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VEGETABLE INSECT PEST CONTROL WITH ENTOMOGENOUS NEMATODES

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ABSTRACT

Entomogenous nematodes are being studied as a potential biological pest control. The symbiotic bacterium contained within the nematode intestine is key to the damage and resulting death of the infected host insect. This paper includes a brief overview of current literature available. Standard and experimental methods of nematode propagation have been described. A wide range of insect pests were collected from the field and tested in the laboratory to determine their susceptibility to nematode infection. In addition, varying species and strains of nematodes were applied to cauliflower and radish plants in the field to assess the control of the cabbage root maggot, a vegetable garden pest which is susceptible to nematode infection.

INTRODUCTION

Entomogenous (propagating within insects) nematodes present a potential biological control against various insect pests. Discovery of these unique organisms took place during the 1800's; great strides in experimentation began with studies of the species type *Neoaplectana glaseri* Steiner (1929) which was found to be a parasite of the Japanese beetle, *Popillia japonica*, in the United States. The ability of this nematode to cause mortality within its host under laboratory conditions created interest in pursuing its use as a biological control agent (Wouts, 1982). However, this work lost emphasis as use of the milky disease bacterium, *Bacillus popilliae*, produced better control results. Therefore, little interest was generated by the discoveries of *N. feltiae* Filipjev (1934) in the U.S.S.R. and *N. bibionis* Bovien (1937) in Denmark.

The study of entomogenous nematodes was revitalized with the discovery of the type *N. feltiae* in the codling moth, *Cydia pomonella* (L.), in the United States by Dutky and Hough (1955) and further researched by Dutky *et al.* (1962). Promising results in controlling the codling moth spurred repetition of this work worldwide. Results of this experimentation presented by Dutky (1968), Poinar (1971), and Benham and Poinar

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(1973) reopened the main avenue of study of entomogenous nematodes as a potential biological control agent.

The phylum Nematoda is divided into two classes: Adenophorea and Secernentea. Within these classes, eleven orders of nematodes have been found to be associated with nineteen orders of insects (Gaugler, 1982). The content of this paper will focus on members of families Steinernematidæ and Heterorhabditidæ which are within the class Secernentea (order Rhabditida).

The biological control potential of entomogenous nematodes is dependent on the mutualistic relationship with an associated bacterium present in the nematode intestines. The relationship between the nematodes and their associated bacteria is one of interdependence. The bacteria rely entirely on the nematodes for protection and transport into a host. Conversely, the nematodes feed upon the bacteria which provide the nourishment necessary for nematode reproduction (Gaugler, 1981). Within twenty-four hours after infecting a host, the number of bacteria have sufficiently reproduced so as to cause damage to the major organs of the insect body. Generally, the host's feeding and movement are interrupted, and death occurs approximately forty-eight hours after infection. The nature of the bacteria *Xenorhabdus nematophilus* (associated with the genus *Neoaplectana*) and *X. luminescens* (associated with the genus *Heterorhabditis*) is such that upon their release antibiotics are produced so that other pathogens are prevented from entering the cadaver, and decomposition of the cuticle is slowed down. It is after the infective nematode larvæ have emerged from the host that the bacteria cease to produce antibiotics, and other microorganisms can then enter into the cadaver to complete the decomposition process.

The entomogenous nematodes discussed in this paper are naturally occurring in the soil (this is generally true for the class Secernentea). Various techniques for mass propagation of nematodes have been used for commercial application purposes (more detail on this will be presented later).

The infective ability of the entomogenous nematodes is specific to their biology and life cycle. The life cycle consists of six stages: egg, four larval stages, and adults. It is the juvenile that is infective: the third-stage larvæ is responsible for this ability in *Neoaplectana* whereas the second-stage larvæ is infective in *Heterorhabditis*.

Within the *Neoaplectana*, the infective free-living larvæ enter into the host insect via the mouth, anus, or spiracles (Gaugler, 1981). The larvæ then pass through the alimentary canal lining of the insect into the body cavity, and then begin to feed on the hemolymph. This material builds up in the section of the nematode intestine that harbors its symbiotic bacteria; numbers of bacteria increase and are released through the anus of the nematode into the host's body cavity. The bacteria cause a lethal septicemia in the insect with mortality resulting within a 24-48 - hour period (Gaugler, 1981).

The nematodes mature into fourth-stage larvæ, then develop into male and female adults as they feed on the associated bacteria and the decaying matter of the host. The female nematodes lay eggs which hatch into first-stage larvæ; immatures continue to develop into adults. If the food supply is adequate, the females again lay

eggs . As the host decays and nourishment is depleted, first-stage larvæ may hatch from eggs or may hatch within the female from unlaidd eggs (*endotokia matricida*). Feeding ceases and the late second-stage or third-stage infective larvæ emerge from the insect cadaver seeking a new host. Thus, two generations of nematodes generally develop within a host, although the amount and quality of food provided by the decaying insect and the number of infective larvæ that originally entered into the insect can cause variation from this cycle (Wouts, 1982).

The infectivity of *Heterorhabditis* begins with the free-living, second-stage larvæ entering the insect host. The nematodes pierce through the alimentary canal into the insect's body cavity, as with *Neoplectana*, where the third-stage larvæ initiate feeding and release their associated bacteria. Larvæ then develop into hermaphroditic fourth-stage females, whereas fourth-stage amphimictic larvæ are found in *Neoplectana*. If nutrients are available, females deposit eggs; the resultant larvæ pass through the four immature stages and develop into second generation adults of both sexes. When the nutrient supply diminishes, *endotokia matricida* occurs and the hatched first-stage larvæ mature into the infective second-stage which then leave the insect cadaver, searching for a new host. Again, as similar to the *Neoplectana*, two generations of nematodes are produced within a single insect host, though it is possible that the second generation may be bypassed if the food supply becomes inadequate. If this occurs, eggs produced within the hermaphroditic females hatch into first-stage larvæ which mature into the second-stage, capable of infecting a new host (Wouts, 1982).

The control potential of entomogenous nematodes has been demonstrated under laboratory and field conditions with many insects species. Various strains of *N. carpocapsæ* have been found to have a host range of approximately 250 insect species (Gaugler, 1981). An expanded range in infective ability, though, could prove to have positive or negative results as beneficial insects may be adversely affected. Thus, some experimentation has been conducted to test the effects of nematodes on beneficials. Capinera, *et al.* (1982) found that earthworms were not susceptible to *N. carpocapsæ* infectivity. Kaya, *et al.* (1982) reported that domestic honeybees demonstrated low mortality when sprayed with *N. carpocapsæ* Weiser: mortality occurred among some worker bees during the three-day period after application, but not within the brood. Careful application techniques should be observed when using spraying nematodes against insect pests in areas where bees are present.

Effectivity of entomogenous nematodes as a control agent is closely associated with their environmental requirements. The ideal temperature for nematode growth, reproduction, and infectivity is 25°C, with inhibition of nematode development and activity occurring below 10°C or above 33°C (Gaugler, 1981). Nematodes are susceptible to dessication; thus, high relative humidity is best for survival. Therefore, use of entomogenous nematodes against insect pests is potentially more effective against soil-inhabiting or wood-boring insects than those present above ground such as on foliage (Simons and Poinar, 1973). Effects of sunlight on *N. carpocapsæ* have been examined. It was found that long ultraviolet wavelengths (366 nm) did not negatively affect nematode development, reproduction, or viability. However, exposure of nematodes to

short ultraviolet wavelengths (254 nm) effected high mortality. Generally, only a small amount of radiation shorter than 290 nm reaches the surface of the earth because these wavelengths are absorbed by the ozone layer. Therefore, harmful effects on nematodes were demonstrated under artificial conditions, although nematode sensitivity to sunlight could account for some incongruous results obtained in the field (Gaugler and Boush, 1978). Thus, certain environmental conditions required by nematodes for their survival and viability will determine use as a control agent against certain insect pests. Experimentation with photoprotectants, hydrogels, and other methods of application may serve to broaden the effective use of nematodes in otherwise non-optimal conditions (Gaugler and Boush, 1978; Poinar, *et al.*, 1985).

A basic tenet underlying the research of biological control agents is the desire to promote safer alternatives to the use of pesticides which present hazards to animal and plant life as well as having deleterious effects on the environment. Thus, safety factors should be an important component of evaluations of potential nematode usage. Tests have been conducted using chicks and mice inoculated with either infective nematodes or with the associated bacteria alone to determine the degree of safety to mammals. In all cases, no infectivity nor mortality occurred with the experimental animals (Poinar, *et al.*, 1982). In addition, rats were inoculated with *N. carpocapsæ* and likewise were found to lack signs of infectivity and to have no resulting mortality (Gaugler and Boush, 1979). As was mentioned previously, nematode development and activity is inhibited above 33°C, so mammalian bodies, with temperatures generally above this (normal human body temperature is 37°C), would not be conducive to nematode survival (Kaya, 1977).

According to Gaugler (1981), entomogenous nematodes are considered as parasites rather than microbial pathogens by the U.S. Environmental Protection Agency, and therefore are exempt from government registration. At this time, the bacteria of *Neoplectana* and *Heterorhabditis* are not subject to government registration. No findings to the present, within laboratory experimentation or field usage, have indicated harmful effects on mammals.

The remainder of this paper will be presented in sections according to four directions of experimentation conducted with entomogenous nematodes: a) propagation; b) screening of garden pests using nematodes, and application of nematodes in field trials to control the cabbage root maggot in c) cauliflowers and d) radishes.

Section I: PROPAGATION

Entomogenous nematodes may be obtained commercially, and can be used for propagation to increase numbers and continue the supply. Commercial stocks of *N. bibionis*, *Heterorhabditis heliothidis*, and the "All," "Mex," and "Swed" strains of *N. carpocapsæ* were available for experimentation. Propagation of these was undertaken by applying standard *in vivo* techniques using the larvæ of the greater wax moth,

Galleria mellonella (L.), as well as experimentation with caterpillars of the gypsy moth, *Lymantria dispar*.

Use of *G. mellonella* larvæ has proven to be ideal for propagation of entomogenous nematodes for small-scale laboratory experimentation and is relatively low-cost in terms of rearing and feeding requirements. In addition, the availability of gypsy moth caterpillars, an insect that has proven to be a major forest pest, made it feasible to test the susceptibility of these caterpillars to propagate nematodes.

Adult wax moths were placed in containers to which were added pleated wax paper, stapled at either end, on which the wax moths deposited their eggs. Egg masses were collected periodically and placed on the surface of diet in glass jars with screen lids. The diet, a modification of the recipe used by Mohammed and Coppel (1983), was prepared with the following ingredients:

- 100 ml distilled water
- 150 ml honey, raw or commercial brand
- 50 ml glycerine
- 4 ml Polyvisol Multivitamin supplement
- 454 g Gerber's Hi-Protein babyfood cereal

The distilled water was heated to 80°C; honey and glycerine were then added while swirling. When these ingredients were mixed and the solution cooled to about 50°C, the multivitamin supplement was added. The babyfood cereal was placed in a container and ground to form a fine powder. The warm liquid solution was then added, and mixed into the cereal by hand. The final mixture was crumbly, but not dry. The diet was then stored in a closed container, but was aired periodically to avoid the build-up of moisture. The jars containing wax moth eggs and diet were kept in a darkened area. The eggs hatched within eight to ten days. New diet was added as the *G. mellonella* larvæ continued to grow in size. Approximately fourteen to twenty-one days after hatching, the larvæ were separated from the medium for inoculation with nematodes. The larvæ were placed in groups of twenty-five onto filter paper in petri dishes. The desired strain of nematode was added to distilled water (ca. 5,000 nematodes per 5 ml water). The method of commercial shipment determined the manner of nematode collection: nematodes shipped on a sponge substrate were kneaded into water, while those shipped in vermiculite or charcoal were added directly to water. A microliter pipette was used to take a random sample of the nematode solution, swirled to prevent settlement of the nematodes; the number of nematodes in the pipette were then counted under magnification (20x), and this number was extrapolated to determine the total number of nematodes present. The prepared solution was then applied to each petri dish. Larvæ of *G. mellonella* (L.) died within twenty-four to forty-eight hours after inoculation. The cadavers were then carefully removed (to prevent rupture) from the filter papers and transferred to slightly moistened sponges placed in petri dishes. Infective stage nematodes spewed out of the bodies seven to ten days later; the cadavers were rinsed with distilled water to harvest remaining nematodes and then discarded.

Nematode-laden sponges were stored in petri dishes and placed in a refrigerator at 4°C to increase longevity and maintain nematode viability.

Gypsy moth caterpillar instars IV and V were tested for nematode susceptibility to determine possible usage as an *in vivo* propagation source. The abundance of the caterpillars in the surrounding area made it possible to collect large numbers and feed them on local vegetation (i.e., oak leaves). The *L. dispar* caterpillars were inoculated as described. It was thought that if the caterpillars succumbed to nematode infectivity, the number of nematodes produced per caterpillar would be favorable due to the larger body size of the gypsy moths. The gypsy moth caterpillars were found to be susceptible to *N. bibionis* and the "All" and "Mex" strains of *N. carpocapsæ*. However, infectivity was more difficult and mortality took longer to occur than with *G. mellonella* larvæ. The numbers of nematodes obtained were minimal and were not comparable to nematode production in wax moth larvæ. The nematodes harvested from the caterpillars were used to test a new collection method. Sponges were washed down with distilled water into a beaker. This solution was then centrifuged at 300 rpm for 10 seconds to collect nematodes in concentrated form; the supernatant was discarded. Nematodes were placed on sponges in petri dishes and refrigerated. The viability of these nematodes has not yet been determined.

In addition to *in vivo* techniques for propagation of nematodes, large-scale production can be obtained by a variety of *in vitro* methods. Media for culture include: yeast extract added to a soy-peptone, Bacto-yeast solution (Lower and Buecher, 1970); sterilized chicken offal homogenate inoculated with the associated bacterium (Bedding, 1984); pig kidney/fat homogenate (Bedding, 1981); and a preparation using dog food biscuits (House, *et al.*, 1965).

Section II: SCREENING OF VEGETABLE INSECT PESTS

Insect pests were collected from a variety of vegetables to determine their susceptibility to nematode application under laboratory conditions. A standard operating procedure was designed for experimentation:

TimeStandard Operating Procedure

1. Collection of various insect pests from the field.
 2. Insects were maintained on filter paper in petri dishes for observation for a 24-hour period.
 3. Appropriate diet from the field was supplied for food.
- 0 h
1. After the 24-hour period, any insect mortality was noted and cadavers removed.
 2. Live insects were inoculated with 5000-10,000 nematodes per 10 ml distilled water for 10-15 insects.
 3. Fresh diet was supplied.
- 24 h
1. Insects were observed for slowed activity and/or mortality at 24 h after nematode inoculation.
 2. Fresh diet was supplied.
- 48 h
1. Insects were again observed for slowed activity and/or mortality at 48 h after nematode inoculation. At this point, if nematode application was successful, insects were dead.
 2. If successful, insect cadavers were kept for 7-10 days to accurately assess nematode infectivity as the cause of death. If unsuccessful, the experiment was ended.
- 72 h *
- For some reason, mortality due to nematode infectivity took longer than the normal 24-48 - hour period for some insects. If insects appeared sluggish but were not dead at 48 h, they were observed for mortality at 72 h. Such cases were noted in the results.

Modifications to the standard operating procedure were made during the course of the experiment. Filter paper in petri dishes was replaced with vermiculite to simulate natural surroundings. Also, *G. mellonella* larvæ were added at the time of inoculation as an immediate check to determine insect mortality due to nematode infectivity; this can then be a verification of viability of the nematode stock. Cadavers were observed seven to ten days later for the presence of nematodes spewing from the bodies.

Results are presented in two tables according to use or non-use of the wax moth verification test. In some cases, more than one test was performed using a particular insect.

TABLE I

<u>Insect</u>	<u>Infectivity (+ or -)</u>	<u>Strain or Species of Nematodes</u>
*Cabbage root maggot (<i>Delia radicum</i>)	+	<i>N. carpocapsæ</i> All
Imported cabbage worm (<i>Pieris rapæ</i>)	+	<i>N. bibionis</i>
Striped cucumber beetle adult (<i>Acalymma vittatum</i>)	-	<i>N. bibionis</i>
* Striped cucumber beetle adult	+	<i>N. carpocapsæ</i> All
	+	<i>N. carpocapsæ</i> Swed
	+	<i>N. bibionis</i>
Colorado potato beetle adult (<i>Leptinotarsa decemlineata</i>)	+	<i>N. carpocapsæ</i> All
	+	<i>N. bibionis</i>
Colorado potato beetle larva	+	<i>N. carpocapsæ</i> All
	+	<i>N. bibionis</i>

* Dead at 72 h

TABLE II

<u>Insect</u>	<u>Insect</u> <u>Infectivity</u>	<u>Wax Moth</u> <u>Infectivity</u>	<u>Strain or Species</u> <u>of Nematode</u>
Japanese beetle (<i>Popillia japonica</i>)	-	+	<i>N. bibionis</i>
Three-lined potato bug adult (<i>Lema trilineata</i>)	-	+	<i>N. bibionis</i>
Three-lined potato bug larva	-	-	<i>N. bibionis</i>
* Mexican bean beetle adult (<i>Epilachna verivestis</i>)	+	+	<i>N. bibionis</i>
* Mexican bean beetle larva	-	+	<i>N. carpocapsæ</i> All <i>N. bibionis</i>
* Squash bug adult (<i>Anasa tristis</i>)	+	+	<i>N. bibionis</i>
Squash bug nymph I-II	-	-	<i>N. carpocapsæ</i> All <i>N. bibionis</i>
* Squash bug nymph III-IV	+	+	<i>N. carpocapsæ</i> All <i>N. bibionis</i>
* Striped cucumber beetle	+	+	<i>N. bibionis</i>
*Dead at 72 h			

Viability of the nematodes was demonstrated in most trials except with three-lined potato bug larvæ and squash bug nymph I-II, where mortality of wax moth larvæ did not occur. This result could be due to storage problems with this particular stock of nematodes.

These trials provide preliminary documentation of susceptibility of these economically important vegetable insect pests to control by nematodes.

Section III: FIELD APPLICATION OF NEMATODES TO CAULIFLOWER

Treatments and control were applied to cauliflower plants in the field to ascertain nematode effectivity in controlling the cabbage root maggot, *Delia radicum*. The strains "All" and "Mex" of *N. carpocapsæ*, *N. bibionis*, and *H. heliothidis* and distilled water as the control were inoculated at the base of each plant. Plants were divided into replicates containing nine plants each; five replicates of each treatment and control were randomly spaced between two beds of cauliflowers. Each plant was inoculated with 5000 nematodes per 5 ml of distilled water.

