too often thought of only as trainers of pre-professionals in the health disciplines. The public needs to understand about contributions made by biologists other than those made to medicine.

As to changing the perception held by too many in the educational community, the author can offer only hope. Perhaps, more biologists should be willing to serve as administrators. Another alternative is the education of administrators and colleagues. It may be a matter of telling them time and again just what it is we do. As one of my cohorts has often said, "They don't know and they don't know that they don't know." Perhaps it is time they learn!

AIBS NAMES NEW PUBLIC RESPONSIBILITIES MANAGER

Charles M. Chambers, Executive Director, American Institute of Biological Sciences

Amanda L. Spitler, J.D., has been named the new manager of the Public Responsibilities Program of the American Institute of Biological Sciences, Executive Director Charles M. Chambers announced today. Spitler was most recently Washington representative and legislative analyst for a group of health care clients - including HMO's, physician colleges, major medical centers, and medical specialty societies, in their dealings with federal regulatory agencies and the Congress.

Chambers commented that the AIBS Public Responsibilities Program is the arm of the Institute that represents the interests of professional biologists in national public policy affairs. By providing information and services to concerned biologists everywhere, the program establishes essential liaison between the executive and legislative bodies at the national and state levels and the concerns of all life scientists for the protection of life and improvement of health that research and conservation can bring. He noted that AIBS in particular, and the biology community in general, were indeed fortunate to have a person of Spitler's experience and qualifications to provide leadership in this key area.

She will direct policy analysis and legislative research and publish the information in the Institute's bimonthly newsletter, Forum, and its monthly news column, "Washington Watch" in Bio-Science. She will also manage the AIBS information networks and legislative clearinghouse, that provide up-to-date status of legislative activities of interest to biologists on an individual basis. Spitler will assume her duties on April 1, 1986.

Spitler has been particularly involved in drafting testimony for congressional hearings and preparing monthly legislative news columns for

life science societies. She has received the top award of the Society for Technical Communications for her scientific writing and holds an appointment to the Life Sciences Division on Legal Problems in Basic Biological Research of the American Bar Association.

A native of the Washington, DC area, Spitler is an honor graduate in biology from Wake Forest University. She completed a year of post-graduate studies in public health at the University of Alabama prior to accepting a position in the General Counsel's office of the Department of Health and Human Services as staff liaison with the National Institutes of Health. She completed her studies for the Juris Doctor degree at American University's Washington College of Law in 1985 and has just been admitted to the Pennsylvania and District of Columbia bars. In addition, she has a background in biostatistics and epidemiology and serves as an auxiliary volunteer with the Fairfax Hospital Association in nearby Northern Virginia.

Founded in 1947 as a component of the National Academy of Sciences, AIBS became an independent, Washington based Institute in 1955. Today it is a federation of over 40 professional societies and research laboratories representing more than 70,000 biologists nationwide. The organization is devoted to advancing the basic biological, medical, environmental, and agricultural sciences and their applications, through research and education, to human welfare. Its government relations, publications, and award activities are focal points for national interest in the life sciences. The Institute assists various government agencies including the Agency for International Development, the Environmental Protection Agency, the Department of Defense

and the National Aeronautics and Space Administration with studies, reviews, evaluations, and policy planning in the life sciences.

HARDIN WINS 1986 AIBS DISTINGUISHED SERVICE AWARD

Charles M. Chambers, Executive Director, American Institute of Biological Sciences

Ecologist Garrett Hardin has been named the recipient of the 1986 AIBS Distinguished Service Award, the Institute's President, W. Donald Duckworth announced today. Hardin, currently Professor Emeritus of Human Ecology at the University of California at Santa Barbara, is being recognized for his years of service not only to the science of ecology, but also for his extraordinary success in creating an awareness among the society at large of the limits of the natural resources available to the inhabitants of the planet Earth. He is being particularly honored for his singular role in establishing the public policy debate about the "carrying capacity" of our ecosystem and for his tireless efforts to apply scientific methods and findings to the ethical and political dilemmas posed by population growth and resource depletion. Hardin will officially receive the Distinguished Service Award this summer when he delivers the Plenary Address at the AIBS Annual Scientific Meeting at the University of Massachusetts, Amherst on August 10.

Established in 1972, the AIBS Distinguished Service Award has been given annually to individuals who have made outstanding contributions to biology, both through integration of disciplines and the improvement of public policy through the application of biological knowledge.

With a strong interest in evolutionary genetics and human ecology, Hardin has published twelve books and over 300 scholarly articles. He has written widely for the non-scientific press on topics which cut across a whole range of national policy concerns. Examples are: "In Praise of Waste",

"Living on a Lifeboat, "Carrying Capacity as an Ethical Concept", "Limits to Altruism", and "Filters Against Folly: How to Survive Despite Economists, Ecologists and the Merely Eloquent." In addition, noted Carl Bajema in his nominating statement, "Garrett Hardin has been the major driving force of the Environmental Fund, whose purpose is to help citizens and legislators make more informed decisions concerning population/resources/environment issues".

His interest in citizen education is also shown in the four editions he has written of his textbook BIOLOGY: IT'S PRINCIPLES AND IMPLICATIONS, a popular adoption at the high school level. Hardin is a member of the American Academy of Arts and Sciences, the American Philosophical Society, and an honorary member of the national Association of Biology Teachers. He has served as a national lecturer for Sigma Xi and Phi Beta Kappa.

A native of Dallas, Texas, Hardin received his Bachelor of Science degree from the University of Chicago and his Ph.D. in Biology from Stanford University. In addition, he holds honorary degrees from Puget Sound University and Northland College. While completing his graduate studies he was engaged in laboratory investigations of the ecological aspects of microorganisms. He then joined the research staff of the Carnegie Institution of Washington's Division of Plant Biology at Stanford, investigating algal antibiotics and the possibilities of culturing algae for human food. This led to his early considerations of the inherent contradictions in the policy of

resolving pressures caused by over-population through increased food production alone.

Because of his interest in teaching he next joined the faculty at the University of California at Santa Barbara in 1946 and devoted much effort to developing his introductory textbook. His concerns about governmentally imposed restrictions on abortion lead to his monograph: Mandatory Motherhood: The True Meaning of "Right to Life". He also presented a scientific perspective on this topic in a BioScience article entitled "Some Biological Insights into Abortion."

As a measure of his success in presenting biological themes to the public at large, a poll taken by Friends of the Earth in the early 70's, revealed Hardin as "the single author who had the most different titles mentioned by voters." His efforts to explain the intertwined and causative nature of impacts on an ecosystem led to the popular aphorism: "You can never do just one thing." This concept has strongly influenced the nature of public policy analysis about environmental protection over the last decade.

Hardin has remained active in retirement, serving as Chairman of the Board and Chief Executive Officer of the Environmental Fund and traveling widely to lecture. His scheduled plenary address at the August Amherst meeting will be subsequently published in BioScience.

Founded in 1947 as a component of the National Academy of Sciences, AIBS became an independent, Washington based Institute in 1955. Today it is a federation of over 40 professional societies and research laboratories representing more than 70,000 biologists nationwide. The organization is devoted to advancing the basic biological, medical, environmental, and agricultural sciences and their applications, through research and education, to human welfare. Its government relations, publications, and award activities are focal points for national interest in the life sciences. The Institute assists various government agencies including the Agency for International Development, the Environmental Protection Agency, the Department of Defense and the National Aeronautics and Space Administration with studies, reviews, evaluations, and policy planning in the life sciences.

