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ARKANSAS ACADEMY OF SCIENCE

Forty-ninth Annual Meeting
University of Arkansas
April 2-3, 1965

OFFICERS

President ........................................ Dr. Lowell F. Bailey
President-elect ............................... Dr. James H. Fribourgh
Secretary ...................................... Dr. George E. Templeton
Treasurer ...................................... Dr. Edward E. Dale

SECRETARY’S REPORT

The first business meeting was called to order by President Bailey at 10:45 a.m. with 55 members in attendance. The members were welcomed to the campus of the University of Arkansas at Fayetteville by President Bailey.

As the Secretary’s Report was already published in the Proceedings, reading of the report was omitted, and the report was accepted as published. The Treasurer’s Report was submitted to the Auditing Committee by the Treasurer, Dr. E. E. Dale.

The Editor of the Proceedings, Dr. James L. Dale, reported that Volume 18 of the Proceedings cost approximately $10 per page and emphasized the need for authors to hold the size of articles to a minimum in order that as many as possible of the papers submitted could be published with the existing budget. He also pointed out that submission of the paper in form suitable for publication, promptly upon presentation at the meetings would greatly expedite publication and permit the Editorial Board to release the Proceedings at a much earlier date than it has in the past.

The Secretary reported that while the Academy was not in financial difficulty at the present time, such problems could be expected as our expenditures for the Proceedings exceeded our income last year and the overhead from the NFS grants would be substantially reduced in the coming year. After considerable discussion, it was moved by Dr. J. P. Fulton and seconded by Dr. D. A. Slack that regular membership dues be increased from $3 per year to $5 per year and that the
sustaining membership dues be increased from $5 per year to $10 per year. The motion passed. The Secretary was instructed to notify the membership of this increase and to acknowledge sustaining memberships in an appropriate manner.

A letter to the Academy requesting its endorsement of issuing a commemorative stamp to mark the 100th anniversary of the law to permit use of the metric system in the United States was read to the membership. The President was instructed to send the letter of endorsement.

The President asked the membership to consider the future relationship of the Academy to the Valley Education and Research Foundation and be prepared to discuss at the next business meeting the desirability of co-sponsoring our annual meeting with the Foundation.

Dr. Bailey appointed the following ad hoc committees:

**Nominations**
Dr. J. P. Fulton  
Dr. E. B. Wittlake  
Dr. S. Siegel

**Auditing**
Dr. Clarence Sinclair  
Dr. Victor Hoff

**Meeting Place for 1966**
Mr. M. L. Lawson  
Mr. E. C. Mayes  
Dr. J. H. Fribourgh

There being no further new business, the meeting was adjourned at 11:30 a.m.

The second business meeting was called to order by President Bailey at 1:30 p.m., April 3, with 36 members present.

The minutes of the first business meeting were read.

**COMMITTEE REPORTS**

The Nominating Committee presented the following slate: President-Elect—Dr. Howard Moore; Secretary—Dr. George Templeton; Treasurer—Dr. Victor Hoff.

The motion was made by Dr. Wills and seconded by Dr. Sears that the slate of officers presented by the nominating Committee be elected. They were elected by acclamation.

Dr. Sinclair reported that the Auditing Committee had examined the financial records of the Academy and were satisfied that they are correct and in order.

Mr. Lawson reported for the Committee on a meeting place for 1966. He moved that the Fiftieth Anniversary meeting of the Academy
be held in Little Rock with Little Rock University as the host institution. Dr. Ronald McGehee seconded the motion and the motion passed.

Dr. Lyle Thompson moved that the Committee on Meeting Places be instructed not to consider an institution for a meeting site if it was under censorship by the American Association of University Professors. Dr. Bill Guest seconded the motion and the motion failed.

President Bailey asked for an expression of sentiment regarding the co-sponsorship of our annual meeting with the Valley Educational and Research Foundation.

There was a lengthy discussion. Considerable concern was expressed as to whether the aims and objectives of the Foundation fall within the scope or are directed to the same end as those of the Academy.

It was decided that the Executive Committee be given the authority to co-sponsor the annual Academy meeting with the Foundation on a trial basis for one more year.

The following committee of AAAS Fellows was appointed by the President to nominate other Arkansas Academy of Science members to Fellows in the American Association for Advancement of Science: Dr. D. M. Moore, Dr. J. W. Sears, Dr. P. M. Johnston, and Dr. I. A. Wills.

Dr. Bailey expressed appreciation to Dr. Bill Guest for the work of the local Arrangements Committee and directed the Secretary to write letters of appreciation to Dr. David W. Mullins for use of the facilities of the University and to Mr. Bill Shepherd for the aid in obtaining John Glenn as a speaker for the Academy and for co-sponsorship of the meeting.

Dr. Bailey turned over the gavel to Dr. Fribourgh who adjourned the meeting at 2:15 p.m.

Respectfully submitted,
George E. Templeton
Secretary
### PROGRAM

**Friday, April 2**

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<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>10:45 a.m.</td>
<td>Business Meeting, Animal Science Center</td>
</tr>
<tr>
<td>11:45 a.m. to</td>
<td>Lunch</td>
</tr>
<tr>
<td>1:00 p.m.</td>
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<tr>
<td>1:15 p.m. to</td>
<td>General Session, Address by Breene M. Kerr, Deputy Assistant Administrator, NASA, Science-Engineering Building.</td>
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<tr>
<td>2:30 p.m.</td>
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<tr>
<td>2:00 p.m. to</td>
<td>Joint Meeting — Oklahoma-Arkansas Section of the Mathematics Association of America and the Mathematics Section of the Arkansas Academy of Science, Science-Engineering Auditorium.</td>
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<tr>
<td>5:00 p.m.</td>
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<tr>
<td>2:15 p.m. to</td>
<td>Junior Academy, Science-Engineering Building</td>
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<tr>
<td>4:00 p.m.</td>
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<tr>
<td>2:30 p.m. to</td>
<td>Collegiate Academy, University Hall</td>
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<tr>
<td>4:00 p.m.</td>
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<tr>
<td>4:00 p.m.</td>
<td>Conference of Participating Scientists in NFS Visiting Scientist Program of the Academy, Home Economics Auditorium.</td>
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<tr>
<td>5:30 p.m. to</td>
<td>Academy Banquet, U-Ark Bowl</td>
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<tr>
<td>7:00 p.m.</td>
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<tr>
<td>7:00 p.m. to</td>
<td>Science Fair Awards, U-Ark Bowl</td>
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<tr>
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<tr>
<td>8:00 p.m. to</td>
<td>“Scientific and Technological Frontiers of the Future”</td>
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<tr>
<td>9:00 p.m.</td>
<td>Dr. Karl G. Harr, Jr., President</td>
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<td></td>
<td>Aerospace Industries Association of America, Science-Engineering Auditorium.</td>
</tr>
</tbody>
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## PROGRAM

**Saturday, April 3**

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<td>7:30 a.m. to</td>
<td>Arkansas Science Teachers Association Breakfast, Holiday Inn Motel.</td>
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<td>9:00 a.m.</td>
<td>Address by Astronaut John Glenn, Barnhill Fieldhouse.</td>
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<tr>
<td>9:00 a.m. to</td>
<td>Joint Meeting — Oklahoma-Arkansas Section of the Mathematics...</td>
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<td>10:00 a.m.</td>
<td>Science Talent Search Program, Chemistry Building</td>
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<td>1:00 p.m.</td>
<td>Lunch</td>
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<tr>
<td>12:30 p.m.</td>
<td>Business Meeting, Science-Engineering Building</td>
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<td>1:30 p.m.</td>
<td>Section Meetings</td>
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*Journal of the Arkansas Academy of Science, Vol. 19 (1965), Art. 1*
Arkansas Academy of Science Proceedings, Vol. 19, 1965

SECTIONAL PROGRAM

BIOLOGY AND AGRICULTURE

Chairman: George E. Templeton
University of Arkansas

Session I


COST ANALYSIS OF THE PRODUCTION OF EDIBLE SIZE CHANNEL CATFISH. Andrew H. Hulsey, Fisheries Division, State Game and Fish Commission.

SPECIALIZED WEATHER INFORMATION FOR ARKANSAS AGRICULTURE. Donald A. Downey, Agriculture Service Office, United States Weather Bureau.

PRELIMINARY OBSERVATIONS ON NUCLEAR DIVISION IN VEGETATIVE HYphae OF *CERATOCYSTIS FAGACEARUM*. Jim R. Aist and C. L. Wilson, University of Arkansas.

Session II

THE SWALLOWTAIL BUTTERFLIES OF ARKANSAS (PAPILLIONIDAE: LEPIDOPTERA). E. Phil Rouse, University of Arkansas.


THE BUMBLEBEES OF ARKANSAS (HYMENOPTERA). Leland Chandler and C. Edward McCoy, Jr., Purdue University and University of Arkansas.

EFFECTS OF DIETARY GALACTOSE VERSUS GLUCOSE WITH CORN OIL AND WITH HYDROGENATED COCONUT OIL ON VARIOUS METABOLIC FUNCTIONS IN RATS. Mabel Coleman, University of Arkansas.

EFFECTS OF SATURATED AND UNSATURATED LONG CHAIN FATTY ACIDS FED WITH AND WITHOUT ESSENTIAL FATTY ACID ON VARIOUS COMPONENTS OF LIPID AND CARBOHYDRATE METABOLISM. Joyce T. Burgess, University of Arkansas.
Arkansas Academy of Science Proceedings

THE INTERRELATIONSHIP OF CERTAIN METABOLIC RESPONSES TO THREONINE DEFICIENCY AND TO VARIOUS DIETARY CARBOHYDRATES IN THE WHITE RAT. Elizabeth Bright, University of Arkansas.

DECEMBER FOOD HABITS OF THE MALLARD (ANAS PLATYRHYNCHOS LINN.) IN THE GRAND PRAIRIE OF ARKANSAS. Billy J. Forsyth, University of Arkansas.

CHEMISTRY

Chairman: E. A. Provine
Ouachita Baptist College

Session I

THE ACTIVITY COEFFICIENTS AND THERMODYNAMICS OF HYDROBROMIC ACID IN METHANOL-WATER MIXTURES AND ANHYDROUS METHANOL FROM ELECTROMOTIVE FORCE STUDIES. Mrs. Sharon L. Melton and Edward S. Amis, University of Arkansas.

DISSOCIATION CONSTANTS OF CHLORANILIC ACID AND COMPLEXES OF THIS ACID WITH NICKEL II AND IRON III. Dale K. Cabbiness and Edward S. Amis, University of Arkansas.

THE TEMPERATURE COEFFICIENT OF COVALENT IODINE/IODIDE ION EXCHANGE IN ACETONE. Allen F. Robinette, E. A. Moelwyn-Hughes and Edward S. Amis, University of Arkansas and Cambridge University.

A GEOCHEMICAL STUDY OF GEYSERS — YELLOWSTONE NATIONAL PARK. Joe F. Nix, University of Arkansas.

CARBOXYLATION OF THIOESTERS. Milton O. Peacock, Arkansas A & M College.

DECAY OF Cd\(^{117}\), Cd\(^{119}\), and Cd\(^{121}\). Miss Ann Gibbs, University of Arkansas.

Session II

DECAY OF Tb\(^{162}\). H. Rodney Martin and Ronald A. Harlan, University of Arkansas.

THE UNDERGRADUATE CURRICULUM IN CHEMISTRY. Richard Porter, University of Arkansas.

ENERGY LEVELS OF Er\(^{168}\) FROM (d, p) REACTIONS. Ronald A. Harlan, University of Arkansas.
Arkansas Academy of Science Proceedings

GEOLOGY

Chairman: Tom Freeman
University of Missouri

PALEOZOIC ANALOGUES OF RECENT CARBONATES. Tom Freeman, University of Missouri.

SHALE-LIMESTONE ALTERNATION IN THE UPPER FAYETTEVILLE SHALE. Bruce Saunders, University of Arkansas.

STRUCTURAL GEOLOGY OF THE OUACHITA MOUNTAINS BETWEEN BENTON AND LITTLE ROCK, ARKANSAS. George Viele, University of Missouri.

GEOLOGY OF THE MARZARN SYNCLINORIUM. Larry Lee, University of Missouri.

REPORT ON SOME IRON AND NICKEL MINERALS FROM THE SOAPSTONE DEPOSITS OF SALINE COUNTY, ARKANSAS. Phillip Wicklein and Alden B. Carpenter, University of Missouri.

MONADNOCKS, DIVIDES, AND OZARK PHYSIOGRAPHY. James H. Quinn, University of Arkansas.

BASE-LEVEL CONTROL OF EROSION SURFACES. H. F. Garner, University of Arkansas.

NEW RARE AND SEMI-PRECIOUS MINERAL COLLECTING LOCALITIES IN CENTRAL ARKANSAS. Charles Stone, Arkansas Geological Commission.

HISTORY AND POLITICAL SCIENCE

Chairman: Keith S. Petersen
University of Arkansas


A HISTORY OF THE SELECTION AND TENURE OF SUPREME COURT JUDGES IN MISSOURI. Kay Collett, University of Arkansas.

JAUN LUIS VIVES AND HIS PLAN OF EUROPEAN UNION, 1522. Anne Vizzier, University of Arkansas.

PHYSICS

Chairman: Otto H. Zinke
University of Arkansas

Session I

A THEORY OF NUCLEAR RESONANCE LINESHAPES IN SOLIDS. Frank Biggs and Stephen M. Day, University of Arkansas.
A SEMI-CLASSICAL THEORY OF NUCLEAR RESONANCE BROADENING DUE TO PARAMAGNETIC IMPURITIES. Tin Hla Ngwe and Stephen M. Day, University of Arkansas.

STUDY OF TRANSIENT DISSIPATIVE HEAT FLOW IN METAL FOILS. Paul B. Jacovelli, University of Arkansas.

A NANOCENTIMETER TRANSDUCER. Otto H. Zinke, University of Arkansas.

DISTINGUISHABILITY OF CLASSICAL PARTICLES. Jack G. Dodd, Arkansas Polytechnic College.


THE EFFECT OF HIGH SPEED SAMPLE ROTATION ON NUCLEAR RESONANCE. Arthur C. Cunningham and Stephen M. Day, University of Arkansas.

ATOMIC AND MOLECULAR FORM FACTORS FOR RADIAL DISTRIBUTION FUNCTIONS. Joe M. Guenter, Arkansas A & M College.

GAS-KINETIC COLLISIONAL POPULATION OF 'D LEVELS IN HELIUM. Richard B. Kay, University of Arkansas.

Session II

MEASUREMENT OF THE LAMB SHIFT IN THE N=4 LEVEL OF HE$^+$. Lynn L. Hatfield, University of Arkansas.

THE INITIAL STAGES OF WIRE EXPLOSIONS. Arthur S. Hobson, University of Arkansas.

X-RAY DIFFRACTION STUDIES OF CF$_4$ IN THE LIQUID STATE. Ronald W. Harris, University of Arkansas.

A NUCLEAR RESONANCE STUDY OF CsF. Darrell K. Hutchins and Stephen M. Day, University of Arkansas.

SPIN-LATTICE RELAXATION DUE TO PARAMAGNETIC IMPURITIES. Stephen M. Day, University of Arkansas.

CHARACTERISTICS OF A PLASMA GUN. Charles K. Manka, University of Arkansas.

ELECTRON CAPTURE INTO THE N=4 AND N=3 LEVELS OF H BY FAST H$^+$ IMPACT ON N$_2$. Benny M. Doughty and Horace R. Dawson, University of Arkansas.

X-RAY DIFFRACTION OF BROMINE IN THE LIQUID STATE. Robert W. Greubel, University of Arkansas.

LINE WIDTH STUDY OF $^2S_1$ TO $^2P_0$ TRANSITIONS OF SO$_2$ BROADENED BY ACETYLENE. Charles E. Jones, University of Arkansas.
MATHEMATICS
Chairman: Don Epperson
Medical School
University of Arkansas

The Mathematics Section met jointly with the Oklahoma-Arkansas Section of the Mathematics Association of America. Only papers given by Academy members are listed.

A STUDY OF CERTAIN FINITE RINGS. C. H. Harbison, Little Rock University.

INVERSION PROBLEMS FOR SOME WELL KNOWN MATRICES. T. Sekiguchi, University of Arkansas.

A GRID PROBLEM. M. C. Carter, University of Arkansas.

SCIENCE EDUCATION
Chairman: Irvin A. Wills
John Brown University

LIFE HISTORY OF THE DOTTED WOLF SPIDER, Lycosa punctulata Hentz (Araneida: Lycosidae)1, 2

R. Eason and W. H. Whitcomb
University of Arkansas

Two medium-sized wolf spiders, Lycosa punctulata Hentz and L. rabida Walck., are especially abundant in old pastures and grasslands in Arkansas. The two species are distinguished from most similar wolf spiders by their color, two parallel dark bands on the carapace and a median dark band on the dorsum of the abdomen. L. punctulata and L. rabida are easily distinguished from one another by markings, habits, and the time of year when they mature. L. punctulata lacks the notches at the sides of the dark median abdominal band found in L. rabida and usually possesses large black splotches on the venter of the abdomen, where only small black dots are found on L. rabida. L. punctulata matures (Fig. 1) and mates in the fall, the mated females overwintering and laying eggs in the early spring. L. rabida matures during early summer and midsummer (Fig. 1), and only its immature progeny overwinter. L. punctulata is mostly captured on or near the ground, since it has less tendency to climb into bushes than does L. rabida. In Arkansas, 80% of the collected specimens of L. rabida have been taken two or more feet off the ground in tall grass or bushes.

The life cycle of Lycosa punctulata was selected for investigation because so little information on its biology and ecology had been published. Field notes on where and when L. punctulata has been collected and a little information on its activities in the field have been included by various authors: Hentz (1875), Emerton (1885), Scheffer (1906), Chamberlin (1908), Banks (1910), Comstock (1912), Barrows (1918), Bishop (1924), Bishop and Crosby (1926), Chamberlin and Ivie (1944), and Gertsch (1949). Montgomery (1903) described the construction of an egg sac by this species. Kaston (1948) pointed out that he had taken males only after September 1, a fact of considerable importance. Fitch (1963) apparently observed sexual behavior in the field in September and included observations on the capture of prey. Eason (1964) reported on egg sac construction and on care of the young.

METHODS AND EQUIPMENT

By aid of a headlamp, using a method devised by Wallace (1937), adult or nearly mature spiders were collected at night from pastures, cultivated crops, and surrounding weedy areas. Their eyes shine green in the beam from a headlamp, making the spiders easy to locate.

Captured specimens were placed in half-pint or pint ice cream containers on trays. Their progeny were reared during the second, third,

1Partially supported by N. S. F. grant GB-2195.
2Acknowledgment is given for species identification and other technical assistance by Harriet Exline (Mrs. Don Frizzell) of Rolla, Mo.
Fig. 1. Months in which mature *Lycosa rabida* and *Lycosa punctulata* have been collected.

Total collected — 201

Total collected — 113
and fourth instars in lids of ice cream containers; from the fifth instar through maturity, the spiders were kept in half-pint containers. Petri dish lids covered each container. Water-saturated pieces of sterile absorbent cotton in each container provided water and humidity.

Laboratory temperature fluctuated from 68° to 80° F. Average humidity ranged from 30 to 60%.

The spiders were mated in an aluminum dishpan with steep smooth sides. A male and female, each in its own container, were placed in the pan, and the lids were removed. The containers were left in the pan to provide hiding places prior to courtship and after mating. One mating sequence was recorded on 16 mm. motion-picture film.

Duration of egg incubation and duration of the deutovum stage were determined by cutting into the egg sacs on successive days, following the technique of Whitcomb and Eason (1964).

Measurements, following Dondale's method (1961), were made of carapace widths of captured and reared specimens by means of an ocular micrometer. Growth from instar to instar to maturity were recorded.

Food varied, depending on the size of the spiders and spiderlings. First-instar spiderlings (deutova), which are incapable of feeding, remained inside the egg sac. Second-instar spiderlings were placed in containers and fed the same day that they left the back of the female. The common vinegar fly (Drosophila melanogaster Meiger) and deutova of their own or of other lycosid species were fed to the spiderlings through the fifth instar. Beginning with the fourth instar, a larger species of vinegar fly (D. hydei Sturtevant), second-instar lycosid spiderlings, tiny pyralid moths, and small nymphs of a meadow grasshopper (Family Tetrigoniidae) were also used for food. Leafhoppers and house flies (Musca domestica L.) were added to the diet at the fifth instar. Small moths of various species and small crickets were introduced at the sixth instar. Moths and larvae of the fall armyworm (Spodoptera frugiperda (J. E. Smith)), large crickets, and house flies composed the diet for spiders in the eighth instar through maturity.

House flies, crickets, fall armyworms, and vinegar flies were reared. Other insects were field-collected.

**LIFE CYCLE**

Adult females were brought into the laboratory during November and December and again in March and April. Egg sac construction in the laboratory occurred between November and June, mostly between January and April. The egg sacs were constructed earlier in the laboratory than in the field, since the laboratory spiders were not exposed to the low field temperatures.

Like most wolf spiders, the Lycosa punctulata female constructs her egg sac by first spinning a light scaffolding of silk more or less
parallel to the ground. On top of this, she spins a circular mat of closely woven silk, approximately 20 cm. in diameter; the mat takes form as the female works both clockwise and counterclockwise around a circle. All spinning is done by movements of the abdomen without the help of forelegs or palpi. The female moves her spinnerets from side to side in a brushing motion. She then thickens the mat with up-and-down looping motions of the abdomen. The spinnerets are repeatedly raised about 1/4 inch and lowered, forming and depositing loose loops of silk on top of one another.