Cauliflowers were harvested when ready and the following data recorded for each replicate of each treatment: weight (in ounces) of each head, numbers of harvestable and unharvestable heads, number of dead plants, and number of missing plants. A summary of data and results is presented as Appendix A.

Results were analyzed by computation of sum squares, mean squares, and F-tests of individual treatments using the Macintosh *Stat View 512+* program (Brainpower, Inc.) for the total average weight and the average weight of harvestable cauliflowers of each of the five applications::

TABLE III
One-Factor Analysis of Variance
X = treatment; Y = total average weight

Source	Degr. Fr.	Sum Sqs.	Mean Sq.	F-test
Between treatments	4	309.573	77.393	.999
Error	20	1549.072	77.454	p=.4311
Total	24	1858.645		

TABLE IV
 One-Factor Analysis of Variance
 X = treatment; Y = average weight of harvestable heads

<u>Source</u>	<u>Degr. Fr.</u>	<u>Sum Sqs.</u>	<u>Mean Sq.</u>	<u>F-test</u>
Between treatments	4	134.386	33.597	.469
Error	20	1432.582	71.629	p=.7578
Total	24	1566.968		

Significance in results would show $p < 0.05$; this did not occur in either analysis. Therefore, it was concluded that results did not demonstrate a degree of significance between the applications. Possible explanations for the outcome could be attributed to a pest population which was not high enough in number to cause damage that would reflect differences between treatments and controls or possible predation of cabbage root maggot eggs by a significant population of ants.

Section IV: FIELD APPLICATION OF NEMATODES TO RADISHES

Treatments of nematodes and control were applied to radishes in the field to determine possible effect in controlling the cabbage root maggot. As in the cauliflower experiment, the strains "All" and "Mex" of *N. carpocapsæ*, *N. bibionis*, and *H. heliothidis* and distilled water as the control were inoculated at the base of the plants. The radish bed was divided into twenty-five 2-1/2 foot replicates with a two-inch separation between each. Five replicates of each application were randomly spaced such that one replicate of each application was present in each of five rows (see Diagram 1). This random sampling took into account differences in soil composition and growth conditions due to placement in the bed. Radishes were thinned so that individual plants were one-half to three-quarters of an inch apart such that relative numbers of plants were present in each replicate. However, there was some variation of numbers in replicates. To account for this, inoculation was done in segments: 20,000 nematodes per 20 ml distilled water was evenly distributed at the base of the plants in six-inch sections at a time with five sections per replicate.

Radishes were harvested and the following data recorded for each replicate of each treatment: number of radishes, total weight (in ounces), and ratings of radishes. Radishes were rated according to insect damage (holes, tunnels, etc.) on a scale of 1 to 4: 1 - less than 10% damage, 2 - 10-25% damage, 3 - 25-50% damage, and 4 - over 50% damage. A summary of data and results is presented as Appendix B.

Data were analyzed by computation of degrees of freedom, sum of squares, mean squares, and F-tests at a 95% confidence level with two factors, treatments and rows, using the Macintosh *Stat View 512+* program (Brainpower, Inc.) for average weight of radishes and standard arcsine transformations of proportional data of rating 1 and

ratings 1+2. The use of a two-factor analysis of variance took into account growth differences noted between rows when harvesting: e.g., rows 1 and 5 had significantly larger size radishes than those in rows 2, 3, and 4. Results are presented in tabular form as follows:

TABLE V
Two-Factor Analysis of Variance
 X_1 = treatment, X_2 = row; Y_1 = average weight

<u>Source</u>	<u>Degr. Fr.</u>	<u>Sum Sqs.</u>	<u>Mean Sq.</u>	<u>F-test</u>
Treatment	4	1.263	.316	.30
Row	4	8.882	2.221	2.13
Error	16	16.651	1.041	

TABLE VI
Two-Factor Analysis of Variance
 X_1 = treatment, X_2 = row; Y_1 = arcsine of rating 1 proportion

<u>Source</u>	<u>Degr. Fr.</u>	<u>Sum Sqs.</u>	<u>Mean Sq.</u>	<u>F-test</u>
Treatment	4	.084	.021	2.59
Row	4	.151	.038	4.69
Error	16	.130	.00810	

TABLE VII
Two-Factor Analysis of Variance
 X_1 = treatment, X_2 = row; Y_1 = arcsine of ratings 1+2 proportion

<u>Source</u>	<u>Degr. Fr.</u>	<u>Sum Sqs.</u>	<u>Mean Sq.</u>	<u>F-test</u>
Treatment	4	.089	.022	1.38
Row	4	.346	.086	5.38
Error	16	.255	.016	

Results were not significant at the 5% level for average weight since the F-test in treatment should have been twice that of row to draw statistically significant conclusions. The arcsine transformation was used to normalize otherwise small proportional data prior to F-test analysis; however, the assumptions were not tested. According to an arcsine chart with degrees of freedom at 4 and 16 for error, F-test values above 3.01 would give significant results (Snedecor and Cochran. *Statistical Methods*. Iowa State University Press). The arcsine transformation was used with the

proportional data of least damaged radishes, rating 1 and also ratings 1 and 2 combined. In each case, the F-test of treatment was not significant, but row effects gave numerically significant results. However, since the row effect was significant, it would be more conservative to use treatment with row as the error term. By doing this, the F-test would generate a value of 0.55 for proportional data of rating 1 and 0.26 for proportional data of ratings 1+2; then the treatment is clearly not significant.

Comparisons of proportional data of the four ratings for each of the five applications (treatments) is presented visually in a bar chart in Diagram 2. Analyzing the proportional data of ratings 1+2 here, it is clearly seen that treatment E (the control) lies between proportional data of treatments A, B, and C and those found in treatment D. This supports the conclusion drawn above that the difference between applications did not yield statistically significant results.

At the time of rating, variance in the amount and degree of insect damage in the radishes was such that it was concluded that multiple applications of nematodes during the development of several generations of the cabbage root maggot may have demonstrated significant results. Thus, this initial examination of nematode control of cabbage root maggot in the field can be further tested using repeated applications.

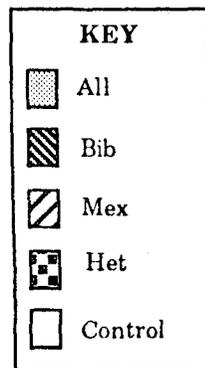
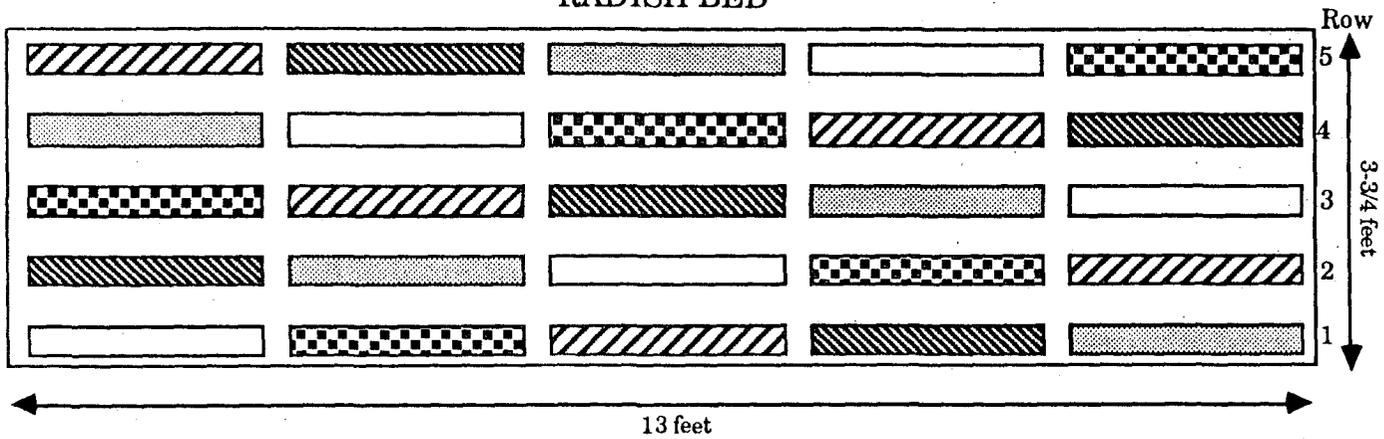
As has been presented, the use of entomogenous nematodes as a biological control of different insect pests has great potential. Susceptibility of many insects (both harmful and beneficial) and refinements in rearing and storage techniques continue to be researched in an effort to make wide-scale usage a verifiably safe and economically worthwhile alternative method for reducing pest damage. Experimental results given in this paper support documented research or present possible variations to standard techniques. Moreover, analysis of field results indicate that further experimentation with multiple applications of nematodes could provide effective pest control in a range of vegetable crops.

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DIAGRAM 1

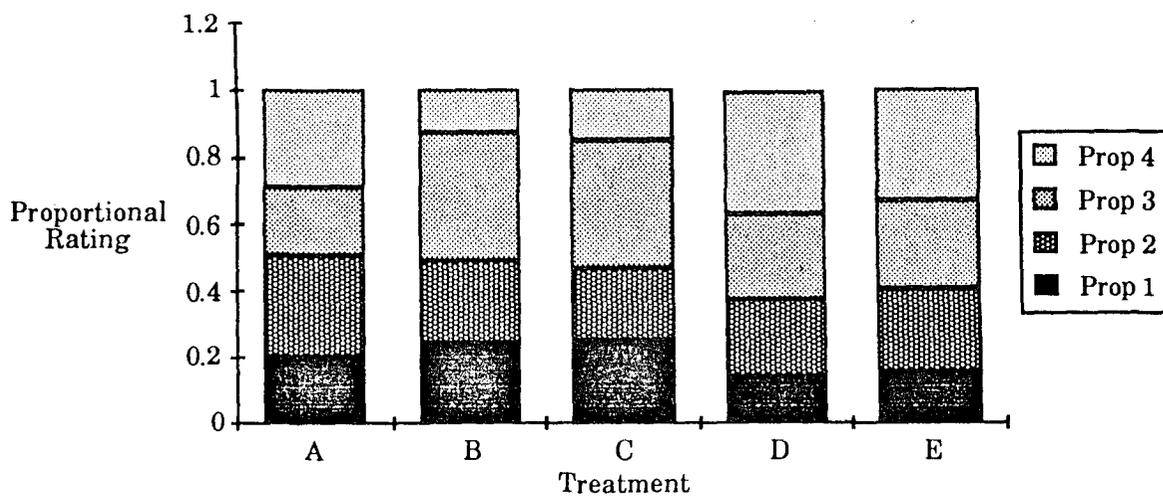
RADISH BED



NOTE: Spaces of 2 inches separate the treatments in each row.

DIAGRAM 2

RADISH RATING COMPARISONS



APPENDIX A (numbers are per replicate)

Treatment	# Harvested	# Unharvested	# Dead	# Missing	Total Average Weight (oz.)	Harvested Average Weight (oz.)
A	6.0±2.4	1.6±1.1	1.2±1.6	0.20±0.45	15±5.7	23±4.3
B	4.8±1.5	2.0±1.2	2.0±1.6	0.20±0.45	12±6.0	21±5.3
C	7.4±1.8	0.80±1.3	0.80±1.3	0	22±9.5	28±11
D	5.6±1.7	1.2±2.2	2.2±1.3	0	17±10	26±10
E	6.4±1.7	1.4±0.89	1.0±1.2	0.20±0.45	18±11	23±9.5

APPENDIX B (numbers are per replicate)

Treatment	# of Radishes	Total Weight (oz.)	Average Weight per Radish (oz.)	Proportion 1	Proportion 1+2	Transformation 1	Transformation 1+2
A	16±5.4	32±26	1.9±1.3	0.21±0.08	0.51±0.19	0.46±0.12	0.80±0.20
B	16±4.6	31±18	1.9±0.85	0.24±0.08	0.49±0.11	0.51±0.10	0.78±0.11
C	16±5.8	34±28	2.2±1.5	0.25±0.09	0.47±0.17	0.52±0.10	0.76±0.17
D	16±3.7	30±21	1.9±1.2	0.14±0.10	0.37±0.21	0.38±0.13	0.64±0.24
E	19±5.0	28±16	1.5±0.56	0.16±0.10	0.41±0.08	0.39±0.14	0.69±0.08

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THE ROLE OF TEMPERATURE IN AERIAL PREDATOR AVOIDANCE BEHAVIOR OF THE FISH *Xiphophorus variatus*

Chris H. Frazier†

ABSTRACT

Predator avoidance behavior of the fish, Xiphophorus variatus at different temperatures was observed and quantified. Predator avoidance was elicited by a moving artificial aerial predator. The major behavioral responses measured were "dive distance" (DD) and "freeze time" (FT).

There was no significant difference among distances of the fish from the surface during aerial predator introduction at the different temperatures ($p > .05$). However, distances of the fish from the surface during aerial predator introduction and DD were inversely related ($r = -.68$; $df = 97$; $p < .01$). The proximal cues used by the fish in this reaction are not known, but this behavior would seem to be selectively advantageous. Both DD and FT were nonlinearly related to temperature. DD exhibited a minimum at 75°F and FT exhibited a maximum at 80°F. These data demonstrate that temperature may effect predator avoidance behavior in fish.

INTRODUCTION

Three important factors which influence the predator avoidance behavior of fish are: 1) temperature, 2) stimulus for escape, and 3) escape behavior. While the effects of (2) stimulus for escape and (3) escape behavior on predator avoidance behavior have been established in the literature, (1) studies of temperature effects upon this same behavior is lacking. This experiment looked closely at the influence of temperature on predator avoidance behavior in *Xiphophorus variatus*.

A major portion of fish behavioral experiments of the past consist of sublethal temperature experiments. The well documented area of sublethal temperature experimentation is understood relative to the impact of temperature on distribution and abundance in nature. According to Brett (1956), there can be no doubt that the lethal temperature exerts limiting effects on the geographic distribution and freedom for successful existence in the confines of lake and stream, or the strata of the ocean. With the importance of temperature on fish distribution stated, it would appear that this effect on various behaviors would be well understood, but apparently this is not the case.

This paper will not emphasize the relatively exhausted area of temperature avoidance behavior but instead look closely at temperature effects upon predator avoidance behavior. Many behaviors in relation to temperature, such as foraging, mating, dominance, etc., have not been well documented. Reasons for this could stem from the difficulty in separating behaviors into quantifiable data or more commonly from the difficulty inherent in experimenting with non-morphological traits. Researchers of temperature effects may not have had interest in possible subtle effects upon behavior.

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A brief discussion of the effects of temperature on fish behavior follows to show the magnitude at which it affects fish behavior. According to Brett (1956), body temperature of fish and other aquatic poikilotherms is entirely dependent on the variation of environmental temperature, with the equilibrium state being reached more rapidly among small forms. Without a means of maintaining an independent body temperature, fish survival is subject to the temperature of the environment in which the fish lives. Behavioral thermoregulation experiments provide information on the ability of fish to regulate body temperature by behavior or other mechanisms. According to numerous authors, fish exhibit preferred body temperatures in heterothermal environments and are sometimes able to maintain uniform body temperatures by behavioral means (Claire et al., 1984). This could account for the migratory behavior of fish in ponds or lakes which have a high degree of variation in temperature. However, the degree of variation in temperatures does not have to be high to promote migration in fish, fine temperature discrimination has been demonstrated in a wide variety of species (Brett, 1956). Responses were obtained for temperature increases as small as 0.3 to 0.10°C. The variation in temperature could result from seasonal changes or in some cases a nuclear reactor cooling reservoir. Whatever the mechanism or process of temperature selection may be, the survival value of moving progressively into thermal conditions which offer a maximum expression for activity is most apparent (Brett, 1956).

It is important to note the survival value for those species with a large temperature tolerance. It is apparent that those species with a large temperature tolerance could enjoy a wider selection of environments and thus their resources would be larger than other less temperature tolerant fish. However, if an increase in temperature tolerance could be obtained without an increase in activity within these temperatures, then this would be of little survival value. According to Brett (1956), the importance of increased activity with increasing temperature tolerance is illustrated by the work done by Fry (1947) and Graham (1949) on the comparison of metabolism of the bullhead and the speckled trout. The bullhead's activity increased with increasing temperature while the speckled trout's activity reached a peak which was considerably much lower than its lethal temperature. Brett (1956) summarizes the all-pervading nature of environmental temperature; the fundamental thermal requirement of fishes is an external environmental temperature most suitable to their internal tissues. Brett (1956) continues by stating that temperature sets lethal limits to life; it conditions the animal through acclimation to meet levels of temperature that would otherwise be intolerable, it governs the rate of development, it sets the limits of metabolic rate within which the animal is free to perform, and it acts as a directive factor resulting in the congregation of fish within given thermal ranges, or movements to new environmental conditions.

An important aspect of predator avoidance behavior is the stimulus for escape. An assessment of a prey's ability to distinguish between a predator and non-predator indicates that all sensory modalities interact to relay "life and death" information. According to Dill (1974), most vertebrates are characterized by a highly developed visual sense which is assumed to be the dominant modality providing information to the prey. At the moment a prey notices a potential predator, the prey must be able to assess the situation in order to determine the potential danger present. Dill (1974) explains that the three features

of the sighted object that may be used in assessment are its size, distance, and relative velocity. If the prey is unable to respond to these three features, the result could be death or injury. A false response could take time and energy from other important behaviors such as feeding or mating.

According to Dill (1974), there has been considerable conflict of opinion regarding the type of warning stimuli to which prey respond. Some authors have suggested that animals respond instinctively to a particular species or a type of predator. However, others consider this type of response to be rather rare and suggested that prey tend to avoid danger signals, novel stimuli, high intensity stimuli, or sudden stimuli. This would be apparent in those predator-prey situations where false reactions would be of little disadvantage. A majority of the literature agrees with the generalized stimulus idea. A study in support of this idea done by Hurley and Hartline (1974) showed that damselfish responded to models of different sizes, shapes, and colors. Many of the shapes did not correlate with the prey's most encountered predator. Experiments done by Dill (1974) showed that zebra danios, *Brachydanio rerio*, reacted to an approaching predator when the rate of change of the angle subtended by the predator at the prey's eye exceeds a certain threshold. Russell's (1967) study showed that *Lebistes reticulatus* reacted to a shadow stimulus. These and many other similar studies have supported the generalized stimulus idea and also have shown the complexity of the interactions of all sensory modalities in the predator avoidance response.