INTEGRATING CORE COMPETENCIES INTO GENERAL BIOLOGY

by Dr. Rosalie Kramer, Indiana University East
presented at Hoosier Association of Science Teachers, Inc.
Annual Meeting, February 15, 1986, Indianapolis, IN

Several problems are apparent in curriculum development at a small commuter campus. The lack of sufficient numbers of students prevents offering separate sections of introductory courses for both majors and nonmajors. Students are often part-time students, who work full or part-time and have families. Their educational goals are extremely pragmatic and job-oriented. Thus they tend to avoid basic skills courses such as writing and mathematics or put them off until after taking several other courses. This puts them at a disadvantage in many of their courses. Finally, some professional programs require sophomore-level science courses for their students, but do not mandate any introductory or prerequisite course-work in the area.

Because of these characteristics and problems, students often were not successful in the science courses in which they were enrolled.

The biology department at Indiana University East addressed the above concerns in several ways.

The first was to formally require a prerequisite course of general biology and/or chemistry for almost all other courses in the biology department.

Secondly, it was decided to redesign the introductory course in biology so that it met the needs of both majors and nonmajors.

The final step was to incorporate certain desirable basic skills or core competencies into the structure of the course. L107, Biological Concepts in a one-semester, five credit hour lecture-laboratory course.

The relatively easy part of this project was the identification of content areas to be included. The faculty in the department designed a course which was basically divided into four sections: (1) basic chemical processes necessary for an understanding of biology; (2) cell structure and physiology, including cell reproduction; (3) concepts of inheritance; and genetic principles, and (4) ecological principles and mechanisms of change (evolution).

It was felt that the above four areas would provide majors and non-majors alike with the fundamental concepts to move successfully into more advanced courses. In addition, the topics included are central to an understanding of biology, and students who take no other science course would have been exposed to the major biological concepts that impact their lives and the world in which they live.

The most difficult part of the course development was the identification and inclusion of basic skills and competencies into the course. We fought the battles of traditional labs and lab techniques (because it has always been done that way) vs. inquiry technique, vs. almost no lab content at all.

After hours of debate, the following skills (competencies) were identified for inclusion in the General Biology Course. (This list is not all inclusive, but no single course can provide every aspect of education to a group of students.)

1. The ability to identify, analyze, and solve problems.
2. The ability to find and retrieve information.

3. The ability to communicate, through a variety of modes, information to other individuals.

4. The ability to perform basic laboratory skills at an acceptable level and to understand the principles behind them.

5. The ability to use mathematics and simple statistics as tools for interpretation of data.

6. The ability to utilize computers as a learning aid and as a means of collecting and manipulating data.

7. The awareness and appreciation of living things and the world around us.

8. The realization that science can be enjoyable and is not something to be feared.

The final step in the procedure was to incorporate the above competencies into the course and to integrate them into the curriculum.

The following are some of the ways in which this was accomplished:

1. Problem solving skills - Here we are talking about scientific method. The skills of observing, predicting, collecting and interpreting data, drawing conclusions, and forming hypotheses. A series of labs are used which require the collection and sharing of large amounts of raw data. Students must then interpret the data and form valid conclusions from these. Often students will be required to transfer the knowledge to some other situation or set of conditions. Labs are designed to coordinate with all the content areas of the course. Two labs deal with observation and inference specifically.

Students are required to write and turn in formal lab reports for 3-5 of the labs done during the semester. Other labs are evaluated by use of laboratory quizzes. All labs and the

conclusions drawn are discussed in class.

2. Information retrieval skills: To accomplish this goal, students are required to abstract 10 articles from current, reputable journals. These are divided evenly over the topics covered in the course. Students are given a library orientation by the public services librarian and provided with a list of appropriate available journals. This accomplishes two things. It gets students into the library and the literature, and improves their information gathering and critical analysis skills.

3. Communications Skills: The journal abstracts mentioned before play an important part in teaching students methods of clear, concise written communication. In addition, lab reports require students to organize their thoughts so as to effectively communicate results. Several of the labs require groups of students to work together and then to share data (often with the entire class.) This involves clear oral communication skills. They learn very readily that there is much to be gained through spending five or 10 minutes discussing and organizing lab work before beginning. We also do a mystery bag lab, designed to teach students how to communicate clearly with others.

4. Basic Laboratory Skills: Here students are exposed to various techniques such as microscopy, measuring, sketching, preparation of materials needed, measuring, making slides, etc. through a series of labs. For example, the chemistry labs stress accurate measurements, while the cell labs require students to develop good microscope habits, make slides, and sketch what they see.

5. Mathematical Skills: Students carry out lab experiments relating to chemistry which require accurate measurement, computation of amounts and

percentages of solutions, and simple mathematical evaluations of data. Graphing is stressed as a means of mathematically presenting data in all lab reports. A population lab requires students to use simple statistics to determine goodness of fit of sets of data collected.

6. Computer Literacy: Students are introduced to computer management of large pieces of data through a coin-flip lab which simulates flipping 1, 2, or 3 coins up to 5000 times. This semester we have added some C.A.I. modules dealing with genetics to give students more experience using microcomputers and manipulating data as well as using them to practice genetic problems and to review concepts.

7&8. Awareness and appreciation of Life, The Enjoyment of Science, and the Lessening of Science Anxiety.

These are somewhat intangible goals that the faculty strive to achieve in a variety of ways. Interesting applications are used liberally as examples during lecture. Films over various habitats and biomes introduce students to areas of the world which may be new to them. Encouragement and timely feed-back play important roles in alleviating anxiety. Students are allowed to do some work over (i.e., abstracts) if they do not do well the first time through. Faculty strive to help students "discover" biology and its basic concepts by being enthusiastic, encouraging and questioning.

The General Biology course at Indiana University East offers students a solid grounding in both biological concepts and important basic skills which will serve them through out their college careers and their lives.

**DELETION MAPPING OF GENETIC "FINE STRUCTURE":
SUPPLEMENTING AD HOC PROBLEM SOLVING APPROACHES WITH ALGORITHMS AND HEURISTICS**

by

John R. Jungck, Dept. of Biology, Beloit College, Beloit, WI

and

Vince Streif, Computer Center, University of Wisconsin-Eau Claire, Eau Claire, WI

INTRODUCTION

The transmission of a realistic analysis of the history of biology is exceedingly important in understanding the context of discoveries, and the personal, psychological, sociocultural, and political matrix in which ideas emerge and are propagated. Biology education typically duplicates the historically important process which led to the discovery of the phenomena under consideration. However, as valuable as these lessons are, the extension of historically employed methods of problem solving may not be most appropriate in the education of students in contemporary laboratory practice.

We argue here that it is frequently important to re-examine tried and true methods of scientific problem solving to see if (1) more efficient and robust procedures can be constructed or borrowed from other fields, and, (2) more pedagogically sound procedures can be developed which provide greater clarity and chance of achieving success on the part of students. We believe that (1) and (2) are intimately connected.

To this end, I (JRJ) have been examining (for the last 15 years) a number of problem solving techniques widely used in genetics, evolution, biochemistry and developmental biology (four courses which I teach frequently). The intent is to help students with techniques and processes which each year a significant number of students have considerable difficulty comprehending and using. We report here a case which has been nicely susceptible to reanalysis and has been successfully used in classrooms for nine years,

namely the deletion mapping of genes. After going through the traditional ad hoc solution which is taught in basic genetics textbooks, we will describe two alternative approaches to solving such problems. We assert that both alternative approaches have several advantages compared to the traditional approach.