Around the edge of the mat, a rim is formed by a series of rapid up-and-down strokes, giving the mat a concave shape. After centering the genital opening over the concave mat, the female pauses, body tense, for three or four minutes. Liquid is then extruded from the genital opening, and rapidly deposited, liquid-encased eggs drop to the mat; within approximately five minutes, oviposition is completed. Within three or four minutes, the female begins to cover the eggs by spinning vigorously back and forth across the egg mass, making wide, high, looping motions with the posterior tip of the abdomen. Within five minutes, a silk covering becomes visible over the rounded egg mass. For approximately 30 minutes, the female continues spinning the covering and thickening the edges.

From 12 to 20 minutes are required to detach the covered egg mass from the scaffolding. The female accomplishes this by pulling at the egg mass with her palpi while tearing silk strands with her chelicerae and by pushing with her legs and lifting with the anterior portion of her body. She rotates the unattached egg sac with her first and third pairs of legs while turning down the seam with her chelicerae and palpi and spinning over the seam. Her egg sac free and complete, the female attaches it to her spinnerets. Half an hour to an hour later, she detaches the egg sac and begins to manipulate it. While she turns it, dark blue spots appear on the sac. She passes it first through her mouthparts, where the surface is moistened, then past the region of the genital opening, from which a scarcely-visible blackish drop of liquid is brushed against the dampened surface. The female usually attaches the sac to her spinnerets and detaches it several times before the coloring process is finished, when the sac is a more or less uniform grayish-blue color. The coloring process takes nearly an hour to complete.

Egg sacs averaged 12.6 mm. by 13.8 mm; the largest sac measured 15 mm. by 16 mm., and the smallest, 7 mm. by 8 mm. These slightly flattened, spherical-shaped sacs contained from 53 to 287 eggs. Females usually made two or three sacs in the laboratory, from 28 to 61 days apart. Although construction occurs at any time of the day or night, most egg sacs made in the laboratory were constructed during early morning hours.

Measurements of 50 Lycosa punctulata eggs averaged 1.36 mm. by 1.22 mm. The pearly-white eggs are ellipsoidal in shape when freshly
laid but assume a rounded, pyramidal shape approximately 24 hours before hatching.

The eggs hatch to become deutova from 9 to 14 days after they are laid. The number of days needed for incubation depends on temperature; a longer time is needed in the winter months, and fewer days, in late spring. The first instar, called the deutovum because many of the organs including the digestive tract are incomplete so it is incapable of feeding, lasts from 12 to 18 days. The average carapace width of deutova from one brood raised in the laboratory was 0.76 mm. (Table 1); for a brood from another female, 0.85 mm. The faintly marked, translucent, white color of the newly hatched deutovum gradually deepens to a pale, tannish-gray just prior to the first molt, and black setae become visible on the legs and body.

At first molting, the deutovum becomes a second-instar spiderling within the egg sac, from 22 to 32 days after the eggs were deposited. At this time, the female perforates the egg sac along the seam, allowing the freshly molted spiderlings to emerge. Young lycosid spiderlings are incapable of opening the egg sac and will die if it is not opened for them. The young stream forth and immediately mount the female's back, the first tending to choose a mid-dorsal location on her abdomen. Within 6 to 12 hours of the first emergence, the egg sac is completely emptied and discarded. While the spiderlings are on the back of the female, the latter attempts to protect the young against predators and apparently gives the spiderlings active care. This is especially evident when she takes the spiderlings to drinking water and gives them access to it (Eason, 1964), allowing them to dismount and remount. The young do not feed or prey on each other while on the female's back. The second instar spiderlings leave the mother from 6 to 14 days after emergence from the egg sac and disperse by ballooning. All factors which stimulate ballooning are not yet known. The following is an account of the ballooning of one brood.

At 4 P.M. on March 17, 1965, second-instar spiderlings, seven to ten days after they left the female, were placed approximately 4 feet above the ground on the twigs of a barren bush. Strato-cumulus clouds covered about 40% of the sky. The light intensity was approximately 1,000 foot-candles, and the temperature was 54° F. The light breeze varied from three to seven miles per hour; the gusts lasted from 7 to 25 seconds. The spiderlings dropped on silken strands and remained suspended from 1 to 3 inches below the twigs, with their legs outstretched until a gust of wind struck. The breeze bore them upward and outward with their silk strands trailing behind them. As the breeze began to lift them, the spiderlings folded their legs under their bodies.

At other times, the Lycosa punctulata spiderlings ballooned in a more conventional manner, clinging to the twigs until the wind pulled out the silken strands. The spiderlings were then borne upward and outward with the strands in the lead.

In a group of 22 reared specimens, the average duration of the
TABLE 1. Width in mm. of the carapace of each instar of *Lycosa punctulata* Hentz

<table>
<thead>
<tr>
<th>Instar</th>
<th>Number of individuals</th>
<th>Range</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st*</td>
<td>10</td>
<td>0.72-0.80</td>
<td>0.76</td>
</tr>
<tr>
<td>2nd</td>
<td>18</td>
<td>0.90-1.03</td>
<td>0.96</td>
</tr>
<tr>
<td>3rd</td>
<td>18</td>
<td>1.11-1.21</td>
<td>1.15</td>
</tr>
<tr>
<td>4th</td>
<td>18</td>
<td>1.23-1.52</td>
<td>1.38</td>
</tr>
<tr>
<td>5th</td>
<td>18</td>
<td>1.55-1.90</td>
<td>1.73</td>
</tr>
<tr>
<td>6th</td>
<td>18</td>
<td>1.90-2.35</td>
<td>2.09</td>
</tr>
<tr>
<td>7th</td>
<td>18</td>
<td>2.25-2.80</td>
<td>2.56</td>
</tr>
<tr>
<td>8th</td>
<td>18</td>
<td>2.80-3.50</td>
<td>3.13</td>
</tr>
<tr>
<td>9th</td>
<td>18</td>
<td>3.24-4.20</td>
<td>3.78</td>
</tr>
<tr>
<td>10th</td>
<td>16</td>
<td>3.84-4.92</td>
<td>4.35</td>
</tr>
</tbody>
</table>

*Recorded from individuals of another series.

TABLE 2. Duration of each instar of 18 laboratory-reared *Lycosa punctulata* Hentz

<table>
<thead>
<tr>
<th>Instar</th>
<th>Number of individuals</th>
<th>Range</th>
<th>Number of days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>—</td>
<td>10-10</td>
<td>10</td>
</tr>
<tr>
<td>2nd</td>
<td>18</td>
<td>13-25</td>
<td>17</td>
</tr>
<tr>
<td>3rd</td>
<td>18</td>
<td>9-17</td>
<td>13</td>
</tr>
<tr>
<td>4th</td>
<td>18</td>
<td>10-22</td>
<td>16</td>
</tr>
<tr>
<td>5th</td>
<td>18</td>
<td>9-41</td>
<td>24</td>
</tr>
<tr>
<td>6th</td>
<td>18</td>
<td>14-34</td>
<td>22</td>
</tr>
<tr>
<td>7th</td>
<td>18</td>
<td>9-52</td>
<td>25</td>
</tr>
<tr>
<td>8th</td>
<td>18</td>
<td>17-53</td>
<td>27</td>
</tr>
<tr>
<td>9th</td>
<td>16</td>
<td>13-50</td>
<td>26</td>
</tr>
<tr>
<td>10th</td>
<td>Adult</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Deutovum stage within egg sac.*
second instar was 17 days (Table 2), and average carapace width, 0.96 mm. The third instar lasted the shortest period of time, with an average of 13 days. The average carapace width of spiderlings in this instar was 1.15 mm. An increased appetite was apparent in spiderlings of the third instar, but it became even more marked during the fourth instar. Spiderlings which were inadequately fed at this stage frequently failed to reach the fifth instar. Average duration of the fourth instar was 16 days; the average carapace width of such spiderlings, 1.38 mm. The fifth instar lasted an average of 24 days, with a wide range between the maximum and minimum number of days. The average carapace width of fifth-instar spiderlings was 1.73 mm, indicating a marked increase in size over that of previous molts. The sixth instar averaged 22 days, with average carapace width of the young spiders, 2.09 mm. The average duration of the seventh instar was 25 days, with an average carapace width of 2.56 mm.

Some of the young spiders had a slight swelling of the palpal tarsi by the eighth instar, an indication that these were males. The females of this instar showed the beginnings of epigynal structures. This instar lasted an average of 27 days, and the spiders had a carapace width averaging 3.13 mm. By the ninth instar, some males were mature, and all the other males had enlarged palpal tarsi, showing signs of reaching maturity. Average length of the ninth instar was 26 days. Like the fifth instar, the seventh, eighth, and ninth instars showed a wide range in the number of days required by various individuals. The average width of the carapace in the ninth instar spiders was 3.78 mm.

By the tenth instar, all males and females had reached maturity. The average carapace width of the spiders was 4.35 mm. However, the average carapace width of adult field-collected spiders was 4.97 mm.

Laboratory-reared males required nine to ten instars to reach maturity; females required ten. Eleven instars were required by specimens reared on a near-starvation diet. Males took an average of 162 days to reach maturity; females, 175 days.

Following the final molt, the males made sperm webs and charged their palpi. Following each mating, another sperm web was constructed, and the palpi were charged again. Approximately four to five hours after mating, the male began to spin threads on the side of the container in an agitated manner. Short periods of spinning were followed by relatively long pauses. The sperm web, an extremely delicate structure, was made between 10 and 17 hours after mating. Neither complete sperm-web construction nor actual sperm induction have yet been observed. Only one sperm web of *Lycosa punctulata* was observed immediately after construction. Its shape was that of a narrow, elongated rectangle, and it extended from the side of the container to the moist cotton.

Mating of a typical pair of dotted wolf spiders, as observed in the laboratory, occurred as follows. The uncovered containers of the
male and female were placed approximately 20 cm. apart in the dish-pan. Immediately, the male began drumming his palpi and turned in the direction of the female's container. Slowly drumming his palpi, the male moved across his container. As he did so, the female turned in the opposite direction and ran out of her container. Apparently, she could not see the male approaching, nor could he yet see her. Upon leaving her container, the female circled around it and stopped about 4 inches from the male. The male raised his forelegs, holding the femora at an approximately 45° angle to the carapace. As the tibiae and metatarsi moved relatively slowly in a short vertical arc, the tarsi vibrated rapidly. Following this, the male raised and lowered his abdomen, while vibrating it vigorously and rapidly. As the abdomen was being lowered, the tibiae, metatarsi, and tarsi of the forelegs were lowered to a position horizontal to the body.

The female approached the male cautiously. For the next 14 minutes, the male and female alternated between approaching one another and pausing, with the male drumming his palpi occasionally. Twenty-three minutes after the male first drummed his palpi, the female turned to face him and approached slowly with her forelegs and her second pair of legs raised, with the femora at right angles to the carapace. The male raised his forelegs and second pair of legs. With rapid, alternating movements of her two anterior pairs of legs, the female applied her tarsi to the male's upraised legs between the femora and tarsi. The male then sprang over the female's cephalothorax, so that his body was dorsal to hers, his cephalothorax over her abdomen. He reached around the side of her abdomen to apply his right palpus to the right orifice of her epigynum; then he moved to the other side of the female to apply his left palpus to her left orifice.

During copulation, the male held the female's abdomen with his forelegs, raising and turning her abdomen as necessary. Upon completion of mating, the male backed off the female and then ran and hid. Later, the two remained together in the dishpan, neither showing signs of aggressiveness nor of interest in the other's presence, although each apparently was aware of the other. The courtship and mating of this pair lasted 104 minutes. Several pairs took approximately 150 minutes, and one pair took about 180 minutes.

**SEASONAL CYCLE**

Under Arkansas field conditions, fertilized *Lycosa punctulata* females appear to overwinter, the males usually disappearing before winter. Construction of egg sacs begins in early March, occasionally earlier, and continues into June. In early April, the first spiderlings molt and leave the egg sac. After remaining one to two weeks on the female's back, they disperse by ballooning and molt again in late April or early May. The female makes a second egg sac and sometimes even a third. Spiderlings of all of the first five instars may be found in the field in June. The first mature spiders are found in September. Mating occurs in September, October, and November. Surprisingly,
survey results in Arkansas agree closely with those of Kaston (1948) in Connecticut, who found mature males only in September, October, and November.

**SUMMARY**

Although *Lycosa punctulata* and *L. rabida* share the same habitat, their niches are separated by distinct maturity peaks, with *L. rabida* maturing, mating, and constructing egg sacs in midsummer and early fall and with *L. punctulata* maturing and mating in late fall and constructing egg sacs in early spring.

Within the egg sac, the duration of the egg stage was from 9 to 14 days; and the deutovum (first instar) lasted from 12 to 18 days. Molting to the second instar occurred within the egg sac. Second-instar spiderlings emerged from the egg sac, mounted the female's back, remained there from 6 to 14 days, and then dispersed by ballooning. Shortly thereafter, they molted to the third instar. From nine to ten instars were required to reach maturity, although a few individuals matured only after they reached the eleventh instar. Males matured in 162 days; and females, in 175 days. Under Arkansas conditions, there was only one generation a year, but females constructed from one to three egg sacs, resulting in distinct broods of young.

**REFERENCES CITED**


Arkansas Academy of Science Proceedings


THE REARING OF WOLF AND LYNX SPIDERS
IN THE LABORATORY (FAMILIES LYCOSIDAE
AND OXYOPIDAE: ARANEIDA)\textsuperscript{1, 2}

W. H. Whitcomb and R. Eason
University of Arkansas

The only way to obtain accurate information on the duration and
number of instars in the life history of a spider species is to rear indi-
viduals of that species. In our search for information on the life cycle
of wolf and lynx spiders, the rearing of several thousand individuals
in the laboratory was necessary. Certain species are much more diffi-
cult to rear in captivity than others. However, we have not yet found
a species that will not live and mature in the laboratory. Daily indi-
vidual attention is required, if for no other reason than to keep records
complete, but in addition to this, the practiced eye can tell whether a
given container is too wet or too dry or whether the spider has other
needs.

The literature on methods of rearing cursorial spiders is widely
scattered among books and journals. Many of the most informative
articles have been published in Europe. The work of Bonnet (1927,
1929, 1930a, 1930b) is particularly well known. Other especially use-
ful articles are those by Berland (1922), Kolosváry (1927), Savory (1926,
1928, 1964), Gerhardt (1924, 1925, 1926, 1927, 1928, 1933), Wiehle
(1909), Hull (1938), Potzsch (1964), and others. New techniques are
being developed by such investigators as Engelhardt (1964), Holm
(1952), Braun (1961, 1963), Papi and Syrjaemäki (1963), Papi and
Tongjorgi (1963), Baccetti et al. (1962), Magni et al. (1962), and others.
In the United States, various workers have found the papers of Baerg
(1937, 1938, 1958, 1963) very valuable. Techniques described in con-
junction with reports of specific experiments are sometimes the most
useful of all. In this connection, papers by Petrunkevitch (1911), Kaston
(1936), Montgomery (1903), Devey (1949), and others should be men-
tioned.

TYPE OF CONTAINER

Wolf spiders must be reared in individual containers. From the
time the spiderlings leave the female's back, they are inclined to prey
on each other. Mature males and females are kept together only
during courtship and mating. We found the type and size of the con-
tainer relatively unimportant, as long as it is large enough to allow the
spider to move about freely and small enough and tight enough to make
adjustment of the humidity possible. For small immature spiders, we

\textsuperscript{1}Partially supported by N. S. F. grant GB-2195.

\textsuperscript{2}Acknowledgment is given for species identification and other technical
assistance by Harriet Exline (Mrs. Don Frizzell) of Rolla, Mo.
prefer the tops of pint cardboard ice cream containers covered with petri dish lids. For large spiders, we use half-pint and pint ice cream boxes. For those hunting spiders that prefer to live on plants, we use gallon cardboard containers covered with glass plates. Inside each container, a branch of the preferred plant is placed in a small jar of water. Cotton placed in the jar mouth, well above the water level, prevents the spider from drowning.

MOISTURE

Moisture can be a critical factor; it is important for drinking and for maintaining correct air humidity. Ample drinking water is required by all species of wolf spiders with which we have worked. However, some species can live longer without water than others. We use a small piece of wet absorbent cotton in the water to allow the spiders easy access to the moisture without the risk of drowning. The cotton must be changed every three days. Air humidity appears to be very important. As reported by Kaston (1965) for spiders in general, the requirements vary sharply from species to species; too much humidity is as serious a problem for some species as too little is for others. *Pardosa lapidicina* Emerton will survive only a few hours in a dry atmosphere. *Lycosa rabida* Walck. and *L. punctulata* Hentz cannot be reared satisfactorily in a moist atmosphere. The natural habitat can give a clue to humidity requirements. Swamp or shore-dwelling species and spiders that dwell permanently in the ground need more humidity than do other species. In any event, if the air humidity remains under the minimum requirement of the species for a prolonged period, the spider goes into a "nervous dance" and dies.

FOOD

Lack of proper or sufficient food is probably the most crucial item in the rearing of cursorial spiders. The feeding problem is particularly acute with spiderlings that have freshly emerged from the egg sac. The young of some species do not need food at once, but others must be fed immediately to prevent a very high mortality rate. It is often difficult to find small enough prey for the freshly emerged young of some species. We had to resort to the flower thrips, *Frankliniella tritici* (Fitch), as prey for second-instar *Oxyopes salticus* Hentz. Many arachnologists solved this problem by allowing the spiders to feed on their siblings. This was quite successful, but if one is attempting to follow an individual throughout its life history, the method is much too risky, since the wrong spider may be killed. The use of deutova (spiderlings which have not yet emerged from the egg sac) of the same species or closely related species solved the matter nicely. The larger spiderlings invariably feed freely on the deutova, and the deutova, since they are without mouthparts, cannot injure the reared spiderlings. In our rearing, however, deutova are used only when other food is unavailable or unacceptable. Much of the time, small flies, crickets, or lepidoptera are used in the diet. For those species that require a certain humidity, we use a small piece of wet absorbent cotton in the water to allow the spiders easy access to the moisture without the risk of drowning.
Rearing of Wolf and Lynx Spiders

For both spiderlings and mature spiders, a constant food supply is a necessity. This means that prey must be reared. We depend on five cultures; these include two species of Drosophila, D. hydei Sturtevant and D. melanogaster Meiger; house flies, Musca domestica L.; house crickets, Acheta domesticus (L.); and the fall armyworm, Spodoptera frugiperda (J. E. Smith). We are experimenting with a strain of wingless Drosophila melanogaster and with the Mediterranean flour moth, Anagasta kuehniella (Zeller). We use moths and beetles from light traps as variants of the diet.

Possibly the most difficult aspect of the feeding problem with older spiderlings and adults is that the effect of less than minimum amounts of food may not be evident for three or four months, when it is too late. Although plenty of food may be offered a week or two before death, apparently many wolf spiders cannot consume more than the tiny amount to which they have become accustomed, even though they are dying of starvation. This is especially serious, since each species has its own critical periods when it must have ample food. This means that preliminary rearing is necessary in some cases to find when these critical times occur. All females, however, must have ample food before the egg sacs are made; otherwise they will fail to construct the egg sacs properly or will destroy them.

SANITATION

Wherever large numbers of animals are handled, disease can be a problem, and spider rearing is no exception. No matter how careful we are about cleanliness, we still lose some spiders from fungi, bacteria, or mites. The first step in reducing these problems is that of ample food and good care; this can be difficult if the natural food and environment are unknown. At the same time, every precaution must be taken to reduce contact with disease-causing organisms. New ice cream boxes are used only once and are then thrown away. Plastic petri dish covers can be thrown away but are generally sterilized and used again. The absorbent cotton is no problem, since it comes from a new roll. However, when there is danger of disease, the cotton cannot be tossed in the bottom of the box. When wet cotton comes into contact with the juices of insects the spider has killed, it forms a very good medium for the growth of many fungi. This can best be avoided by placing the wet cotton in a small sterilized, bakelite dish. For routine situations, we depend on changing containers once or twice a week. In all, eight fungi gave us trouble:

- Aspergillus flavus
- Aspergillus niger
- Aspergillus sp.
- Penicillium sp.
- Beauveria sp.
- Akanthomyces sp.
- Hymenostilbe sp.
- Rhizopus nigricans
Aspergillus flavus appears to be the most serious problem. Dusting or spraying the spores of this fungus on the food of L. rabida was followed by approximately 50% mortality within 30 days. This fungus was then recovered from each of the dead spiders. The two bacteria cultured from diseased spiders have not yet been identified.

Mites of the families Acaridae and Anoetidae give us continual trouble. They enter the spider cultures on insects intended as food. They attack and kill eggs and young spiderlings. Cleanliness must begin in the insect cultures. Often, we must substitute a different method of rearing the insect. For example, we now rear the fall armyworm on culture media instead of on succulent corn. The use of sulfur in the fly and cricket cultures has helped.

**TEMPERATURE**

Temperature is a critical factor, not because of the danger of spider mortality, but because of the difficulty of duplicating nature. The duration of egg incubation, of instars, and of the preovipositional period may be shorter in the continuous warmth of a heated room than in a pasture with its fluctuations in temperature. A constant temperature chamber makes the situation worse. Fortunately, much spider activity occurs in nature at about 20°C, which is normal room temperature; therefore, the distortion of the life cycle in the laboratory is not as serious as it might be. The greatest deviation from nature occurs during winter rearing. After four months of continued spring-like temperatures, the laboratory spiders may be two or three instars ahead of their siblings outdoors. However, if a spider is exposed in a box outdoors to temperatures much below freezing, it will not survive. The newer types of programmed temperature boxes, in which a history of outdoor temperature fluctuations can be duplicated upon demand, should help solve the problem.