The responses produced by the stimuli are of great importance to the predator-prey interaction. Inefficient responses could result in injury or death while correct responses will result in survival. The correct response is vital since the difference between the "quick and dead" may be only a matter of a few milliseconds in reaction time (Roeder, 1959, as cited by Dill, 1974). According to Russell (1967), when *Lebistes* is disturbed, its response is clearly divisible into two parts: initiation of movement, and cessation of movement. Russell (1967) further divides these two responses into four movements: 1) jerk response, 2) single jerk, 3) drifting, and 4) fin and tail movements. (1), (2), and (3) occur when the fish is moving or stationary while (4) occurs only when stationary. Russell's (1967) four movements are a response to a shadow (i.e., aerial predator) while Dill's (1974) study showed the response of zebra danios to aquatic predators (i.e., live predators and models). Dill (1974) only mentions reaction distances (i.e., distance between prey and predator when prey takes flight) and flight (i.e., distance traveled to escape). Dill fails to separate escape behavior any further. Likewise, the Hurley and Hartline (1974) study on damselfish, *Chromis cyanea*, fails to separate escape behavior in detail. Goodey (1985) recorded a two phase response in *Poecilia reticulata* to an aerial predator. The response consisted of a sudden increase in swimming depth (drop), followed immediately by a "freezing period" characterized by body immobility and rapid fluttering of the paired fins, tail and opercula. Goodey's (1985) two phase response was consistent with the response found in this experiment.

METHODS

The variegated platy, *Xiphophorus variatus*, was employed in this experiment because previous tests indicated that they exhibited the escape behavior similar to the guppy, *Poecilia reticulata*. These responses were favored because of the ease in quantifying the behaviors. The platys were obtained from a local aquarium shop. Due to lack of time,

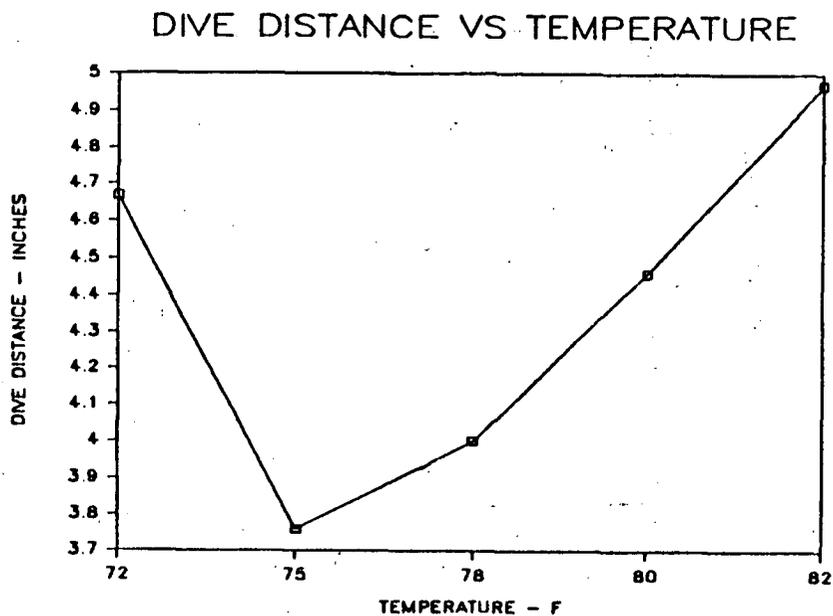
the fish were not laboratory reared, thus, the fish could have experienced aerial predators before. The experimental error due to non-laboratory reared fish was assumed to be very low.

The predator was a wooden bird-shaped figure with the extremities a lighter color than the body. Five tanks (10 gal. each) were used to hold the fish at five different temperatures. Tank contents included three small flower pots, four plants, one sponge filter, one 100 watt heater, and a thermometer. One of the five tanks stayed at room temperature (72 °F) without a heater. A sixth tank was the experimental tank. A tank divider was used to control the depth of field for filming purposes. Ten fish were placed in each of the five tanks but numbers decreased to give a total of 39 fish tested. The distribution of fish in tanks consisted of 6 in 72°F, 9 in 75°F, 9 in 78°F, 5 in 80°F, and 10 in 82°F. Fish were allowed to acclimate for 3 weeks before exposure to the predator. The fish were fed commercial flake food.

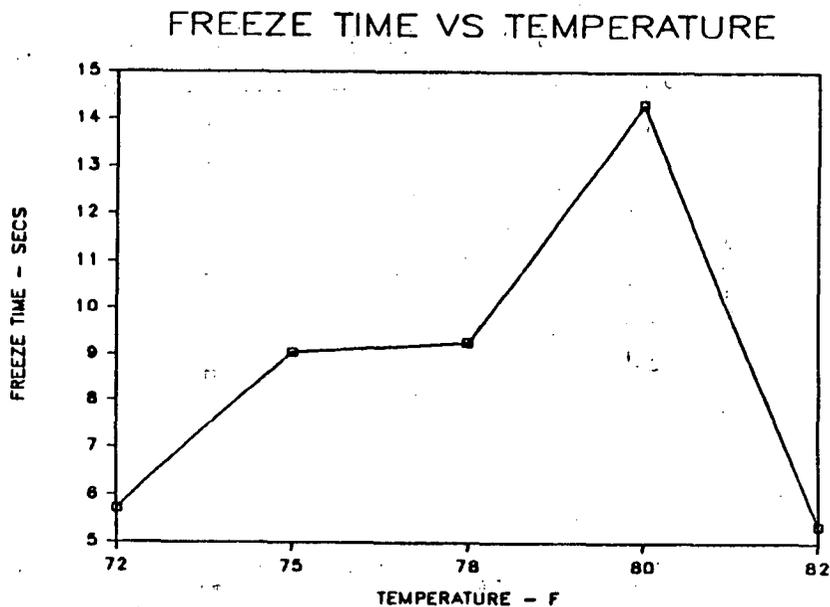
Each fish was moved and simply allowed to acclimate to the experimental tank for 20 minutes. This was enough time for most fish to swim actively in the new tank. The predator was placed on a pulley which was attached to a small cord strung across the tank. To discount noise as a potential stimulus, the pulley was passed over the tank without the predator attached; this did not elicit any escape response. The predator was released when the fish was near the surface. The entire run was recorded with a video camera for later quantification. A small measuring tape was placed on the side of the tank and this was used to measure distance dropped. Freeze time was measured with a stop watch to the nearest second.

To reduce variation arising from differences in the position of the fish at the moment of exposure to the predator, the test was run 5 times on each fish with an average of 3 minute intervals between runs. No habituation was detected. The experimental tank was situated with fluorescent light directly above the tank. This allowed a shadow approximately twice the size of the predator to pass directly above the tank.

RESULTS

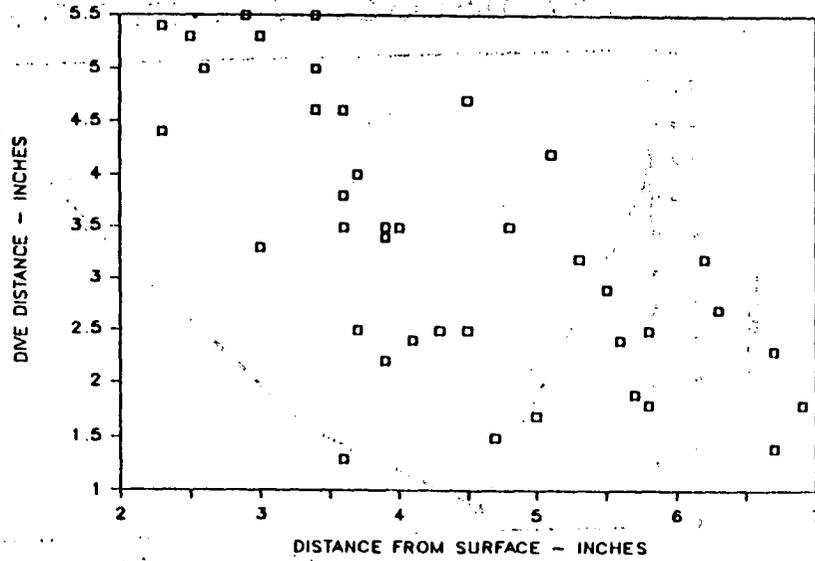


GRAPH 1 Effect of temperature on DD with the smallest DD at 75°F. The lowest temperature (72°F) produced a relatively high DD.



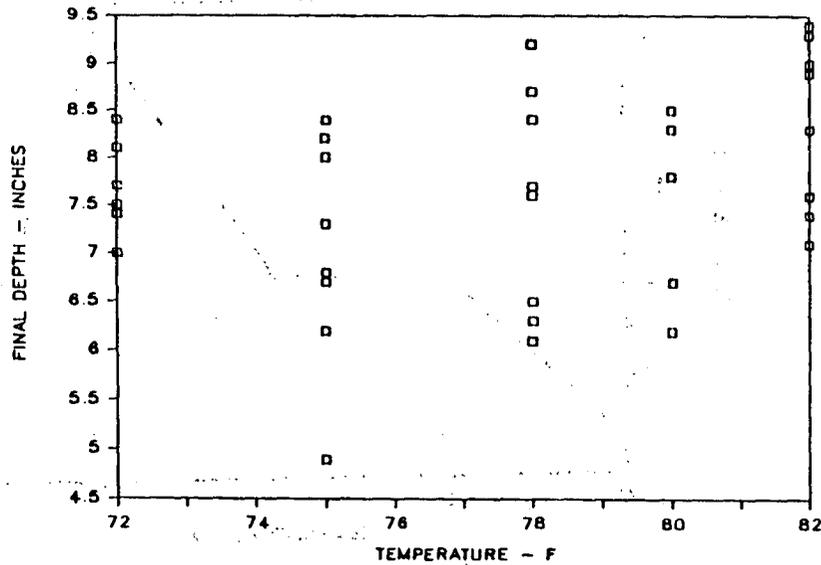
GRAPH 2 Effect of temperature on FT with the smallest FT at the highest temperature tested (82°F).

DIVE DIST. VS DIST. FROM SURFACE



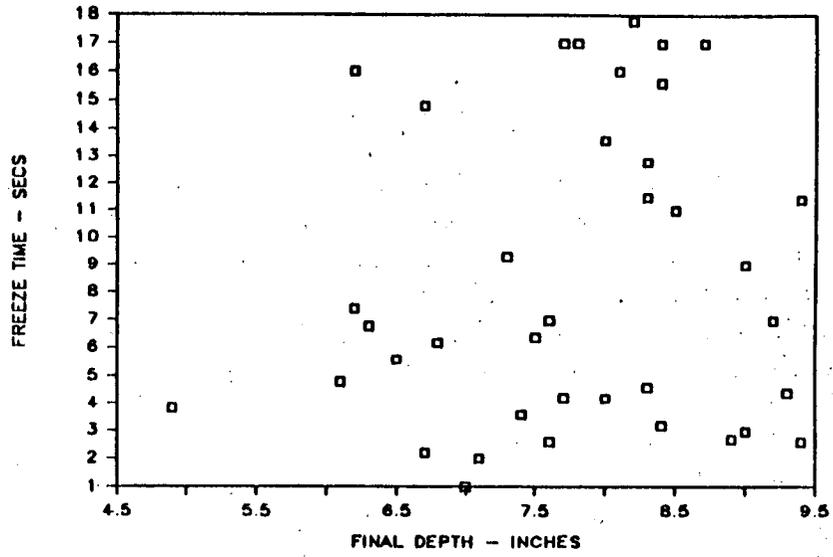
GRAPH 3 Inverse relationship of DD with distance from the surface. The closer the fish was from the surface, the greater the DD.

FINAL DEPTH VS TEMPERATURE



GRAPH 4 Effect of temperature on FD. This non-significant relationship helps illustrate a common final depth to which the fish dove among the temperatures tested.

FREEZE TIME VS FINAL DEPTH



GRAPH 5 Non-significant relationship between FT and FD. There was no change in FT as the fish dove further.

DISCUSSION

To prevent the introduction of experimental error due to non-equal distances from the surface at the time the predator was introduced, the distance from the surface among the different temperatures was correlated. An analysis of variance was also performed. A non-significant correlation ($p > .05$) was discovered between the distance from the surface and temperature along with a non-significant ($p > .05$) value for the analysis of variance. This allowed experimental error to be controlled due to the similar distances from the surface among the tanks.

The two major behaviors, dive distance (DD) and freeze time (FT), were recorded at the five temperatures and the means were graphed against temperature. Graph 1 shows the relationship between the means of DD and temperature. DD was smallest at 75°F with large DD's at 72°F and 82°F. Although the correlation is low ($r = 0.346$, $p > .05$), it is interesting to note the DD trend among the different temperatures. DD increased from 75°F to 82°F but 72°F produced a relatively large DD of 4.67 inches.

One reason for the unusually high DD at 72°F could have been that some fish's activity increases with increasing temperatures over the complete biothermic range, whereas some fish reach a peak for activity level which is much lower than their upper lethal temperature (Brett, 1956). 72°F may have been a temperature close to the fish's lower lethal temperature. This would be reasonable since the platy is a tropical fish from Rio Panuco to Rio Cazonos, Mexico. If so, then this temperature may be the beginning of an increase in activity towards the lower lethal temperature. This has yet to be tested.

Another explanation, based on the assumption that 72°F approaches the fish's lower lethal temperature, is that the fish's behavior may have become abnormal or sporadic due to being stressed. The stress may also produce an increase in activity which enables the fish a better chance to move into a less stressful environment. This behavior is also seen in isopods, which move faster in a dry environment which increases their chances of finding a moist environment. The lack of literature on the lower lethal effects on fish behavior does not support or disprove this idea. According to Brett (1956), the recognition of an ability among fish to perceive and select a limited thermal range has found significance in its relation to temperatures for optimum activity. Although the correlation between DD's and temperature is non-significant, the trend of DD's at different temperatures produced an unusual relationship which is difficult to explain. Explanations for this relationship can only be hypothesized until further research, using a wider temperature range, is performed.

Graph 2 shows the correlation between the means of FT and temperature. Although the correlation is non-significant ($p > .05$), the trend of FT among the different temperatures is interesting to note. The peak in FT occurred at 80°F but dropped sharply at 82°F. Although a non-significant correlation existed, an analysis of variance showed that there existed a significant difference ($p < .05$) of FT among the five temperatures tested. A Fisher's LSD on the five temperatures showed the two extreme temperatures, 72°F and 82°F, differed significantly from the peak at 80°F. FT increased and then dropped off sharply at the highest temperature. This is similar to the DD's in the sense that the DD's decreased with decreasing temperature except at the lowest temperature. This sharp drop at 82°F may also be an indication that as the temperature causes stress, behavior begins to become abnormal. The fish may not be able to function correctly at this extreme.

However, the longest FT at 80°F may or may not be advantageous to the fish's survival. A short FT may mean capture by a predator who waits long enough for the prey to move, whereas a long FT may cause the prey to become a 'sitting duck' to an alternative predator. Whether or not a long FT is advantageous has yet to be tested and requires knowledge of the platy's natural predator-prey relationship.

The highly significant correlation ($r = -0.685$, $p < .01$) shown in graph 3 shows that fish closer to the surface, dive further. The fish seem to have an ability to determine the distance they are from the surface and dive accordingly. Size, shape, color, and speed of the predator could also play a role in the fish's DD. These first three; size, shape, and color, are supported by Hurley and Hartline (1974) as an escape stimulus whereas the fourth is independent of escape response. The reason why the fish dive farther when closer to the surface seems obvious. The farther away from the predator, the better the chances of being out of reach from the predator's diving ability.

This correlation helped prompt the question, is there a final depth common to all the fish tested? An analysis of variance proved to be non-significant ($.05 < p < .10$) (i.e., the final depth at the different temperatures was similar). Graph 4 shows this trend. The data show that the fish were not just diving to the bottom but instead diving to relatively different distances at the different temperature. To make certain no experimental error was involved, deeper tanks would be needed. By using deeper tanks, the final depth could be determined with a higher degree of accuracy. The data suggest that there does exist a depth common to all fish tested. It would be interesting to determine if this common depth maximizes evasion from above and below. If so, then this common final depth would have serious genetic and evolutionary implications. According to Seghers (1973), the antipredator strategy of Guayamare guppies appears to be a compromise between the risk of capture from above and below the water surface. Because the Guayamare River is infested with a host of aquatic predators there must be strong selection against remaining in deep water.

Graph 5 illustrates the non-significant relation ($p > .05$) between final depth and FT. This relation was tested due to the idea that as the fish dove to a deeper depth, they took less time to freeze. This type of behavior would seem advantageous in that the farther the distance dove, the better the chances of escape and hence less freeze time needed. But the data do not support this idea and show an independent relation between the final depth and FT.

If an independent relation exists between final depth and FT, there could also exist an independent relation between DD and FT. A non-significant correlation ($p > .05$) between FT and DD indicates that FT and DD behavior were independent of one another. A reason for this could have been the broad range of temperatures employed. Graph 1 and 2 illustrate that the middle range temperatures (75°F, 78°F, 80°F) show an increase in both DD and FT over temperature. If a narrower range of temperatures were employed, then a relation between the two behaviors might have existed. The spectrum of temperatures employed may seem small but Bull (1936, in Brett, 1956) has been able to demonstrate particularly fine temperature discrimination in a wide variety of species. But the FT and DD at the temperatures tested show that these two behaviors are independent. This finding is supported by Russell (1967), who found an independent relation between FT and DD

in *Lebistes reticulatus*. However, Russell (1967) also points out that these behaviors need not be completely independent of one another. According to Wiepkenia (1962, in Russell, 1967) the incompatibility of two motor patterns does not mean the incompatibility of corresponding major (i.e., causal) tendencies. Russell (1967) continues by pointing out that there is no reason why FT and DD should not both be considered as manifestations of fear. This seems reasonable in the sense that if DD occurs then FT follows and *vice versa*. However, observations showed that FT did not always follow DD and DD did not always occur before FT. Eikman (1955, in Russell, 1967) observed that the changes which occur in the prey-seizing behavior of *Bufo* occur at different rates for different measures of the response. My observations, along with Russell's and Elkman's, support the idea that FT and DD are independent behaviors. Reasons for this independence have yet to be tested. The diversity of predators may be a plausible reason for the two behaviors being independent. If so, this independence would be advantageous because the separation of behaviors would allow the fish to use energy and valuable time doing the "right" behavior, while ignoring any unnecessary behavior. The geographical diversity may also be a force which causes a separation in the two behaviors. As the geographical location changes, so do the pressures that shape the fish's behavior and survival. As a fish swims to different areas, even a small area, the fish will encounter different obstacles such as plants, rocks, caves, etc.. These obstacles may produce an alternative to DD and FT behaviors. This way the fish takes advantage of their natural surroundings without wasting energy on behaviors that are not needed (i.e., DD and/or FT). A scenario for this explanation would be a fish that freezes under or 'inside' a plant without diving. A fish that dives but keeps swimming under a rock ledge is another example.