RELEVANCE OF NEW MATH TO BIOLOGY

Mathematics has not been stressed in the biology curriculum. The usual reasons given for this are that biology students have difficulty in studying mathematics, few biologists have a broad background in mathematics and mathematics is not fundamental to an adequate biological understanding. We counter that students are frequently not enamoured with mathematics because they (1) feel mathematics is neither relevant to their own lives or biology, (2) are left out when pedagogy of the type: "It is intuitively obvious that" or "Anyone could show in a simple number of steps", are exercised on them, and (3) are selectively screened on the basis of gender and other personal characteristics as possessing mathematical prowess. All three of these subjects abound in the mathematics education literature. Less frequent in the literature is the simple observation that (4) calculus was developed for and by physicists, not biologists and (5) that calculus is not always the most useful tool in college biology. Most of the mathematics presented in this paper has been developed in the last 20 years.

Most biology students that take first year college calculus do not use it in their first two years of college biology. In fact, many textbook authors

bend over backwards to avoid the inclusion of mathematics in areas of biology where it is used routinely at the professional level. Seymour Papert has gone so far as to state:

Giving students the most powerful instruments of composition offers children an opportunity to become more like adults, indeed like advanced professionals, in their relationship to their intellectual products and to themselves. In doing so, it comes into head-on collision with many aspects of school whose effect, if not whose intention, is to infantilize "the child."

(Schwartz, 1983)

Furthermore, our personal experience is that when we have introduced alternative methods to those presented in textbooks, students respond frequently that (1) they didn't know math was and is appropriate to biology, (2) the methods become the ones of choice as the complexity of the problems increase, and (3) they are frequently surprised that (as such is the case in this paper) different kinds of mathematics can be employed on a problem and all provide equivalent results.

PEDAGOGICAL RATIONALE

Elsewhere I (Jungck, 1985) have argued that teaching frequently leads to research questions. When students have trouble understanding a concept, to what degree does our (the teachers') familiarity with the shared paradigms of our discipline blind us from seeing the lack of cohesion or the presence of intuitive leaps within our methodology. I, therefore, see learning roadblocks as an incentive to explore alternative approaches to these problems.

The development of algorithms and heuristics to solve problems has a number of other merits:

(1) Thomson and Stewart (1985)

note that the development of algorithms makes each step in obtaining a solution highly explicit. Therefore, the instruction of knowledge is not hidden; it is available to all for scrutiny.

(2) Algorithms can be employed diagnostically. There is a rich literature on students' conceptions of science which they bring to the classroom (cf: Driver, 1983; Siegler, 1983; Brumby, 1984; Fisher, 1985; Osborne & Bell, 1983; and Kinnear, 1985). Successful teaching may involve the ability of the teacher (i) to infer the kinds of rules that students are employing to interpret their experience and to solve presented problems, in order to (ii) challenge those beliefs with empirical counterexamples.

(3) Algorithms fail when faced with new problem domains or with steps of great computational complexity (e.g., NP-complete problems). This is an asset in education. Unsolved problems should be a motivating factor to students. If turn the crank algorithms do not exist for all problems, then imagination, intuition and industriousness of scientists can contribute to science. Secondly, since many NP-complete problems do not hinder all science from proceeding, we might infer that humans are processing information, recognizing patterns, and solving problems in ways unlike contemporary computer programs in their execution.

(4) Both humans and computers can employ heuristics which, while they do not have the same guarantee of results as algorithms, do provide a "rule of thumb" for a way to proceed and usually have known cases where they are likely to fail. Thus, the use of judgment (with aesthetic and other values involved) in decision making is an explicit opportunity to students.

(5) If satisfactory algorithms and heuristics can be articulated for solving particular kinds of problems, computer analogs can be tested for:

- (a) Efficiency
- (b) Speed
- (c) Robustness
- (d) Reliability
- (e) Memory requirements
- (f) Iterative processes

The development of working computer "solvers" is an empirical demonstration of the methods' abilities in solving the problems in a finite number of well described operations. Also, such programs immediately become a labor saving device in the field or laboratory because once you are sure that your data is of a given problem-type, the computer cannot only store the data, but analyze it as well. Furthermore, if ambiguities or inconsistencies appear in the data, appropriate theorem checks can be employed to detect and highlight them to the scientist. Finally, students using such programs can not only get beyond the process of solving a problem, they can use experience with many sets of data to develop a more robust intuition about subtleties of differently posed problems and complex patterns in the context of specific problems.

GRAPH THEORY IN BIOLOGY

In 1968, Joshua Lederberg stated that he hoped the applications of graph theory he found "could make it (organic chemistry) much easier for students to learn basic principles and to solve vexatious problems of classifying chemical compounds so that computers could be more readily applied to retrieve chemical information. It may be a forerunner of similar mathematical simplifications that will be applied to chemical genetics...". In a series of earlier papers, we illustrated the utility of graph theory to several problems in genetics, such as analysis of pedigrees, determination of inbreeding coefficients (Bertman and Jungck, unpublished); systematization of the properties of the genetic code (Bertman and Jungck, 1978, 1979; Jungck, in

press); protein and nucleic acid sequencing (Jungck, Dick & Dick, 1982). Graph theory is a non-numerical branch of modern mathematics considered part of topology, but also closely related to algebra and matrix theory (Ore, 1963). It has already made substantial contributions to biology in the area of taxonomy (Estabrook, 1968; Sneath and Sokal, 1973; Fitch, 1977; Penny, 1982) and ecology (Cohen, 1978). (Also see a nice high school paper on graph theory by Chartrand and Will, 1980.) Graph theory has great instructional utility because of the diversity of applications which can be learned without concomitantly learning a tremendous amount of sophisticated computational procedures.

Subsequent to our earlier effort, we learned about Gilmore and Hoffman's (1964) solution to the "Benzer problem" as it was discussed in two general texts on graph theory (Roberts, 1976; Busacker and Saaty, 1965). Benzer (1962) presented a method for the rapid mapping of point mutations, without resorting to numerous three point crosses (the classical method; for pedagogy see Mertons, 1972), by employing overlapping deletions. The construction of topological maps of deletion mutants has become a common exercise in genetic problem books (e.g., Stansfield, 1969, p. 219; Kuspira and Walker, 1973, pp. 505-508) and genetic laboratory manuals (e.g., Snustad and Dean, 1971; Hudock, 1967). The purposes of this paper are to present two alternative instructional stratagems for teaching about Benzer's fine structure analysis of the gene and classical complementation mapping in a formal axiomatic fashion and, secondly, to present an algorithm for computerized determination of solutions to such problems from raw data. One benefit of the algorithm, besides allowing automatic reduction of vast amounts of data, is that it further reduces the solution to a variety of genetics problems to a series of elementary steps which can be easily understood by the neophyte geneticist.

TRADITIONAL AD HOC SOLUTION

Rather than discussing Benzer's problem abstractly, let us examine a concrete example and then compare the solutions of Benzer (1959) and Gilmore and Hoffman (1964). Readers unfamiliar with the genetic mapping experiments are referred to Benzer (1961). Generally, we can explain these experiments by indicating that mutations in a chromosome which overlap will not be capable of recombining to form a prototroph while nonoverlapping deletion mutants can recombine to form prototrophic recombinants (+) or the absence of prototrophic recombinants (0). Stansfield (1969) presents the following data (p. 213) from such an experiment:

Table I. Data from a "Benzer experiment"

	1	2	3	4	5	6	7
1	0	+	0	0	+	0	0
2		0	0	0	+	+	0
3			0	0	+	+	0
4				0	+	0	0
5					0	0	0
6						0	0
7							0

The matrix elements could be completely filled in; however, because of symmetry around the diagonal, this process would only provide redundant information. Secondly, the diagonal is unnecessary information because no deletion mutant can recombine with itself to form a prototroph.