**MEASUREMENTS**

Without an indicator of body size to compare the different stages of development in a given species, laboratory rearing would lose much of its value. Body weight is useless because of the immediate effect of food intake. Several linear characters were compared by Dondale (1961) for use as indicators. He found carapace width especially satisfactory. Since we found carapace width easier to measure than other factors, and since it is quite constant between individuals in the same stage of development, carapace width measured with an ocular micrometer was consistently used in all our laboratory rearing.

**CONCLUSION**

In conclusion, it can be stated that spider rearing requires much individual attention if an accurate account of the life history is to be obtained. Variations in food intake and other factors can change the number and length of instars. Care must be taken that all factors are
Rearing of Wolf and Lynx Spiders

as near optimum for each individual as possible. For this reason, we have obtained much more accurate results by rearing 30 individuals rather than 300 of any given species.

LITERATURE CITED


Rearing of Wolf and Lynx Spiders


SPECIALIZED WEATHER INFORMATION FOR ARKANSAS AGRICULTURE

Donald A. Downey

The advent of meteorology into the field of agriculture has been of fairly recent occurrence in the United States and even more recent in Arkansas. In the past, the link between agriculture and weather, if indeed there has been a link, has been between the climatologist and agriculturist, rather than between the meteorologist and the agriculturist. Even more discouraging was the tendency for the agriculturist to be his own meteorologist or climatologist, and to ascribe to so-called abnormal weather conditions aberrations in his data which may or may not have been weather induced. An even more serious shortcoming was the omission of such weather information entirely. This was perhaps inevitable, since the meteorologist or climatologist was almost always physically located at an airport station and not at the University or Experiment Station. This lack of communication is now being broken down by the assignment of Weather Bureau Agricultural Meteorologists to Universities and Agricultural Experiment Stations.

In the Weather Bureau itself, the fields of climatology and agricultural meteorology have unique, but often overlapping, interests in relation to their potential contributions to the field of agriculture. Long and sometimes heated discussions, on more or less a philosophical plane, have taken place between agricultural meteorologists and climatologists to try to define somewhat precisely the effective role of each in what they may contribute to agricultural technology. These discussions often generate more heat than light, but there has come to pass an understanding that each has a role to play in a study of the complex interrelationships that are present in a climatological-plant complex or a meteorological-plant complex. I think that climatology plays the lead in the broad definition or description of the environmental characteristics peculiar to certain plant or animal species, whereas the agricultural meteorologist will have to more specifically describe these climatic characteristics in meteorological terms as they apply to a particular crop or animal.

With increasing technology, the proliferation of specialists in all fields becomes almost overpowering, and the fields relating to weather and agriculture are no less prolific, ranging from bio-climatologists to bio-meteorologists to micro-climatologists to micro-meteorologists ad infinitum. With or without a specific definition of their roles, each has something to contribute to understanding some aspects of crop-weather relationships.

After these few introductory remarks, almost imperceptibly defining the limits within which we might work, I should describe briefly
the organization of the Mid South Weather Project as it concerns Arkansas.

Historically, the most voracious user of specialized weather information has been the aviation industry. But in 1958, farm organizations and a few Congressmen sensed the value that such a specialized weather service might have for agriculture and funds were raised to begin a pilot weather project at Stoneville, Mississippi. After three years, during which time the service was well received by agricultural interests in Mississippi, the service was expanded to include NE Louisiana, West Tennessee, the Missouri Bootheel and eastern and southern Arkansas. In January, 1963, the service was further expanded to include the entire state of Arkansas.

The staffing of the Arkansas project consists of one individual. Basically, the service has four phases:

1) Specialized weather forecasts originate in a central forecast center at Memphis. In addition to the usual terminology in the body of the forecast, an agricultural advisory is added, which spells out the forecast in more precise terms, and gives drying conditions, percent sunshine, amounts and coverage of precipitation, wind direction and speed, dew intensity and duration and dew-point ranges.

2) Special weather reporting stations are added to the weather network during the growing season to give additional observations of air temperature, rainfall and soil temperature.

3) A special weather teletype network is available for radio and TV stations at a nominal monthly charge. Forecasts, climatological summaries, radar reports, agricultural weather advisories, soil temperature forecasts, harvest weather forecasts, hourly weather and other items pertinent to agricultural interests are immediately available to these subscribers for dissemination to users in the area. This type of mass dissemination of weather information is a vital link in the service between the meteorologist and the user ... in this case the cotton planter, the soybean and rice producer, the orchardist, the vegetable producer, the broiler and cattle industry.

4) The initiation of technical studies to investigate plant-weather relationships. Of necessity, these studies must primarily be slanted toward attempting to solve, or partially solve, practical economic problems that beset the individual grower. They are essentially applied, rather than basic in nature.

During its short and often rigorous life, a plant is constantly exposed to a changing environment. The change is as much induced by the growth of the plant itself as by day to day changes in meteorological conditions. The emerging seedling, unprotected from direct insolation from the sun, is exposed to a harsh combination of weather elements. Heavy rainshowers may pack and seal the soil so that the seedling has difficulty emerging initially. Surface soil temperatures on a clear warm day may rise to 125° F. and fall to 50° F. during the night. Severe
weather, common during the spring months, may spawn hail and high 
wind to further damage the emerging seedling. As the season pro-
gresses and the plant grows, it is subject to the same violent weather 
types, but the growth also results in modifications in temperature and 
humidity within the plant canopy itself. The effective radiating surface 
shifts from the soil surface to the top of the canopy. Shading within 
the canopy, plus proximity to a moist soil surface, will cause the max-
imum temperature to shift from the soil surface to the top of the canopy, 
with an actual temperature "inversion" resulting within the canopy. This 
resulting stable condition may have important implications in such 
diverse events as the resultant dispersion of an insecticide spray or the 
dissemination and transport of spores within the plant canopy. Dif-
fferences of as much as 20° F. were noted in 1963 at the six-inch level 
between irrigated and non-irrigated soybeans. Humidity differences 
in excess of 40% were noted between the same levels on a hot, sunny 
day in August. It is difficult to imagine that such divergent temperature 
and humidity regimes do not effect quite profound changes in insect 
behavior or micro-organism responses, and, indeed, physiological re-
sponses in the plant itself.

The contributions which meteorology can make to agricultural tech-
nology are broadly twofold:

1) The operational implications of the short range forecasts are 
of paramount importance. This is where the Agricultural forecaster at 
Memphis comes into the picture. The day-to-day decisions on spray-
ing, the application of defoliants or planning haying operations can 
be seasoned and weighed with the forecast in mind. I should say 
here, the "latest" forecast in mind. Nothing is as perishable as a 
forecast, and if the planter uses the 4 a.m. forecast instead of the 
available 10 a.m. forecast, he is discarding the latest thinking on the 
current weather situation, and biasing his decision on obsolete infor-
mation. The responsibility for the improvement of the short-range and 
the five-day forecast is in the realm of the dynamic and synoptic meteor-
ologist and is out of our hands. Researchers at the General Circulations 
Laboratory at Washington are attacking this problem using computer 
and mathematical techniques.

2) The second realm, and the one which is often less appreciated, 
is that in which the agricultural meteorologist tries to detect the major 
contributor, in a series of complex weather-plant relationships, to a 
certain end result in the plant. These first clues may well result in an 
empirical solution and may be concerned with isolating parameters 
which are not controlling the end result. He can then focus his atten-
tion on the elements most pertinent to the problem at hand. Field 
studies on cotton, soybeans and rice have been, or will be initiated 
and it is anticipated that these studies will result in practical applica-
tions.

The phrase "team effort" or "team approach" possibly has been 
over-worked recently, but that is essentially what is needed to partially
solve, or at least to gain some insight into the complex factors which go to make up the end product of yield or quality that is desired. Such an effort has been a long time coming in really bringing agriculture and weather together, but at least now some halting steps have been taken in that direction.
OBSERVATIONS ON NUCLEAR DIVISION IN VEGETATIVE HYPHAE OF CERATOCYSTIS FAGACEARUM

James R. Aist and C. L. Wilson
University of Arkansas

INTRODUCTION

There has been considerable controversy in recent years concerning nuclear division in vegetative hyphae of various fungi (1-9). Much of the controversy centers around a failure to find distinct metaphase plates. Ward and Ciurysek (6) contend that this may be due to staining of chromosome matrix as well as chromosomes. More refined staining techniques are needed, since the nuclei of most fungi are relatively small, and details of nuclear divisions are hard to demonstrate with existing techniques.

The major emphasis of this paper is on the techniques used in preparing material for study of nuclear division. A unique type of vegetative nuclear division is also described.

MATERIALS AND METHODS

The fungus used in this study was an isolate of Ceratocystis fagacearum (Bretz) Hunt which was maintained at 26°C on 10% V-8 Juice agar medium.

Material for staining was prepared by inoculating cover slips with a spore suspension or with an agar block cut from the periphery of a growing culture.

Dilute (3:1), sterile V-8 Juice filtrate was used in preparing spore suspensions in order to increase the growth rate and size of the hyphae on the cover slips. The filtrate was added to the agar block with an inoculating loop which was also used to spread the filtrate evenly over the surface of the cover slip. Sterile water was added to the filter paper prior to incubation to insure 100% relative humidity. The material was incubated at 26°C for 3-10 days. Cover slips for inoculation were prepared as follows: three or four filter papers were placed in a Petri dish and moistened with water. A microscope slide was then placed on the paper, and three 22 x 40 mm No. 1 cover slips were spaced across the slide. The Petri dishes were then autoclaved.

Preparations used for photographs were stained by the HC1-Giemsa method (schedule below).

1Published with the approval of the Director of the Arkansas Agricultural Experiment Station.
2Mr. Aist is an undergraduate research participant and Dr. Wilson is Associate Professor in the Department of Plant Pathology.
Nuclear Division in Ceratocystis fagacearum

Staining Schedule Used for the HCl-Giemsa and Feulgen Techniques*

(Cover Slip Cultures)

1. Carnoy’s fluid — 10-90 min.
2. 95% alcohol — 15 min.
3. Acetone — 20 min.
4. 95% alcohol — 15 min.
5. 70% alcohol — 15 min.
6. 50% alcohol — 15 min.
7. 1 Normal HCl (room temp.) — 10 min.
8. 1 Normal HCl (60° C) — 10 min.
9. H₂O, 3 changes — 5 min.
10. ½ buffer-½ H₂O, 2 changes — 5 min. (for Giemsa only)
11. Buffer (all buffers pH 7±.02) — 10 min. (for Giemsa only)
12. Giemsa stain (2 drops Giemsa per ml. buffer) — 30 min., or Feulgen reag. — at least 90 min.
13. Buffer — Rinse (Giemsa) or, Water — Rinse, 3 changes (Feulgen)
14. Acetone — Xylene (20-1) — 1 sec.
15. Acetone — Xylene (14-6) — 5 sec.
16. Acetone — Xylene (6-14) — 10 sec.
17. Xylene, mount in balsam.

RESULTS

Material obtained from agar block inoculations was superior to that obtained from spore suspensions. The hyphae from agar blocks often fanned out evenly over the cover slip, with no aerial growth which could subsequently interfere with staining. Hyphae growing from agar blocks often attained a diameter of about 8μ whereas hyphae obtained from spore suspensions did not exceed 4μ. Addition of V-8 Juice filtrate greatly facilitated growth and resulted in an increased size of the hyphae. Although nuclei in the larger hyphae were approximately the same size as those in the smaller hyphae, details of prophase and anaphase were more distinct, perhaps because the chromosomes were not as confined.

Giemsa stained material was superior to both basic fuchsin and iron-alum haematoxylin stained material. Chromosomes could often be resolved in Giemsa preparations, but not in Feulgen or iron-alum haematoxylin preparations. All divisional stages observed in Giemsa-stained material were also observed in Feulgen preparations.

Acetone was a very useful addition to the staining schedule (3). Treating cover slip cultures with acetone prior to staining caused the nuclei to stain more differentially and removed certain cytoplasmic interference (Figs. 1, 2).

These techniques have also been used in staining vegetative nuclei of Aspergillus nidulans (Eidam) Wint. and three other members of the

*Adapted from a staining schedule obtained from Dr. James Dale, Department of Plant Pathology, University of Arkansas

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Fig. 1 — Vegetative nucleus of *C. fagacearum* at anaphase. This was an unusually well synchronized anaphase. Lower nucleus had already begun to migrate into branch. 2600X.

Fig. 2 — Vegetative nucleus of *C. fagacearum* at telophase of division perpendicular to the longitudinal axis of the hypha. Note the spindle, particulate nuclei, and the absence of cytoplasmic interference. 2600X.
Nuclear Division in *Ceratocystis fagacearum*

genus *Ceratocystis*: *Ceratocystis ulmi* (Buisman), *Ceratocystis virescens* (Münch) Bakshi, and *Ceratocystis ambrosia* (Bakshi). In each case the quality of staining was similar to that obtained with *C. fagacearum*, with no changes in the staining schedule being necessary.

Division of nuclei in vegetative hyphae of *C. fagacearum* was unique in that it occurred perpendicular to the longitudinal axes of the hyphae (Fig. 1). Anaphase movement was not synchronized and spindles were usually seen only between chromatids or groups of chromatids which had already separated. Metaphase chromosomes occurred against hyphal walls and showed end-to-end association.

Observations of nuclei in vegetative hyphae of *C. ulmi*, *C. virescens*, and *C. ambrosia* indicated that nuclear division in these related species may be similar to that found in *C. fagacearum*.

Other aspects of the behavior of these nuclei, such as nuclear migration and chromosome associations, as well as a detailed description of the division process, will be presented in another publication.

**DISCUSSION**

The use of cover slip cultures for the study of fungus nuclei should reduce nuclear distortion. The hyphae are less likely to be physically distorted, as is the case when cellophane strips or homogenized hyphae are used. Study of the material is also facilitated, since the hyphae tend to be fixed in one plane on the cover slip.

The type of growth exhibited by the fungus is important. A suppressed type of growth (as opposed to aerial growth) is to be preferred, since aerial growth may result in a thick mat of tangled hyphae that interferes with dehydration. Study of nuclear behavior in fungi which normally exhibit aerial growth may be facilitated by using a mutant strain (natural or induced) which has suppressed growth. Such a mutant strain of *Aspergillus nidulans* was used to test the applicability of the HC1-Giemsa technique as stated above.

The significance of divisions perpendicular to the longitudinal axes of hyphae of *C. fagacearum* is not known. If later detailed investigations show similar divisions in several related fungi, this may prove to be of taxonomic value.

Association of metaphase chromosomes to hyphal walls, unilateral unsynchronized anaphase movement, and appearance of spindle—usually between separated chromatids only, also distinguish asexual nuclear division in *C. fagacearum* from classical mitosis. Since metaphases with distinct chromosomes, and spindles are involved, this type of division appears to be an evolutionary form of classical mitosis.
LITERATURE CITED


THE SWALLOWTAIL BUTTERFLIES OF ARKANSAS
(LEPIDOPTERA; FAMILY PAPILIONIDAE)

E. Phil Rouse*
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Six species of swallowtails are found in Arkansas, and are among the most common butterflies in the state. They have knobbed antennae and characteristic long-tail like projections at the posterior edge of the hind wings. These butterflies are medium to large with the fully spread wings measuring 2-5 inches. The papilionids may be separated from other butterflies by the 4-branched cubitus in the front wing, and by the two anal veins in the front wing and only one in the hind wing.

KEY TO THE PAPILIONIDAE OF ARKANSAS**

1. (a) Striped greenish white on brownish black; red spot at anal angle of hind wing. Long tail. Zebra swallowtail, Papilio marcellus Cr.

   (b) Color combinations not as above ............................................... 2

2. (a) Males yellow with black pattern, hind wing with some blue submarginally, or, males often match females. Underside of female reflects the dark wing pattern of the male. Upperside of female front wing black with one row of submarginal yellow spots along with a row of blue spots medially. Hind wing with two orange spots, and may also have a slight orange color in the submarginal spots ..................................... Tiger swallowtail, Papilio glaucus Linn.

   (b) Color combinations not as above, mostly black with blue or yellow spots .................................................. 3

3. (a) Black or dark brown with a medial yellow spot or band. No blue present above except in hind wing with a vestigial spot anterior to the small orange spot in the anal region. Blue laterally across hind wing beneath. Large butterflies with a wing spread of 4-4½ inches. Three orange spots underneath the hind wing, two of them side by side in center of the wing .................. Giant swallowtail, Papilio cresphontes Cr.

   (b) Black with blue or yellow spots in the front wing and with blue medial in the hind wing ........................................... 4

*Mr. Rouse is curator of the Entomological Museum, University of Arkansas.

**This key is prepared especially for the use of the collectors of Arkansas swallowtail butterflies. If an identification of an exotic species is needed, specimens may be sent to the Department of Entomology Museum, University of Arkansas, Fayetteville, Arkansas.
4. (a) Black with yellow spots; two full rows and a partial 3rd row of yellow spots in front wing. Hind wing with one orange spot with black center in the anal region; a vestige of orange spot may be present in the cubital region. Upperside of hind wing with a submarginal blue spot or band

   Black swallowtail, Papilio polyxenes asterius Stoll.

(b) Black with yellow or grey spots in front wing. No medial spots present or if so not yellow and are indistinct 5

5. (a) Black or blue-black with a row of submarginal spots which are small, gray, and indistinct in front wing. Hind wing from upper view with no orange spots. Underside of hind wing brilliant metallic blue with orange and black spots

   Pipe Vine swallowtail, Papilio philenor Linn.

(b) Black with blue-grey to blue on hind wing. One row of submarginal yellow spots and an indistinct row of median spots as viewed from above, but can be readily seen from beneath. Hind wing above has costal and anal orange spots. Hind wing beneath has two rows of orange spots superimposed on blue-green

   Spicebush swallowtail Papilio troilus Linn.

The Zebra Swallowtail, Papilio marcellus Cr. is a beautiful long-tailed brownish grey and white striped butterfly. Because it feeds extensively on papaw (Asimina triloba), the more mountainous regions where papaw is abundant, may be more heavily populated than the delta regions of Arkansas. This species shows great seasonal variation, but can not be confused with any other North American species.

The Tiger Swallowtail, Papilio glaucus Linn., is a large yellow butterfly with black stripes in the front wing and hind wing margins, but in some of the males of this species the color pattern is very similar to the dark bluish-black females. These beautiful butterflies may readily be taken along streams and water courses in the summer and fall as their preferred hosts are Wild Cherry (Prunus), Birch (Betula), Popular (Populus), and various other trees and shrubs commonly found near streams. Its attraction to garden flowers brings it into cities and towns, although it is typically a butterfly of woods and savannahs.

The Giant Swallowtail, Papilio cresphontes Cr. Feed largely on citrus in the Southern United States and prickly Ash (Zanthoxylum) in the North. It is a large dark-colored butterfly with yellow spots on the wings. It is somewhat migratory and is likely to be collected in places where other papilionids are taken. It is best collected from flowers.

The Spicebush Swallowtail, Papilio troilus Linn., is also somewhat migratory, and is not difficult to collect from most of the regions of Arkansas. The Spicebush (Benzoin), and ornamental shrubs in towns are often defoliated by its voracious larvae. Since this species also feeds on sassafras (Sassafras), it may be widely distributed. It is seen commonly near shady woods or mud puddles. This species is blackish,
with a row of yellowish spots, and with extensive blue-grey areas in the rear half of the hind wings.

**Papilio philenor** Linn. the Pine Vine Swallowtail is largely black with the hind wings shading into metallic green posteriorly. The larvae feed on Dutchman’s pipe (*Aristolochia serpentaria* and *A. macrophylla*) a climbing shrub from which the species derives its name. The adults may be collected in the summer from button bush which grows usually where moisture is abundant. The adults like to light on flowers which they visit avidly.

The Black (or Parsnip) Swallowtail, **Papilio polyxenes asterius** Stoll. is black with two rows and a partial third row of yellow submarginal spots on the front wing. The larvae feed on carrots, parsley, and other related plants. The adults of this species are also greatly attracted to flowers. It can usually be collected from fields, roadsides, meadows, gardens, and open spaces.

The larvae of the papilionids are smooth bodied and have scent glands, or osmeteria which give off a disagreeable odor. They evert these from the upper part of the prothorax when disturbed.

There may be several generations per year. All species overwinter as pupae in the form of a naked chrysalis, attached to plant stems by the tail and supported by a loose silken girdle about the middle.
A SYNOPSIS OF THE CICADIDAE
OF ARKANSAS (HOMOPTERA)

C. E. McCoy
University of Arkansas

The cicadas, or "locusts" as they are sometimes called, are among the largest and most conspicuous of North American insects. In addition to their size, the loud piercing song of the males attract attention even when the insects are unseen. Each species has a distinctive song and they can be identified in this way as accurately as one identifies song birds. The sound producing organs are located at the base of the abdomen.

The periodical cicadas of the genus Magicicada are unique in their inordinately long developmental period, seventeen years in the northern U. S. and thirteen years in the south. The seventeen year form extends into extreme northern and western Arkansas. Most of those found in the state are of the thirteen year type. Three pairs of sibling species make up the two series. For example, M. septendecim is indistinguishable from M. tredecim. They are identified only by the locality and the year of emergence which indicates the brood to which they belong. They are considered as valid species because of the temporal separation which isolates them except for sympatric coemergence every 221 years.

The large green and black "dog-day" cicadas belonging to the genus Tibicen have a much shorter life cycle and are present every year. This group is preyed upon by the largest of our wasps, the cicada killer, Sphecius speciosus. The female wasp paralyses the cicadas and places two or three in an underground cell. A single egg is deposited upon the last victim to be placed in each cell. The cicadas are fed upon by the wasp larvae, secure in its private dining room.