In summary, DD and temperature produced a non-significant correlation. Highest DD was observed at 82°F and 72°F may cause a stressed environment due to the tropical fish's adaptation to higher temperatures. Experiments at temperatures higher than 82°F and lower than 72°F need to be performed.

FT and temperature were non-significantly correlated. 82°F produced a short FT. Once again, a stressed environment may have been the cause. Although tropical fish are adapted to warm temperatures, 82°F may have been too warm for the fish to behave normally. Results indicate that high temperatures (i.e., 82°F) may have had an effect on the FT of the platy.

Distance from the surface and DD were inversely related. These results indicate that fish may have an ability to determine the distance they are from the surface. This relation seems obvious due to its escape advantage.

A common final depth among the fish tested was discovered. This depth varied to a small but non-significant degree. This depth may be a result from pressures selecting a depth which maximizes evasion from above and below. Further research needs to be done to test this hypothesis.

Final depth and FT were non-significantly correlated. This relation was tested due to the idea that as the fish dove to a deeper depth, they would take less time to freeze. This idea was not supported as final depth and FT were independent of one another.

DD and FT proved to be independent behaviors. This finding is supported by past studies that have found the same relationship. The advantages of this independence have

been speculated upon but not tested. One possible reason for this independence is that a fish's surroundings may serve as an alternative to the two escape behaviors.

ACKNOWLEDGEMENTS

I would like to express my appreciation for Dr. Kesler's enthusiasm in his animal behavior course. This enthusiasm sparked the beginnings of this animal behavior directed inquiry. His interest, concern, and statistical knowledge helped make this directed inquiry possible. My gratitude also goes to Valerie Gray's proofreading abilities.

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**ATTEMPTED SYNTHESIS OF THE ISOTHIAZOLO [2,3-a]
BENZIMIDAZOLE AND 1,2 THIAZINO [2,3-a]
BENZIMIDAZOLE RING SYSTEMS**

David Dawson†

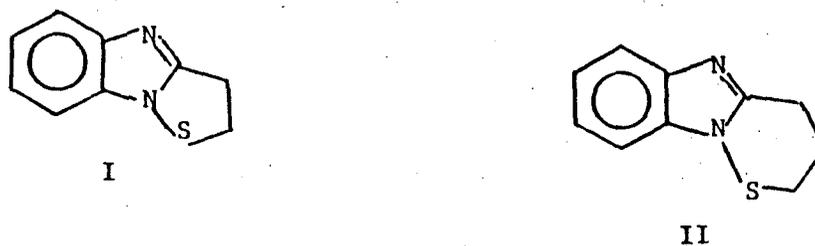
ABSTRACT

The goal of this research was to synthesize new heterocyclic systems, specifically 1,2-dihydroisothiazolo [2,3-a]benzimidazole and 1,2,3-trihydro 1,2 thiazino[2,3-a] benzimidazole. Two different techniques were used, a ring closure reaction with sulfenyl chlorides and an acid catalyzed rearrangement of a sulfoxide.

INTRODUCTION

The goal of this research was to synthesize new heterocyclic systems, specifically 1,2-dihydroisothiazolo[2,3-a]benzimidazole(I) and 1,2,3-trihydro 1,2 thiazino[2,3-a]benzimidazole(II), whose structures are given below.

Figure 1



Approach 1

The first approach consisted of making the sulfenyl chloride III and then attempting a ring closure with triethylamine. The scheme attempted is shown in figure 2.

Approach 2

The second approach was modeled after an acid catalyzed rearrangement of the sulfoxide(V) to compound VI reported by Figala *et al.* (1986). It is believed that the mechanism of the reaction involves intermediates of compounds VII and VIII. This scheme is shown in figure 3.

† David is a senior chemistry major from Fort Smith, AR.

Figure 2

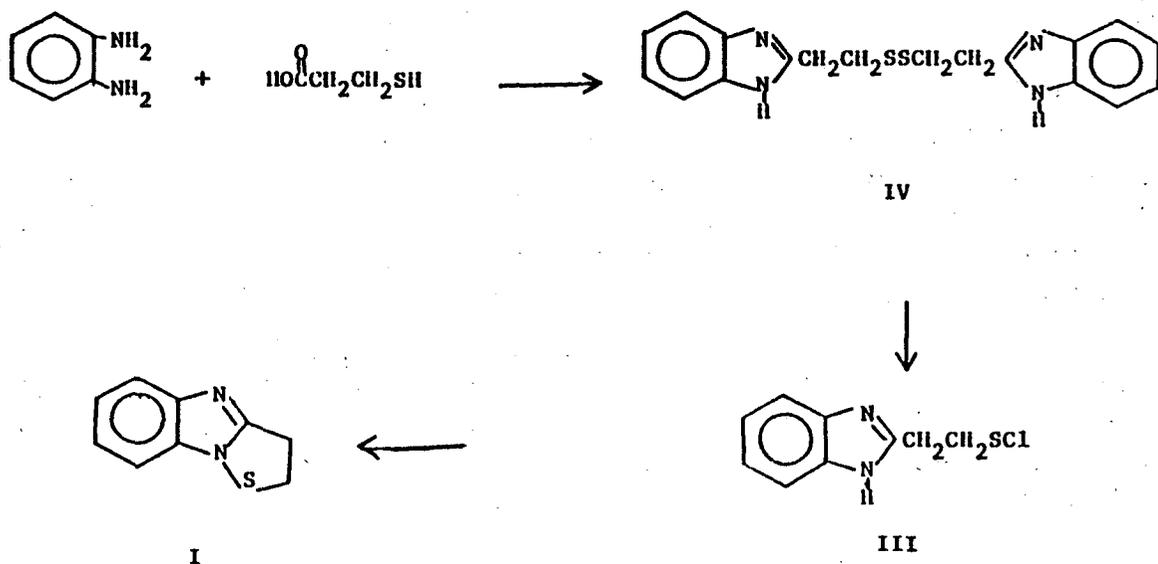
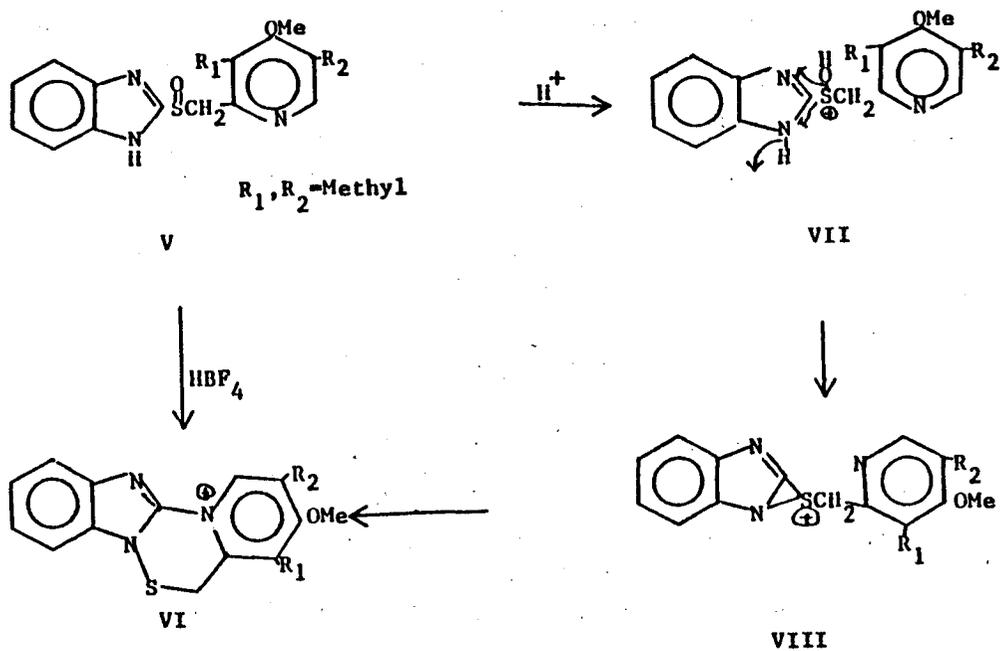


Figure 3



MATERIALS AND METHODS

Syntheses

2-Ethyl disulfide benzimidazole(IV)

10.8 g of O-phenylenediamine(Aldrich) and 15.9 g of Beta-mercaptopropionic acid (Aldrich) was added in 100 ml of 4N HCl. Reflux for 45 minutes to 2 hours. After cooling and filtering, the filtrate was made basic with ammonium hydroxide. The solid was collected and recrystallized several times from ethanol or aqueous ethanol. (M.P. experimental 214-15, lit 217-18) 2-chloro methyl benzimidazole(IX)

Chloroacetic acid (14.2g)(Aldrich), 10.8g of O-phenylenediamine and 100 ml of 4N HCl were refluxed for 45 min., left standing overnight, diluted with 200ml of H₂O, filtered, cooled, and neutralized with aq. NH₄OH. The solid was dissolved in hot dioxane, treated with carbon and let stand at room temperature to crystallize.(M.P. experimental 146, literature 149-50)

2-Methyl benzimidazole sulfide benzimidazole(X)

0.09g of KOH was dissolved in 1 or 2 drops of water. The chloro methyl product(.25g)(IX) was dissolved in DMSO as was the 2-mercapto benzimidazole (.225g) (Aldrich). The solution was allowed to stand and the precipitate washed with water. The precipitate was then filtered.

Methyl phenyl sulfoxide

Methyl phenyl sulfoxide was prepared according to the methods of Johnson, *et al.*

2(2 Amino ethyl sulfide)benzimidazole(XII)

2-Mercapto benzimidazole (5g) (Aldrich) and 7g of beta-bromoethylamine*HBr (Aldrich) was refluxed 3 hrs. in 28 mls H₂O and 7 ml EtOH to give 6.1 grams of product on cooling. 96% yield.

2(N-acetyl 2 amino ethyl sulfide) benzimidazole(XIII)

All of compound XII was added to acetic anhydride and heated. Addition of aqueous ethanol formed the product.(6.43g) M.P. 197-99

2(N-acetyl 2 amino ethyl sulfoxide) benzimidazole(XIV)

0.1 g of compound XIII was added to 2 ml of methanol, chilled to 0°C, and stirred. To this was added 0.86g of m-chloroperoxybenzoic acid in 2 ml of methanol over a 30 min. period. The liquid is then poured into a watch glass and the methanol evaporated. The solid formed and was washed with water and filtered. M.P. 70-72°C.

2(2 amino ethyl sulfoxide) benzimidazole(XV)

0.1g of compound XIV was added into 2 ml of 1M NaOH and heated at 70°C for 30 minutes. The solution was made acidic and a solid precipitated. This solution was dissolved in water to remove the salt. The solid was filtered.

RESULTS

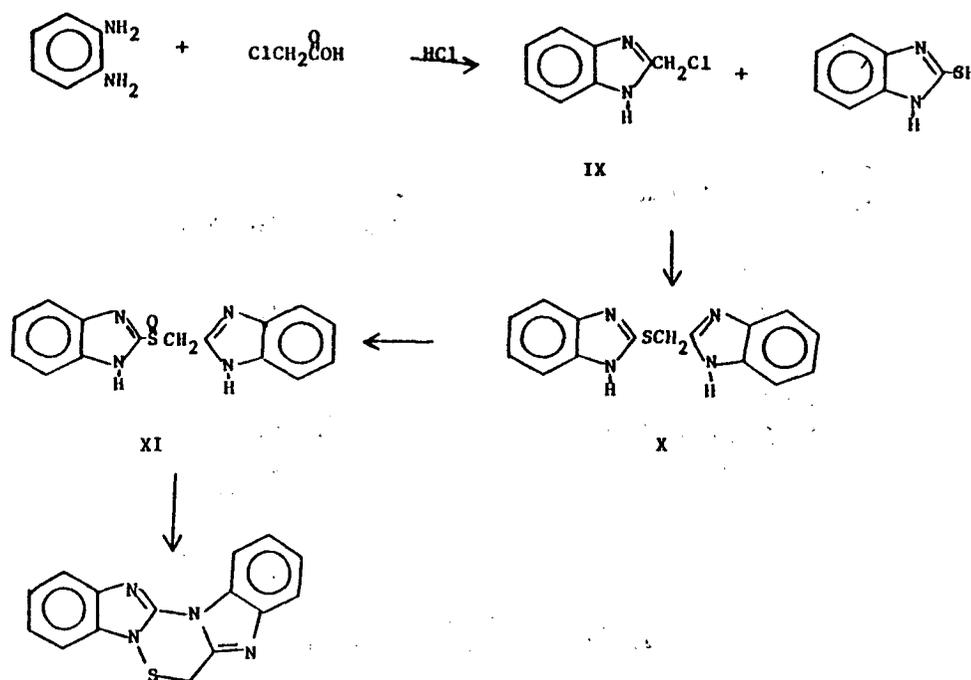
Approach 1

O-phenylenediamine and beta-mercapto-propionic acid were heated with aqueous hydrochloric acid forming the disulfide(IV) (M.P. experimental 214-15, lit 217-18) in good yield using the procedure of Gerhardt and Castle(1). Disulfides can be readily converted to sulfenyl chlorides with chlorine in hexane. Because the disulfide(IV) was not soluble in hexane, tetrahydrofuran was used as a solvent. However, it was found to be unsatisfactory because it rapidly reacts with chlorine. The disulfide(IV) was also treated with sulfuryl chloride, using the method of David Lawson *et al.* (1959) in an attempt to synthesize compound III. Apparently, the sulfuryl chloride chlorinated the benzene ring rather than forming compound III.

Approach 2

O-phenylenediamine and 2-chloroacetic acid were heated with hydrochloric acid to form 2-chloromethyl benzimidazole(IX) (M.P. experimental 146, literature 149-50). (Im *et al.*, 1985) Compound X was made by reacting 2-chloro-methyl-benzimidazole(IX) with 2-mercapto-benzimidazole in DMF and KOH. This followed closely the reaction set forth by Im *et al.* (1985) to make timoprazole.

Figure 4



I attempted to synthesize the sulfoxide(XI) from the sulfide using m-chloroperoxy benzoic acid, hydrogen peroxide(Bordwell, *et al.*, 1955) and potassium periodate. The

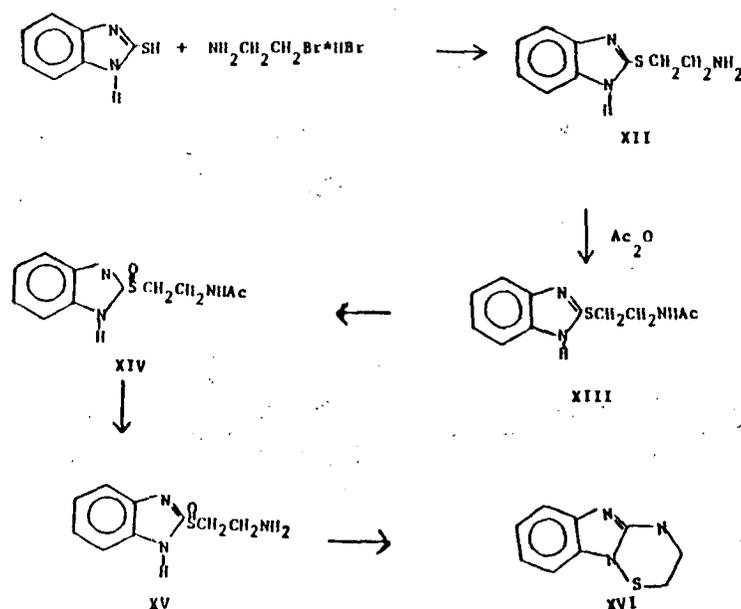
m-chloroperoxybenzoic acid seemed to be the best but the compound XI was not isolated due to problems with a suitable solvent.

This same approach was used with a different system to also close the ring. Compound XII was made by refluxing the mercaptan with amino ethyl sulfide bromine *HBr in aqueous ethanol for 3 hours. Compound XII was then acetylated with acetic anhydride to form compound XIII(M.P. 197-99) and the material was oxidized with m-chloroperoxybenzoic acid to form compound XIV(M.P. 70-72°C). The acetate was hydrolyzed with 2 ml of 1M NaOH and heated for 30 minutes at 70°C to form compound XV. The ring closure reaction would then form compound XVI.

DISCUSSION

The two syntheses were never taken to completion. The first attempt failed due to the difficulty in making sulfenyl chloride because the chlorine added to the benzene ring. A suitable way to chlorinate the sulfur atom must be found before the ring closure reaction can be attempted. The second method was not completed due to lack of time. The sulfoxide was synthesized, but the acid catalyzed rearrangement reaction was not attempted. More time needs to be spent on this reaction and on following its progress.

Figure 5



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SOME FACTORS AFFECTING DEFENSIVE ATTRIBUTION †

Karen Beardslee,* Marshall Cheney,** Steve Harmon,*** Al Taylor****

ABSTRACT

The purpose of this experiment was to investigate the attribution of responsibility to an accident victim as a function of the following variables: severity of the consequences, perceived similarity of the subject to the victim, gender of the victim, and gender of the subject. Sixty-four subjects were presented with four stories describing four different accidents with either a male or female victim, dire or non-dire consequences, and the victim being either a college student (similar) or a non-college student (dissimilar). An identical set of four questions which dealt with the notion of responsibility of the victim and the subject's perceived similarity to the victim followed each story.

It was shown that the male subjects attributed significantly more responsibility to the victims with non-dire consequences than with dire consequences. The only perceived similarity in the experiment was due to the gender of the victim, not the college/non-college condition.

INTRODUCTION

Some kinds of accidents are bound to occur and could happen to virtually anyone. When one hears of an accident, for the most part he sympathizes with the victim. If, however, a person feels the accident is serious he may begin to have vague feelings that the accident was *not* beyond the victim's control. This belief was held by Elaine Walster. She hypothesized that the tendency to try to assign responsibility to someone when a person hears about an accident increases as the consequences become more serious. Her experiment (1966) included four conditions using tape recordings. Under the guise of choosing materials and procedures to be used in a future study, the subjects were asked to assess the responsibility of a high school student whose car was involved in an accident when it rolled down a hill. Two experiments were constructed by a variation in potential sufferers. In one set of conditions there was damage to the car (thus, driver only suffers). In the other set of conditions there was damage to the car and, in addition, a possibility of injury to bystanders. Within each of the conditions the consequences were either trivial or serious. The results corresponded with Walster's predictions. Significantly more responsibility was assigned for severe consequences than for mild ones. This held true when the victim alone was involved and when others were involved. An interesting result was found when male-female differences were analyzed. Men assigned more responsibility when the consequences were dire. However, females assigned responsibility equally, regardless of consequences.

† This data was presented to the Tennessee Psychological Association in November, 1986.

