College of

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Mathematics

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Single Neuron Contribution to Turning While Crawling in the Marine Slug *Tritonia Diomedea*
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Abstracts

Biology

Surviving Subplate Cells in Swiss Webster Mice

Blythe Bowman, Jason Fechter, Julie Carter,
Kimberly Trobaugh, and John Frank
Faculty Mentor: Barbara Clancy

The mammalian cortex is a thin sheet of neurons covering the outermost portion of the brain. It matures above an area called the *subplate,* whose function it is to organize and direct the cortical neurons during the early stages of development. After this initial organization, conventional developmental theories hold that these subplate neurons die because their role is completed. However, a subset of these cells remains in the adult brain of many mammals, including humans, where they connect to the surface of the cortex, cortical layer I. These cells are identified by their characteristic placement and distinctive Nissl staining. Although little is known about these neurons past early developmental ages, it is well established that they are disrupted in many disorders, including schizophrenia and Alzheimer's Disease. It has not been established if these neurons remain in mature mice, the preferred species for numerous contemporary genetic studies. We sought to determine 1) if a mouse model could be used to study these cells and 2) if their distribution and connectivity remain intact across normal aging. We deposited retrograde fluorescent tracer on the cortical surface of Swiss Webster mice. Labeled subplate cells were found in motor, somatosensory, and visual cortices at varying ages (6 weeks - 14 months), confirming their widespread connections to layer I across aging in the mouse model. Our results indicate that this initial cortical connection pattern is either preserved or reformed across all ages studied.

The Effect of Arsenic on Phosphorus in *Daphnia magna*

David S. Johnson
Faculty Mentor: Kristen Keteles

A 21-day chronic toxicity study of sublethal concentrations of arsenite (As III), arsenate (As V), and phosphorus was conducted on *Daphnia magna* (Straus), a freshwater crustacean. Phosphorus and arsenic are chemical analogues where arsenic often replaces phosphorus in organisms exposed to arsenic, thereby interfering with physiological processes devoted to development and reproduction. In separate beakers, each neonate – less than 24hr old – was subjected to a treatment of no arsenic-no phosphorus (control), 100 ppb arsenite, 100 ppb arsenite-100 ppb phosphorus, 3 ppm arsenate-100 ppb phosphorus, 3 ppm arsenate, or 100 ppb P for 21 days. Those daphnids exposed to only arsenite showed an average mortality of 18 days, had a 50% reduction in average of number of broods and a 30% reduction in brood size. All other daphnids survived to the end of the study. In the presence of both arsenite and phosphorus, the daphnids exhibited reproduction values close to the controls. This indicates that phosphorus has an antagonistic affect on the toxicity of arsenite. The daphinds exposed to only phosphorus had the highest productivity. Although arsenate is highly toxic and more closely resembles phosphorus chemically, daphnids exposed to only arsenate did not show a significant reduction in brood size or fecundity. The arsenate-P treatment daphnids did express higher brood sizes than the arsenate treatment, but not significantly and not as large a brood size as strictly phosphorus treated daphnids. This provides evidence that there may be an inverse relationship between the toxicity of arsenate and the amount of phosphorus present.

Single Neuron Contribution to Turning While Crawling in the Marine Slug *Tritonia Diomedea*

Roger Redondo
Faculty Mentor: James A. Murray

Tritonia diomedea crawls using its ciliated foot surface as the sole means of propulsion. Turning while crawling involves the raising of a small portion of the lateral foot margin ipsilateral to the side of the turn. The cilia in the lifted area can no longer contribute to propulsion, and this consequent asymmetry in thrust turns the animal towards the lifted side. The details of this mechanism vary according to the

angle of turning. Others in our laboratory are studying these differences in turning mechanisms.

Foot contractions are initiated by neurons located in the pedal ganglia of the brain. Pedal 3 (Pd3) has been shown to receive synaptic input from flow receptors (Murray *et al.* 1992) and may be necessary for turning (Murray 1994; Willows *et al.*)

Cell Cycle Synchronization in C3H/MCA Cells by Serum Withdrawal

Ulysses Beauregard Haley, Dana Strassle, and Fumiyo Kubo
Faculty Mentor: Steven W. Runge