Cicadas, particularly the periodical ones, cause measurable damage to young orchards and ornamental plantings as a result of their egg laying habits. The eggs are placed deep in the tissue of small branches. The twigs are frequently damaged so severely that the terminals are killed. The young nymphs fall to the ground immediately after hatching. They burrow into the soil where they feed on the roots of the trees. Accumulating evidence suggests that large numbers of them contribute to a condition known as "decline" in apple orchards.

KEY TO THE CICADIDAE OF ARKANSAS

1. Veins M and Cu of forewing separate at base ........................................ 2
   Veins M and Cu of forewing united at base (Fig. 1) ........................................ Melampsalta calliope (Wlk.)

2. Pronotum with prominent lateral carina extending nearly or all of its length; hind collar of pronotum variable ........................................ 5
Cicadidae of Arkansas

Pronotum with rounded sides; hind collar of pronotum projecting abruptly outward — Magicicada

3. Prothoracic pleura reddish; abdominal sternites reddish brown to yellow; 27-33 mm. — M. septendecim or M. tredecim

Prothoracic pleura black; 19-28 mm.

4. Apical tarsal segment black at tip; abdominal sternites black or with narrow apical band reddish-brown to yellow, at times interrupted medially — M. cassini or M. tredecassini

Apical tarsal segment entirely reddish or with a narrow black band covering no more than 1/3 of the segment; abdominal sternites black basally with broad, uninterrupted reddish apical bands — M. septendecula or M. tredecula

5. Abdomen translucent from beneath; prothoracic carina becoming obsolete anteriorly; veins of forewings clouded at tip — Cicada heiroglyphica (Say)

Abdomen opaque; prothoracic carina reaching anterior margin; veins of forewings not clouded

6. Humeral angles of pronotum produced as a quadrate lobe; head narrower than front margin of pronotum — Okanagan viridis

Humeral angles of pronotum not expanded; head as wide or wider than anterior margin of pronotum

7. Front wings with two anterior crossveins perpendicular to longitudinal veins, the anterior one placed at center of preceding cell (Fig. 2) — Diceroprocta vitripennis (Say)

Anterior crossveins of forewing oblique forming about a 45° angle with longitudinal veins; the anterior one placed before middle preceding cell — Tibicen

8. Hind collar of pronotum nearly or completely black

Hind collar of pronotum almost wholly pale

9. Color fulvous and black; mesonotum fulvous, central area and irregular lines at margin black; abdominal sternites with wide, polished median spots; 31-34 mm. T. lyricen (De G.)

Color green and black; mesonotum black with narrow pale lines and spots; median vitta of sternites small or absent; 32-36 mm. — T. chloromera (Wlk.)

10. Apical 1/3 of forewing fuscous; color chiefly greenish buff with few black marks on mesonotum; 30-33 mm. — T. superba (Fitch)
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Forewing clear or clouded only about the two anterior crossveins; abdominal color dark brown to black ............................................. 11

11. Abdominal segments above with at least posterior margins brownish ................................................................. 12

Abdominal segments above not paler on posterior margins, sometimes with pruinose white markings ............................ 13

12. Anterior crossveins covered by brownish clouds; brown of abdominal segments extensive; 32-35 mm. ....... T. resh (Hald)

Anterior crossveins not surrounded by clouds; brown on abdominal tergites confined to hind margins; 35-40 mm. ............................................. T. marginalis (Wlk.)

13. Size larger; forewings 50 mm. or more in length .................................................. 14

Size smaller; forewings under 50 mm. in length .................................................. 15

14. Mesonotum ferruginous, marked with black as follows: elongate spot either side of middle anteriorly, a small spot lateral of these, a spot on each side margin and a large transverse spot posteriorly which has a narrow point extending forward along midline; length, 38-40 mm. ............................................. T. resonans (Wlk.)

Mesonotum black, lateral margins and inverted V fulvous, latter extended to reach pale cruciform elevation on rear margin; 40-42 mm. ............................................. T. auletes (Germ.)

15. Abdomen with median row of pruinose white spots above; markings and mesonotum, entire side margin of abdomen and band across pregenital segment also white pruinose;

31-38 mm. ............................................. T. dorsata (Say)

Abdomen without median white spots .................................................. 16

16. Body length under 29 mm. .................................................. 17

Body length over 29 mm. .................................................. 18

17. Pale posterior margin of pronotum broad; mesonotum with two longitudinal pale marks near midline .......... T. aurifera (Say)

Pale posterior margin of pronotum narrowed by dark band along incision; mesonotum with four longitudinal pale marks ............................................. T. canicularis (Harr.)

18. Costa of forewing obtusely bent near middle; inconspicuous lateral white marks on tergite I;

30-33 mm. ............................................. T. linnei (Sm. & Gross.)

Costa of forewing not so bent .................................................. 19

19. Underside of abdomen with broad, parallel-sided black
Cicadidae of Arkansas

stripe covering middle 2/3 of sternites; side margins of sternites also black; 32-36 mm. \textit{T. robinsoniana} Davis

Median stripe on underside of abdomen obsolete or if present not occupying more than middle 1/3 of segments and tapering conspicuously posteriorly; side margins of sternites pale; 29-35 mm. \textit{T. pruinosa} (Say)

NOTES ON ARKANSAS CICADIDAE

1. \textit{Melampsalta calliope} (Walker) occurs from Virginia and Georgia to Texas and Colorado. It has not been recorded from Arkansas but this is almost certainly due to inadequate collecting.

2-7. \textit{Magicicada} contains six species, three each in the northern seventeen-year series and the southern thirteen-year series. All six have been taken in the state. Two broods of 13-year cicadas out in recent years have provided the material on hand. They both cover the state. Brood 19 was out in 1946 and 1959 and will be expected again in 1972. Brood 23 was seen in 1963 and will be expected next in 1976. We have specimens of \textit{M. tredecim} from Craighead County in 1963; \textit{M. tredecassini} from Mississippi County in 1963, and from Washington County in both 1946 and 1959; and \textit{M. tredecula} from the same county and the same years. Alexander and Moore took all three species from Sharp, Fulton, and Independence Counties in 1959. Additional records of \textit{M. tredecim} from Hempstead and Benton are in the literature as is a record of \textit{M. tredecassini} from Crittenden County.

Brood 4 of the seventeen-year series occurs principally to the north and west of the state and occasionally a few individuals are found in Arkansas. \textit{M. septendecim} is recorded from Washington and Sharp Counties, and \textit{M. cassini} and \textit{M. septendecula} are recorded from Washington, Crawford, and Sebastian Counties. This brood was out in 1964 but no collections in the state were made. These cicadas usually appear as adults from mid-May through June.

8. \textit{Cicada heiroglyphica} Say occurs from the eastern seaboard westward to Kansas and Oklahoma. We have recorded it from Washington, Lincoln and Benton Counties during late May and early June.

9. \textit{Okanagana viridis} Davis is a resident of the Mississippi valley and has been recorded from Arkansas by Davis (1930). We have no specimens but would expect this species to be present in southeast Arkansas during late June or July.

10. \textit{Diceroprocta vitripennis} (Say) is a very common cicada throughout the alluvial areas of eastern and southern Arkansas and along the Arkansas River. We have it from Lee, Lincoln, Arkansas, Desha, Hempstead, Little River, Crawford, and Fulton Counties with collection dates ranging from June 12 to July 11.
The genus *Tibicen* contains the large green and black species which are so common over much of North America during the summer and early fall. We have thus far recorded only eight of the sixteen species which may reasonably be expected to occur in the state. We expressly solicit specimens from all parts of the state.

11. *T. lyricen* (DeG.) known only from one Washington County specimen taken in October.

12. *T. chloromera* (Walker) Washington County — July to October; Poinsett County June 25 and Lincoln County July 2.

13. *T. superba* (Fitch) is recorded from Arkansas by Davis (1930) and should be present in the western portion of the state.

14. *T. resh* (Haldeman) is also a western species and has been taken in Hempstead and Crawford Counties during July and August.

15. *T. auletes* (Germar) and *T. resh* are our largest species with wing lengths in excess of 50 mm. We have three specimens of *T. auletes* collected in Washington County during October.

16. *T. aurifera* (Say) is known from Washington County in September and Nevada County in October.

17. *T. canicularis* (Harr.) is represented by a single specimen from Washington County taken in October.

18. *T. lineae* (Sm. and Gross.) is likewise represented by a single specimen taken in Washington County in September.

19. *T. pruinosa* (Say) is our most common "dog-day" cicada, "locust", or "jar fly" as some call them. It certainly occurs abundantly over much of Arkansas. We have material from Washington, Benton, Hempstead and Lee Counties with collection dates ranging from June 29 to September 30.

*T. davisi* (Sm. and Gross.) and *T. figurata* (Walker) have been recorded from extreme southeast Arkansas by Davis (1930). *T. similaris* (Sm. and Gross.) is known from Mississippi and may also occur in that part of the state. *T. robinsoniana* Davis is known from southern Missouri and should be included in our fauna. The lack of specimens or of adequate descriptions prevents the inclusion of these species in the present key. *Pacarina puella* Davis is known from Louisiana, Oklahoma and Texas and should be sought in the southwestern portion of Arkansas. This very small species is about 3/4 inch long, and either a deep brown or green in color. It is sufficiently distinctive that it will not be mistaken for any other cicada which we expect to encounter.

**LITERATURE CITED**

Cicadidae of Arkansas


Fig. 1. Base of forewing of *Melampsalta*

Costa
Medius
Cubitus
Arculus

Fig. 2. Tip of forewing of *Diceroprocta*

Ant. C. V.
THE BUMBLE BEES OF ARKANSAS
(HYMENOPTERA, APIDAE,Bombiniae)
Leland Chandler and C. Edward McCoy, Jr.
Departments of Entomology, Purdue University & University of Arkansas, respectively.

PREFACE

The Department of Entomology, University of Arkansas, undertook a visiting scientist program during the summer of 1964. The major objective of this program was to further the development of a biotic systematic program which would contribute to the many facets of entomological research and teaching. In 1964, the emphasis was placed on the organization of the Hymenoptera section of the university collection.

The role of the university collection is often not well-understood. Its central position in a university program cannot be overemphasized; however. Locally, it serves as a reference library of biological forms; it preserves materials for both biological and historical analysis; its data are not only the pinned and preserved specimens but the labels and accompanying notes. From a synthesis of these data, patterns of distribution, dispersal, faunal change, seasonal occurrence and ecological amplitudes can be derived. These are the dynamic aspects of a collection.

To the science of entomology, the collection serves as a regional repository and contributes basically to studies of wider geographic scope. Usually, such a collection has both strengths and weaknesses among insect groups reflecting, in general, the interests of faculty, students and other contributors.

A collection, pinned in drawers and held in cabinets, cannot serve a great number of persons. Contrawise, an individual engaged in putting names on museum specimens does not have sufficient opportunity to study the populations in the field. There is, therefore, a definite need for a cooperative endeavor between the groups which can be achieved through publications.

This is the intent of this paper. The bumble bee species of the state are listed, keys are presented for their identification, and the distributional records as now known are included. Much of the latter information is presently fragmentary. Interested persons can, however, contribute to these sections and include studies on behavior, pollination, population dynamics and other biological aspects. In turn, the specialist can direct his attention to these same or similar studies.

ACKNOWLEDGMENTS

The senior author accepted the invitation to participate in the 1964 summer and spent from June 15 to August 12 at Fayetteville. He is...
especially grateful, for their interest, contributions and courtesies, to Dr. Charles Lincoln, departmental chairman; L. Rolston, L. Warren and W. Whitcomb; to Phil Rouse, museum curator; and, to students K. Bell, W. Jones and D. McNeal.

INTRODUCTION

Bumble bees are of two kinds, the nest-making species with queen and worker castes of the genus *Bombus*; and, the parasitic species which have no worker caste of the genus *Psithyrus*. Females of *Bombus* have the hind tibiae expanded, fringed with long hairs, the central portions bare. This development is called a corbicula and it is in these corbiculae that pollen is collected for transport to the nest. Popularly, these are called pollen-baskets. The females of *Psithyrus* do not collect pollen and have lost these pollen-baskets. While the fringes may have somewhat longer hair, the central area is also covered with hairs. Female *Psithyrus* invade the nests of the true bumble bees and utilize the existing workers in provisioning and tending the parasitic brood.

Several recent publications are available that treat the bumble bees in more detail. In addition, each contains a list of references invaluable to the investigator. These references are Stephen (1957) on western America, LaBerge and Webb (1962) on Nebraska bumble bees, Mitchell (1962) on the bees of the eastern United States and Medler and Carney (1963) on the bumble bees of Wisconsin. A check list of North American species may be found in Muesebeck, *et al.* (1951) and the supplement (Krombein, 1958). Milliron (1961) published on a different classification of the bumble bees but this is beyond the scope of this paper. Hazeltine and Chandler (1964) presented a preliminary atlas for the identification of female bumble bees.

Franklin (1913) recorded six species of *Bombus* and one of *Psithyrus* as occurring in Arkansas. We have added one additional species of *Bombus*, but believe that *B. fervidus*, recorded by Franklin, does not occur within the state.

KEY FOR THE IDENTIFICATION OF GENERA AND SEXES OF BUMBLE BEES OCCURRING IN ARKANSAS

1. Antennae 12-segmented; abdomen with six visible abdominal segments; with a sting; inner tarsal claws much shorter than outer ones and diverging from them .................................. Females .......... 2

1'. Antennae 13-segmented; abdomen with seven visible abdominal segments; without a sting; inner tarsal claws nearly equal in length to the outer ones and nearly parallel to them .................................................................................. Males .......... 3

2. Hind tibia bare centrally, fringed with long hairs (possessing a pollen basket); abdomen covered with hairs obscuring the surface; last abdominal segment straight in profile, not at all, or weakly ridged .............................. (queens & workers) *Bombus*
2'. Hind tibia covered with hairs leaving no central bare area (without a pollen basket); abdomen shining, hair sparse and not obscuring the surface to any extent; last abdominal segment curved downward in profile with strong lateral ridges ........................................ (females) Psithyrus

3. Hind tibia somewhat flattened, hairs in central area irregularly dispersed, occasionally with much of the area shining; face usually with some yellow hairs ......................................................... Bombus

3'. Hind tibia somewhat rounded, hairs stiff and covering the outer surface uniformly; face with dense, bristly black hair, never with yellow hairs ......................................................... Psithyrus

KEY FOR THE SEPARATION OF FEMALE BOMBUS

1. Dorsum of thorax entirely yellow ......................................................... 2

1'. Dorsum of thorax largely black or with a distinct black hair band between the wing bases ......................................................... 4

2. First abdominal segment yellow, usually with a median, apical notch; remainder of abdomen black .......................................................... B. impatiens

2'. First abdominal segment yellow, second segment with either yellow or rusty hair ......................................................... 3

3. Second abdominal segment with yellow hairs, sometimes in the form of two yellow lobes, sometimes crescent-like .......................................................... B. bimaculatus

3'. Second abdominal segment with rusty hairs, usually crescent-like but occasionally covering most of the segment .......................................................... B. griseocollis

4. Black band between wings well-defined, its edges more or less parallel ......................................................... 5

4'. Black area between wings irregular covering most of the posterior part of the thorax at times; not a well-defined band ......................................................... 6

5. First two abdominal segments yellow; remainder of abdomen black .......................................................... B. fratermus

5'. First four abdominal segments yellow; remainder of abdomen black .......................................................... B. fervidus

6. Top of head with some yellow hairs, occasionally forming two yellow lines; posterior part of thorax usually with some yellow hairs; ocelli placed below a line drawn tangentially across the tops of the compound eyes; first abdominal segment with varying amounts of yellow, second and third segments yellow, remainder black; fourth and fifth antennal segments subequal, third segment as long as fourth and fifth combined .......................................................... B. nevadensis auricomus
6. Top of head with hairs all black; posterior part of thorax usually black; ocelli placed above a line drawn tangentially across the tops of the compound eyes; first abdominal segment largely yellow, second and third segments yellow, remainder black; fifth antennal segment longer than fourth, third somewhat shorter than the fourth and fifth combined B. americanorum

KEY FOR THE SEPARATION OF MALE BOMBUS

1. Eyes large, bulging from the sides of the head; ocelli large and set below the level of the top of the eyes 2

1'. Eyes normal, not bulging from the sides of the head; ocelli small and set above the level of the top of the eyes 4

2. First abdominal segment yellow, second with a median rusty patch or nearly all rusty B. griseocollis

2'. First abdominal segment yellow, or occasionally black, second segment wholly yellow without rust colored hairs 3

3. First two abdominal segments yellow, remainder of abdomen black; black band between wings sharply defined; malar space reduced to a line B. fraternus

3'. First three, or at least second and third abdominal segments yellow, remainder of abdomen black; either no black hairs between wing bases or the black area irregular; malar space well-defined B. nevadensis auricomus

4. First five abdominal segments yellow, remainder of abdomen black, yellow or with reddish hairs 5

4'. Yellow confined to first and/or second segments, occasionally yellow laterally on the fourth segment but this is not continuous with the yellow of the first segments 6

5. Tip of abdomen usually with reddish hairs, but these may also be yellow or black; black band between wings poorly defined; yellow hairs of body dull yellowish B. americanorum

5'. Tip of abdomen with black hairs; black band between wings usually well-defined; yellow hairs of body bright lemon yellow B. fervidus

6. First segment of abdomen yellow; (occasionally the yellow hairs will encroach somewhat upon the median portion of the second segment); remainder of abdomen black; space between eye and mandible (malar space) short B. impatiens

6'. First segment of abdomen yellow, second segment with a crescent or bilobed yellow area; yellow hairs of ventral surface occasionally covering fourth segment (var. ridingsii); space between eye and mandible long B. bimaculatus
BOMBUS NEVADENSIS AURICOMUS (ROBT.)

*B. nevadensis* is a polytypic species with an eastern (*B. n. auricomus*) and a western (*B. n. nevadensis*) subspecies. The two subspecies may be differentiated in the females by the color of the pile on the dorsum of the thorax; this being entirely yellow in *B. n. nevadensis*, and extensively black, posteriorly, in *B. n. auricomus*. In the males, the apical abdominal segments of *B. n. nevadensis* have yellow pile; these segments have black hair in *B. n. auricomus*. Only the eastern subspecies has been recorded from Arkansas.

Females of *B. n. auricomus* are often confused with those of *B. americanorum*. The key characters, however, will separate the two species rather readily.

*B. n. auricomus* has been collected in the following counties: Arkansas, Benton, Desha, Lafayette, Lee, Washington and White.

BOMBUS FRATERNUS (SMITH)

This is a widespread, easily recognized species. In addition to the characters given in the key, the pile of *B. fraternus* is much shorter and appears more oppressed than any of the other species of bumble bees.

We have records of its occurrence as follows: Ashley, Benton, Chicot, Clark, Crittenden, Desha, Grant, Little River, Lonoke, Nevada, Sebastian and Washington.

BOMBUS GRISEOCOLLIS (DeGEER)

*B. griseocollis* differs from all other species in Arkansas by the presence of rusty (ferruginous) pile on the second abdominal segment. Typically, this color is restricted to the anterior portion of the second segment, but in some workers and males, it tends to cover the entire segment. There is also a tendency for this to fade in older or worn individuals, being more yellow in appearance. The position of the ocelli are diagnostic, however.

The males of *B. griseocollis* are "big-eyed" as are those of *B. n. auricomus* and *B. fraternus*. In all three species the males exhibit a territoriality behavior. The tendency for *B. griseocollis* males to occupy terminal branches of isolated trees has given rise to the local name of "shade bees".

*B. griseocollis* has been recorded from the following counties: Arkansas, Benton, Franklin, Grant, Lafayette, Little River, Logan, Marion, Miller, Montgomery, St. Francis, Sebastian and Washington.

BOMBUS AMERICANORUM (FABR.)

This is the most widespread and most common species of bumble bee in Arkansas. It is also the most variable in color pattern. As men-
tioned previously, the females resemble those of *B. n. auricomus*; the males (with the apical abdominal segments black) are difficult to distinguish from *B. fervidus* and only genitalic characters are reliable (see Medler and Carney, 1963). In addition to being the most abundant, it is also the most vicious species of bumble bee in the state.

There is a considerable controversy as to the correct name to be applied to this species. According to our usage, *B. pennsylvanicus* (DeG.) is a synonym.

*B. americanorum* has been collected in the following counties: Arkansas, Benton, Boone, Clark, Cleveland, Craighead, Crawford, Franklin, Grant, Hempstead, Lafayette, Lawrence, Lincoln, Little River, Logan, Lonoke, Miller, Mississippi, Phillips, Prairie, St. Francis, Sebastian, Sevier, Sharp, Washington and White.

### BOMBUS FERVIDUS (FABR.)

Franklin (1913) stated that *B. fervidus* was absent from the greater part of Arkansas. We have not been able to locate the early collection records to which Franklin alluded. It is certainly probable that *B. fervidus* occurred within the state during the early 1900's. However, it also appears certain that the species does not now occur in Arkansas. Any record based upon males should be confirmed by studies of the genitalia. The females are distinct.

The range of *B. fervidus* is essentially more northern than any of the other species. Medler and Carney (1963) have shown that certain species in Wisconsin have withdrawn northward within recent times. Similar instances are indicated in Indiana and the early records of bumble bee species in Illinois (Frison, 1919) complement Medler's study.

The value of collections as a source of historical and distributional data is emphasized by this example.

### BOMBUS BIMACULATUS CR.

*B. bimaculatus* queens are among the first to appear in the spring. Workers and males are produced extremely early in the season. During the summer, this species is rarely encountered, but there is a short period of activity in late summer or early fall.