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Later experiments (Walster, 1967 and Shaver, 1970) failed to corroborate such findings. The Shaver experiment used an adaption of the original Walster experiment. Shaver added another variable: age. In addition to describing the person as a "16 year old high school student," she added a 19 year old college student and a 22 year old graduate student to other conditions. Again the subjects were told the study was a pretest of stimulus material to be used in future studies. Shaver used booklets rather than tapes. Although failing to replicate Walster's experiment, she did find that assignment of responsibility increased with the age of the stimulus person. This could be a reflection of legal and moral tradition though.

MATERIALS AND METHODS

Subjects

Sixty-four Rhodes College students, the majority of which came from introductory psychology classes, served as subjects in this experiment with the restriction that there be an equal number of males and females.

Apparatus

The apparatus used in this experiment were booklets containing four stories with each story followed by questions. The stories consisted of four neutral texts. The sex of the character in the story, a short description (either college student or no description), and the consequences of the situation were manipulated and varied from text to text and booklet to booklet. The order of presentation of the stories were randomized within the packets with the restriction that no subject received the same text twice and that each text was read by the same number of subjects. The questions following the stories contained scales ranging from one to five. In approximately half of the booklets the scales were reversed (one being totally responsible, became not at all responsible).

Procedure

The test booklets were divided into two stacks designating between male and female subjects. The order of the booklets were randomized within the stacks to create a blind situation so the experimenter would not be aware of which set of texts were going to a particular subject. After the subjects received the booklets, a standard set of instructions were read telling the subjects to carefully read the stories and answer the follow-up questions. (At the beginning of the experiment the subjects were told that they were participating in a study to gather information for a future study.) The subjects were asked to indicate their sex on the back of the test booklet to double-check for accuracy and insure cell constancy.

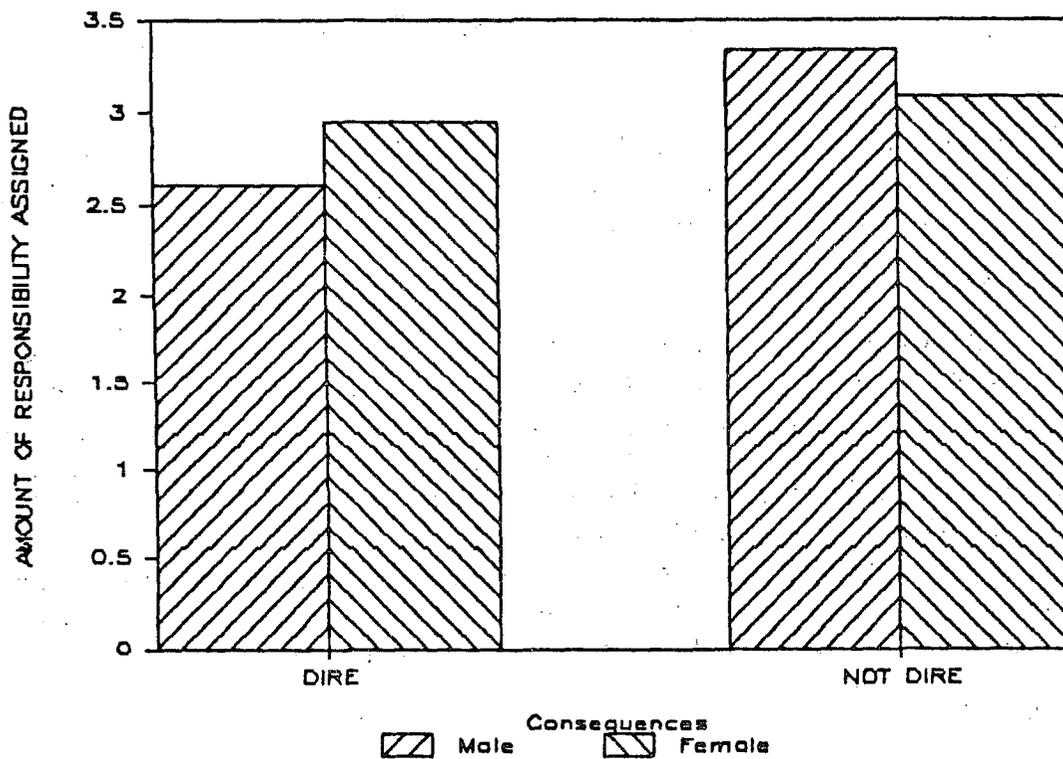
Design

A $2 \times 2 \times 2 \times 2$ factorial design was used. It was a between-subjects and within-subjects design with four variables: sex of the subject, sex of the text character (victim), perceived subject similarity to the victim, and consequences.

RESULTS

The results were analyzed using an analysis of variance. The results indicated that the severity of the consequences significantly influenced the assigning of responsibility, $F(1,60) = 7.760$, $p < .0071$, $X = 2.781$ (dire consequences), 3.211 (non-dire consequences). A significant difference was found in the interaction between the severity of the consequences and the sex of the subject, $F(1,60) = 3.902$, $p < .0499$, $X = 2.953$ (female subject reading dire consequence), 3.078 (female-not dire), 2.609 (male-dire), 3.344 (male-not dire).

Figure 1

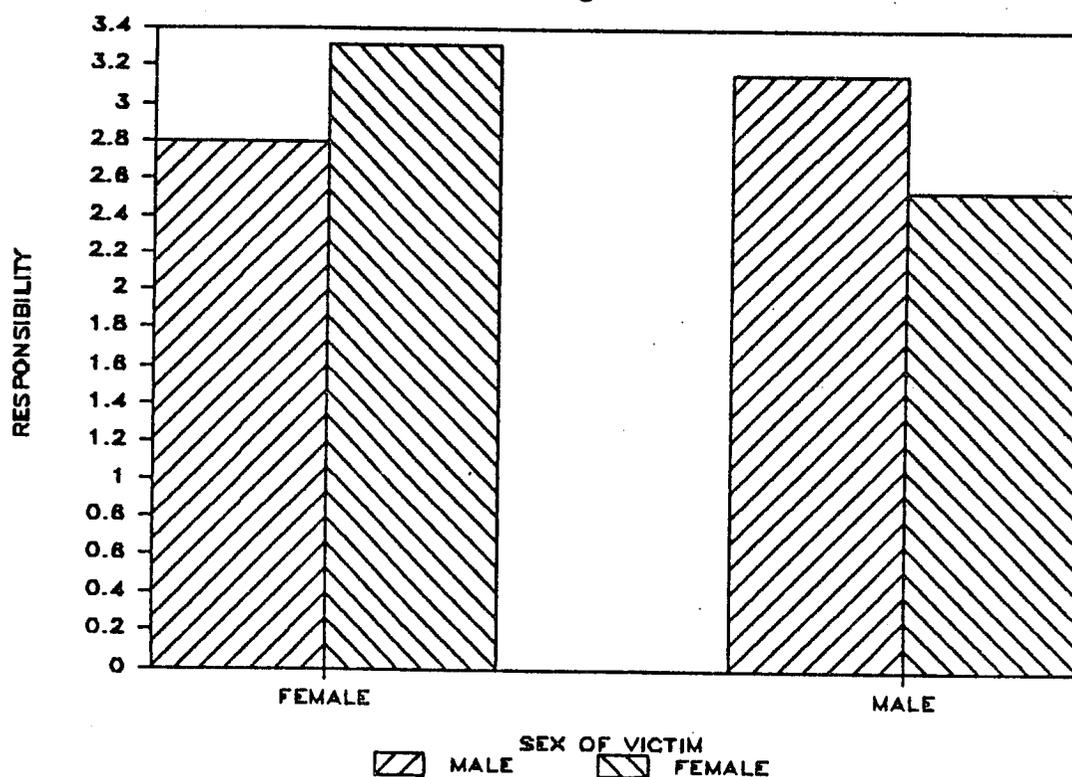


Furthermore, when perceived similarity was analyzed, a significant difference was found in the interaction between the sex of the subject and the sex of the text character (victim), $F(1,60) = 24.573$, $p < .0000$, $X = 3.313$ (female subject/female victim), 2.547 (female/male), 2.797 (male/female), 3.172 (male/male). (Figure 2)

DISCUSSION

The results of the present experiment fail to support the findings of Walster (1966) that people attribute more responsibility as the consequences become more serious. While a significant difference was found due to consequences, when the interaction between the sex of the subject and consequences was analyzed, it was found to be true only in males. In this experiment, males attributed more responsibility when the consequences were not dire. Females attributed about the same amount of responsibility regardless of consequences (means were 2.953 for dire and 3.078 for not dire). This latter finding, however, does coincide with the findings of Walster.

Figure 2



When similarity scores were analyzed, the predictions of Shaver (1970) failed to be replicated. Subjects did not attribute more responsibility to the victim on the basis of the description given (either college student or no description). When no description was given, subjects perceived the victim as similar to themselves—that is, within their age range (18-24). However, even though they perceived the victim as being similar, this similarity was not significant when attributing responsibility. Since similarity was a between-subjects variable, the subjects had nothing in which to compare the victims. One way to resolve this is to make similarity a within-subjects variable. Then subjects would be able to detect a difference between a person described as a college student and one with no description. Regarding similarity, the only significant difference found was the interaction between the sex of the subject and the sex of the victim.

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MAGNETIC STUDIES OF MARINE SEDIMENT CORE 7P

Alan R. Spiest†

ABSTRACT

The fields of paleomagnetism and rock magnetism provide geologists with an arsenal of investigative techniques. Paleomagnetic studies of marine sediments enable geologists to determine the declination, inclination, and intensity of the ancient magnetic field. Rock magnetic studies yield information concerning such factors as the types and sizes of the remanence carrying minerals. After necessary background information is given, magnetic studies of marine sediment core 7P, which was taken from the Bermuda Rise in the Western Atlantic, will be discussed.

INTRODUCTION

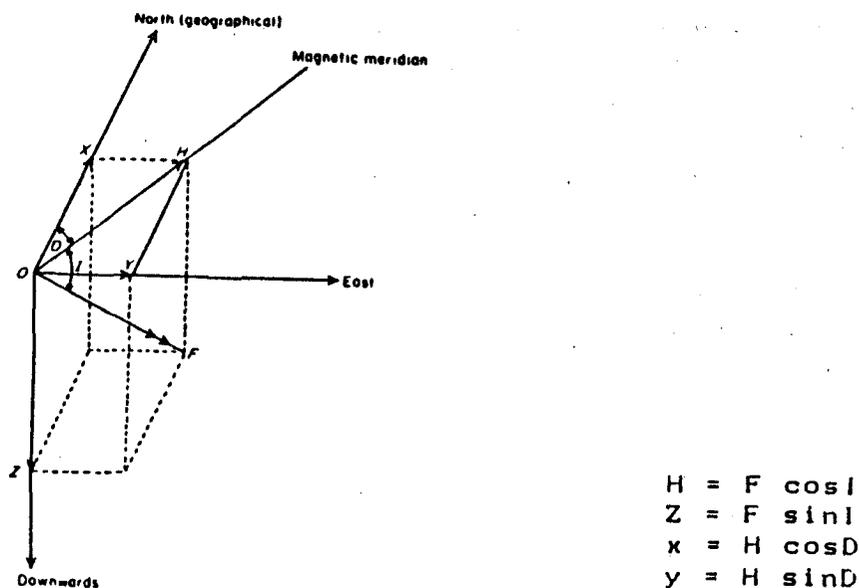
The earth's magnetic field can be approximated as a dipole field, i.e. field lines running from the south magnetic pole to the north magnetic pole. In fact, if one could locate a magnetic dipole tilted 11.5° with respect to the axis of rotation of the center of the earth, the resulting field at the surface would be nearly identical to the present field. The geomagnetic field is believed to originate in the earth's liquid outer core, which is composed mainly of iron and nickel. One hypothesis assumes that rotation about the earth's axis allows the liquid outer core to move relative to the solid inner core. A net current, caused by friction, sets up an initial magnetic field, which is intensified due to Lenz's Law. Finally, the earth's magnetic field varies in a number of ways on time scales ranging from less than a second to millions of years (Merrill and McElhinny, 1983).

The terms declination and inclination must be introduced before discussing paleomagnetism and rock magnetism. Anyone who has used a compass should be familiar with declination (D), i.e. the deviation of a compass needle from true north. Inclination (I), however, may be less familiar. It is an angle that the total magnetic field, F, makes with the horizontal. For example, the inclination is 0° at the magnetic equator and is $+90^\circ$ at the north magnetic pole. (See figure 1) With this in mind, one should now be in a position to understand the basic principals of paleomagnetism and rock magnetism.

To give a full treatment of paleomagnetism and rock magnetism is not the intent of this paper. Hence, this author will briefly discuss concepts and terminology that are applicable to marine sediment core 7P. Magnetic grains align themselves with the geomagnetic field as they settle out of a water column. The resulting sediment acquires a depositional remanent magnetization. Declination information obtained from depositional magnetization in sediment cores is widely accepted as accurate. However, the initial inclination, obtained from these deposits is possibly shallower than the true inclination. (Collinson, 1983). Once the particles are deposited on the substrate, they acquire, because of grain rotation in pore spaces, a post-depositional remanent magnetization (PDRM). The PDRM accurately records the geomagnetic field that influenced the magnetic carriers shortly after their deposition (Verosub, 1977). An analysis of the PDRM of marine sediment cores

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Figure 1



(Merrill & McElhinny, 1983)

gives a geologist average values for the direction and, hopefully, the intensity of the ancient geomagnetic field at a particular core site.

Only rock magnetic information pertinent to core 7P will be discussed. Rock magnetism refers to the study of the magnetic properties of sediment samples. Areas of interest include the kinds of remanence carrying minerals, the shape and grain size of the DRM carriers, and how these magnetic particles are affected by factors such as temperature and pressure. For example, here at URI, Dr. King *et al.* are using various magnetic parameters (to be discussed) to determine the relative magnetic grain sizes of sediment samples. Interestingly enough, grain sizes of some sediment cores are related to warm and cold climatic conditions. Because the age of a core increases with depth, one can correlate grain size at a particular level with some ancient climatic event, e.g. glacials and interglacials. There are various subtleties involved, but, generally speaking, glacial periods are associated with larger grains; finer grains accompany interglacials. Although grain sizes can be fairly well determined by magnetic means, the "magnetic mineralogy of deep-sea sediments is not yet well known..." (Merrill and McElhinny, 1983). Nevertheless, rock magnetism provides geologists with a wealth of information.

MARINE SEDIMENT CORE 7P

Rock magnetic studies of deep-sea sediment cores performed by King, 1985 (personal communication, Aug. 1986); Bloemendal, 1985; and Robinson, 1986 have consistently shown that larger magnetic grains are associated with glacials: smaller grains are found

during interglacials. The relative size of magnetic grains studied at URI lie within the 0.01-100 μm range. Also, the sediment grain sizes as a whole, i.e. the non-magnetic grains, have been larger and smaller during glacials and interglacials, respectively. Deep-sea core 7P, taken from the Bermuda Rise, is different in that sediment grain sizes are generally larger during interglacials and smaller during glacials.

In fact, core 7P was chosen for study because of its anomalous behavior. But why are core 7P's grain sizes opposite of what one would expect *a priori*? Strong sub-bottom currents on the Bermuda Rise accompany interglacials; hence, finer grains are swept away, and only larger particles settle on the ocean floor. The currents are not nearly as strong during glacials; therefore, a substantial number of finer grains are deposited. Hopefully, various magnet parameters will clearly show the above behavior.

To determine the relative magnetic grain sizes of sediment core samples, King *et al.* (1982, 1985) used the ARM vs. low-field susceptibility method. ARM (anhysteretic remanent magnetization) is a remanent magnetization acquired in a direct magnetic field superimposed on a slowly decaying alternating magnetic field. The various subtleties need not be considered here; suffice to say that ARM is sensitive to small magnetic grains. Likewise, low-field susceptibility (χ) is a measurable magnetic parameter that is more sensitive to coarse magnetic grains (King *et al.*, 1982). An ARM/ χ vs. DEPTH plot shows, by its peaks and valleys, at what depth the core is composed of fine and coarse grains, respectively. Furthermore, an oxygen isotope plot unequivocally shows, for reasons not discussed here, what depths in marine sediment cores correspond to glacials and interglacials. One should see from the above statement that, in many cases, an ARM/ χ vs. DEPTH plot can be used as an approximate oxygen isotope plot, i.e. peaks in ARM/ χ vs. DEPTH plots correspond to interglacials (fine grains); valleys correspond to glacials (coarse grains). However, in the case of core 7P one would expect the ARM/ χ vs. DEPTH plot to be the inverse of its oxygen isotope record because larger grains settled during interglacials, and a substantial number of smaller grains settled during glacials.

RESULTS AND DISCUSSION

Initial intensity, declination, and inclination values were obtained, and the initial susceptibility (χ) of core 7P's samples were measured. The collected data is displayed at the end of this paper in graph form, and conclusions drawn from the available magnetic data are based on the plot of AVERAGE MASS SUSC. vs. DEPTH because susceptibility is an accurate indicator of relative magnetic mineral content (Kent, 1982). Almost all of the marine sediment samples analyzed at URI by King *et al.* have magnetic concentrations of approximately 1% by volume; hence, susceptibility values are usually on the order of 10^{-5} . The measurements of core 7P yield values on the order of 10^{-6} - an order of magnitude less than expected. Therefore, I propose that magnetic mineral concentrations in core 7P's samples are $\ll 1\%$ by volume. The increasing susceptibility trend as one proceeds down-core is not unusual. Likewise the relative frequency independence of the susceptibility measurements (shown by the SUSC(hi)/SUSC(low) vs. DEPTH plot) is common in marine sediments studied at URI.

Unfortunately, I was unable to obtain an ARM/ χ vs. DEPTH plot of marine sediment core 7P because of laboratory equipment failure. Consequently, it remains to be seen

whether or not the desired plot is indeed the inverse of the oxygen isotope record. If the above holds true, King *et al.* will have developed a fast, powerful, magnetic method for determining relative grain sizes of marine sediment cores.