Traditionally, to begin to solve this problem, Row One is analyzed for overlaps because it contains the most information of any of the rows. Thus, since Deletion Number 1 overlaps with 3, 4, 6 and 7 (because they all have zeroes

in the matrix) and does not overlap with Deletion Numbers 2 or 5, we can draw the following map of the deletions (Figure 1).

In each successive step, this topographic map is modified by shortening or lengthening each of the lines (as required) representing a deletion or, in some cases, literally transposing a deletion line to the right or left.

If we proceed to the next steps, we see several such modifications. Thus, in analyzing Row 2, Deletion 5 has to be moved completely and Deletions 3, 4 and 7 have to be elongated (Figure 2).

Conversely, shortening of Deletions 6 and 3 is necessary after examining Row 3 (Figure 3).

Luckily, Row 4 does not require any modification of our topograph. On the other hand, the data in Row 5 requires substantial revision; we must now transpose Deletion 5 all the way to the left and extend both Deletions 6 and 7 to the left accordingly to now overlap Deletion 5.

Similar to the case of Row 4, neither the data in Row 6 or Row 7 (a diagonal element only) necessitates modification of our topograph. It should be noted in passing that the absolute length of any deletion line is arbitrary and that we do not have any reason for assigning the overall left-right orientation. This traditional ad hoc solution of "Benzer's problem" did not allow a student to process a given piece of information only once. In order to solve a problem this way, the student must conscientiously retrace all her previous steps at each successive step. Thus, as above, this frequently involves multiple lengthening, erasing, and transposing different deletion lines. In addition, this usually requires a fabulous memory of what you've done before and/or constant rechecking. Furthermore, the arbitrary lengths of lines yield

solutions that are not parsimonious. More intervals of the linear chromosome may be illustrated in a solution than are defensible based solely on the original matrix of data.

A GRAPH THEORY ALGORITHM

Roberts' (1976) graph theory solution of the "Benzer's problem" avoids these potential sources of error. Let us begin by representing each mutant by a vertex in a graph (Figure 5a). Then we can process all the data in Table I row by row in a continuous series of steps, without any erasures or backtracking, by simply connecting any two vertices representing overlapping deletions with an edge; i.e., we construct the intersection graph equivalent to Table I (Figure 5b). Second, we construct the complement of the intersection graph by placing edges between all the vertices not connected in the intersection graph (Figure 5c).

Now we are at a point in a solution where we can check to see if the original intersection graph is, in fact, consistent with the expectations of a linear genetic map. First, the intersection graph should contain no Z4's (Figure 6) which are four vertices connected together into open squares with no diagonals.

On checking Figure 5 (b), we see that it does not contain any Z4's and, therefore, Figure 5 (b) is a legitimate graph of an overlapping deletion experiment according to this criterion.

Secondly, the complement of the intersection graph (Figure 5c) should be capable of being made transitive. Most readers are familiar with the transitive relationship: if $a < b$ and $b < c$, then $a < c$. In graphs, a closed loop is transitive if $a \rightarrow b$ and $b \rightarrow c$, then $a \rightarrow c$ also (Figure 7).

Since both criteria are shown to hold for the data in this example, we are

thus assured it is worth proceeding to solve the problem. The next step is to find all the maximal cliques (synonyms: complete subgraphs, universal graphs, cliques) of the original intersection graph (Figure 5b). Cliques originally referred to exactly what the reader might first construe them to mean; namely, a group of n persons who all speak to one another (Festinger, 1949). Thus, a maximal clique is the largest subgraph in a graph in which all the vertices are connected by edges. There are four maximal cliques in Figure 5b (see Figure 8).

Thus, in this example there are four maximal cliques and each vertex was contained in at least one maximal clique. Next we order these maximal cliques in the same order as the direction between noncommon vertices of two maximal cliques in the transitive complement of the intersection graph (refer back to Figure 7). Thus, for example, Vertices 1 and 2 are not common to maximal cliques A and B and are connected $2 \rightarrow 1$ in Figure 7; therefore, we say the order of the maximal cliques is $B \rightarrow A$. By applying similar reasoning to all the maximal cliques, Figure 9 (a) can be obtained.

The penultimate step in the solution is to find the Hamiltonian path connecting all the maximal cliques. A Hamiltonian path is a path connecting all of the vertices, but traverses through any one vertex only once. In Figure 9 (a), it is very easy to see that B has all outgoing edges and thus must be a beginning point of the Hamiltonian path. Also, since D has all incoming edges, it must be the end of the Hamiltonian path. Therefore, the Hamiltonian path shown in Figure 9 (b) emerges easily.

Finally, we now are able to construct the interval graph equivalent to that shown earlier in Figure 4. We simply construct a line with the maximal cliques ordered in the same relative sequence as their Hamiltonian path and

then each deletion will overlap those maximal cliques of which it is a vertex. Thus, Figure 10, produced in this way, is topologically equivalent to the topographic map of the deletions, seen in Figure 4, produced by the traditional solution method.

Inspection shows that the only difference between Figures 4 and 10 is the left-right orientation which was arbitrary anyway and the ambiguity of the lengths of lines in Figure 4. Figure 10 has four intervals of deleted regions of the chromosome and is a parsimonious solution. Although the graph theory solution to "Benzer's problem" seems longer than the classical solution, it has the three distinct advantages of (1) depending on a formal series of logical steps which can be axiomatized, of (2) being adaptable to automatic processing on a computer, and of (3) producing a parsimonious solution. To reiterate the steps involved in the graph theory solution of "Benzer's problem", for easy reference, the steps are laid out in Table II.

Table II. Steps in the graph theory solution of "Benzer's problem"

1. Convert each deletion mutant into a vertex.
2. Construct the intersection graph by placing an edge between each pair of vertices which represent overlapping deletions.
3. Construct the complement of the intersection graph.
4. Check for absence of Z_4 's in the intersection graph.
5. Determine whether the complement of the intersection graph can be made transitive.
6. Find all the maximal cliques in the intersection graph.
7. Order these maximal cliques in the same way as in the transitive complementary graph.
8. Find the Hamiltonian path of all the ordered maximal cliques.

9. Construct the interval graph by assigning deletions to each interval of the line, which sequentially orders the maximal cliques, for all the cliques to which the deletion vertex belongs.

Thus, the algorithm is capable of processing the original recombination matrix data through each of these nine steps.

A HEURISTIC SOLUTION

However, let us reconsider the original problem (Table I) in a different way. In 1965, Shkurba developed a matrix manipulation to a canonical form which allowed an analysis of Ger-shenzon's "hypothesis that supplementary nutrition of *Drosophila* larvae with preparations of DNA caused mutations which affect whole sections of the chromosome." We can easily see that this biological problem is exactly equivalent to the "Benzer" problem. Therefore, let us consider Shkurba's solution because we contend that by considering the 3 kinds (ad hoc, algorithmic, and heuristic) of solutions to topological mapping of genes, we will offer students multiple ways of understanding problem solving. The first step in Shkurba's solution is to convert the matrix as displayed in Table I to the fully symmetrical form and to use blocked out cells in the matrix rather than zeroes and ones because it is easier to visualize when one has reached an appropriate canonical form of the matrix which he refers to as possessing the "basic property".