Although color variants are not now considered deserving of nomenclatorial status, the varietal name *ridingii* was given to a color form in which the fourth abdominal segment is extensively covered with yellow hair instead of black. This variant occurs throughout the range of the species and has been taken in Arkansas.

The county records of *B. bimaculatus* are: Benton, Franklin, Mississippi, Montgomery and Washington.
BOMBUS IMPATIENS CR.

The color and color pattern of B. impatiens is remarkably stable. There has been some confusion with B. bimaculatus, especially if there is a reduction in the amount of yellow pile on the second segment of the latter. The difference in malar space, however, is constant.

B. Impatiens is known from the following counties: Dallas, Grant, Hempstead, Washington and White.

PSITHYRUS VARIABILIS (CR.)

This is the only species of Psithyrus recorded from Arkansas. It is a parasite of B. americanorum. The females have the dorsum of the thorax covered with yellow hair, but the pleura are largely black. The abdomen is sparsely covered with blackish hairs, the cuticle being almost completely visible and shiny. The last abdominal sternite is strongly bent downward.

The thorax of the male is similarly colored except for a tendency toward a black interalar band. The abdomen is more densely covered with hair with varying amounts of yellow hairs on segments 2, 3 and 4. Although the top of the head has a large amount of yellow hair, the face is covered with stiff, black hairs, never with an admixture of yellow.

Our only record of P. variabilis is from Washington County.

LITERATURE CITED


Bumble Bees of Arkansas


EFFECT OF DIETARY GALACTOSE VS. GLUCOSE WITH CORN OIL AND WITH HYDROGENATED COCONUT OIL ON VARIOUS METABOLIC FUNCTIONS IN RATS

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and
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It has been shown in several reports that the responses of metabolic systems vary with different dietary combinations. For example, the source of glucose in the diet (that is — glucose, fructose, galactose, etc.) influences the metabolic route which the carbohydrate takes. There have been changes in the extent of lipogenesis, and changes in the amount of glucose converted to glycogen and to other products associated with glycolysis, as a result of the carbohydrate fed. Much comment and controversy has arisen over the variations in cholesterol and phospholipid levels in the body as a result of the fatty acid content of the dietary fat. The interrelationships of carbohydrate and fat metabolism have been shown to be affected by dietary sources also.

This particular study was designed to notice any influence by the type of dietary fat and the use of galactose as an indirect source of glucose on various adaptive metabolic responses in the albino rat. The particular responses which were used to evaluate any adaptations to the diet were the levels of total lipid, cholesterol, phospholipid, nitrogen, and glycogen in the liver, and the cholesterol concentration of the serum.

Male, weanling rats, weighing an average of 59 g at the beginning of the study, were fed a nutritionally adequate diet with the types of carbohydrate and fat as the only variables. The rats were divided into 4 groups, each of which received a 15% fat, 60.55% carbohydrate, 20% protein diet. Group I served as the primary control group, and was fed corn oil (CO) with glucose. Group II was fed the same source of unsaturated fat, CO, with galactose. Group III was fed a saturated fat, hydrogenated coconut oil (HCO), with glucose; and Group IV was fed HCO with galactose. These diets were continued 3 weeks, at the end of which time, the rats were decapitated and the livers and serum saved for analysis.

The overall differences between effects of diets on growth of the rats are shown in this growth curve. (Fig. 1) Galactose depressed the growth rate whenever it was fed, and HCO depressed the growth rate slightly when fed with glucose. The growth rate was extremely low when HCO and galactose were fed in the same diet. This was

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Fig. 1. Growth of rats fed different carbohydrate-fat combinations for 3 weeks.

Group I = CO + G
Group II = CO + GAL
Group III = HCO + G
Group IV = HCO + GAL
an effect of an inefficient use of either galactose or HCO, since all groups ate about the same amount of food. (Fig. 2).

The glycogen content of the livers decreased when galactose was fed as compared with feeding glucose. The diet of HCO and glucose caused a slight decrease in glycogen as compared with CO and glucose. This is consistent with reports from other studies in which either HCO or galactose was fed. The effects of galactose and HCO seem to be additive when fed in the same diet, since the group fed HCO and galactose had the most extreme glycogen reduction either as per cent of total liver or per 100 g of body weight. (Fig. 3).

Studies in which activities of various enzyme systems were measured showed that when HCO was fed, there was an increase in glucose-6-phosphatase activity over that exhibited when CO was fed. There was a similar increase when galactose was the dietary carbohydrate instead of glucose. Since this enzyme catalizes the reaction from G-6-P to glucose, the decrease in glycogen could be due to increased hydrolysis of G-6-P to glucose with a resultant decrease in G-6-P available for other pathways. Since galactose is converted to G-1-P before going to G-6-P, it might be expected to be a better precursor of glycogen than glucose, but the interconversion of G-1-P to G-6-P has been shown to be sufficiently rapid so that the 2 compounds serve metabolically as a single pool.

Some researchers have found that in the conversion of galactose to glucose there is an accumulation of large quantities of galactose or galactose-1-phosphate. They think this excess of galactose-1-P inhibits an enzyme necessary in the normal utilization of glucose. It is known that in galactosemia, the inherited metabolic disorder in which the enzyme which converts Gal-1-P to G-1-P is missing, there is another enzyme system which increases in activity with age. Possibly this enzyme system could increase in activity when diets containing large amounts of galactose are fed, and help eliminate the accumulation of galactose-1-P. The study would have to be continued over a longer period of time to prove this theory.

There is also a possibility that relatively low levels of liver glycogen in rats fed galactose were an effect of mobilization of glucose for fatty acid synthesis, since the total lipid expressed as per cent of the liver was higher in rats fed galactose than in those fed glucose (Fig. 3).

As shown in other studies with rats, the dietary unsaturated fat caused more total cholesterol in the liver than did the saturated fat. Also the diets containing galactose resulted in higher cholesterol levels in both liver and serum than did diets containing glucose. When CO and gal were fed together, serum and liver cholesterol values were higher than in any of the other groups.

Phospholipid content of the liver was higher when saturated fat was fed than when CO was fed. There were no significant differences
Fig. 2. g weight gain/g food intake for groups of rats fed different carbohydrate-fat combinations for 3 weeks.

Fig. 3. Percent of protein (P), glycogen (G), lipid (L) and water in livers of rats fed different carbohydrate and fat combinations for 3 weeks.
in phospholipid values between the groups fed the two sources of glucose.

Per cent hepatic nitrogen (and hence, hepatic protein) was found to be slightly greater in rats fed diets containing galactose instead of glucose.

There were interesting physiological effects when galactose was fed with either fat. After two days on the diets both groups developed polyurea, and after 13 or 14 days developed a dense lenticular opacity. These effects lasted from the time of first appearance throughout the experimental period.

These effects, as well as the striking reduction in weight gain of the galactose-fed rats, indicate that they were in a state of relative protein deficiency in comparison to the glucose-fed controls, due to increased excretion of nitrogen-containing compounds. A test with phlorogulcinol indicated the presence of galactose in the urine. Possibly then, the renal tubules were so saturated with galactose they were unable to reabsorb many of the amino acids and peptides back into the blood stream, causing this protein deficiency.

As yet the cause for cataracts is not certain, but they are associated with both galactosemia and diabetes. It has been suggested that the excessive amounts of galactose in the urine prevent re-entry of other essential substances which require the same pathway in the body, and this deficiency somehow results in cataract formation. Also the inhibition of aerobic glycolysis by galactose has been linked with marked derangements of metabolic processes in the lens, causing cataract formation.

This leads to a little more insight into the intricacies of metabolic interrelationships which, as we learn more about them, seem to become even more complex.
EFFECTS OF SATURATED AND UNSATURATED LONG CHAIN FATTY ACIDS FED WITH AND WITHOUT ESSENTIAL FATTY ACID ON VARIOUS COMPONENTS OF LIPID AND CARBOHYDRATE METABOLISM

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The degree of saturation of long chain fatty acids and the availability of essential fatty acids in diets fed to rats have been shown to affect metabolic pathways in the liver of the rat. Variations in the type or amount of dietary fat seem to alter serum and liver cholesterol patterns. Essential fatty acid deficiency has resulted in increased basal metabolic rate and increased oxidation of several acids of the Kreb’s cycle.

The purpose of this experiment was to investigate what influence, if any, the degree of saturation of long chain fatty acids, when fed with and without essential fatty acid, would have on various components of lipid and carbohydrate metabolism.

The experiment (pilot and follow-up) was designed to permit comparisons between effects of the following factors on various metabolic functions: (1) presence of essential fatty acids in naturally occurring fats containing long chain polyunsaturated fatty acids (corn oil versus tuna oil), (2) supplementation of fats containing long chain saturated fatty acids with an essential fatty acid (hydrogenated peanut oil versus hydrogenated peanut oil plus linoleic acid), (3) combination of saturated and unsaturated fats with or without essential fatty acid (hydrogenated peanut oil plus linoleic acid versus hydrogenated peanut oil plus tuna oil), and (4) degree of saturation of dietary fatty acids, with and without essential fatty acids (corn oil versus hydrogenated peanut oil plus linoleic acid, tuna oil versus hydrogenated peanut oil, and hydrogenated peanut oil plus tuna oil versus either tuna oil or hydrogenated peanut oil).

All rations contained 20% by weight of protein, approximately 380 calories per 100 grams ration and adequate amounts of minerals and vitamins. The rats fed corn oil served as the control.

The pilot study groups were fed 15% fat diets and the follow-up study groups were fed 5% fat. The group given tuna oil ration in the pilot study did not accept the oil, and after one week was given a 5% tuna oil (TO) ration. The vitamin E content of TO rations was doubled to prevent oxidation of this highly unsaturated oil.

Analysis was made at two and four weeks in the pilot study, and at one day, and two and three weeks in the follow-up study.

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Livers were assayed for activities of the glucose-6-phosphatase and fructose diphosphatase enzyme systems, for glycogen, total lipid, cholesterol and phospholipid. Serum was assayed for cholesterol.

Results will deal only with the pilot study except when noted, because all data for follow-up have not been collected.

As expected from previous reports, rats fed an essential fatty acid deficient diet did not gain as much weight as did those fed corn oil (CO) or hydrogenated peanut oil plus linoleic acid (HPO+L). After four weeks, the CO fed group had gained only slightly more weight than the group fed HPO+L, thus degree of saturation did affect weight gain, but to a lesser extent than did essential fatty acid deficiency (Fig. 1).

Food efficiency, grams weight gained per gram of food eaten, was greater for CO fed group than for the other three groups; and the next to highest food efficiency was shown by the rats fed TO. Supplementing HPO with L resulted in greater food efficiency than feeding HPO with no supplement. These data suggest that food efficiency is more dependent on degree of saturation than on presence of essential fatty acid (EFA). Food efficiency ratios for each group at 4 weeks were as follows: CO, 0.46±0.01; HPO+L, 0.35±0.01; HPO, 0.31±0.01; and TO, 0.41±0.01.

The activity of glucose-6-phosphatase (G-6-Pase), the enzyme which removes phosphorus from glucose-6-phosphate to give glucose, was slightly altered by the type of fat in the diet. There were only slight differences in G-6-Pase activity among groups at two weeks. By four weeks feeding TO in place of CO resulted in greater G-6-Pase activity. This may have been due to EFA deficiency in the TO group, or to differences in the utilization of the two oils, or to the lower level (5%) of TO compared to the 15% CO diet. If this rise in G-6-Pase activity in the TO group had been due only to EFA deficiency, it seems that feeding HPO would have resulted in greater activity than would feeding HPO+L, but this was not the case. Thus, EFA deficiency was not solely responsible for increased G-6-Pase activity (Fig. 2).

Feeding TO or HPO+L in place of CO caused higher fructose diphosphatase activity at four weeks when compared to the control. The enzyme, fructose diphosphatase (FDPase), removes phosphorus from fructose 1,6 phosphate to give fructose-6-phosphate. Because of lack of a 5% fat control for the 5% TO diet, I cannot conclude that either EFA or degree of saturation had an influence on FDPase activity. However, you will notice that by four weeks EFA deficient groups showed slightly increased FDPase activity over the activity in these groups at two weeks (Fig. 3).

Saturated fat without EFA was the only dietary fat which significantly influenced liver glycogen when compared to the control group. Calculations for the overall period showed that group 3 had a significantly lower percentage of liver glycogen than did the group fed
Effects of Saturated and Unsaturated Fatty Acids

Figure 1. Growth rate of rats fed a 15% fat diet for 28 days. CO — corn oil, HPO — hydrogenated peanut oil, L — linoleic acid, and TO — tuna oil.
Figure 2 Total glucose-6-phosphatase activity (units/100 g body weight) of rats fed a 15% fat diet for 28 days. CO — corn oil, HPO — hydrogenated peanut oil, L — linoleic acid and TO — tuna oil.
Figure 3 Total fructose-1,6-diphosphatase activity (units/100 g body weight) of rats fed a 15% fat diet for 28 days. CO—corn oil, HPO—hydrogenated peanut oil, L—linoleic acid and TO—tuna oil.
Figure 4  Total liver lipid and glycogen (percent of liver) of rats fed a 15% fat diet for 28 days.  CO — corn oil, HPO — hydrogenated peanut oil, L — linoleic acid, and TO — tuna oil.
Effects of Saturated and Unsaturated Fatty Acids

HPO+L. If depressed glycogen levels in livers from the HPO group were due to EFA deficiency, then a comparable 15% TO diet would be expected to give similar results. Indeed, even with the 5% TO diet, the average percentage of glycogen in livers from rats given TO was somewhat lower than that of control rats (3.92±0.66 versus 5.09±0.37), although this difference was not significant at the 5% level due to wide variations within the TO group (Fig. 4).

The feeding of polyunsaturated fat resulted in greater changes in liver lipids within groups from two to four weeks than did the feeding of saturated fat. Feeding CO or TO for four weeks raised lipid levels significantly over those in livers from rats fed saturated fat for the same period. The higher liver lipid levels may have been due to increased lipid synthesis by the liver, mobilization of lipids from adipose tissue to liver, lipid storage in the liver, or a combination of these factors (Fig 4).

Serum cholesterol levels (mg cholesterol per 100 ml serum) for the overall experimental period were higher in the CO (209±11) and TO (162±13) fed groups than in the groups fed a saturated fat (HPO+L, 163±7 and HPO, 146±7). Serum cholesterol levels were not significantly different with or without linoleic acid supplement; thus under the conditions of this experiment, EFA did not show an effect in lowering serum cholesterol.

These results call for more work pertaining to the inter-relationships of fats in the diet with carbohydrate and lipid metabolism. Some questions may be answered in the follow-up by feeding the other fats at the level at which TO was accepted, and by doing assays at intervals from a few days to several weeks while the rats continue to eat the specified fat diet.
THE INTERRELATIONSHIPS OF CERTAIN METABOLIC RESPONSES TO THREONINE DEFICIENCY AND TO VARIOUS DIETARY CARBOHYDRATES IN THE WHITE RAT

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The importance of the relative amounts of amino acids in a protein is a well known and accepted fact. An amino acid imbalance results from any change in the proportions of the amino acids in the diet that results in an adverse effect which can be prevented by supplementing the diet with a relatively small amount of the most limiting amino acid(s) (1).

Threonine deficiency has been one of the most widely studied imbalances, partly because its manifestations in the white rat are similar to those of the calorie-protein deficiency disease, kwashiorkor, in humans.

As with all nutritional factors, amino acid deficiency does not function completely independently. One of the most pronounced symptoms of threonine deficiency is the deposition of excess lipid in the liver. However, the amount of liver lipid appears to depend partly on the type and the amount of carbohydrate in the diet (2).

It is not known just how the dietary carbohydrate influences the development of the threonine deficiency. This particular study was designed to observe the effect of various carbohydrates on threonine deficiency, and at the same time to gain some information about the influence of the amino acid imbalance on the handling of different carbohydrates.

Male weanling rats were used, six rats in each of six groups. All of the rations contained 9% casein as the sole protein source. At this level, tryptophan, methionine and threonine are the limiting amino acids. Three of the rations were supplemented with all three of these amino acids. The other three were supplemented with only tryptophan and methionine and, therefore, were deficient in threonine.

The dietary carbohydrate was either glucose, fructose, or a 1:1 combination of the two.

After the animals had been fed the diets for two weeks, they were sacrificed and the livers removed for analysis.

The total amount of liver lipid was determined as well as liver cholesterol and phospholipid levels. Triglyceride values were calculated by subtracting the sum of the phospholipids and cholesterol from the amount of total lipid. Livers were also assayed for concen-
Responses to Threonine Deficiency

Tritation of glycogen and for activities of the glucose-6-phosphatase (G-6-Pase) and fructose-1,6-diphosphatase (FDPase) enzyme systems.

Threonine deficient diets containing each of the different carbohydrates were as readily consumed as the corresponding threonine supplemented diets. However, within each subgroup, that is, threonine supplemented or threonine deficient, diets containing fructose were not as readily accepted as those containing glucose (Table 1).

The threonine deficiency resulted in a decrease of weight gain with each of the carbohydrates. However this decrease was only slight when the dietary carbohydrate was glucose. Generally, decreased food intakes accounted for decreased weight gain. However, there was a significant interaction of the fructose and threonine deficiency in depressing the food efficiency ratio of the group receiving this diet (Table 2).

Figure 1 illustrates the relative liver weights and the major components of the liver (g/100 g of body weight).

The substitution of fructose or the glucose/fructose combination for glucose in either the threonine supplemented or the threonine deficient diets, resulted in increased liver sizes. However, only with the threonine deficient diets did this substitution result in an increase in the milligrams of liver lipid per 100 g of body weight.

Although the liver sizes did not vary significantly between the group receiving threonine and the groups not receiving it with each carbohydrate, the livers of the animals fed the threonine deficient diets contained more lipid than those of their supplemented control group.

Levels of glycogen, protein and water were largely reflective of the total liver size.

Some differences in the composition of the total lipid were also found (Fig. 2). The level of cholesterol increased with the omission of threonine from the glucose and the glucose/fructose diets, and the phospholipid level increased slightly with the substitution of fructose for glucose in the threonine deficient diets. However, the total accumulation of lipid in the liver appears to be chiefly due to the net deposition of triglycerides.

Two types of enzyme adaptation have been proposed: an increase in specific activity and an increase in relative liver size (3). The total activity (i.e., units per 100 g of body weight) would represent the combination of the two methods, while specific activity (i.e., units per 100 mg of liver nitrogen) would represent the part of the adaptation accomplished by preferential synthesis of the enzymes. The graph (Fig. 3) shows both total and specific activity.

With both threonine supplemented and threonine deficient diets, the activities of the two enzyme systems follow similar patterns. Dietary
Table 1. Food intake and weight gain of rats on low protein diets, with or without supplemental threonine, and with various dietary carbohydrates.

<table>
<thead>
<tr>
<th>Diet</th>
<th>Food Intake</th>
<th>Weight Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total/kg/wk</td>
<td>Total/kg/wk</td>
</tr>
<tr>
<td>I</td>
<td>1G + Th</td>
<td>114 ± 5²</td>
</tr>
<tr>
<td>II</td>
<td>F + Th</td>
<td>102 ± 6</td>
</tr>
<tr>
<td>III</td>
<td>G/F + Th</td>
<td>121 ± 3</td>
</tr>
<tr>
<td>IV</td>
<td>G - Th</td>
<td>113 ± 3</td>
</tr>
<tr>
<td>V</td>
<td>F - Th</td>
<td>93 ± 6</td>
</tr>
<tr>
<td>VI</td>
<td>G/F - Th</td>
<td>118 ± 6</td>
</tr>
</tbody>
</table>

1G — glucose, F — fructose, G/F — glucose/fructose (1:1), Th — threonine
²Standard error of the mean

Table 2. Utilization of low protein diets, with or without supplemental threonine, and with various dietary carbohydrates. Gram weight gain per gram food intake.

<table>
<thead>
<tr>
<th>Diet</th>
<th>Gram weight gain/kg food intake</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1G + Th</td>
</tr>
<tr>
<td>II</td>
<td>F + Th</td>
</tr>
<tr>
<td>III</td>
<td>G/F + Th</td>
</tr>
<tr>
<td>IV</td>
<td>G - Th</td>
</tr>
<tr>
<td>V</td>
<td>F - Th</td>
</tr>
<tr>
<td>VI</td>
<td>G/F - Th</td>
</tr>
</tbody>
</table>

1G — glucose, F — fructose, G/F — glucose/fructose (1:1), Th — threonine
²Standard error of the mean
Figure 1  Composition of the liver.

* G = glucose, F = fructose, GF = glucose/fructose (1:1), TH = threonine, W = water,
P = protein, Gl = glycogen, L = lipid; T = triglycerides, etc. Ph = phospholipids,
C = cholesterol.

Figure 2  Composition of the liver lipid.
Figure 3  Response of the activities of glucose-6-phosphatase (G-6-Pase) and fructose-1,6-diphosphatase (FDPase) to low protein diets, with or without supplemental threonine, and with various carbohydrates.  A units per 100 g body weight,  B units per 100 mg liver nitrogen (specific activity).  G = glucose,  F = fructose,  GF = glucose/fructose (1:1),  Th = threonine, One unit of activity = the amount of enzyme which will release 1 &gamm;i;g Pi/minute.
fructose stimulated the activities of both systems. The response to the glucose/fructose combination was generally intermediate to that to glucose and to fructose.

The omission of threonine from the glucose diet resulted in a slight decrease in the G-6-Pase activity. This depression was due entirely to a decrease in the specific activity since the nitrogen contents of the livers of the two glucose-fed groups were the same. In one extensive study of G-6-Pase activity (4), the only treatment found to decrease the activity of this enzyme system was the feeding of a protein-free diet. This suggests that the effect of an amino acid imbalance is similar to that of a protein-free diet, and not merely an indication of a decrease in the level of utilizable protein.