ACKNOWLEDGEMENTS

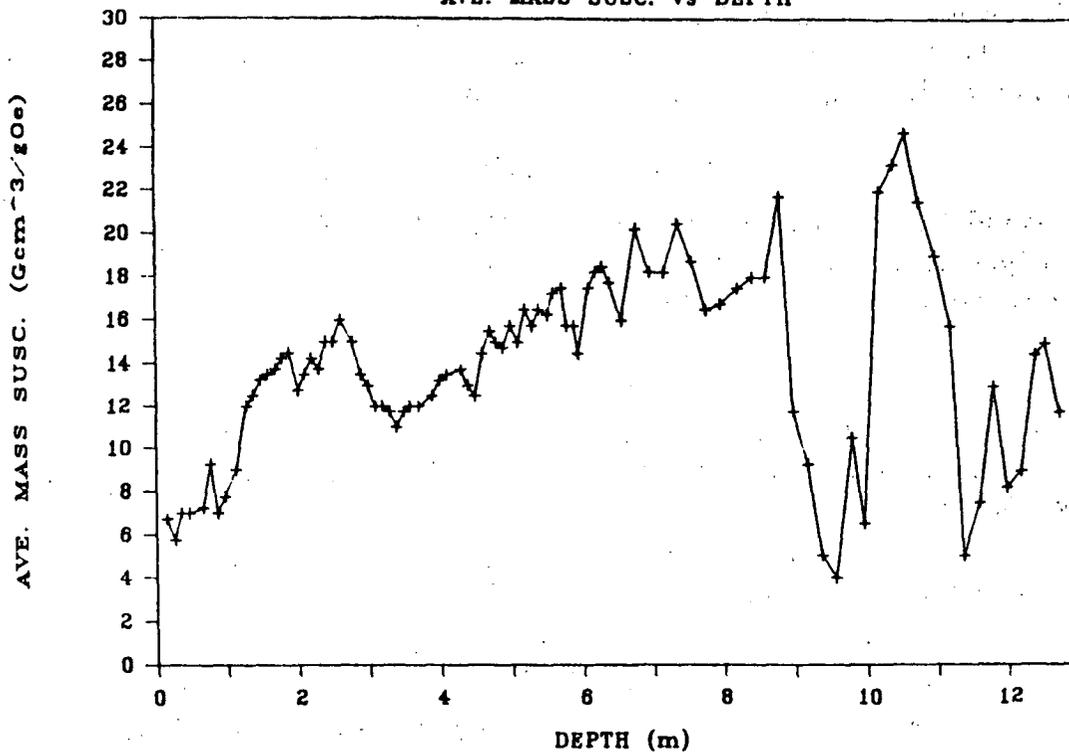
I would like to thank sincerely Dr. John King, Frank, Paul, Jan, and San-Jay. Without their help, support, patience, and guidance, my summer research experience at GSO would have been neither rewarding nor fulfilling.

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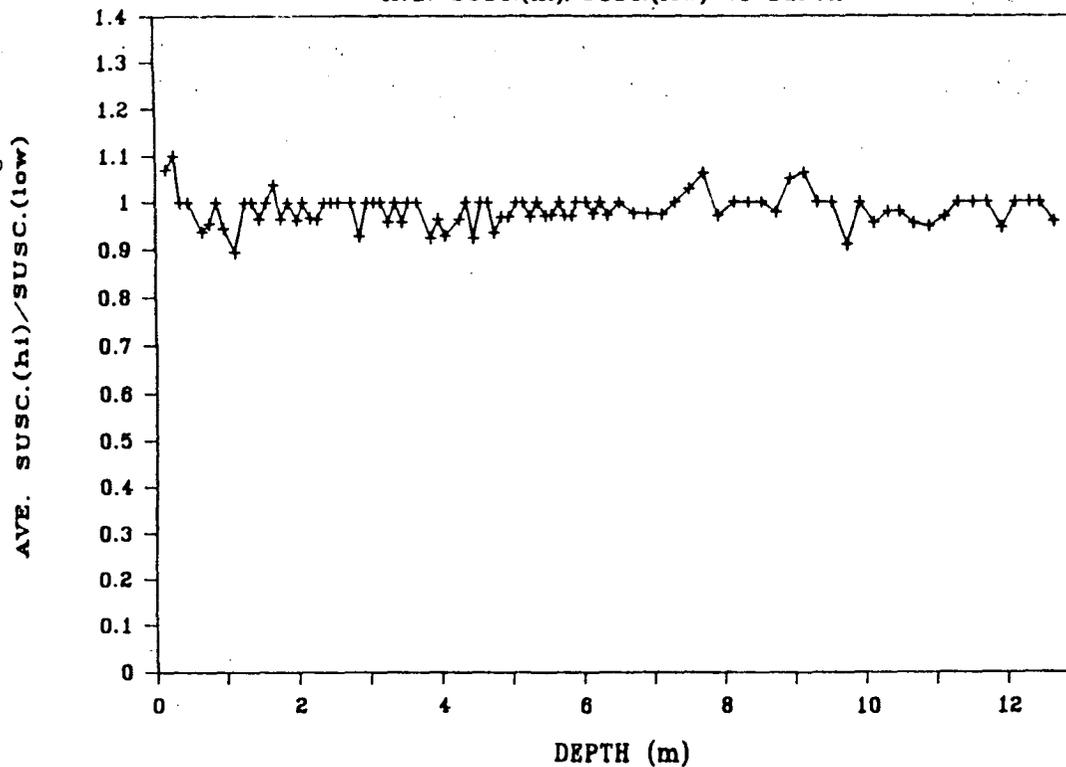
CORE 7P: Samples 1 & 2

AVE. MASS SUSC. vs DEPTH



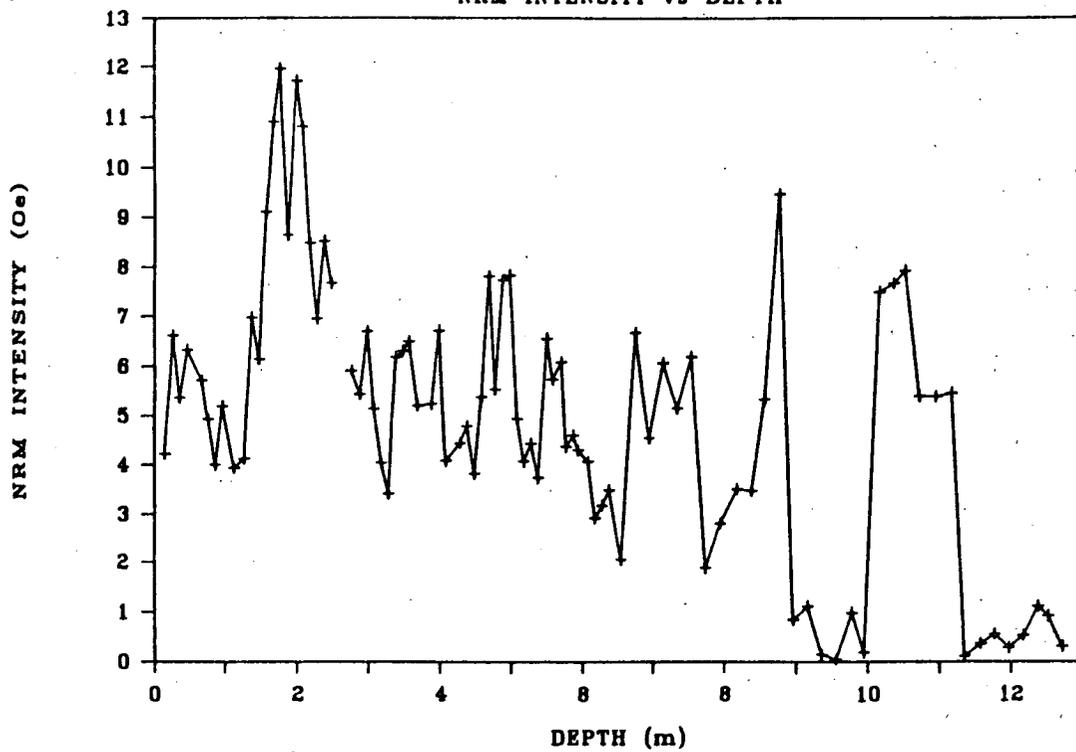
CORE 7P: Samples 1 & 2

AVE. SUSC.(hi)/SUSC.(low) vs DEPTH



CORE 7P: Samples 1 & 2

NRM INTENSITY vs DEPTH



THE SPECIAL THEORY OF RELATIVITY

Allan Bacon†

ABSTRACT

In this paper, the basic principles of special relativity are discussed. Relativistic expressions are developed for position, time, length, mass, momentum and kinetic energy. Effects such as length contraction and time dilation are discussed.

INTRODUCTION

“Relativity grows from an attempt to formulate an operational definition of the *length* of a moving object, and of the *time* measured by a moving observer” (Christy, 1965). According to classical theory, however, the length of a moving object is the same as when it is at rest, and time is constant. Thus, the theory of relativity presented a radical change in the traditional ideas of physics. Problems with the classical theory had already started to appear, though. Since Maxwell’s equations described light as an electromagnetic wave, the prevalent classical views dictated that the wave be transmitted in some medium. Nonetheless, attempts by Michelson and Morley and others to detect this medium were unsuccessful. In 1905, Einstein presented his principle of relativity which explained *a priori* the failure of all experiments designed to detect the drift of an ether or such medium (Rindler, 1982). In this paper, I will derive the relativistic expressions for position, time, length, and mass as well as expressions for momentum and kinetic energy.

To begin, the classical ideas of time and length should be examined. There is an intuitiveness about time. Common experience is ordered in terms of events, some which happen “before” others. A later event would be assigned a larger value for its time coordinate. Time can be measured in terms of different length intervals, e.g., the period of oscillation of a quartz-crystal oscillator. Furthermore, in the classical view, every observer’s time is the same as everyone else’s. I.e., if an event happened at 4 o’clock for one person, it happened at 4 o’clock for any other observer, regardless of the observer’s relative velocity (Christy, 1965).

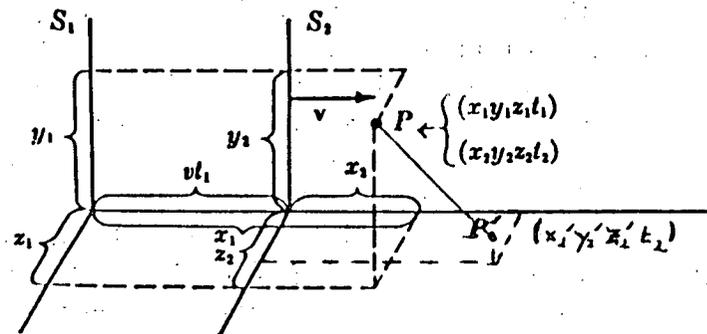
The idea of length seems equally fundamental. Length can be measured using a rigid, standard unit, such as a ruler. On this ruler, “two...points are separated by [a unit distance] if they can be brought into coincidence with the two fiducial marks, simultaneously” (Christy, 1965). If the two points are stationary, the distance between them is the absolute value of the difference of the numbers on the stick at each point. The difference would be the same for anyone with an identical ruler. If the points are in motion, “the two readings [must] be taken *simultaneously* in order to measure the distance at that time” (Christy, 1965). Classically, these distances would be the same if taken by two different observers, as long as they were taken at the same two points. This agrees with everyday experience. However, one can see that if observers disagreed on the simultaneity of the measurements, they would disagree on the distance (Christy, 1965).

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The measurement of time and distance is always carried out in comparison to some standard of reference. "A frame of reference is a conventional standard of rest relative to which measurements can be made" (Rindler, 1982). One special class of frames of reference are the inertial frames of reference. In these frames, "particles not subject to external forces move at constant speed in unvarying direction" (Bergmann, 1974). That is, an inertial frame is one in which Newton's first law holds. Furthermore, a system of coordinates chosen so that Newton's first law holds is called a Galilean coordinate system.

Assuming two coordinate systems in relative uniform motion, we now determine the equations which relate the time and space coordinates of a body. These are the Galilean transformation equations for Newtonian mechanics [see figure 1].

Figure 1 (Christy, 1965.)



We assume that the clocks at rest in \$S_1\$ and \$S_2\$ were both set to read zero at the moment their origins coincided. As seen by someone at rest in \$S_1\$, the origin of \$S_2\$ will be at \$(vt_1, 0, 0)\$ at a time \$t_1\$. Therefore, since the coordinates of the point \$P\$ are \$(x_1, y_1, z_1, t_1)\$ and \$(x_2, y_2, z_2, t_2)\$, we see that:

$$x_2 = x_1 - vt_1$$

$$y_2 = y_1$$

$$z_2 = z_1$$

and, under our assumptions,

$$t_2 = t_1$$

The time statement shows the classical concept of absolute time. Another classical concept, constant length, can also be easily shown. The length between two points, \$P\$ and \$P'\$, is equal to (in \$S_2\$),

$$\begin{aligned} L_2 &\equiv \sqrt{(x'_2 - x_2)^2 + (y'_2 - y_2)^2 + (z'_2 - z_2)^2} \\ &= \sqrt{((x'_1 - vt_1) - (x_1 - vt_1))^2 + (y'_1 - y_1)^2 + (z'_1 - z_1)^2} \\ &= \sqrt{(x'_1 - x_1)^2 + (y'_1 - y_1)^2 + (z'_1 - z_1)^2} \equiv L_1 \end{aligned}$$

where \$L_1\$ is the length in \$S_1\$.

Differentiating each side with respect to t_2 and t_1 , respectively and noting that $dt_1 = dt_2 = dt$, we see that:

$$\dot{x}_2 = \dot{x}_1 - v$$

$$\dot{y}_2 = \dot{y}_1$$

$$\dot{z}_2 = \dot{z}_1$$

or,

$$\dot{\vec{r}}_2 = \dot{\vec{r}}_1 - \dot{\vec{v}}_1,$$

thus arriving at the classical idea of addition of velocities.

At this point, it is important to discuss Einstein's principle of relativity in the restricted sense. It says that "if, relative to R , R' is a uniformly moving coordinate system devoid of rotation, then natural phenomena run their course with respect to R' according to exactly the same general laws as with respect to R ." (Einstein, 1920) That is, "the laws of physics are identical in all inertial frames" (Rindler, 1982).

The principle of relativity was the first of two axioms Einstein utilized in his development of the Special Relativity Theory. The second axiom was that c , the speed of light in a vacuum, was a constant when measured in any inertial frame. Obviously, though, the statement that c is constant contradicts the Galilean transformation. If, in figure 1, the velocity of light is \vec{c} in S_1 , then it should be equal to $\vec{c} - \vec{v}$ in S_2 . Therefore either the axiom or the Galilean transformation must be incorrect. However, the velocity of light had been proved constant by Michelson and Morley in 1887. Their experiment determined that the speed of light was equivalent in all directions in their laboratory. Under the Galilean equations, the only way this could happen would be if the laboratory was at rest with respect to the "ether frame" that supposedly carried the light waves. Since the experiment worked half a year later when the earth was in a different frame, the only plausible result was that the speed of light was constant (Christy, 1965). Therefore, the Galilean transformations must be in error.

Accepting the two axioms, another transformation between the S_1 and S_2 inertial frames is needed. This is done with the Lorentz transformation equations. Taking again the S_1 and S_2 in figure 1, we let S_2 move in the x -direction with velocity \vec{v} . Since there is no relative motion in the y - or z -directions, we have:

$$y_2 = y_1$$

$$z_2 = z_1$$

In order to keep the two frames from having different values for c , though, the transformation of the x -coordinate must differ from the Galilean transformation (Christy, 1965). There are two other requirements to be placed on the transformation. First, the equations should reduce to the Galilean expressions, at small velocities, since they agree well with experiment there. Second, the transformation equations should be linear in order to give a one-to-one correspondence (Christy, 19665). Now try a linear transformation,

$$x_2 = \gamma(x_1 - vt_1)$$

where $\gamma \rightarrow 1$ as $v \rightarrow 0$.

For the time coordinate, a similar transformation is used,

$$ct_2 = \alpha(ct_1 - \beta x_1)$$

where $\alpha \rightarrow 1$, $\beta \rightarrow 0$ as $v \rightarrow 0$

(Christy, 1965). Next, assume that a spherical light wave left the origin at the initial time $t_1 = t_2 = 0$. The second axiom requires that at a later time,

$$c = \frac{\sqrt{x_1^2 + y_1^2 + z_1^2}}{t_1} = \frac{\sqrt{x_2^2 + y_2^2 + z_2^2}}{t_2}$$

Squaring the function, we get,

$$0 = x_1^2 + y_1^2 + z_1^2 - c^2 t_1^2 = x_2^2 + y_2^2 + z_2^2 - c^2 t_2^2$$

Now, substituting with the transformation equations, we obtain,

$$x_1^2 - c^2 t_1^2 = \gamma^2 (x_1 - vt_1)^2 - \alpha^2 (ct_1 - \beta x_1)^2$$

or

$$x_1^2 (1 - \gamma^2 + \alpha^2 \beta^2) - t_1^2 (c^2 + v^2 \gamma^2 - c^2 \alpha^2) - 2x_1 t_1 (c\alpha^2 \beta - v\gamma^2) = 0.$$

So, in order to solve for the general, nontrivial case, the coefficients of x_1^2 , t_1^2 and $x_1 t_1$ must vanish.

$$1 - \gamma^2 + \alpha^2 \beta^2 = 0$$

$$c^2 + v^2 \gamma^2 - c^2 \alpha^2 = 0$$

$$c\alpha^2 \beta - v\gamma^2 = 0$$

Solving the system of three equations with three unknowns, one obtains:

$$\alpha = \gamma = \frac{1}{(1 - (v/c)^2)^{\frac{1}{2}}}$$

$$\beta = v/c$$

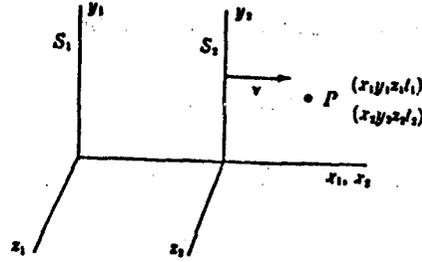
Finally, substituting back into the assumed equations,

$$x_2 = \frac{x_1 - vt_1}{\sqrt{1 - (v/c)^2}}$$

$$y_2 = y_1$$

$$z_2 = z_1$$

Figure 2 (Christy, 1965.)



$$t_2 = \frac{t_1 - \frac{vx_1}{c^2}}{\sqrt{1 - (v/c)^2}}$$

If v/c is set equal to zero, the equations reduce to the Galilean equations, thus approximating the classical case where v is small relative to c . There is a major difference between the two transformations, however. In the Galilean case, distances and time intervals are absolute, whereas in the Lorentz equations distances and time intervals are relative to the observer. (Christy, 1965)

Two interesting examples of the relativity equations are length contraction and time dilation. Using figure 2, assume that the object is at rest in S_2 and an observer in S_2 measures the length of the object to be L_2 .

To find the length as seen by an observer in S_1 , we use the Lorentz transformation equations.

$$L_2 \equiv x'_2 - x_2 = \frac{(x'_1 - vt'_1) - (x_1 - vt_1)}{\sqrt{1 - (v/c)^2}}$$

where t'_1 and t_1 are the times when an observer in the S_1 frame measures the length. In order that the length be correctly measured, however, the measurements must be taken *simultaneously* in S_1 ; i.e., $t'_1 = t_1$. Therefore, the equation reduces to:

$$L_2 = \frac{x'_1 - x_1}{\sqrt{1 - (v/c)^2}} = \frac{L_1}{\sqrt{1 - (v/c)^2}}$$

or,

$$L_1 = L_2 \sqrt{1 - (v/c)^2}$$

(Christy, 1965).