At this point, we will alter from our previous process by presenting Shkurba's answer first and then returning to an analysis of the process whereby he arrived at his conclusion. We will use the same example as before. First, table I is easily completed to make a fully symmetrical matrix as seen in Figure 11.

Second, try to gather all the black squares about the diagonal in

order (1) to minimize the moment of the matrix and (2) to make sure that no squares are unattached to other squares by less than a full side. Furthermore, Shkurba says that (3) all arrowheads should be pointing toward the same corner of the matrix. These three conditions, if they can be satisfied, represent the conditions for constructing an interval graph of the deletion mutants. Thus, if we rearrange rows and columns in Figure 11, we see that the conditions are approached if we interchange the order of 5 and 6 mutants (Figure 12).

Only one additional third step is required in this case to draw all the black squares together and satisfy the conditions for the "basic property"; this is simply achieved by inserting mutant 1 between mutants 4 and 6 in Figure 12 (see Figure 13).

We can easily see that the diagonal can be represented as four overlapping blocks (Figure 14).

Now it is a trivial problem to assign a mutant to an interval corresponding to the block (and only that block or blocks) to which it belongs (see Figure 15).

Figure 15 is isomorphic with Figure 10. The overlapping blocks in Figures 13 and 14 correspond exactly to "maximal cliques." Shkurba is able to present an algorithm employing the theory of partially ordered sets; however, we want to use his "basic form" to illustrate the power of heuristics. While heuristics are thought to be weaker methods than algorithms, for simple problems such as occur in undergraduate textbooks, our students usually preferred the Shkurba method over the other two because by a little trial and error they could quickly convert a data matrix into the "basic form." Students have quite powerful pattern recognition experience and they find it easy to check their progress towards a "basic form" solution to such problems. However, if the

matrix is extremely large, most students prefer to use the graph theoretic algorithm.

CONCLUSION

Biological problem solving can be taught in three different ways: (1) Historically based; i.e., by simply presenting the way a famous scientist solved a particular type of problem for the first time; (2) Algorithmically; i.e., by employing a mathematical technique which explicitly lays out each step to take in a solution path; and (3) Heuristically; i.e., by a rule of thumb or weak method which is likely to lead to a solution. We have illustrated each of these three approaches to a specific problem; namely, the deletion mapping of genes.

We believe that students have much to gain by learning the two new approaches described. First, they will learn powerful techniques which can easily be used to solve similar problems. For each, interval graphs can be used to sequence proteins (Jungck, Dick, and Dick, 1982), nucleic acids, complementation groups in genetics, food webs and niches, archaeological layers, preferences in psychological series or preferences in tastes, etc. By moving from a line to a circle, circular genetic maps, restriction maps, and boxity in food webs can be understood.-

Second, by replacing an ad hoc technique with more general mathematical techniques, biologists will be better able to communicate with mathematicians. Especially with the availability of computers, it is easier to employ these powerful methods in laboratory analysis of data. If data can be rapidly analyzed, particular genetic crosses can be identified which may violate the linear chromosome hypothesis if a Z4 arises. Also, when extremely large data sets are obtained, the computer program can be employed to check results.

Third, the conditions stated explicitly in an algorithm can be used to discuss what happens when they are violated. Thus, circular genetic maps, overlapping genes, and when one gene's intron is another gene's exon all violate the assumptions of the algorithm presented herein. Students can see that such violations are illustrative of new genetic phenomena and are not simply the fault of poor experimental technique.

We have developed two computer programs in BASIC on a Tektronix 4052 related to this paper. First, one program will generate "Benzer" problems with as many deletion mutants and intervals as the user specifies. This program offers many more opportunities for students to develop their skill than exist in any textbook or book of problems. Second, another program will draw the intersection graph and the complementary graph on a Tektronix 4662 plotter for any intersection matrix which is input. Both program lists are available upon request.

ACKNOWLEDGMENTS:

The teaching of Martha O'Kennan (previously Bertman) and the collaboration of B. Dennis Sustare were essential to the development of the ideas in this paper. Figures 1 through 10 were previously published in Jungck, Dick and Dick, 1982. Gregg and Amy Dick developed the Hamiltonian path technique described herein. Discussions with James Stewart and Angelo Collins at the Department of Curriculum and Instruction, University of Wisconsin - Madison, were important in developing the articulation of the ideas. Also, many, many students in genetics classes at Clarkson University and Beloit College were exceedingly helpful in pushing us to develop these ideas in a more understandable fashion. All of this help is greatly appreciated.

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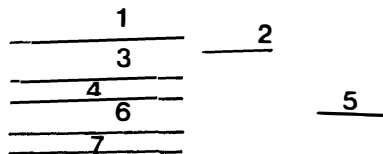


Fig. 1. Topograph of row 1, Table 1.

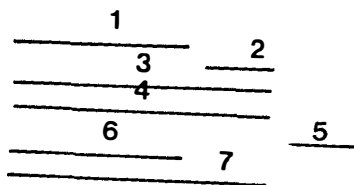


Fig. 2. Topograph modified by row (Table 1) data.

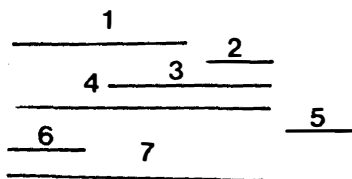


Fig. 3. Topograph modified by row 3 (Table 1) data.

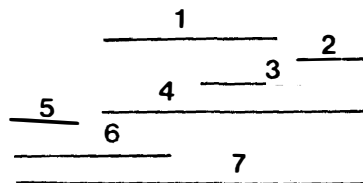


Fig. 4. Topograph modified by row 5 (Table 1) data.

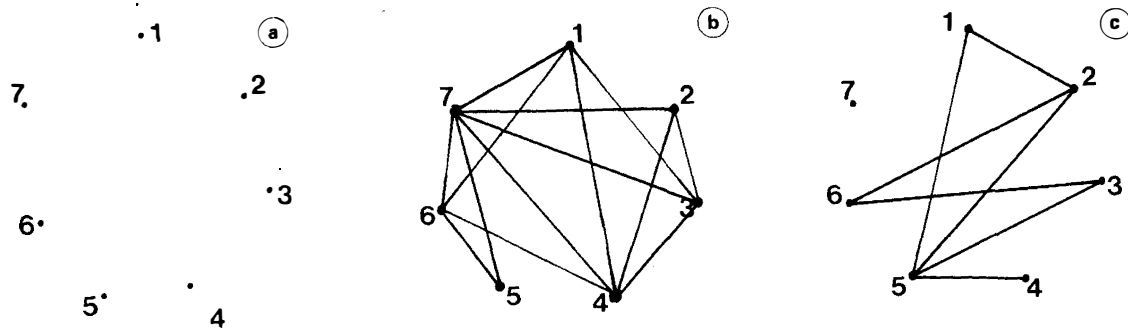


Fig. 5. (a) Seven vertices which represent the seven peptides employed in Table 1. (b) Intersection graph of Table 1 data on the vertices shown in (a). (c) Complementary graph of the intersection graph shown in (b).

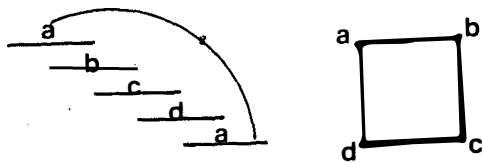


Fig. 6. The successive overlapping of the four fragments on the left are represented by the intersection graph, a Z_4 , on the right. Such representations imply a circular structure.