The reaction catalyzed by G-6-Pase represents the final step in net glucose formation. The activity of FDPase could be indicative of the participation of the Embden-Meyerhof pathway (EMP) in glucose formation.

The relative changes in activities of these two enzyme systems in response to fructose feeding could be suggestive of the proportion of glucose formation due to the EMP. This is, a 1:1 ratio of the stimulation of the G-6-Pase and FDPase activities in response to fructose feeding would be consistent with a direct conversion of fructose to glucose via the EMP. A stimulation of the activity of FDPase less than that of G-6-Pase would indicate that some amount of fructose was being converted to glucose via a route not involving fructose-1,6-phosphate. Difference in degree of stimulation also might indicate a change in the synthesis or breakdown of glycogen.

Total G-6-Pase activity increased with the substitution of either fructose or the glucose/fructose combination for glucose in the threonine supplemented diets. This was accompanied by a proportionately smaller increase in the FDPase activity (figure 4), resulting in a greater difference between the activities of the two systems as compared with the difference for the glucose control group. Omission of the threonine supplement from the diet resulted in a much greater stimulation of FDPase activity by both fructose and the glucose/fructose combination. Differences between the activities were again greater with fructose than with glucose, but were less with the glucose/fructose combination.

Presumably, the greater the differences between the activities, the more precursors must be reaching glucose-6-phosphate by a route other the reversed glycolysis (i.e., EMP). One source of the glucose-6-phosphate would be the breakdown of glycogen. However, this was probably not the case, since those groups having the greater differences between the enzymes' activities, also showed a net increase in liver glycogen. Glycogen deposition would represent a drain on the glucose-6-phosphate and would indicate an even greater utilization of a pathway other than the EMP than is suggested by the relative enzyme activities.
Figure 4. Difference in the total activities of glucose-6-phosphatase (G-6-Pase) and fructose-1,6-diphosphatase (FDPase) enzyme systems in response to low protein diets, with or without supplemental threonine, and with various carbohydrates. 

G = glucose, F = fructose, GF = glucose/fructose (1:1), Th = threonine.
The data from the study suggest that the degree of participation of the pathways bypassing fructose-diphosphate may be modified by a deficiency of threonine. The mechanism(s) by which an amino acid imbalance can influence relative activities of alternate pathways of carbohydrate metabolism is not clear.

The possibility that the major pathway of the conversion of fructose to glucose may not be the EMP has been proposed by several authors (5-7). Although most of the previous studies were with purified enzyme systems, the fact that the substitution of fructose for glucose in the diet has been shown to stimulate at least two enzyme systems of the hexose monophosphate shunt (HMS) (8,9) suggests that the shunt may play an important role in fructose metabolism.

There has been much recent discussion about the relationship of lipogenesis to the shunt as well as to other NADPH producing systems. The majority of the reports indicate that the degree of lipogenesis influences the activity of the HMS rather than visa versa. In any case, the levels of liver lipid found under the conditions of this study do not correlate with the proposed pathways of carbohydrate utilization, as suggested by the relative activities of the two enzyme systems. Other factors, such as increased fatty acid oxidation, may possibly operate to decrease the net amount of lipid in livers in which the HMS is quite active.

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DECEMBER FOOD HABITS OF THE MALLARD
(ANAS PLATYRHYNCHOS LINN.)
IN THE GRAND PRAIRIE OF ARKANSAS

Bill Forsyth
University of Arkansas

INTRODUCTION
Recognizing the need for more study of the food habits of wintering waterfowl in Arkansas, the Arkansas Game and Fish Commission and the University of Arkansas began in 1960 this cooperative project (PR-W-56-R-1) to determine the winter food habits of the mallard (Anas platyrhynchos) in the Grand Prairie Region of eastern Arkansas. The objectives of the investigation were to determine the kinds of food eaten and the food preferences by analyzing the crop contents.

Very little recent information has been published concerning the winter food habits of the mallard in Arkansas. McAtee (1918) analyzed 1,725 gizzards, of which only a small portion were taken in Arkansas. Martin and Uhler (1939) examined the contents of 382 gizzards, from several species of ducks collected in Arkansas, but only five were taken from the Grand Prairie area. The most recent intensive study of the Grand Prairie was that of Wright (1959) in which 583 mallard crops were examined.

Arkansas is a major rice-producing state. In both 1960 and 1961, a total of 384,000 acres was devoted to rice culture, most of which was in the Grand Prairie area (U.S.D.A. 1961 and 1962). About one-half of the rice acreage is rotated with soybeans, cotton, cattle and fish (Wright, 1959). The concentration of wintering waterfowl in this area is enhanced by rice culture, and the practice of flooding the rice fields for hunting purposes and for fish culture after the rice has been harvested. The major forest cover types in the Grand Prairie area are bottomland hardwoods along the rivers and terrace hardwoods or "flatwoods" next to the bottoms (Holder, 1951).

ACKNOWLEDGMENTS
I wish to express my appreciation to the Arkansas Game and Fish Commission for providing equipment and financial assistance. I wish especially to express my gratitude to Dr. Douglas James, under whose supervision this study was completed and for his careful review of this manuscript. I am indebted to Harold Alexander for his advice and assistance.

METHODS
The 300 crops collected for this investigation were obtained at the Standard Ice Company, Stuttgart, Arkansas, on December 7, 18, and 30, in 1960, and on December 2 and 3, in 1961. These were taken.
Food Habits of the Mallard

from ducks killed by hunters in the Stuttgart area and brought to the above establishment for cleaning. Each crop was wrapped in cheese cloth, placed in containers of 10 per cent formalin, and labeled.

In the laboratory each specimen first was assigned a catalog number. Then the crop contents were removed and wrapped in a piece of wet cheese cloth for immersion in water to measure the volume by displacement. Next the contents were placed in a numbered petri dish and dried by heating. When dried, the contents were separated and identified by comparing the contents with reference collections in the University of Arkansas Herbarium.

The percentage of the total bulk of each of the identified constituents was estimated visually after spreading the contents on a grid. Using the percentages of bulk the relative volume of each kind of food was calculated from the total volume.

RESULTS AND DISCUSSION

In the 300 crops analyzed, rice was the dominant food composing the largest per cent of the total volume and the largest per cent of weight (Table 1). Rice was followed by Echinochloa*, then soybeans, Paspalum, witchgrass, bull paspalum, and sorghum, in decreasing order of volumes. Rice was followed in decreasing order of weight by Echinochloa, Paspalum, witchgrass, bull paspalum and sorghum. Rice also was the most frequent in occurrence (frequency in Table 1) followed by Echinochloa, bull paspalum, Paspalum, and insects. ("Frequency" is the per cent of the crops in which a particular item was found, and "occurrence" is the number of crops in which a particular item was found.)

Rice comprised 70 per cent of the total volume, 79 per cent of the total weight, and occurred in 90 per cent of the crops. This volume of rice was considerably higher than that found by Wright (1959) in the same area, in which rice composed 47.4 per cent of the total volume. Dillon (1959) found that rice composed only 24.3 per cent of the total volume, in a rice growing region of Louisiana. However, rice was the major single food item in both of these studies.

Echinochloa was second to rice and composed 17 per cent of the total volume, 12 per cent of the total weight and occurred in 70 per cent of the gullets. Wright (1949) found the per cent total volume of Echinochloa to be somewhat less than this, totaling 11.1 per cent, and placing third in importance behind rice and acorns. Dillon (1959) reported that the combined total of Echinochloa colonum and Echinochloa crusgalli was 28.7 per cent of the volume yielding a combined volume greater than that for rice, but separately ranking third and fourth respectively.

Soybeans comprised 4 per cent of the volume, 2 per cent of the

*Jungle rice and barnyard grass are combined in the genus Echinochloa.
Table 1. Analysis of the Contents of 300 Mallard Crops

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Volume (cc.)</th>
<th>Percent Volume</th>
<th>Weight (grms.)</th>
<th>Percent Weight</th>
<th>Occurrence</th>
<th>Frequency (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Rice</td>
<td>Oryza sativa</td>
<td>6,107</td>
<td>70</td>
<td>2,631.5</td>
<td>79</td>
<td>270</td>
<td>90</td>
</tr>
<tr>
<td>Barnyard grass</td>
<td>Echinochloa crusgalli</td>
<td>1,431</td>
<td>17</td>
<td>440.9</td>
<td>12</td>
<td>210</td>
<td>70</td>
</tr>
<tr>
<td>Jungle rice</td>
<td>Echinochloa colonum</td>
<td>325</td>
<td>4</td>
<td>90.4</td>
<td>2</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Soybeans</td>
<td>Glycine soja</td>
<td>325</td>
<td>4</td>
<td>90.4</td>
<td>2</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Paspalum</td>
<td>Paspalum</td>
<td>1,370</td>
<td>1</td>
<td>40.9</td>
<td>1</td>
<td>210</td>
<td>70</td>
</tr>
<tr>
<td>Common witchgrass</td>
<td>Panicum capillare</td>
<td>178</td>
<td>2</td>
<td>61.7</td>
<td>1</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Bull paspalum</td>
<td>Paspalum boscianum</td>
<td>130</td>
<td>1</td>
<td>40.6</td>
<td>1</td>
<td>66</td>
<td>22</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Sorghum vulgare</td>
<td>73</td>
<td></td>
<td>33.2</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Acorns</td>
<td>Quercus</td>
<td>46</td>
<td></td>
<td>16.0</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Marshpepper smartweed</td>
<td>Polygonum hydropiper</td>
<td>5</td>
<td></td>
<td>2.3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Pennsylvania smartweed</td>
<td>Polygonum pennsylvanicum</td>
<td>3</td>
<td>2</td>
<td>1.4</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Swamp smartweed</td>
<td>Polygonum hydropiperoides</td>
<td>3</td>
<td>2</td>
<td>1.4</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Flatssedge</td>
<td>Cyperus</td>
<td>3</td>
<td></td>
<td>1.2</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Insects</td>
<td>Insecta</td>
<td>2</td>
<td></td>
<td>0.9</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Inorganic</td>
<td></td>
<td>2</td>
<td></td>
<td>1.5</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Unidentified</td>
<td></td>
<td>2</td>
<td></td>
<td>1.0</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Snails</td>
<td></td>
<td>1</td>
<td></td>
<td>1.1</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Smartweed</td>
<td></td>
<td>T</td>
<td></td>
<td>T</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Panicum</td>
<td></td>
<td>T</td>
<td></td>
<td>T</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Crayfish</td>
<td></td>
<td>T</td>
<td></td>
<td>T</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>8,626</td>
<td>100</td>
<td>3,428.9</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Sum of categories less than 1 per cent.
Food Habits of the Mallard

weight, and occurred in 6 per cent of the crops, and was the third most important food item in the present study. The per cent of soybeans found by Wright (1959) was 6.1 per cent and ranked fourth in importance as a food item. Dillon (1959) did not find soybeans in his investigation, and the third ranked food item was *Paspalum plicatulum*.

*Paspalum species* constituted 4 per cent of the total volume, 3 per cent of the total weight, occurred in 18 per cent of the gullets and ranked fourth in importance. This was not found to be a major item by Wright (1959), or Dillon (1959).

*Panicum capillare* composed 2 per cent of the total volume, 1 per cent of the total weight, occurred in 6 per cent of the crops and ranked fifth in importance. *P. capillare* was not a major food in the study by Wright (1959) and was not present in the results of Dillon (1959).

The large amount of rice found in the 300 crops analyzed indicates that it was the most important food available to the mallard during the month of December in the Grand Prairie Region of Arkansas. *Echinochloa*, soybeans, *Paspalum*, witchgrass, and bull paspalum were also major food items of the mallard diet, but the combined weights and volumes were approximately only one-third that of rice. The combined volumes of rice and *Echinochloa* comprised 87 per cent of the total volume and their combined weights were 91 per cent of the total weight. The weight and volume of rice was greater than the combined weights and volumes of all other identified items.

**SUMMARY**

This study was conducted in order to determine the winter food habits of the mallard in the Grand Prairie area of eastern Arkansas.

The 300 duck crops used in this investigation were collected at the Standard Ice Company in Stuttgart, Arkansas.

Rice was the principle food based on weight and volume. Rice was followed by *Echinochloa*, then soybeans, *Paspalum*, witchgrass, bull paspalum and sorghum in decreasing order of volumes. Rice was followed in decreasing order of weights by *Echinochloa*, *Paspalum*, witchgrass, bull paspalum, and sorghum.

Rice was the most frequent in occurrence, followed by *Echinochloa*, bull paspalum, *Paspalum*, and insects.

The weight and volume of rice was greater than the combined weights and volumes of all other identified items.

**LITERATURE CITED**


PALEOZOIC ANALOGUES OF RECENT CARBONATES

Tom Freeman
University of Missouri

Analogues of carbonate sediments accumulating today can be found in Paleozoic limestones of northern Arkansas. Examples are drawn from the Joachim Limestone (Ordovician), the Pitkin Limestone (Mississippian), the Plattin Limestone (Ordovician), and the Fayetteville Shale (Mississippian).

Logan, et al. (1964) proposed a classification based on the arrangement of the basic geometric units (hemispheroids and spheroids) from which common stromatolites and oncolites are built. Their type LLH-C/LLH-C, exemplified by algal mats in Western Australian salinas, occurs in the Joachim Limestone. More commonly however, Joachim stromatolites are of the SH-V/LLH-C variety, and reflect interarea scour by tidal currents. Both types attest to an intertidal environment of growth.

SS-1/LLH-C structures occur in the Pitkin Limestone. These oncolites are analogous to recent ones in south Florida (Ginsburg, 1960), and suggest water depths on the order of 0.5-8’. The particular mode, “I”, reflects infrequent movement of the oncolites in moderately agitated water.

Shinn and Ginsburg (1964) described the environment of Recent dolomite formation in the Bahamas and Florida Keys. The sites of formation are inches above mean high tide level and are characterized by (1) laminated sediment, (2) mud cracks, (3) stromatolites, and (4) burrows. “Partly dolomitized gastropod shells and pellets show that the dolomite is a penecontemporaneous replacement of calcium carbonate” (Shinn and Ginsburg, 1964). The Plattin Limestone of northern Arkansas is replete with (1) laminated rock, and (2) mud cracks, and locally displays (3) stromatolites and (4) burrows. Dolomite in the Plattin has been discovered through X-ray, petrographic, and staining techniques. Though not volumetrically important, except within local beds, this dolomite is believed to reflect conditions analogous to those described from the Recent by Shinn and Ginsburg (1964).

Illing (1954) described a variety of sand-size grains from the Bahamas which have acquired the all-inclusive term “Bahamite”. Several of these grain types occur in limestone in the upper part of the Fayetteville Shale near Oxley, Arkansas. These include (1) ooids, (2) pellets, (3) grapestones, and (4) encrusted lumps. All these suggest waters supersaturated with respect to CaCO₃, and the lime “mud” of the upper Fayetteville is probably a direct precipitate from sea water. In addition to the “Bahamite”, crinoids and a variety of foraminifers occur in this limestone, and they serve as nuclei for the ooids. The foraminifers include Endothyra sp., Apterinella sp., Gloivialvulina sp., Calcitornellia sp., and Paleotextularia sp.
REFERENCES


SHALE-LIMESTONE ALTERNATION IN THE
UPPER PORTION OF THE FAYETTEVILLE
FORMATION NEAR MARSHALL, ARKANSAS

W. Bruce Saunders
University of Arkansas

INTRODUCTION

The Fayetteville Formation is extensively exposed near Marshall, Arkansas, where it includes two distinct portions; a lower black shale unit, and an upper unit of alternating shale and limestone. A study of the upper portion of the outcrop was made in the Fall of 1964, which involved field work and laboratory investigations. Field work included measuring, collecting, and describing the rocks of the exposure. Laboratory investigation involved more detailed examination of the rock units by means of the binocular microscope, and, in the case of selected rock samples, the use of the petrographic microscope. The detailed examination of the Marshall exposure was undertaken for the purpose of providing information concerning the environment of deposition of the upper portion of the Fayetteville Formation.

STRATIGRAPHY

The Fayetteville Formation, of late Mississippian age, was named and described for exposures near Fayetteville by Simonds (1891, p. 42-48). In this area, the formation contains three mappable units:

1. a lower black shale,
2. a middle tan, quartz sandstone known as the Wedington Sandstone Member,
3. an upper black shale unit.

In the Marshall area, the Fayetteville Formation is made up of two distinct portions; a lower portion, composed of concretionary, calcareous, black shale, and an upper portion, composed of alternating beds of concretionary, calcareous, dark-grey shale and limestone.

Sections of the Fayetteville Formation similar in appearance to the Marshall outcrop also occur at Alco, Stone County, 15 miles east of Marshall; at Mountain View, Stone County, 28 miles east of Marshall; and at Bragg’s Mountain, Muskogee County, Oklahoma, 120 miles west of Marshall. Similar sections are also known to occur elsewhere

1Department of Geology.

2Professor R. H. Konig, University of Arkansas, assisted greatly in laboratory investigations and in the editing of this manuscript. Professor James H. Quinn, University of Arkansas, also provided helpful suggestions for the final preparation of this paper.
in northeastern Arkansas. This report is restricted to the examination of the exposure at Marshall, however, the similarity of alternation in the other exposures indicates similar environments of deposition.

The exposure examined extends more or less continuously for 1400 feet along the northeast side of State Highway 65. Bedding in the outcrop dips one-half to two degrees to the northwest. Due to dip, and to the orientation of the roadcut, a total thickness of 115 feet of upper Fayetteville strata is exposed.

**LITHOLOGY**

The most striking feature of the Marshall exposure is the uniform alternation of shale and limestone layers. (Plate 1).

Shale is similar in appearance from the bottom to the top of the exposure, but differs markedly in carbonate content (21% carbonate by weight in the lower-most shale unit increasing gradually to 46% in the upper shale units). The shale is silty throughout the section. Shale composes 69 per cent of the measured portion of the outcrop, and is more abundant in the lower half of the section than in the upper half.

Four additional kinds of rock occur in the measured section. These include lithographic limestone; sparsely fossiliferous, fine-grained limestone; oolitic, phosphatic, bioclastic calcarenite; and pellet phosphorite.

Lithographic limestone is present in the exposure as a continuous unit approximately 13.5 feet thick. On a fresh surface, the rock is dark brown, somewhat waxy in appearance, and displays sub-conoidal fracture. Microscopic examination discloses unoriented, irregularly shaped calcite grains making up the majority of the rock. Most of the calcite grains are less than .0089mm in diameter, although some larger grains (averaging 0.045mm in diameter) are also present. Impurities, including iron oxide, pyrite, and quartz occur as accessory constituents. The quartz grains are strongly angular in outline.

Dense, sparsely fossiliferous, fine-grained limestone is the most abundant of the carbonate rocks, and it represents approximately 18 percent of the measured section. This type of rock makes up all of the more uniformly alternating limestone units. These limestones are essentially identical from the top to the bottom of the exposure. They differ only in that some beds contain more pyrite, fossils, or color banding than others. The color banding consists of occasional dark brown bands in otherwise dark grey rock, and is probably caused by concentrations of iron oxide, and/or organic material. Fossils, mostly brachiopods and pelecypods, contained in the rock provide little evidence of having been abraded or fragmented. The fossils are filled with rock material essentially identical to the enclosing matrix. Many of the shells have been partially replaced by pyrite. Most of the fossils are oriented with their long axes parallel to bedding planes.

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Limestone lentils and lenticular calcareous concretions, which appear to be completely enclosed within the shale, are composed of fine grained limestone. Some of the calcareous concretions are fossiliferous. The uncrushed living chamber of an orthoconic nautiloid, Rayonnoceras, approximately five inches in diameter was found oriented horizontally in a calcareous concretion. The preservation of the Rayonnoceras indicates that the concretions formed soon after deposition, and before compaction, of the enclosing sediment.

Oolitic, bioclastic, phosphatic limestone is scarce in the section; an aggregate thickness of only a few feet of this type of rock was observed. The thickest phosphatic limestone unit is only six inches thick, whereas most units are less than four inches thick. On a weathered surface, most of these units display well developed fissility.

The lower portion of several of the phosphatic limestone beds contains rounded pebbles averaging 10mm in diameter. These pebbles were apparently derived from an indurated, fossiliferous, silty limestone.

Many of the fossils in the phosphatic limestone units have been broken into fragments, but complete shells of gastropods and pelecypods are abundant. The shells are filled with a reddish-brown, fine-grained, fossiliferous sediment similar in texture and color to the rounded pebbles contained in the lower portions of these units. In some places, fragments of shells retain fine-grained sediment on the concave surface, apparently indicating transportation of the fossils after their initial deposition. Thus, fossils filled with a sparsely fossiliferous, non-oolitic sediment are enclosed in oolitic, highly fossiliferous limestone which is different in texture and color.

One orthoconic nautiloid 25mm long was observed, oriented with its long axis and apical end pointing downward, perpendicular to bedding. The long axis of some ooliths and fossil fragments are arranged around the shell so as to indicate "drag" apparently caused by downward penetration of the shell into what was evidently an unconsolidated lime mud or ooze (Fig. 1).

Minerals identified in the phosphatic limestone, besides calcite, include quartz, pyrite, hematite, and phosphatic material (callophane). The phosphatic material is contained in ooliths, in fossil fragments, and as disseminated grains scattered throughout the rock. Phosphate averages approximately 20 percent of these rocks by volume. Individually, ooliths average approximately 2mm in diameter, and vary in shape from spherical to ellipsoidal. Many ooliths are concentrically banded about distinct nuclei of undetermined composition.