Consequently, the observer in S_1 finds the length shorter than the length measured by an observer in S_2 by a factor of $\sqrt{1 - (v/c)^2}$.

For the expression for time, we assume two clocks have been synchronized while at rest relative to each other. In figure 2, one clock in S_2 moves with a constant velocity \vec{v} in the x -direction relative to S_1 . The clock, S_1 , is located at a fixed point, x_1 . Let,

$$T_1 \equiv t'_1 - t_1$$

be the time between two events as measured by an observer in S_1 . Using the Lorentz equations of transformation, the observer in the S_2 frame would record the time interval as,

$$T_2 \equiv t'_2 - t_2 = \frac{(t'_1 - t_1) - (v/c^2)(x'_1 - x_1)}{\sqrt{1 - (v/c)^2}}$$

where x_1 and x'_1 are the positions in S_1 where the events occur. Assuming that the two events occur at the same place (i.e., $x'_1 = x_1$), the relation simplifies to

$$T_2 = \frac{T_1}{\sqrt{1 - (v/c)^2}}$$

Therefore, the time interval in S_2 between two "moving" events is longer than the time interval between the events as recorded at rest by the observer in S_1 . Thus the phrase "time dilation" is used for this relativistic effect (Christy, 1965).

Next, consider the case of relativistic mass and momentum. Consider the collision of two particles that bind together after the collision [see figure 3].

Figure 3 (Shadowitz, 1968.)

BEFORE COLLISION	AFTER COLLISION
<p>Diagram showing two particles of mass m moving towards each other with velocity $2v$.</p>	<p>Diagram showing a single particle of mass $2m$ moving with velocity v.</p>
<p>Diagram showing a particle of mass m moving with velocity $w = \frac{2v}{1 + \frac{v^2}{c^2}}$.</p>	<p>Diagram showing a particle of mass M moving with velocity v.</p>

Using the Galilean transformation, one particle would be at rest before collision and one would be moving with a velocity $2v$. After the collision, the new particle would have mass $2m$ and velocity v . Therefore, mass is conserved ($2m$ before and after the collision), and the momentum is conserved ($2mv$). However, the kinetic energy is not conserved. Before the collision it is

$$\frac{m}{2}(2v)^2 + 0 = 2mv^2$$

But, afterwards it is,

$$\frac{1}{2}(2m)v^2 = mv^2$$

Therefore the quantity mv^2 is converted into internal energy of some sort. (Shadowitz, 1968)

Using the Lorentz transformation, however, the velocities are different. In this case, before the collision, one particle will be at rest and the other will have a velocity,

$$w = \frac{2v}{1+(v^2/c^2)} \quad (1).$$

After collision, the velocity of the particle will be v . Mass is conserved, but momentum is not, being $\frac{2mv}{1+(v/c)^2}$ before and $2mv$ after the collision (Shadowitz, 1968).

There was no reason to believe that the conservation laws of mass and momentum were invalid, though. Einstein solved the dilemma by allowing that mass was a variable, dependent on the velocity. Now we develop an expression for the moving mass. The Lorentz observer will state the conservation of mass and momentum by

$$m_w + m^\circ = M_v \quad (2)$$

and

$$m_w w = M_v v \quad (3)$$

so, from equation (3) we obtain

$$m_w = \frac{v}{w} M_v.$$

Using this in equation (2) along with equation (1), we get

$$M_v = \frac{m^\circ}{1 - (v/w)} = \frac{2m^\circ}{1 - \frac{v^2}{c^2}}$$

so, letting $\beta = v/c$

$$m_w = \frac{v}{w} \left(\frac{2m^\circ}{1 - \beta^2} \right) = \frac{m^\circ}{\sqrt{1 - (w/c)^2}}$$

But since w and v are arbitrary,

$$m = \frac{m^\circ}{\sqrt{1 - \beta^2}} = \frac{m^\circ}{\sqrt{1 - (v/c)^2}}$$

Now, with this expression for the relative mass, the momentum can be obtained from the definition of momentum, the product of the mass and the velocity:

$$p = mv = \frac{m^\circ v}{\sqrt{1 - (v/c)^2}}$$

As with the other relativistic expressions, this equation gives values that are close to the classical value of $m^\circ v$ except when v is comparable to c . (Shadowitz, 1968)

Finally, we derive expressions for the kinetic energy and total energy of a particle. Since the energy of the particle at rest is $m^{\circ}c^2$ and the energy of the particle in motion is mc^2 , the kinetic energy is simply the difference between the two. Subtracting, we obtain,

$$K = (m - m^{\circ})c^2 = m^{\circ}c^2 \left(\frac{1}{\sqrt{1 - (v/c)^2}} - 1 \right)$$

When $v \ll c$, the binomial expansion gives,

$$K = M^{\circ}c^2 \left(\left(1 + \frac{v^2}{2c^2} + \dots \right) - 1 \right) = \frac{1}{2}m^{\circ}v^2 \left(1 + \frac{3}{4}(v/c)^2 + \dots \right)$$

And, of course, for slow speeds (relative to c), this approximation gives the usual expression, $K = \frac{1}{2}m^{\circ}v^2$.

The total energy for a particle of rest mass m° is then

$$E = (p^2c^2 + m^{\circ 2}c^4)^{\frac{1}{2}}$$

where p is the relativistic momentum. The total energy of a photon (with an obvious rest mass of zero) is

$$E_{\text{photon}} = pc = h\nu$$

from the Einstein relation, where h is Planck's constant and ν is the frequency. Then, with $\lambda = c/\nu$, $p = h/\lambda = \hbar k$ where $\hbar = \frac{h}{2\pi}$ and $k = \frac{2\pi}{\lambda}$, we have obtained the DeBroglie relation.

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A Word With... Dr. Harold Lyons

D. Davidson Oxley

Inside the Gothic walls of the Chemistry Building are rooms filled with modern analytical instruments: chromatographs, various spectroscopic instruments, automatic integrators, electronic balances. While every member of the department is undoubtedly proud of their well-equipped facilities, one professor, Dr. Harold Lyons, would be quick to add that modern instruments have one major flaw - they fail to "build character" among students. But all is not lost. For many years here at Rhodes, Dr. Lyons has been building character within his students.

Dr. Lyons began his study of chemistry during the Great Depression by working during the day and attending the City College of New York at night. After receiving the Bachelor of Science degree, he served five years as a Naval Officer during World War Two. Returning from the Pacific in 1945 meant finding a job and ultimately starting a family. But before too long, Dr. Lyons had decided to continue his study of chemistry at Oklahoma State University. Analytical chemistry and electronics were his major interests, due in part to extensive training he had received in the Navy. Several doctoral-level chemistry jobs came his way during the following years, jobs which paid well and allowed him to make practical use of his expertise in analytical chemistry. But, Dr. Lyons admits that his goal had long been to teach college chemistry. So, in 1958 he decided to take a sixty percent pay cut in order to teach at a small Southern school named Southwestern.

Although Dr. Lyons has been a professor at Rhodes for the past twenty-nine years, his work has by no means been limited to the ivy-covered walls of Kennedy Hall. In fact, from 1962 until 1985, he also served as Professor and Director of the Pathology Graduate Program at the University of Tennessee, Memphis. Among the numerous research projects he has undertaken are the biochemical study of protein-polysaccharide complexes in intervertebral discs, a study which won him a National Institutes of Health grant, and the study of serum from cancer patients through the use of differential pulse polarography. He also served for many years as a consultant to the Tennessee State Medical Examiner's Office.

What does Dr. Lyons feel is his greatest contribution to science? He says it's simply in educating young scientists. While he admits he is very proud of having founded the state's first toxicology lab here in Memphis and of his many successful research projects, he emphasizes that he most enjoys teaching students and seeing those students succeed. And what does he think about the academic environment here at Rhodes College? He loves it. Over the years he has been offered several wonderful opportunities elsewhere but has always turned them down in favor of the unique atmosphere and high quality of education here at Rhodes. He says that he has no plans for the future except to continue teaching and researching.

* * * *

Dr. Harold Lyons is Chair of the Department of Chemistry and the Schering-Plough Professor of Chemistry. He is married and has three sons, all Rhodes graduates.

BIOLOGY ALUMNI DIRECTORY

Updated versions of the directory will follow in future issues of the Science Journal.

The directory which follows is compiled from the responses given on the alumni questionnaire. We thank those of you who responded to our requests for information; we have been able to 'discover' that many of you have earned advanced degrees that we were unaware of. We hope the directory that follows will be of some use as you check for classmates and friends. The format used in this directory is:

Name (maiden name), address, phone number; occupation, spouse's name, number of children.

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KENNEDY, DAVID, 728 OAK HILL DRIVE, SHREVEPORT, LA 71106,
318-861-6859; RETIRED PHYSICIAN, NELL

CLASS OF 1930

SPANN, JEANNETTE, 1960 NORTH PARKWAY #404, MEMPHIS, TN 38112,
901-272-0162; MEDICAL TECHNOLOGIST, RETIRED

CLASS OF 1933

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RETIRED, ANN, 1

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AR 71603, 501-879-2586; RETIRED, AUDREY, 3

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916-223-3382; MEDICAL DIRECTOR, 6

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SALES, GERTRUDE, 4

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RETIRED, MARY ANN, 4

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DENTIST, RITA

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RHONDA, 2

GRIFFIN, DAVID, 1300 36TH STREET, VERO BEACH, FL 32960,
305-231-1024; ORTHOPEDIC SURGEON, SHEILA, 3

HALL, DAVID, 1018 NORTH ARTHUR, LITTLE ROCK, AR 72207,
501-664-2185; UROLOGIST, VICTORIA, 2

KULP, ROY, 4311 LONGLEAF DRIVE, MEMPHIS, TN 38117, 901-683-3647;
RADIOLOGIST, KATHY, 4

MCKEAN, RANDY, 105 MONTICELLO WAY, FAIRBURN, GA 30213,
404-461-1959; ENDODONTIST, BETTY, 1

MURPHY, JIM, 1805 EUCLID ROAD, DURHAM, NC 27713, 919-544-7304;
COMPUTER MANAGER, JANINE, 4

NICHOLS, JOHN, 243 COLLEGE STREET, MUNFORD, TN 38058,
901-837-2170; DENTIST, CATHERINE, 2

RHEA, RASCOE, 225 FRANKLIN, SELMER, TN 38375, 901-645-7817;
DENTIST, SIMMS, 2

RICKOLL, WAYNE, 1525 BOONE STREET, BRYAN, TX 77843, 409-775-3730;
ASSISTANT PROF. BIOLOGY

WILLIAMS, DOUG, ROUTE 2 BOX 523 E4, CRAWFORDVILLE, FL 32327,
904-926-3984; WILDLIFE ECOLOGIST, DEVA, 2

YATES, LINDA, 1401 DEXTER ROAD/PO BOX 8, CORDOVA, TN 38018,
901-754-7855; EMERGENCY MEDICINE

CLASS OF 1970

COLLINS, LANI, 5165 KIMBARK WOODS DRIVE, MEMPHIS, TN 38134,
901-388-9626; MEDICAL TECHNOLOGIST

DANIEL, NICKY, 1406 HARBERT AVENUE, MEMPHIS, TN 38104;
901-722-8712; INTERNAL MEDICINE, MIMI, 3

DUNLAP, CHARLIE, 2420 BUFFALO LANE, SODDY-DAISY, TN 37379,
615-842-6832; ORAL SURGEON, DEBBY, 2

HAMILTON, BRUCE, 45 FIELDCREST DRIVE, JACKSON, TN 38305,
901-668-5817; DENTIST, JAN, 1

HENRY, ROBERTA (PLENGE), 12405 NE 22ND STREET, VANCOUVER, WA
98684, 405-840-9562; NURSE MIDWIFE

OGBURN, WALTER, 393 TERRACE DRIVE, OVIEDO, FL 32765,
305-365-9317; SR. ENVIRONMENTAL SCIENTIST, MARLYN, 2

PEDERSEN, MARTHA, 127 RIVERVIEW DRIVE, ST. ROSE, LA 70087,
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PEDIGO, JOE, 1971 CRAIGMONT BLVD, CLARKSVILLE, TN 37043,
615-552-4801; PEDIATRICIAN, MARTY, 2

PIENAAR, STEVE, 5331 MURFF AVENUE, MEMPHIS, TN 38119,
901-682-8023; TRAC-WORK, INC., JANE, 2

PURVIS, JOHN, 1954 PETIT BOIS, JACKSON, MS 39211, 601-366-0852;
ORTHOPEDIST, GAYLA, 3

ROWLAND, ROSS, 717 COVE DRIVE, BILOXI, MS 39531, 601-388-7707;
CHAPLAIN, TENDRA, 3

TERRY, PAT (SIMPSON), 4951 SAGEWOOD DRIVE, MEMPHIS, TN 38116,
901-346-8381; TEACHER, HOWARD, 2

THOMAS, TOM, 5150 GRAPE, HOUSTON, TX 77096, 713-665-5305; ASSOC.
PROF. MEDICINE, GERALDINE

UNDERWOOD, JOYCE (MCCONNELL), 525 PINWOOD DRIVE, NICHOLASVILLE,
KY 40356, 606-885-9898; HOMEMAKER, DALE, 2

WALTEMATH, GARY, 104 KENNER AVENUE, NASHVILLE, TN 37205,
615-292-9652; DENTIST, 3

CLASS OF 1971

BURNETT, RONNY, 1606 CASTLE DRIVE, JONESBORO, AR 72401,
501-932-0439; DENTIST, STACY, 3

DAVIS, JACK, 138 BRENTWOOD DRIVE, DAPHNE, AL 36526, 205-626-5017;
PHYSICIAN, SUSAN, 2

DESALVO, GENYTH (SMITH), 2601 CRESTWOOD ROAD, MARRERO, LA 70072,
504-348-3763; BAKERY OWNER, MIKE, 2

DOOLITTLE, BOBBY, 211 EAST HENDRIX STREET, GREENSBORO, NC 27401,
919-275-6778; PHYSICIAN, KATHRYNN, 2

JONES, CHARLES, 162 S GEORGIA AVENUE, MOBILE, AL 36604,
205-432-8019; OPHTHALMOLOGIST, MISSY, 2

KLEIER, BOBBY, 1905 HIDDEN OAKS, MEMPHIS, TN 38138, SURGEON,
JULIE, 3

MARLEY, BO, 116 WESTOVER DRIVE, CLARKSDALE, MS 38614,
601-627-4687; OB-GYN, GAYLA, 1

MCCARTY, JAY, 4713 SPRINGWILLOW ROAD, FORT WORTH, TX 76109,
817-763-8083; DERMATOLOGIST, PAT, 2

MILLER, RICHARD, 2150 COLLEGE STREET, MONTGOMERY, AL 36106,
203-269-1952, PATHOLOGIST, MARCIA, 2

MILLS, JIM, 1003 BRENTWOOD RT 4 BOX 263A, MILAN, TN 38358,
901-686-8098; DENTIST, DEBORAH, 2

MORGAN, TOM, 8461 PAGET COURT, MEMPHIS, TN 38138, 901-756-0708;
CORP. REAL ESTATE, SHERRI, 1

NIESEN, CHUCK, 115 GLEN ROAD, WEBSTER GROVE, MO 63119,
314-962-8831; DENTIST, SUSAN, 3

SATTERTHWAITE, JOHN, 200 HUNTING HOLLOW ROAD, GREENVILLE, SC
29615, 803-297-1663; ANESTHESIOLOGIST, SHARON, 2

THOMPSON, CHARLES, 4921 MARCEL COVE, MEMPHIS, TN 38122,
901-767-4776; DENTIST, BELINDA, 3

VERNON, MINOR, 4712 MOOR PARK, MACON, GA 31210, 912-477-3598;
PEDIATRICIAN, NATALIE, 2

WILLIAMS, JEFF, 5115 TWINWOODS STREET, MEMPHIS, TN 38134,
901-386-9481; PEDIATRIC DENTIST, PATTI, 3

CLASS OF 1972

ATKINSON, BILL, 302 HAMPSHIRE COURT, CLARKSVILLE, TN 37043,
615-645-5413; ASST. PROF. BIOLOGY, JANET

DODSON, BILL, 2015 R STREET NW, WASHINGTON, DC 20009,
202-232-1543; PSYCHIATRIST, JANIS

GOLDEN, SONNY, 182 GREENBRIAR ROAD, MEMPHIS, TN 38117,
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GRAHAM, JAN, 3500 PARK ROAD, OCEAN SPRINGS, MS 39564,
601-875-1830; PARK RANGER

KESLENSKY, SUSAN (SCHWAB), 5423 BRAEBURN DRIVE, BELLAIRE, TX
77401, 713-666-1964; HOMEMAKER, JERRY, 2

MCKINNEY, JAN (WESTBROOK), 9420 STATESVIEW DRIVE, KNOXVILLE,
TN 37922, 615-690-2153; PHYSICAL THERAPIST, JAMES, 3

MILLER, MARCIA (EASKER), 2150 COLLEGE STREET, MONTGOMERY, AL
36106, 203-269-1952; PHYSICAL THERAPIST, RICHARD, 2

RUTLEDGE, JACK, 111 W 75TH STREET #5R, NEW YORK, NY 10023,
212-362-7741; NJ STATE HEALTH COMMISSIONER

SMOOT, JOHN, 115 SHAGBARK, BATESVILLE, MS 38606, 601-563-5061;
FAMILY PRACTICE, MARY, 3

YIELDING, SUSAN (WORKMAN), 386 HUNTERS RIDGE, MARIETTA, GA
30068, 404-973-8997; HOMEMAKER, ALEX, 2

CLASS OF 1973

BARKLEY, RICK, 201 NORTHWIND DRIVE, GOODLETTSVILLE, TN 37072,
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BIBEE, DOUG, 105 VAN WINKLE DRIVE, LAKE JACKSON, TX 77566,
409-265-6375; SR. DEVELOPMENTAL CHEMIST, MARY, 3

CROOM, LINDA (KUILEMA), 309 ROBIN HOOD DRIVE, MORGANTON, NC
28655, 704-437-7854; HOMEMAKER, DORWYN, 1

DAVIS, KATHY (JORGENSEN), 87 OUTER DRIVE, OAK RIDGE, TN 37830,
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VASCULAR SURGEON, 2

DEW, ROGER, 4212 DEVINE STREET, COLUMBIA, SC 29205, 803-738-9114;
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PATHOLOGIST, DABNEY, 2