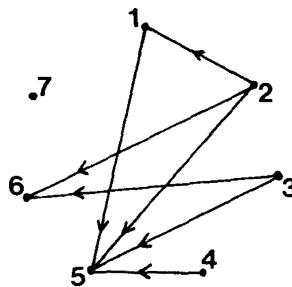


Fig. 7. Transitive orientation of the complementary graph illustrated in Fig. 5c.

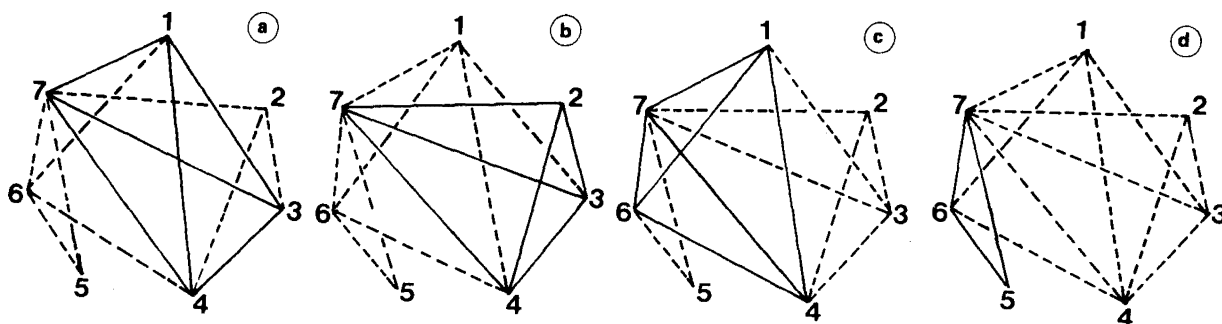


Fig. 8. The four maximal cliques contained in Fig. 5b. Each maximal clique is outlined in solid lines. (a) Maximal clique A contains vertices 1, 3, 4 and 7. (b) Maximal clique B contains vertices 2, 3, 4 and 7. (c) Maximal clique C contains vertices 1, 4, 6 and 7. (d) Maximal clique D contains vertices 5, 6 and 7.

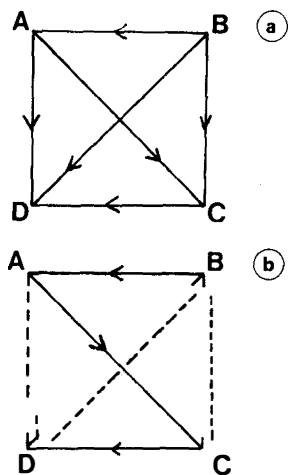


Fig. 9. (a) The order relationships between the maximal cliques shown in Fig. 8. (b) The Hamiltonian path in Fig. 9 (a) is shown in solid lines ($B \rightarrow A \rightarrow C \rightarrow D$).

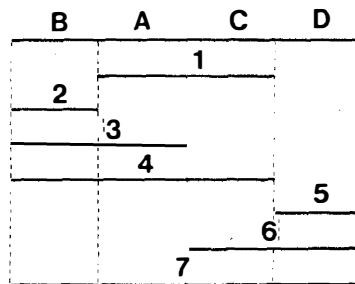


Fig. 10. Interval graph of the deletions (1 through 7) overlapping the four maximal cliques (A through D) ordered on a Hamiltonian path.

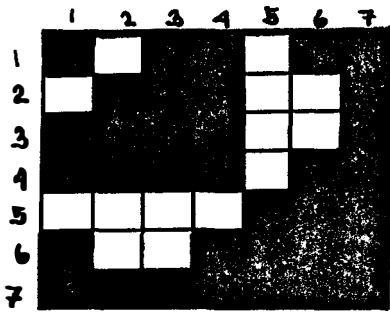


Figure 11. Symmetrical matrix for the data in Table I.

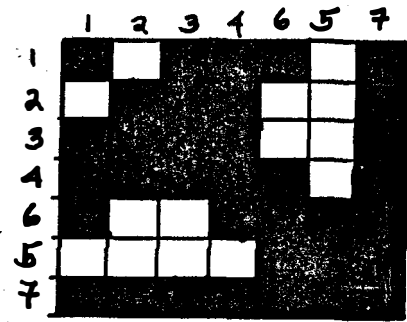


Figure 12. A rearrangement of Figure 11 which has mutants 5 and 6 interchanged in the sequence of their rows and columns.

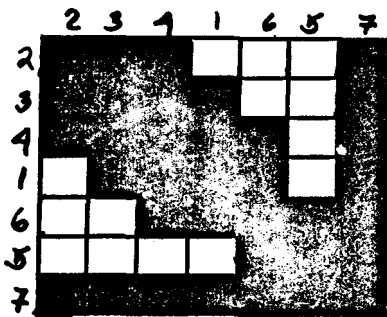


Figure 13. Matrix form of Table I which has Shkurba's "basic property"; achieved by inserting mutant 1 between mutants 4 and 6 in Figure 12.

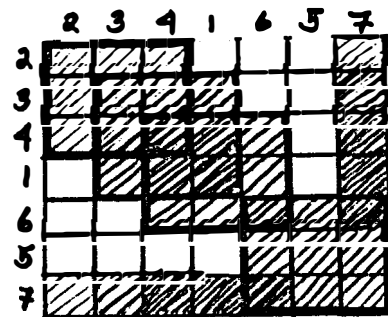


Figure 14. The four overlapping blocks contained in matrix form depicted in Figure 16.