The only other type of rock identified is a unit two feet thick which may be called a pellet phosphorite. It is extremely fissile, black, and not calcareous. In thin section, angular fragments of detrital material, including scattered quartz grains and fossil fragments are...
Shale-Limestone Alternation

Identifiable. Ooliths compose approximately 10 percent of the rock. Approximately 50 percent of the rock consists of rounded pellet-like masses. These pellets may be of organic origin; they are of various shapes and sizes, and display indistinct boundaries. The ooliths and pellets are richly phosphatic.

SUMMARY

Initial examination of the Fayetteville age rocks at Marshall indicated that the limestone-shale units in the upper portion of the Fayetteville Formation are the product of cyclic changes in the depositional environment. Closer examination, however, indicates the complexity of the alternation involved. This is demonstrated by the presence in the exposure of lithographic limestone; fine-grained limestone; oolitic, phosphatic, bioclastic, limestone; and pellet phosphorite (Figure 1).

A marine environment suitable for the formation of oolitic and pellet phosphorites is considered to be one of shallow water with gentle agitation. The source of the phosphate is not entirely clear. It may be of organic origin, since it is definitely associated with fossil shells and pellets, or some of the phosphate may have been derived by precipitation from sea water. The precipitated phosphate could then replace shells, ooliths, and pellets.

The presence of lithographic limestone is also considered to indicate a shallow, protected, marine environment at the time of deposition (Careozzi, 1960 p. 211). The lithographic limestone at Marshall is very uniform in texture, color, and composition, and is probably the result of chemical precipitation. The remarkably low content of clastic material, such as quartz, in the lithographic limestone as well as in some of the other types of rock indicates an area of deposition not subject to contamination with such material. This would generally require isolation from products of continental erosion, including wind blown silts and stream transported sands and silts.

In retrospect, both the phosphorite and the lithographic limestone probably required a sheltered, shallow, depositional environment for their formation. The environmental situation which could have provided such a setting cannot be definitely inferred from the examination of one rock exposure. However, Quinn (1959, p. 33) states that the upper portion of the Fayetteville Formation becomes greatly thickened and calcareous along a line extending from Fort Douglas to Batesville, Arkansas, and suggests that the thickened part represents a large east-west trending reef which was as much as 200 feet high at the end of Fayetteville time. Such a reef could have produced shallow, sheltered, lagoonal environments within the reef proper, or landward to it. The lithologic nature of the rocks in the exposure at Marshall appear to conform to such a theory.
Figure 1. Schematic diagram of the upper portion of the Fayetteville Formation near Marshall, Arkansas, showing relative position of different lithologic units: A — fine-grained limestone; B — lithographic limestone; C — pellet phosphorite; D — oolitic, phosphatic, bioclastic limestone; E — calcareous grey-black shale, concretionary in places.
Shale-Limestone Alternation

BIBLIOGRAPHY


A STRUCTURAL AND PETROLOGICAL NOTE
ON THE MAZARN SYNCLINORIUM

Larry J. Lee
University of Missouri

Abstract

During the fall of 1964, 3500 readings were taken on planar surfaces (S-surfaces) over a 288 square mile portion of the Mazarn Synclinorium. Fold solutions were plotted in the field by locating two points lying in the axial plane of the fold, one generally being the fold axis and the other the rake of the trace of the axial plane on the face of the outcrop. Pole points of planar elements from the northwest, southeast and northeast areas of the Mazarn Synclinoria were plotted on a Schmidt "equal area" net and contoured. The data when contoured shows the fold geometry of the basin. From this geometry a maximum depth of about 15,300 feet was calculated and a dynamic system of uplift and gravity slide proposed.

Deformation undergone by the Mississippian Stanley Shale and the Ordovician Big Fork Chert were compared and classified by fold style. It was found that the Stanley Shale was folded by flexural flow and flexural slip mechanisms, with the interlayered sandstones exerting the strongest influence on the geometry of the folding, while the Big Fork Chert folded quasi-flexurally. The difference in deformation between the two formations probably being due to a higher mean ductility in the Big Fork as compared to the mean ductility of the Stanley Shale.

Samples of the sandstones were taken randomly throughout the basin. Thin section studies show the sandstones, classified on the basis of mineral composition, to be quartzites and arkoses.

Readings taken in the Mazarn Synclinorium as well as a traverse south on State Highway 7 to the Hot Springs, Clark County border suggests that deformation of the basin decreases in the western portion of, as well as south of, the synclinorium.

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REPORT ON SOME IRON AND NICKEL MINERALS
FROM THE SOAPSTONE DEPOSITS OF
SALINE COUNTY, ARKANSAS

Phillip Wicklein and Alden B. Carpenter
University of Missouri

Pentlandite, the $\alpha_2$ form of native iron, monoclinic pyrrhotite and pyrite have been identified by X-ray methods from the Inman, Anderson and Duke-Warner soapstone pits, Saline County, Arkansas. The phase equilibria data for the system Fe-Ni-S indicates that these minerals probably formed at moderately low temperatures, perhaps 200-250° C.

Nickelian hexahydrite of the approximate composition (Mg$_6$Ni$_4$) $\text{SO}_4 \cdot 6\text{H}_2\text{O}$ has been identified by optical and X-ray methods as a secondary mineral in the soapstone pits.
MONADNOCKS, DIVIDES AND OZARK PHYSIOGRAPHY

James Harrison Quinn
University of Arkansas

The physiography of the Ozark country has been described in terms of rejuvenated peneplains since the 1890s. According to Bretz (1965) the concept has only recently been challenged by Quinn (1956) and by Hack (1960). Quinn has argued for pedimentation, and Hack has denied the validity of the Davis scheme of sequential stages in cycles of erosion leading to peneplanation, substituting in its place "dynamic equilibrium". Bretz strongly reaffirmed his faith in the idea that the surfaces of the Ozarks are peneplains. He seemed to rely on depth of weathering under humid conditions which furnished clay to fill caves in support of his ideas of peneplanation. He denied it was ever arid enough in the Ozarks to produce pedimentation (and questioned the necessity of concomitant aridity). His statements concerning escarpments and pediments seem obscure and provide some doubt that origin of erosional escarpments and the mechanics of pedimentation are clearly understood. Pedimentation is simply erosion of backwasting of escarpments. Surfaces thus produced are called pediments. Union of a number of pediments produces an extended surface of planation usually termed a pediplain. Depending on environmental conditions the waste may be deposited locally, as in the Basin and Range Province in southwestern United States, or removed by reduced or periodic stream flow. The chief distinction of a pediplain is that the base level of erosion is that of the producing escarpments. The escarpments are ordinarily initiated as valley walls. It may thus be stated the base level of pedimentation is stream level, which in turn may be at any distance above sea level, depending solely on relief. Conversely, a peneplain is a surface of erosion, reduced by downwearing to or nearly to sea level. In other words, a peneplain is a low-relief surface of erosion with sea level as its datum. As a matter of practicality, proponents of the peneplain idea consider a peneplain as a surface of erosion sloping gently toward the sea, carved to the lowest gradient at which water will flow.

The peneplain concept acquires its compelling and very authoritative stature at the point where the idea of rejuvenation is employed. Elevation of a peneplained surface or lowering of sea level is said to permit commensurate dissection. The concept of the graded stream is invoked to provide an explanation of the chain of events set in motion by "uplift". Entrenchment, alluviation, valley widening, terraces or lack of terraces, and alluvial products are explained in terms of uplift, stillstand, and loss of elevation by downward erosion. This is the point of paramount importance in geomorphology and stratigraphy since it is the fundamental basis for the idea of "tectonic" control of land forms, erosion and sedimentation.

One path of investigation concerning the question of the origin of the Ozark surfaces is consideration of the validity of the graded
stream concept and its applicability to the processes connected with "rejuvenation". The second path of investigation involves consideration of the land forms developed by peneplanation in contrast to those formed by pedimentation. A third area involves the question of cave and soil development and destruction.

The graded stream concept employs the idea of energy balance among three factors: load, slope, and volume-velocity. A change in the value of one of the three factors requires compensatory adjustment of one or both the others so that unity of energy disposition is attained. If slope is steepened, velocity increases, capacity to transport load increases, erosion ensues. Thus load is increased and slope is lowered to the point where a new balance is reached. Leopold and Maddox (1953) demonstrated that no such relationship exists. They did not reject the idea of the graded stream but substituted adjustments in channel shape to account for balance in place of energy spent on load.

Even if the graded stream concept were valid, elevation or lowering of the land (or sea level) would not necessarily be directly and accurately reflected in commensurate entrenchment or alluviation of a stream bed. This reaction could theoretically be produced by reduction or elimination of load or increase in the volume and velocity of the stream. In order for a stream profile to be directly keyed to "changes in base level" the corollary factors of available load and water supply would be required to remain constant. Streams would need to be supplied with a full load of all kinds of sediment at all times and the climatic conditions responsible for water supply would need to remain unchanged and unchanging. Both of these requirements are non-existent in nature. Extreme fluctuations of climate, especially during Pleistocene time are well documented (Quinn 1956, 1957, 1958a, b, 1961). Availability of sediment depends principally on the nature of the terrain adjacent to streams and the quantity and nature of plant cover on that terrain (Gilluly, Waters and Woodford, 1959, p. 71-3, fig. 5-8; Longwell and Flint, 1962, p. 179, fig. 10-1). Planation in response to diastrophic uplift, pause or stillstand has no basis in fact. Beyond the graded stream idea (Davis 1899) no one has explained a possible mechanism of process. The idea is accepted without explanation or proof. Again, assuming for the moment load and volume are constant, it is still a simple matter to advance additional considerations concerning origin of the Ozark surfaces. Provided it is assumed peneplains exist, and provided it is agreed the definitions proposed by the author of the idea be permitted to stand, it is still possible to distinguish the characteristics of peneplains and pediments or pediplains and apply these criteria to the Ozark, Boston Mountain and Ouachita surfaces. It must be reasonable to suppose that the conditions producing the physiography of the Ozarks may also have produced the similar and for the most part identical surfaces in the more southerly portions of the province.

Bretz (1965, p. 13-14) has called the northern escarpment of the Boston Mountains a "retreating" cuesta. Likewise a second, lower
Escarpt to the north, the Eureka Springs (—Burlington) escarpment is "stratigraphically the edge of the retreating Mississippian formations". The surfaces and escarpments involved, from top to bottom are: Boston Mountain plateau; Boston Mountain escarpment; Springfield plateau; Eureka Springs escarpment; and Salem plateau (—Ozark peneplain of Bretz 1965). Bretz repeatedly called attention to monadnocks throughout the Ozark area which he said represent an older and higher level than that on which they stand. He also pointed out that the monadnocks invariably are located on the stream divides or near them where the divides themselves have "retreated" slightly from their former position.

A monadnock by definition is composed of rock more resistant to erosion than is the surrounding material. Thus monadnocks are left as erosion residuals by downwearing of the surrounding terrain. It would be expected such residuals should be randomly distributed wherever the factors causing their special "erosion resistance" produced them. On the basis of this definition the erosion remnants of the Ozarks are not monadnocks but buttes which have survived incomplete escarpment retreat, where escarpments have been generated as the walls of entrenched stream channels (Fig. 1).

Major features such as the Boston Mountain and Eureka Springs scarps are not initiated as valley wall escarpments but are a product of the union by pedimentation of a series of drainage basins oriented normal to trunk streams or strand lines (Fig. 2).

Given a vegetated, sloping, reasonably level surface with a base datum, such as the strand line or a major trunk stream, a series of drainage nets tend to form normal to the base line each developing a drainage area in an integrated pattern. Rate of entrenchment depends on quantity of water available, rate and uniformity of flow and nature of the substrate. Where sediment is too fine to form bed-load, gulleying is uncontrolled. Where sand is released in the erosion of the channels it tends to blanket the stream bed (Quinn 1959) at a given but fixed distance downstream from head waters. The blanket serves to inhibit or prevent bed erosion. This relationship contributes to long profiles steep at the head which otherwise slope uniformly through the rest of their length. This relationship likewise provides for much faster headward erosion than downward channel entrenchment.

Deterioration of precipitation rates causes reduction of plant cover and leads to wasting of channel sides producing retreating escarpments. Where aridity is moderate, periodic flow of streams removes waste but does not permit entrenchment and valley sides erode to the point where they meet opposed wasting slopes thus producing a gently undulating surface of erosion graded to stream base. Unless alluviation has been extensive all surfaces slope toward major drainage lines. A series of pediment basins thus produced may continue to waste. First, every tributary provides two slopes to be eroded. These meet others and are destroyed. Second, the divides between drainage basins waste away.

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producing a single arcuate primary escarpment parallel with and facing the base line or strand (Fig. 3). Third, the primary escarpment will continue to waste as long as the upland above the escarpment remains or until it is similarly destroyed. Change from arid to humid conditions may arrest the process at any point, providing renewed entrenchment. The escarpments also furnish nick points which contribute to acceleration of dissection rate. It is this relationship which may account in part for the fairly universal expression of multiple erosion surfaces where the highest is most deeply entrenched and most extended. Choking the lower levels with sand or bed load from the upper levels likewise contributes to the progressive differences in magnitude of the plateaus and escarpments.

Some characteristics of soil profiles, caves, and the relative condition of surfaces merit attention. In northern Arkansas the soil profiles of the Boston Mountain, Springfield and Salem plateaus are about equally expressed in terms of maturity. For the most part the surfaces have been stripped to bedrock and retain only a thin covering of alluvium or colluvium as the case may be. The plateau surfaces developed on limestones contain some caverns. The 'soil' on the Mississippian, Boone Formation contains considerable red clay which is insoluble residue from surface solution of limestone of that formation. It is this red clay that has accumulated in some caverns which lacked drainage. The clay disperses through water standing in passages or chambers and gradually settles to the floor. Periodic replenishment of the clay washed in by meteoric water produces some crude stratification of the accumulating sediment.

It would seem that on an old peneplaned surface a mature soil profile would have been developed which should include an 'A' horizon of gray silt or sand-loam of considerable depth. Any clay should have been washed deep into 'B' and 'C' horizons and not be available for filling in caves.

Finally, the caverns of northern Arkansas are singularly devoid of vertebrate animal remains belonging to extinct faunas. (The single known site is Conard Fissure [Brown 1908].) This circumstance leads to the conjecture that the caves of northern Arkansas very recently have been made available for occupancy, and those formerly available have been almost totally destroyed. Availability may be attributed to recent opening or, of course, recent drainage. Destruction of older caverns requires stripping deep enough and extended enough to have obliterated them.

The escarpments, divides and buttes of northern Arkansas have been produced in arid times by pedimentation of extensive surfaces dissected by stream entrenchment during humid times. No conceivable processes of peneplanation and 'rejuvenation' can account for these land forms. The chief difference between the events necessary to peneplanation and pedimentation is that the peneplain concept requires bevelling to sea level, and uplift in three diminishing episodes, whereas...
that of pedimentation requires sufficient initial relief to accommodate the dissection, coupled with a series of arid-humid climatic fluctuations otherwise known to have occurred in connection with Pleistocene climatic changes.

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Fig. 1. Dendritic drainage net

A. Tertiary divides between second or third order streams
B. Secondary divide between second or first order streams
C. First order truck stream or strand line
   Arrows point direction of back-wasting of valley walls
Fig. 2. Two drainage "basins" which have been entrenched and the divides mostly destroyed by pedimentation.

A. Butte or erosion remnant on tertiary divide
B. Butte or erosion remnant on secondary divide
C. Spur or erosion remnant still attached to upland
D. Trunk stream or strand line as in Fig. 1

Note: The Boston Mountain escarpment, in Washington County, Arkansas demonstrates approximately this stage of pedimentation.
Fig. 3. Arcuate escarpment parallel with trunk or strand line, produced by merging of pediments of basins 1 and 2. Arrows point direction of back wasting.

A. Butte or erosion remnant standing on secondary divide

B. Primary escarpment. Continuation of the arid regimen would promote continued back-wearing of the primary escarpment, producing straightening of its salients. Scarp would 'retreat' to the point where it meets an opposing escarpment from beyond primary divide.
BASE-LEVEL CONTROL OF EROSION SURFACES

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Several recent papers dealing with mountain regions (Dresch, 1958; Garner, 1959; Cotton, 1960; Garner, 1963; and Mackin, 1959) raise the issue of base level control of elevated erosion surfaces. In a personal communication to Cotton (1960, p. 477) at that writer's request, L. C. King states, "Re base level, I have never abandoned this concept, which places a limit upon downward erosion either by running water or by mass movement, and if it does not appear stated in my own work that is just because I have accepted the concept and have not seen any reason to discuss it further, understanding that there are two kinds, local and general."

It is certainly true that the control of erosion surfaces by base level has gone unquestioned in the literature for many decades. But elevated erosion surfaces have been noted and cited by literally scores of authors as evidence of the grading of a land surface to some regional strand and the subsequent elevation of said surface. If alternative interpretations are possible they should certainly be noted, for they bear on major geomorphic concepts and have influenced tectonic evaluations of the nature of orogenesis and epirogenesis. The problem has two major aspects, (1) the nature of any control mechanism and (2) the character of alternative reference datums, if any.

The control of one phenomenon by another necessitates some form of interaction. If one may regard the marine strand as approximating the location of regional base level at any one time, then the interaction in question is necessarily between the surface of erosion and the strand. The latter is usually and unrealistically regarded as fixed. For the moment, I will regard this as a provisionally tolerable fiction, for it is not the various theories of erosion surface genesis but rather the mode of datum control that is in question here.

As noted by King (in Cotton, 1960) base level places rather specific downward limits on fluvial erosion. Gravity, of course, shows no similarly abrupt response to this limit and submarine mass movements are well documented by Shepard (1963) and many others. Nevertheless, excepting marine oscillation, there is little direct interaction between terrestrial surfaces of erosion and marine water bodies. And submarine mass movements can hardly be considered as affecting more than the margins of the erosion surfaces in question. Therefore, because essentially all surfaces of erosion display evidence of the influence of running water and it is the consensus that fluvial agents are of primary importance in their formation, running water is here acknowledged as the principal agent of interaction through which base level may exert influences on subaerial erosion surfaces.

Establishing that there is some fluvial interaction between base level and land surfaces is no new thing and does not, in itself, estab-
lish that the interaction is effective geologically, i.e. that base level can actually be claimed to have controlled the gradation of an erosion surface during its development. Two dimensions of activity are involved, space and time. And at the outset, it is freely admitted that given an infinite amount of time a given agent can act effectively across any space to which it has access. To those who subscribe to base level control without reservations, it is apparently not so obvious that fluvial agents do not have equal access to all land surfaces under all environments. Some are spatially limited.

The fact that gravity alone could, in theory, cause all land surfaces to slope toward ultimate low points on the earth’s surface is beside the point. Base level would not be involved. And the fact that an infinite amount of time is not available (geologically) for the development of any regional erosion surface has long been recognized. But the fact that regionally extensive erosion surfaces do exist proves that sufficient time was periodically available for their development, whether they are base-level controlled or not. It is not the specific purpose of this paper to determine the probability of occurrence of one or another of the various types of erosion surfaces. Rather, the writer will try to demonstrate that spatial restrictions on fluvial action necessarily vary the degree to which a given type of erosion surface can respond to regional base level in the limited available time for surfaces so influenced. Temporal restrictions are therefore also important and together with spatial restrictions are potentially capable of reducing regional base level influences over certain types of erosion surfaces to insignificance.

Three distinct degrees of spatial and temporal limitation are imposed on fluvial activity by the three principal theories of regional erosion surface genesis.

According to the Peneplaination Theory of Davis (1902) a peneplain is the product of perennial rivers flowing to regional base level. Fluvial interaction between the developing surface and base level is constant, equal in temporal duration to the humid environment responsible for the flow, and spatially competent across tremendous distances. Free admission of the probable interruption of the formative processes by epiorogenic adjustments, orogenic movements, glacio-eustatic shifts or climate changes does not change one relationship. A peneplain, if developed, would involve maximum fluvial interaction with base level and, therefore, maximum base level control to the extent that said control exists.

The Pediplanation Theory of King (1953) advances the idea that most extensive erosion surfaces are pediplains, products of semiaridity, and therefore reflect intermittent fluvial erosion. In at least some instances — possibly the majority — flow reaches base level every wet season. Fluvial interaction is, however, discontinuous and in many regions runoff endures for as little as a third to a half of each year as long as the environment persists. In comparison with humid conditions, semiarid fluviation shows a distinctly reduced temporal inter-
action between any resulting erosion surface and regional base level. Clearly, spatial continuity also suffers as annual runoff dwindles. But it must be noted that, given sufficient time, a semi-arid erosion surface should respond to any existing regional base level controls.

The Planation-Aggradation Theory of Quinn (1957) proposes that many extensive erosion surfaces are a response to arid erosion processes imposed in desert environments. In such instances, fluvial activity is ephemeral. In “wetter” deserts (those with 5-10 inches of annual rainfall) an entire year’s precipitation may fall in a few minutes and flow continues for only a few hours because of intense evaporation and infiltration. In “dry” deserts (those with less than 5 inches of annual rainfall) such as the Sahara, Atacama and Nubian, rain may fall only every few years or every few decades and then not everywhere. Fluvial activity is therefore reduced below that of humidity and semi-aridity by a factor of several hundred to several thousand.

Arid runoff is limited to the area occupied by the arid environment for the most part. Indeed, it is usually restricted to a small part of the environmental area at any one time. And a specific geographic point may endure droughts of hundreds of years (Garner, 1959, p. 1356). Even where the environmental margins extend to base level, runoff rarely attains this potential goal (Gignoux, 1955, p. 3). In such instances fluvial interaction with regional base level is minor. In combination with mass movement over a very long period, coastal desert erosion surfaces might develop slopes toward regional base level. They could incline toward inland deflation depressions with equal ease. But where the arid region is inland (as many are) ephemeral fluvial interaction with base level is, to all intents and purposes, nonexistent. Where there is no interaction there can be little control.