HERMANN, ROBERT, 676 UPTON ROAD NW, ATLANTA, GA 30318,
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JONES, HAROLD, 1112 GREENWAY DR. W., MOBILE, AL 36608,
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LANGDON, RUSS, 4016 MALONEY ROAD, KNOXVILLE, TN 37920,
615-573-1995; ANESTHESIOLOGIST, GLORIA, 2

MCWILLIAMS, VIVIAN (DELLINGER), ROUTE 4 EMMETT STILL ROAD,
LOGANVILLE, GA 30249, 404-466-1106; VETERINARIAN, JOE, 1

RANDLE, MICHAEL, 46-362 NAHEWAI STREET, KANEHOE, HI 96744,
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REECE, LINDA, 1650 ROLLING HILLS, MEMPHIS, TN 38127, 901-358-4817;
PHARMACIST

SMITH, RICK, 324 CHARLES STREET, LITTLE ROCK, AR 72205,
501-666-5496; ASSOC. PROF. PSYCHIATRY, SUSAN, 1

TODD, BET, 4616 ALLENCREST LANE, DALLAS, TX 75234, 214-490-9204;
TOXICOLOGIST, WILLIAM

CLASS OF 1974

ALLEN, CINDY, 814 CHATWOOD STREET, MEMPHIS, TN 38122,
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BEAZLEY, COOPER, 2218 NORTH MEADOW DRIVE, CLARKSVILLE, TN 37043,
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BROWN, INGRID (KASTNER), 1311 WHITE OAK COVE, JONESBORO, AR 72401,
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BRYANT, DICK, JR., P.O. BOX 48643, DORAVILLE, GA 30362;
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CRENSHAW, MARTHA, 4964 OWENS COURT, STONE MOUNTAIN, GA 30083,
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ENVIRONMENTAL ENGINEER, KATHY, 2

DIGAETANO, DOLORES, 1254 VINTON, MEMPHIS, TN 38104, 901-726-6269;
PSYCHIATRIST, MIKE, 1

DOLEN, BILL, 1758 SOUTH DEARBORN WAY, AURORA, CO 80012,
303-752-3641; PEDIATRIC ALLERGIST, CAROLYN, 2

EDWARDS, CHIP, 293 EVANSDALE ROAD, LAKE MARY, FL 32746,
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EPPS, MICHAEL, 11 NORTHWOOD AVENUE, JACKSON, TN 38301,
901-424-6453; OB-GYN, CAROLYN, 2

GRAVES, THEO (SIZOO), 23608 RIM ROAD EAST, GRAHAM, WA 98338,
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GRIGGS, CLARE, 8086 CLAREDALE STREET, MEMPHIS, TN 38134,
901-372-7262; TEACHER, JOHN

HILL, DON, 416 SKYLINE VISTA, RUSSELLVILLE, AR 72801,
501-967-3393; INTERNAL MEDICINE, CAROL, 1

ISRAEL, LILLIAN (LYLE), 116 CRESTVIEW DRIVE, BIRMINGHAM, AL
35213, 205-879-1490; PEDIATRICIAN, GEORGE, 2

JONES, MISSY (MEYERS), 162 S GEORGIA AVENUE, MOBILE, AL 36604,
205-432-8019; HOMEMAKER, CHARLES, 2

MCCRARY, BRYANT, 332 SOUTHERN CIRCLE, GULFPORT, MS 39501,
601-896-6876; PEDIATRICIAN, MARGARET, 4

SACHRITZ, ANN (BAIRD), 716 HAZY MEADOW COURT, BRANDON, FL 33511,
813-684-3244; HOMEMAKER, NATHAN, 2

SCOTT, CAROL, 3751 HILLTOP PLACE, SPRINGFIELD, MO 65804,
417-831-6341; OPTOMETRIST, JON

UTHMAN, ED, 7807 CLAREWOOD, HOUSTON, TX 77036, 713-778-9905;
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501-935-7542; NURSE, MICHAEL, 2

CLASS OF 1975

ANDRUS, ANITA, 323 SNOOK STREET, SALMON, ID 83467, 208-756-4658;
MASSAGE THERAPIST

CHUNN, ANDY, 919 MURREY DRIVE, PULASKI, TN 38478, 615-363-8933;
H.S. BIOLOGY TEACHER, PAM, 2

COLE, FRANK, 110 PONDEROSA DRIVE, FAYETTEVILLE, GA 30214,
INTERNAL MEDICINE, DEBORAH, 2

DUCKWORTH, BILL, 265 OLD CLAIRTON ROAD, PITTSBURGH, PA 15236,
412-653-0140; SAFETY ENGINEER

MADDUX, BEN, 5213 MARY STARNES, MEMPHIS, TN 38117, 901-682-8187;
UROLOGIST, BECKY, 2

MARTINO, WILMA (THAXTON), 5104 ALPHONSE DRIVE, METAIRE, LA 70006,
504-888-6552; HOMEMAKER, CARL, 2

MILLER, MERRY (NOEL), 3403 DIXON ROAD, DURHAM, NC 27707,
919-493-5955; PSYCHIATRIST, BARNEY, 1

MONTGOMERY, TOM, 1410 ANGIE DRIVE NW, CULLMAN, AL 35055,
205-734-2284; PHYSICIAN, CINDY, 2

PERA, KATE, 51 SOUTH MCLEAN #9, MEMPHIS, TN 38104, 901-726-0986;
CATERING DIRECTOR

RIES, RUSSELL, 6124 HILLSBORO ROAD, NASHVILLE, TN 37215,
615-373-1880; FACIAL PLASTIC SURGERY, SUSIE, 3

SCHARDT-CANNON, CC (SCHARDT), PO BOX 63, GOESSEL, KS 67053,
316-367-8253; PHYSICIAN ASSISTANT, WILLIAM, 2

SHAMEL, BLAIR, 11747 MAYWIND COURT, SAN DIEGO, CA 92131,
619-693-1950; MARKETING MANAGER, CINDY, 2

SUTHERLAND, SCOTT, 205 EDGEWOOD DRIVE BOX 1100, CADIZ, KY 42211,
502-522-6169; OPTOMETRIST, MARY ANN, 3

WALTERS, JIM, 7124 N BRENTWOOD DRIVE, FORT MYERS, FL 33907,
813-481-3427; RADIOLOGIST, LYN, 2

CLASS OF 1976

CHUGDEN, ROB, 4924 CRAIG AVENUE, METAIRIE, LA 70003, 504-889-0735;
EMERGENCY MEDICINE, ELIZABETH, 2

CROWDER, ROY, 119 HIGHLAND, RIPLEY, TN 38063, 901-635-1339;
DENTIST, SHEILA, 1

FRIEDMAN, LANE, 3196 S MARYLAND PARKWAY, LAS VEGAS, NV 89109,
702-732-2042; INTERNAL MEDICINE

GROGAN, JANE (THOMAS), 881 CONCORDIA COURT, COLLIERVILLE, TN 38017,
HOMEMAKER, RANDY, 1

HENRY, CHARLES, 5809 HAWTHORNE STREET, LITTLE ROCK, AR 72207,
501-664-4807; OPHTHALMOLOGIST, SARAH, 1

JOE, PENN, 4298 RENNERS ROAD, MEMPHIS, TN 38128, 901-767-8442;
OB-GYN, CLARA, 1

KELLERMANN, ARTHUR, 149 PALISADE STREET, MEMPHIS, TN 38111,
EMERGENCY MEDICINE, LEILA

KIBBY, TOM, 404 ANITA STREET; DURHAM, NC 27701, 919-688-6413;
OCCUPATIONAL MEDICINE, DAYNA, 2

KINSLOW, HENRY, 139 WOODLAND DRIVE, EL DORADO, AR 71730,
501-863-3232; ATTORNEY

MEYERS, JIM, 3860 PARADISE BAY DRIVE, GULF BREEZE, FL 32561,
904-932-6602; PSYCHOLOGIST, JUDY, 1

ROSELL-DAVIS, ROSIE (ROSELL), 718 SEMMES STREET, MEMPHIS, TN
38111, 901-452-6721; PH.D. STUDENT, M.S.U., JOSEPH

SILVER, MARTHA (HORTENSTINE), 209 LAKEWOOD DRIVE, MOBILE, AL
36608, 205-344-5735; OTOLARYNGOLOGY, DAVID, 2

TENCH, PAIGE (WILSON), 4406 WYOMING, NASHVILLE, TN 37209,
615-383-4485; PHYSICIAN, DANIEL

CLASS OF 1977

ALLEN, LOUISE (RUTKOWSKI), 521 STONEWALL STREET, MEMPHIS, TN
38112, 901-272-3582; DENTIST, RAY, 1

BEAVER, TERINELL, 5370 WALNUT GROVE ROAD, MEMPHIS, TN 38119,
901-683-0991; GERIATRICS

CLARY, MIKE, 4208 GENYTH STREET, MEMPHIS, TN 38128, 901-377-6590;
HEAD FOOTBALL COACH, NANCY, 2

DOLAN, BETH (TIERNEY), 3237 WESTMINSTER, DALLAS, TX 75205,
214-373-3554; ASST. PROF. INT. MEDICINE, MICHAEL, 1

FREELAND, LYNDA, 2219 WEST RIVER TRACE #2, MEMPHIS, TN 38134,
901-372-1548; INTERNAL MEDICINE

GODFREY, SAM, ROUTE 2 BOX 159, NATCHEZ, MS 39120, 601-446-7694;
ATTORNEY, PATTY

GRAVES, JIM, RD 3, OSWEGO, NY 13126, 315-343-8364; LIBRARIAN

HANNA, THERESE (LOGUE), 147 HAZELCREST DRIVE, JACKSON, MS 39212,
601-373-8503; HEALTH PLANNER/ANALYST, WILLIAM, 2

HESTON, PAT (FLYNN), 2120 UNIVERSITY CIRCLE, MEMPHIS, TN 38112,
901-278-7401; PED. INFECTIOUS DISEASE, JERRY, 2

HICKS, DOT (NEALE), 1475 VANCE AVENUE, MEMPHIS, TN 38104,
901-274-2133; SYSTEMS ENGINEER, JOHN

HOPPER, CURTIS, 5317 HUNTERS RIDGE, NASHVILLE, TN 37211,
615-833-1129; PUBLIC WATER SUPPLY INSPECTOR, PAMELA

JANSEN, MARK, 1016 EVERGREEN, ARKADELPHIA, AR 71923, 501-246-7689;
PHYSICIAN, CINDY, 1

MANGUM, SPUR, 908 DRIFTWOOD DRIVE, MERIDIAN, MS 39301,
601-681-8560; ANESTHESIOLOGIST, LAURIE

MARA, ROBIN (MATTIS), 403 ROLLINGWOOD CIRCLE, FAYETTEVILLE, NC
28303, 919-323-4836; WRITER, DESIGNER, NEIL, 1

MAY, TOM, 801 S RODNEY PARHAM #5-B, LITTLE ROCK, AR 72205,
501-223-2254; PHYSICIAN, MARY

MELTON, STEVE, 325 SHELLY STREET, DYERSBURG, TN 38024,
901-286-2834; PEDIATRICIAN

PHELPS, BILL, 720 CABIN JOHN PARKWAY, ROCKVILLE, MD 20850,
301-251-8589; MOLECULAR BIOLOGIST, JUDY, 2

RHEA, RANDY, 2310 MOUNT VERNON ROAD SW, ROANOKE, VA 24015,
703-345-2223; PHYSICIAN

STEGMAN, MARC, 7719 WILLOW VINE COURT #28-225, DALLAS, TX 75230,
214-692-1412; NEPHROLOGY

SUDDERTH, BRIAN, 4 PHEASANT DRIVE, BENTON, AR 72015, 501-776-0638;
PHYSICIAN, LYNN, 1

WEEMS, AMELIA (CHRISTIAN), 247 ALEXANDER STREET, MEMPHIS, TN
38111, 901-323-9979, PUBLIC HEALTH NURSE, JOHN

WEEMS, JOHN, 247 ALEXANDER STREET, MEMPHIS, TN 38111, 901-323-9979;
EPIDEMIOLOGY, AMELIA

WILLIAMS, LARRY, 1779 PRINCETON WOODS DRIVE W, MOBILE, AL 36618,
205-343-3542; ASST. PROF., DIANE, 1

CLASS OF 1978

AUSTIN, STEVE, ROUTE 6 BOX 92, MARTIN, TN 38237, 901-581-5845;
PSYCHIATRIST, 3

BELLUOMINI, GARY, 934 BRANTLEY DRIVE, KNOXVILLE, TN 37923,
615-693-5932; NUCLEAR ENGINEER, PAMELA, 2

EASTHAM, DUNK, 320 ELMIRA PLACE NE, ATLANTA, GA 30307,
404-688-2421; PEDIATRICIAN

GNADT, JIM, 1775 RED BARN ROAD, ENCINITAS, CA 92024,
619-753-6768; POST-DOC, SALK INSTITUTE, GWEN, 1

HESTON, JERRY, 2120 UNIVERSITY CIRCLE, MEMPHIS, TN 38112,
901-278-7401; CHILD PSYCHIATRY, PAT, 2

INGLE, BOB, 2672 CENTRAL TERRACE, MEMPHIS, TN 38111,
901-327-6740; GASTROENTEROLOGIST, GINGER, 1

LONGMIRE, LISA, 113 BLUEGRASS POINT, HENDERSONVILLE, TN 37075,
615-824-2221; MEDICAL TECHNOLOGIST

MASTERS, STEVE, 7632 SABRE DRIVE, KNOXVILLE, TN 37919,
615-693-4032; PHYSICIAN, WENDY

PEVAHOUSE, JOE, 2412 NORTH FILLMORE, LITTLE ROCK, AR 72207,
501-664-8876; PHYSICIAN, BRYN

PHELPS, JUDY (PANIPINTO), 720 CABIN JOHN PARKWAY, ROCKVILLE, MD
20850, 301-251-8589, ASSOC. SCIENTIST, BILL, 2

SCHAEFFER, BETH (DEMING), 8164 DOGWOOD VILLA, MEMPHIS, TN 38138,
901-755-7892; HOMEMAKER, SANDY, 2

SCHAEFFER, SANDY, 8164 DOGWOOD VILLA, MEMPHIS, TN 38138,
901-755-7892; ACCT. SYSTEMS ENGINEER, BETH, 2

SCHULZE, DALE, 6350 CHERRY TREE LANE NE, ATLANTA, GA 30328,
404-255-1258; GRAD STUD., LANGUAGES

CLASS OF 1979

BARNETT, ARDEN, 1157 WEST DRUMMOND PLACE #1, CHICAGO, IL 60614,
312-472-8229; PSYCHIATRIST

BATEY, EDDIE, 6536 FERN CREEK, MEMPHIS, TN 38115, 901-795-1757;
GUIDANCE COUNSELOR

BENOIST, MIMI (WARD), 3536 HILLTOP ROAD, FORT WORTH, TX 76109,
817-926-2743; BANKER, JOHN, 1

CAMPBELL, MARY (PALMER), 14 GARDEN COURT, ELIZABETHTOWN, PA
17022, 717-533-6687; PHYSICIAN, BILL

CARROLL, ELAINE (TOULON), 3481 FAIRWAY DRIVE, COLLEGE PARK, GA
30337, 404-768-1709, TEACHER, MARK, 1

CASH, MYRON, 1852 PATRICK ROAD, MEMPHIS, TN 38114, 901-744-0955;
RESEARCH TECHNICIAN

CRENSHAW, CAROLYN, 6913-I ROSWELL ROAD NE, ATLANTA, GA 30328,
404-395-0351; MANAGEMENT CONSULTANT

HAMMOND, MARK, 1707 KIMBROUGH ROAD, GERMANTOWN, TN 38138,
901-754-6617; INTERNAL MEDICINE, ANGELA

HAYNIE, BOB, 213 DONNA DRIVE, LITTLE ROCK, AR 72205, 501-835-0170;
PEDIATRICIAN, LAURA, 2

HIGGINBOTHAM, LARRY, 200 STONEWALL STREET #1, MEMPHIS, TN 38112,
901-274-0231; DENTIST, BETH

HIGMAN, ROSS, 1634 MOORE ROAD, MONTECITO, CA 93108, 805-969-1527;
REAL ESTATE

JONES, GERRY, 435 EAST 70TH #14-A, NEW YORK, NY 10021,
212-744-5945; PHYSICIAN, JEAN, 1

MCCALLUM, LEE, RTE 1 BOX 401 BASCOMB ROAD, JACKSON, TN 38305,
901-668-0576; PHYSICIAN, BARBARA, 1

MCMULLEN, TRICIA, 5122 MASON ROAD, MEMPHIS , TN 38117,
901-685-5815; VOLUNTEER WORK

MITCHELL, CAROL, 1262 ESSEX DRIVE, MEMPHIS, TN 38119, 901-685-2528;
INTERNAL MEDICINE

MURPHY, ROBERT, 2803 FLAKEWOOD, LITTLE ROCK, AR 72207,
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PHILLIPS, SPIKE, 12700 WYOMING WOOD COURT, ORLANDO, FL 32824,
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POSNER, STEVEN, 5108 S. DAWSON #4, SEATTLE, WA 98118, 206-723-5827;
ENGINEER

SALING, RUTH (DEUFEL), 424 NINTH STREET SE, MINNEAPOLIS, MN 55414,
612-623-8288; TEACHER, KENNETH

SHENK, ANDY, 130 MURLYN ROAD, HAMDEN, CT 06518, 203-288-4604;
POST-DOC, YALE, ELIZABETH, 1

STONEKING, HAL, 3737 EAST LEE STREET EXT, GREENSBORO, NC 27406,
919-698-0527; INTERNAL MEDICINE, CAROLE

THOMPSON, KEITH, 238 ROBINHOOD DRIVE, FLORENCE, AL 35630,
205-766-0036; INTERNAL MEDICINE, CAROL, 2

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CLASS OF 1980

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The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry, no matter how small, should be recorded to ensure the integrity of the financial statements. This includes not only sales and purchases but also expenses and income. The text suggests that a systematic approach to bookkeeping can help in identifying trends and managing cash flow effectively.

In the second section, the author provides a detailed explanation of the double-entry system. This method ensures that every transaction is recorded in two different accounts, maintaining the balance of the ledger. The author explains how debits and credits work and provides examples to illustrate the process. This system is crucial for preventing errors and ensuring that the books are balanced at all times.

The third part of the document focuses on the preparation of financial statements. It outlines the steps involved in calculating the profit and loss account, the balance sheet, and the cash flow statement. The author stresses the importance of reviewing these statements regularly to gain insights into the financial health of the business. It also mentions the need for transparency and accuracy in these reports.

Finally, the document concludes with some practical advice for small business owners. It suggests that investing in good accounting software can save time and reduce the risk of errors. Additionally, it recommends seeking professional advice from accountants or auditors when needed to ensure compliance with tax laws and other regulations.