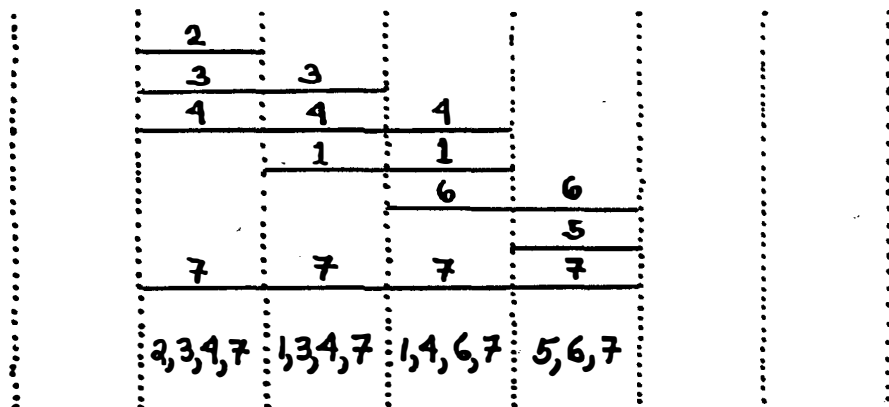


Figure 15. The interval graph determined by the Shkurba (1965) method on the same data employed throughout this paper. Each block in Figure 14 is given one interval on a line and the mutants are represented by lines extending over each interval (block) of which they are a member.

```

100 REM **BENZER'S PROBLEM**
110 DIM A(20,20),B(20),C(20)
120 A=0
130 B=0
140 C=0
145 PRINT "ENTER DEVICE NUMBER OF OUTPUT";
147 INPUT Q
150 PRINT "LIBENZER'S PROBLEM__How many mutants? MAX=20 ";
160 INPUT N
170 IF N<0.5 OR N>20.5 THEN 150
180 PRINT "Enter 0 if deletions overlap; Enter + if two strains ";
190 PRINT "can recombine and yield wild type._"
200 PRINT "J-----KHH ";
210 FOR I=1 TO N
220 PRINT " ";
230 PRINT USING 240:I
240 IMAGE 2DS
250 PRINT "HHHJ---K";
260 NEXT I
270 PRINT
280 FOR J=1 TO N
290 PRINT
300 PRINT USING 310:J;
310 IMAGE 2d," ",s
320 FOR I=1 TO J
330 IF I=J THEN 360
340 PRINT " ";
350 NEXT I
360 PRINT "0 ";
370 IF J=N THEN 470
380 FOR I=J+1 TO N
390 GIN X,Y
400 INPUT A$
410 PRINT @32,21:X,Y
420 IF A$="0" THEN 440
430 A(J,I)=1
440 PRINT " ";
450 NEXT I
460 NEXT J
470 REM **SUBDIVIDE CIRCLE**
480 SET RADIANS
490 R=25
500 FOR I=1 TO N
510 T=-(I-1)*2*PI/N+PI/2
520 B(I)=R*COS(T)
530 C(I)=R*SIN(T)
540 NEXT I
550 REM **PRI PTS. & LABELS**
560 PRINT "LINTERSECTION GRAPH OF BENZER'S EXPERIMENTS"
570 GOSUB 590
580 GO TO 680
590 FOR I=1 TO N
600 X=B(I)+65
610 Y=C(I)+50
620 PRINT @Q,21:X,Y
630 PRINT @Q,20:X,Y
640 PRINT @Q,21:X+B(I)/5-1,Y+C(I)/5
650 PRINT @Q:I
660 NEXT I

```

```

670 RETURN
680 REM **CONNECT INTERSECTIONS**
690 FOR J=1 TO N-1
700 FOR I=J+1 TO N
710 IF A(J,I) THEN 740
720 PRINT @Q,21:B(J)+65,C(J)+50
730 PRINT @Q,20:B(I)+65,C(I)+50
740 NEXT I
750 NEXT J
760 PRINT @Q,21:0,10
770 PRINT "PRESS return TO CONTINUE: ";
780 INPUT B$
790 REM **DRAW COMPLEMENTARY GRAPH**
800 PRINT "LCOMPLEMENTARY GRAPH"
810 GOSUB 590
820 FOR J=1 TO N-1
830 FOR I=J+1 TO N
840 IF NOT(A(J,I)) THEN 870
850 PRINT @Q,21:B(J)+65,C(J)+50
860 PRINT @Q,20:B(I)+65,C(I)+50
870 NEXT I
880 NEXT J
890 PRINT @Q,21:0,10
900 PRINT "PRESS return TO CONTINUE: ";

```

**A RESEARCH-ORIENTED HONORS PROGRAM FOR UNDERGRADUATE BIOLOGY STUDENTS
AT WESTERN ILLINOIS UNIVERSITY**

Paul M. Nollen, Dept. Biological Sciences, Western Illinois University

An honors program for undergraduate students originated in the College of Arts and Sciences at Western Illinois University in 1975. From a very humble beginning this program has burgeoned into a university-wide organization. All of the six colleges within the university now participate in the honors program and most departments have an advisor for honors students. In general two types of honors programs were established. One of these, called general honors, involves taking a specific number of in course honors credits where students do extra work, usually extra writing, in regularly scheduled courses. The second, called departmental honors, are programs designed by departments utilizing specialized courses only for honors students. Most of these have some research component that culminates in an honors thesis. The Department of Biological Sciences was one of the first departments to design a program to fit into the guidelines for departmental honors. The staff of the biology department opted for a research-oriented program with students being supervised by faculty mentors. This close student-faculty relationship was designed to foster an atmosphere more like the small college situation but also giving the students a greater variety of research areas because of the larger staff at a medium-sized university like WIU. This program, established in 1978, has graduated 43 honors students and now has 13 junior and senior biology honors students enrolled (Table 1). It is recognized as the most successful program in recruiting and graduating honors students of any department on campus.

The biology program is a two-year plan of study usually taken during the junior and senior year by students with a 3.5 GPA or better (Table 2). During the junior year, students select a

research project, carry out background reading, write a grant proposal for support, and give a presentation to the other honors students on their project. All of this is accomplished in two, one-hour seminars.

The first seminar, taken in the fall semester, is made up of weekly presentations by biology staff who have projects available for honors students. At the present time, approximately half of the department faculty, representing a good cross section of disciplines, participate in the honors program. Toward the end of the semester the students rank the projects they would like to attempt in order of preference. As biology honors coordinator and seminar director, I match students with projects and advisors. Sometimes two students want the same project and second choices are assigned. However, in all but two or three cases students have been able to work with the project and advisor at the top of their list.

The second junior honors seminar is taken during the spring semester and involves the rest of the required work. The first few weeks of the semester are devoted to background reading on the individual projects. During this time, the students receive training in word processing for later use in writing reports and their honors thesis. In cooperation with their advisor, each student writes a grant proposal addressed to the University Honors Council for support of their research. Funding of up to \$200 is provided by the Honors Council, the Department of Biological Sciences, or the Institute for Environmental Management, which is located on the WIU campus. Some of these proposals have been funded by the Honors Council of the Illinois Region over the past 5 years. During the latter part of the semester, each student presents a formal

seminar to the other honors students explaining his or her project. This presentation includes background material, experimental methods, and expected results.

With all the necessary preliminary work out of the way including background reading and acquisition of support, the project is carried out during the first term of term of the senior year. In a few cases the projects extend into the final term, but this is the exception rather than the rule. Most projects are designed to be completed in a 16-week semester. Longer projects may be attempted but they usually must be started during the summer or even during the spring semester of the junior year. In all cases 3 hours of credit are given for the research project.

The final requirement for the biology honors program is the completion of an honors thesis based on the results of the research project. The Honors Committee of the department has set up guidelines for writing this thesis, which are patterned after the graduate thesis regulations. After being read for appropriate revisions by the advisor, the honors coordinator and a member of the departmental honors committee, the student defends the thesis in an oral examination. These exams take about an hour and are conducted by two members of the honors committee plus the advisor. After successful defense of the thesis, the student is awarded 3 hours of credit.

Students enter the departmental honors program by invitation from the honors committee. Each spring the committee scans the grade sheets of all the biology majors and invites those with GPA's close to 3.5 or better to join the program. Transfer students with honors credentials are hard to identify and the honors committee depends on the academic advisors to recommend these people for the program. Usually about half of those eligible enter the program. Some students are

not interested in research and others think it involves too much work. Actually the program fits in quite well with our regular curriculum for departmental majors. The research and thesis hours are taken in the place of electives and only the two hours of seminars are over and above the requirements.

The University Honors Council requires all honors students, whether they are taking general or departmental honors, to enroll in 6 hours of general honors courses. Several of these courses are offered each semester in various areas of social sciences or humanities and at all undergraduate levels. They provide a forum for honors students from various disciplines to interact in studying a subject usually uncommon to all. The students in the biological sciences use general honors courses to satisfy basic curriculum requirements and thus they are not additions to their plan of study.

The research projects undertaken by the honors students are not trivial pursuits or rehashed experimentation. In some cases the honors students work along with graduate students and many of the honors theses approach the standards expected of masters theses. In the area of ecology, several students have been included in the ongoing Long Term Ecological Research project on Illinois Rivers funded by NSF and jointly sponsored by the Illinois Natural History, Water, and Geological Surveys; Illinois State Museum; and WIU. These studies have concentrated on macrofauna of the Mississippi River benthos. Another student carried out his project in the Florida Keys, where he was serving as a scout camp counselor, on the web making characteristics of crab spiders in two different habitats. Two other projects involved studies on ecological parameters of man-made impoundments such as cooling and strip mine lakes.