Lest it be suggested that the writer has argued himself into a corner, it is necessary to answer the obvious question, “What replaces regional base level as a leveling datum for widespread arid erosion surfaces?” The answer would seem to be climatic zonation. The present moisture zonation is both geographic and topographic in nature and closely reflects a corresponding atmospherically stratified moisture zonation keyed to latitude. Along most of the world’s coasts poleward from a few degrees either side of the equator there are two 30-40-degree-wide belts characterized by low-level coastal dryness. These belts reflect the adiabatic gap between sea level evaporation and minimum precipitation elevation and their vertical effectiveness ranges from a few inches to several thousand feet. The height of the corresponding water-deficient atmospheric zone and the intensity of related land dryness is a function of several factors including ocean surface temperature and prevailing wind (Garner, 1959, p. 1353). Because they fringe the strand and have great potential temporal duration, resulting arid erosion surfaces are at least potentially capable of undercutting and displacing all erosion surfaces developed at higher levels. They are frequently confused for elevated wave-cut marine terraces (Fig. 1).
Text Figure 1. Continental atmospheric moisture zonation and climate belts; (A) Sea level — evaporation surface, (B) Adiabatic gap — undersaturated air, (C) Minimum precipitation elevation, (D) near-saturated air—triggered precipitation, (E) Moisture depleted air, (F) Frost zone, (G) Coastal Deserts, (H) Semi-arid steppes, (I) Humid uplands, (J) Semi-arid transition, (K) Desert plateaus, (L) Frigid peaks, (Elevations are in feet.) In this instance the sea to the left is assumed to be cold, that to the right warm.
A second geographically correlative atmospheric zone overlies
the low-level dry zone and is characterized by adiabatically or pres-
sure-front triggered precipitation in appreciable amounts. Precipita-
tion climbs to a maximum within this second zone and where it reaches
the humid climatic level it is bordered above and below by semiarid
transition zones in many cases. To the extent that they actually occur,
humid peneplaination and semiarid pedimentation are dependent on
the environments represented in this zone. Any resulting erosion sur-
faces could only widen at the expense of landscapes developed inland
at higher levels and would, in turn, be subject to sapping from below
by arid planation processes keyed to coastal deserts. Such intermediate-
elevation moist zones are very broad on continental flanks facing warm
seas. On opposing continental flanks the moist atmospheric zone is
thin or absent and correlative land climates are narrow or lacking
(Fig. 1).

A third geographically correlative atmospheric zone reflects water-
depleted air which has risen through the zone of adiabatic and pres-
sure-front triggered precipitation. Elevated, inland arid regions are
the result. The Tibetan and Andean plateaus coincide with this elev-
ated dry zone and in the latter area the vertical span is some 3,000-
4,000 feet. Within this zone arid erosion surfaces are environmentally
delimited with respect to topography and land elevation. Developing
erosion surfaces necessarily grade to local base levels which become
progressively more obscure with time. The resulting topographic product
of arid planation-aggradation processes naturally exhibits some relief
as a reflection of the composite local base-level controls—detailed
studies of most erosion surfaces show similar relief features (Fig. 1).

At least the arid planation processes are closely tied to an atmos-
pheric zone a few thousand feet "thick" and not to a single horizon
(e.g. base level). Though the water-deficient atmosphere zones, like
the others and base level, are subject to some vertical fluctuation,
long-term planation can be effected within the interval of zonal over-
lap determined by mean zonal fluctuation (Fig. 2). The planation pro-
cess can thereby continue within a permanently arid interval so long
as the atmospheric zone is not displaced either upward or downward
more than fifty per cent. The arid erosion surface itself could prob-
ably survive periodic zonal displacements in excess of fifty per cent so
long as the average protracted environment at the elevation of the
erosion surface was arid. In this manner, though the controlling zone
fluctuates, the leveling datum for the elevated arid erosion surface
remains fixed at the base of the interval which remains dominantly
arid. The temporal weakness of ephemeral arid fluviation is there-
fore probably compensated by long-term stability of the erosional
datum. Widespread planation at one general elevated level is there-
fore more than possible.

It should be noted that regardless of what each of the three
major environments accomplishes in terms of long-term erosion, each
is sufficiently distinct to cause a contrasting terrain configuration.
Text Figure 2. High-level arid atmospheric zonation and gradation datum; (A) Mean position of moisture depleted air zone, (B) Maximum zonal depression, (C) Maximum zonal elevation, (D) Vertical scope of long-term zonal oscillation, (E) Residual, permanently or dominantly arid zone of protracted planation, (F) Regional slope change keyed to long-term climate zone boundary position.
Therefore, a transition from an area dominated by one type to that dominated by another should be characterized by at least a change in regional slope. The most pronounced slope changes of this type should occur between zones of greatest environmental contrast where there is the least fluvial interaction. The slope breaks at the heads of mountain piedmonts and those at the margins of elevated mountain plateaus are probably of this type and the higher type can hardly be said to grade to regional base level under such circumstances (Fig. 2).

The issue of the relative merits of the various erosion theories is not yet resolved. Each has its backers. But the spectre of intermittent climate change threatens each and the oscillating-base-level and graded-stream hobgoblins linger in the background ready to haunt any who wish to invoke them. Nevertheless, one relation is evident from the preceding discussion. Base level control, to the extent to which it occurs and for those erosion surfaces to which it applies, is a mixed blessing. Surfaces subject to it can readily have their reference datums changed, particularly in orogenic belts. Surfaces keyed to zonal atmospheric conditions may be more stable than previously believed and it is possible that the true erosional datums for intermediate and low-level planation processes are also zonally established rather than tied to an admittedly fluctuating base level horizon.

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THE EVOLUTION OF THE MISSOURI SYSTEM

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Should the chief and associate justices of State Supreme Courts be appointed by governors or elected by voters; should they serve for life terms or for limited terms; and, if for limited terms, should these terms be long or short? These queries long have been vital issues in the "great debates" of American political science. In seeking to obtain judicial objectivity, impartiality, and responsibility, the several states have responded with several plans at different times. The agreed-upon plan at a particular time in an individual state has reflected the contemporary political environment, governmental philosophy, or pressing public problems. Missouri's Non-Partisan Court Plan, a pioneer in state government, is highly regarded by virtually all students of the administration of justice; therefore, it would be beneficial and interesting for us to contemplate the progressive course of the method of selection and the matter of tenure of judges in that state.

In the colonial period, judges of the colony Supreme Courts were appointed by the Royal Governor, and the Governor, sitting with his council, acted as the highest court of the colony. Following the American Revolution, state governments began their existence with appointive judges. Thus, when Missouri obtained statehood on August 10, 1821, her constitution, written in 1820, provided that:

... the Governor shall nominate, and by and with the advice of the Senate, appoint the judges of the Supreme Court . . . each of whom shall hold office during good behavior.¹

Andrew Jackson, as the chief apostle of the movement in the United States which rejected political aristocracy and exalted the "common man" and as the victor in the 1828 presidential election, ushered in a dramatic era of democratic changes on the national, state, and local levels of government. "Jacksonian democracy" sought — and largely achieved — universal manhood suffrage, popular election of officials, short terms and rotation in office, and the "spoils system." The state of Mississippi, with the general election of 1832, became the first state to reflect these trends by adopting the popular election of judges for short terms of office.

Missouri's second constitutional convention was called by the voters in 1844, with almost 35,000 in favor of having the convention and 14,000 in opposition. While this convention was drafting a new constitution during the following year, several resolutions calling for elective judges were tabled.² Finally, Article V of the proposed con-

¹Constitution of Missouri, 1820, Article V, Section 13.
stitution provided that the State Supreme Court was to consist of three judges appointed by the Governor with the consent of the Senate for twelve-year terms. Thomas Hart Benton, sixty-three-year-old senior United States Senator from Missouri, was a "Jackson man" with a long record for more democracy in government; thus, in harmony with his record, he could have been expected to take the lead in advocating an elective judiciary with a limited tenure. Mr. Benton, however, was more concerned — at that time — that the convention maintain constitutional restrictions on banking. Incidentally, while Missouri's constitutional convention was meeting in 1845, New York adopted the method of popular election of State Supreme Court judges for limited terms. Nevertheless, the product of the convention was rejected by the voters of Missouri in the subsequent general election of 1846 by a majority of 10,000 votes. In this defeat, the determining issue was not an elective judiciary but rather legislative apportionment based on population.3

An amendment to the constitution of Missouri of 1820 limiting the terms of Supreme Court judges to twelve years received the mandatory two-thirds-majority vote in the Fourteenth General Assembly in 1846, the year of the defeat of a proposed constitution.4 Subsequently, the Fifteenth General Assembly, as required for adoption by the constitution, ratified the amendment. Moreover, during this regular session in 1848, another amendment was proposed which provided for the popular election of Supreme Court judges for a six-year term.5 When the succeeding legislature of 1850 ratified the amendment,6 Missouri joined the states with elective judges. Political party nomination was by a state-wide convention.

In general, a quiescent period in Missouri ensued upon the subject of judicial selection and tenure, and it was not a polemic topic until the 1930's, more than 80 years later. For example, following the Civil War, the constitutional convention of 1865 — meeting in the Mercantile Library in St. Louis — was primarily concerned with purging the state government of those officials who had been sympathetic to the Confederate States of America. Consequently, there was no discussion whatever concerning the selection and tenure of judges;7 however, the "Drake Convention" — so termed because of the powerful influence of the convention's vice-president, Charles D. Drake — did

4Laws of Missouri, Session Acts, 14th General Assembly, 1846-1847, p. 5.
6Laws of Missouri, Session Acts, 16th General Assembly, 1850-1851, p. 4-5.
7Journal of Missouri Constitutional Convention of 1865, p. 96-100.
Evolution of the Missouri System

pass a resolution vacating all judicial offices and providing for the filling of these positions by appointment of the Governor.8

At Missouri's fourth constitutional convention, which met in Jefferson City in 1875 and lasted for almost three months, debate was long and bitter over the questions of election by districts and election of judicial officials on separate days from other political officials.9 It was evident that the elective principle was firmly entrenched. The basic law finally agreed upon by the delegates included a judicial article that provided for the election of five Supreme Court judges to serve for ten-year terms.10 The 44th General Assembly, convening in 1907, enacted a method of nomination of judicial officers by party primary.

During Missouri's fifth constitutional convention, there was even less effort made to change the method of selection and the length of tenure than had been made in 1875.11 Many of the 83 delegates to the 1922—1923 convention, which convened in Jefferson City, believed that the practice of nomination by judicial nominating convention should be reintroduced;12 however, such a resolution was not proposed formally. A section of the constitution which was drafted by this convention provided for nomination of judicial candidates at a date different from the nomination of other candidates—to prevent the selection of judges from falling under political consideration and excitement which pervades during general elections.13 If the proposed document had obtained popular ratification, this stipulation would have had the effect of again establishing judicial nominating conventions.

Fifteen years later, a special committee of the St. Louis Bar Association observed that

... the system of nominating judicial candidates through party conventions, which was abandoned more than a quarter of a century ago, was as bad as, if not worse than, the present system. ... a return to that system would result in even more hopeless political entanglement of the judiciary than exists at the present time, for the steam-rolling effectiveness of machine politics today is, in our opinion, even greater than it was in the days of party conventions.14

8Constitution of Missouri, 1865, Article VI.
10Constitution of Missouri, 1875, Article VI, Sections 4, 5, 12, 13, 24, 25, 30.
11Debates of Missouri Constitutional Convention, 1922-1923, 206th day.
12Ibid., 176th day, pp. 24-34.
Just prior to the First World War, there was a growing demand for judicial reform, an influence of the "Progressive era." Various organizations began to discuss the "thorny" problems involved, to make studies, and to make suggestions for change. For example, the American Judicature Society, an organization supported by professors of law, judges, and leading lawyers, was formed in 1913. One of its chief objectives was to "secure some method of selection more satisfactory than popular election has proven to be." 15

In 1921, Albert M. Kales—Professor of Law at Harvard University, author of several books and articles on the legal process, and member of the Illinois bar—advocated a plan whereby the people would elect a chief justice to serve for a short term, who would—in turn—select men to fill vacancies in the "court of last resort." The associate justices would sit for an indeterminate period, going before the people at periodic intervals for popular confirmation, and they would serve as an advisory body for the appointment of lower court judges. 16

Harold J. Laski, eminent English political scientist, formulated a plan in 1926 which would have the Governor appoint the lower court judges from a list of three names submitted to him by a committee composed of the judges of the Supreme Court, the Attorney General, and the president of the state bar association. When a judge was to be selected for the higher judicial posts, Laski would have them selected from existing judges. 17

The Supreme Court of Missouri established a Judicial Council in 1934, which was composed of eleven men—nine were appointed by the Supreme Court, two ex officio members were chairmen of the Judiciary Committees of the Senate and of the House of Representatives of the General Assembly. 18 The Council was to conduct studies and to make annual reports and recommendations for enhancing the administration of justice in Missouri.

The first positive step in the movement for reform of judicial selection in Missouri was taken in the spring of 1936, with the creation of a special committee on judicial selection and tenure by the St. Louis Bar Association. 19

In February, 1937, the House of Delegates of the American Bar

15 Ibid., Volume I, Number 1, 1917, p. 3.
18 Rules of Supreme Court of Missouri, Missouri Reports, Volume 334, pp. xix-xx.
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Association, composed almost wholly of representatives of state bar associations, adopted the following general plan as the most acceptable substitute available for direct popular election of State Supreme Court judges — a plan which resembles Harold J. Laski’s previously-formulated recommendation.

(1) The filling of vacancies by appointment by the Governor or other elected official(s) from a list named by another agency. This other agency to be composed of high judicial officers and laymen selected for this one purpose, holding no other public office.

(2) If further check on these appointments is desired, confirmation by the State Senate or other legislative body may be used.

(3) After a period of service, the judge is eligible for either reappointment, or to go before the people, who would vote upon the question “shall Judge Blank be retained in office?”

In the meantime and after several months of intensive research, the special committee of the St. Louis Bar Association on judicial selection and tenure — which had made an exceptionally able study of the subject — submitted a preliminary report on September 20, 1937. This report — in brief — stated that nominations were to be by a state judiciary commission, composed of one lawyer and one layman from each of the three appellate districts, and the chief justice was to be the chairman. The bar in each district was to elect the law members; the Governor was to appoint the lay members — one from each district. Commission members had staggered nine-year terms. The submission of three nominees for possible appointment by the Governor was to be rendered by the commission when and if there was a vacancy or one became imminent by virtue of the failure of an incumbent to file a declaration of candidacy sixty days before the last general election preceding the expiration of his term of office.

Within the subsequent two-year period, Professor Israel Treiman of Washington University, Vice-chairman of the committee on judicial selection and tenure, with the competent assistance of members of the bar, took charge of the drafting of a proposed constitutional amendment which was approved by the Missouri Bar Association in 1939. As a result of a joint resolution by the Missouri and St. Louis Bar Associations, the proposed constitutional amendment was presented to the General Assembly. The regular procedure for amending the constitution of Missouri consisted of two steps: firstly, approval by two-

thirsd majority of all members elected to both chambers of the General Assembly; secondly, popular ratification by a simple majority of the voters voting thereon in the subsequent general election.\textsuperscript{23}

After being introduced into the House of Representatives, the plan was referred to the Committee on Constitutional Amendments. Representatives of the Missouri and St. Louis Bar Associations, as well as other interested citizens, appeared in behalf of the Court Plan, and no one appeared to oppose it. Nevertheless, the committee without any explanation reported the amendment “unfavorably.”\textsuperscript{24}

The abortive attempt to induce the legislature to submit the Plan to the state’s voters did not discourage — and only momentarily delayed — proponents, who immediately began to take steps to place it on the ballot by means of an initiative petition.\textsuperscript{25} By this method, signatures of five per cent of the voters of two-thirds of the Congressional districts were needed to place the Plan on the ballot at the forthcoming election.\textsuperscript{26} On July 2, petitions bearing 74,075 signatures — twice the necessary number — were filed with Secretary of State Dwight H. Brown in Jefferson City.\textsuperscript{27}

The Missouri Bar Association — of which Kenneth Teasdale, a leading St. Louis attorney, was president — led the vigorous fight for adoption of the progressive plan. A determining factor in their success was the enlistment of support by lay agencies representing all interests of and all sections of the state. The Missouri Institute for the Administration of Justice, an outgrowth of the Missouri Bar Association Conference on Criminal Justice in February, 1937, was the chief organ of the campaign. J. Lionberger Davis, an outstanding civic leader, was chosen as its president and Kenneth Teasdale as its counsel.

In organizing the Missouri Institute for the Administration of Justice, letters were sent to one hundred communities and chambers of commerce asking for recommendations of prominent laymen who would be interested in a program to improve the administration of justice.\textsuperscript{28} The idea was to get a representative body composed of citizens who would have the confidence of their home communities and, therefore, whose leadership would elicit the support of their respective communities.

A strenuous state-wide campaign was waged — funds were solicited; speakers’ bureaus were organized; and a four-page paper, “The

\textsuperscript{23}Missouri Bar Journal, Volume 10, Number 8, October, 1939, p. 135.
\textsuperscript{24}Missouri House Journal, 60th General Assembly, 1939, p. 698.
\textsuperscript{25}Bar Journal, op. cit.
\textsuperscript{26}Revised Statutes of Missouri, 1939, Section 12287.
\textsuperscript{27}Missouri Bar Journal, Volume 11, Number 6, June, 1940, p. 85.
\textsuperscript{28}Daniel Bartlett, “Missouri Bar Conference on Criminal Justice,” Missouri Bar Journal, Volume 8, Number 3, March, 1937, pp. 36-38.
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M.I.A.J. News," was broadcast throughout the state. Moreover, the metropolitan press whole-heartedly supported the Plan. In short, Missourians — all the way from Hannibal to Neosho — received a valuable education in one important phase of the administration of justice.

Coincidentally, and perhaps not wholly unfortunately, the August primary of 1940 gave rise to a "public display of the evils of political selection in their darkest hue." In the weeks preceding the primary, a special committee — assisted by two local bar associations in St. Louis — investigated all judicial candidates, and then published a list of recommendations omitting a number of unfit incumbents. Initially, the dominant political organization endorsed the founding of the committee but, straightway, abandoned it when its findings proved inconvenient. In the August primary election, characterized by a "state-wide resurgence of machine power," five of the rejected judicial candidates were nominated.

In the general election of 1940, there was a total of 980,836 votes cast on the proposed amendment; therefore, according to the state's constitution, a minimum of 490,418 votes was required for adoption. There were 535,642 votes cast "for" the Plan — an endorsement of over 45,000 votes in excess of the mandatory minimum. On December 5, 1940, just thirty days after the election, the Plan went into effect. The Plan was the only proposal which the voters approved; six others were rejected, most by sizable majorities. Its most thunderous endorsement was in metropolitan centers — Jackson County, St. Louis city, and St. Louis County. The Plan was limited to the selection of State Supreme and Appellate Court judges in metropolitan counties; thus, it was first tested where the need was felt most keenly.

The progressive — but hectic and uncertain — course of the Plan continued. The first regular measure introduced into the legislature at its subsequent regular session — House Joint and Concurrent Resolution Number One — called for the submission of a constitutional amendment that, in effect, would repeal the Missouri Court Plan. The resolution passed the House of Representatives and the Senate by formidable margins.

At the subsequent general election of November, 1942, the people voted on Amendment Number Four, which read as follows:

Amendment repealing an amendment to Article VI of

29 *Journal of the American Judicature Society*, Volume 24, August, 1940, p. 64.
30 *Constitution of Missouri*, 1875, Article XV, Section 2.
31 *Roster, op. cit.*, 1943-1944, p. 6.
Missouri Constitution, relating to the nomination, appointment, and election of judges in certain courts.\textsuperscript{33}

This Repeal Amendment was soundly defeated: of 605,609 votes cast on the amendment, there were about 390,000 negative and 215,000 affirmative votes. Many citizens of Missouri — and other interested observers — were delighted that the Missouri Non-Partisan Court Plan was, at last, to be given a trial!

Although the Plan had an obvious, resounding mandate, a number of delegates to the Missouri constitutional convention of 1943—1944 were zealous in their antagonism to the Plan. Indeed, it became the most controversial question that had to be resolved by the delegates; however, after many debates, manifold proposals, and multitudinous votes, the Plan was adopted by the convention by a voice vote.\textsuperscript{34}

Article V of the Missouri constitution of 1945 deals with the Judicial Department of the state; the non-partisan selection of judges is delineated in Section 29 of this article.

Recently, Glenn R. Winters, executive director of the American Judicature Society and editor of its journal, observed that the adoption of this court plan was "the greatest single event in the history of judicial reform in this century."\textsuperscript{35} Missouri has given us an effective example; a dozen states have adopted all of or a part of the provisions of the "Missouri Plan," and more are headed that way. For example, the Arkansas Judiciary Study Commission, created by the 1963 Arkansas General Assembly, in its recent report to the 1965 General Assembly recommended a slight variation of the Missouri Plan. It is inevitable that progress of this kind is slow, due to a traditional reluctance to change practices which have been in effect for long years, partly to a lack of knowledge on the part of bodies which can make—or initiate—such changes. By its persuasive, progressive example, Missouri has contributed to the Nation's welfare.

\textsuperscript{33}Roster, op. cit., 1943-1944, p. 6.

\textsuperscript{34}Constitution of Missouri, 1945, Article V.

\textsuperscript{35}Kansas City Star, April 15, 1964.