In the area of genetics, projects were completed on genotoxicity and mutagenicity of various chemicals, such as air pollutants and pesticides, as determined by micronucleus assays on blood cells and mutation rates in Drosophila. One study involved an electrophoretic study of allozymes in various Drosophila populations.

Projects in physiology and cell biology have dealt with the effects of caffeine and alcohol on the fetal development of mice and cultures of mouse and chick fibroblast cells. Two projects on trophoblast-lymphocyte cross-reactive antigens in pigs and cows brought together the research talents of people from WIU and the SIU Medical School in Springfield as well as the cooperation of two local farmers.

In the area of microbiology, parasitology projects have concentrated on various aspects of the life cycle of an eyefluke that can be maintained in the laboratory in chickens. Behavioral responses of the miracidial stage including phototaxis, geotaxis, chemotaxis, and magnetitaxis were investigated. The project dealing with magnetic fields was carried out with the cooperation of the Physics Department and the results correlated well with what has been found for iron-containing bacteria - a positive north-seeking reaction. This was the first report on the influence of magnetic fields on any parasite. Bacteriology projects have centered around growth and plasmid studies on mouth-inhabiting bacteria and chemical characterization of insecticidal strain of free-living bacteria.

As documented above, our honors students have carried out a variety of projects not necessarily limited to the laboratories at WIU. Students have benefited from the cooperation of other departments and agencies within WIU and the State of Illinois. These projects have resulted in the presentation of 20 papers at scientific meetings ranging from regional to international in

scope. So far results from these projects have been incorporated into three published papers.

The WIU chapter of Phi Kappa Phi, a national honor society, sponsors an annual undergraduate research paper contest. In the last seven years, biology honors students have captured nine of the possible 21 first, second and third place awards. In 1985 our students made a clean sweep of the awards.

What advantages and rewards are available for the academically talented student who participates in the honors program? Official designation on the transcript and special recognition at graduation are one type of reward. On campus honors students may live on honors floors of dorms where study hours are regulated and interaction with other honors students is available. Computer facilities purchased especially for the honors students is another advantage of the program. During the school year, several social and cultural events are hosted by the University Honors Council for the honors students. Other less tangible things may be, in the long run, more valuable. Our honors graduates have been very successful in being accepted by professional and post graduate schools (Table 3). This may be partly explained by completion of the research projects. Many of our students have benefited from the in-depth letters of recommendation written by their research advisors. In many cases during interview sessions, the topic of discussion is dominated by the student's research project. One student credited her honors thesis as an important factor in her selection for a research position over other well qualified applicants. Finally, another less obvious but very important reward may be the satisfaction of completing a meaningful research project that is viewed as a useful contribution to science.

Table 1. Participation in the Biology Honors Program

Graduated Honors Students		Honors Students in Progress	
Year	Number	Year	Number
1978-79	7	1985-86	7
1979-80	3	1986-87	<u>6</u>
1980-81	6		13
1981-82	9		
1982-83	4		
1983-84	4		
1984-85	<u>10</u>		
Total	43		

Table 2. Outline of the Departmental Honors Program in Biology

Junior Year

First Semester

Honors Seminar--1 hour credit

1. Presentation of projects by departmental staff
2. Selection of projects and approval by advisor

Second Semester

Honors Seminar--1 hour credit

1. Background reading
2. Instruction in word processing
3. Preparation of a grant proposal to support the project
4. Presentation of a seminar on the project

Senior Year

First Semester

Honors Research--3 hours credit

Carry out planned research

Second Semester

Honors Thesis--3 hours credit

Write a thesis on the project and defend it in an oral examination

Complete at least 6 hours of general honors courses

Maintain a 3.5 GPA or higher

Complete all the other requirements for a major in botany, microbiology, or zoology.

Table 3. Post Graduate Study or Occupations of Honors Students

<u>School or Job</u>	<u>Number</u>	<u>School or Job</u>	<u>Number</u>
Medical School	21	Optometry School	1
Graduate School	7	Physical Therapy	1
Dental School	5	Respiration Therapy	1
Medical Technology	2	Sanitary Engineer	1
Research Labs	2	Peace Corps	1
Veterinary School	1		

STEERING COMMITTEE

		<u>MEMBERS AT LARGE</u>
PRESIDENT	- Ted Michaud Dept Biology Carroll College Waukesha, WI 53186- 414/547-1211x279(Off) 414/542-4307(Home)	3RD YEAR - Don Huffman Dept Biology Central College Pella, IA 50219- 515/628-5203(Off) 515/628-1573(Home)
PRESIDENT ELECT	- Jan Kemp Dept Biology Central College Pella, IA 50219- 515/628-5203(Off) 515/628-9409(Home)	Sr. Julia VanDenack Dept Biology Silverlake College Manitowoc, WI 54220- 414/684-6691x28(Off) 414/684-6691(Home)
1ST VICE PRESIDENT	- Malcolm Levin Dept Env Studies Sangamon State Univ Springfield, IL 62708- 217/786-6720(Off) 217/483-4803(Home)	2ND YEAR - Jerry Foote Dept Biology Univ Wis-Eau Claire Eau Claire, WI 54701- 715/836-3176 or-4166(Off) 715/834-5923(Home)
1ST VICE PRESIDENT ELECT	- Barbara Newman Biomedical Sciences Southwest Mo State Univ Springfield, MO 65802- 417/836-5300(Off)	Ingemar Larson Dept Biology Augustana College Rock Island, IL 61201- 309/794-7361(Off) 309/788-9668(Home)
SECRETARY	- Richard E. Wilson Dept Biology Rockhurst College Kansas City, MO 64110- 816/926-4048(Off) 816/361-3542(Home)	1ST YEAR - Gr. Marion Johnson Dept Science St. Xavier College Chicago, IL 60655- 312/779-3300(Off)
PAST PRESIDENT	- Ray Reed P.O. Box 1035 Jefferson Comm College Louisville, KY 40201- 502/584-0181(Off) 502/897-2373(Home)	Wallace R. Weber Dept Biology Southwest Mo State Univ Springfield, MO 65802- 417/836-5883(Off) 417/887-1383(Home)
EDITOR BIOSCENE	- William Doemel Dept Biology Wabash College Crawfordsville, IN 47933- 317/262-1400x219(Off)	EXECUTIVE SECRETARY- Edward S. Kos AMCBT CENTRAL OFFICE Rockhurst College Kansas City, MO 64110- 816/926-4049(Off) 816/333-9519(Home)

September 26 - 27
Thirtieth Annual Meeting
Association of Midwest College Biology Teachers
at
Sangamon State University
Springfield, Illinois
Theme
Biologists and Public Policy
Call for Contributions

Since SSU has been mandated as the Public Affairs Institution of the state of Illinois, it seemed appropriate to look at the contributions of biologists to public policy - the biologist as consultant, advocate, educator and researcher. This is our first call for presentations. We are especially asking for papers that focus on biologists as citizens who because of their special expertise and skills have much to contribute to public debate and to public policy issues such as the nature of science education, and the effects of new knowledge and techniques in biology on medical and ethical issues. What role should biologists play? For whom should we consult and how should we go about maintaining the "objectivity" of scientists in controversial social issues that hinge on biological knowledge?

Don't consider this request a limitation. Sessions on teaching ideas, laboratory techniques, computers as teaching and learning tools and curricular discussions are planned as well. Poster presentations are also encouraged.

Plan to participate in the 1986 meetings. You can begin that preparation now by sending in the following application.