Apoptosis, programmed cell death, is a naturally occurring process that occurs in multicellular organisms that removes damaged or old cells without a negative impact on the surrounding tissue. Chemotherapeutic treatments for some types of cancer are aimed at selectively inducing apoptosis in cancer cells with little or no damage to the surrounding tissues. One common method of treatment is the use of anti-cytoskeletal agents such as Taxol, which induces apoptosis by stalling dividing cells during metaphase of mitosis. This is a vital point during the mitotic process that, if interrupted, will result in apoptosis of the cell. However, very little research has been done on the effect of such anti-cytoskeletal treatments on events other than mitosis. Treatment of non-dividing cells would offer considerable insights into other potential modes of action of these anti-cytoskeletal agents. Normal, non-cancerous, cells such as C3H10T1/2 cells are contact inhibited and thus stop dividing upon reaching confluency. However, most cancerous cells, such as C3H/MCA cells, are not contact inhibited and therefore must be forced to stop dividing. One method used to prevent cell division in cell lines that are not contact inhibited is serum starvation. Fetal bovine serum, FBS, is used as a source of hormones and growth factors for cultured cells and typically constitutes 10% of C3H/MCA cell culture medium. This research indicates that a reduction of FBS to 0.1% or 0.05% of the total culture media volume results in $\sim$90% of C3H/MCA cells in culture to remain in G_0/G_1 phase of the cell cycle as determined by flow cytometry analysis of DNA content. Cell media with FBS concentrations above 0.1% did not result in sufficient reductions in the number of dividing cells in the whole populations. This method of cell cycle synchronization will allow studies on the effect of anti-cytoskeletal agents on C3H/MCA cells while minimizing the effects of these agents on blocking mitosis.

The Role of Intracellular pH in Apoptosis Induced by Various Drugs

Fumiyo Kubo
Faculty Mentor: Steven W. Runge

There are two ways in which cells die. One of them, called necrosis usually results from injury. The other way is that cells are induced to commit suicide is called apoptosis. Necrosis can be initiated by mechanical damage or exposure to toxic chemicals. In necrosis, cells swell and the cell contents leak out their contents leading to inflammation in the surrounding tissues. On the other hand, in the process of apoptosis, cells shrink and break into small membrane-wrapped pieces. The neighboring cells or other phagocytic cells engulf these cell fragments, thus inhibiting the inflammatory response.

Maintenance of intracellular pH is crucial for normal cell functions. Therefore, cells maintain intracellular pH using a combination of intracellular buffering systems and plasma membrane proteins that pump out excess protons or import buffers (or a combination of the two). Many apoptotically active drugs cause an intracellular acidification, but is it not firmly established that this acidification is necessary for apoptosis to occur. We have hypothesized that the intracellular acidification is a requirement and that apoptosis induced by a variety of stimuli will be inhibited if the cells are clamped at a neutral or slightly alkaline pH. Experiments using C3H-10T1/2 cells (untransformed mouse fibroblast) and C3H/MCA cells (mouse fibrosarcoma) have been supportive of our hypothesis. Cells that are induced to undergo apoptosis but have been simultaneously clamped at pH 7.4 have significantly reduced levels of apoptosis relative to similarly treated cells that are not clamped at pH 7.4.

Intracellular Acidification and Apoptosis

Kyla Shelton and Jeff Steele
Faculty Mentor: Steven W. Runge

Apoptosis is an organized self-destruct mechanism used by cells in multicellular organisms for a wide variety of purposes. In most instances the individual cell's death helps the organism more than if it were to survive. For example DNA damage can cause apoptosis, which would keep damaged cells from replicating. Apoptosis is a complex process composed of many steps and events. One of these events is intracellular acidification. Acidification is known to occur during apop-

tosis and our laboratory (and others) has reported that lowering intracellular pH is sufficient to induce apoptosis. However, it has not been established whether this is an essential step in the process, or simply a phenomenon that occurs due to some other event. Here we use two experiments to investigate intracellular acidification as it relates to apoptosis. In the first, the effect of acidification on p35, a baculovirus-derived caspase inhibitor, function is tested to observe to what extent p35 inhibits caspase activity at various pH levels. Cells transfected with P35 have a reduced rate of apoptosis in response to serum withdrawal at physiological pH, but die apoptotically upon clamping intracellular pH at acidic levels. This experiment will show if the inability of the p35 to prevent apoptosis at low intracellular pH is due to the cellular acidification being further down the biochemical cascade than caspase activity or if the low pH is simply reducing the ability of p35 to inhibit the caspases. The second experiment involves inducing apoptosis with UV light on normal cells that are free to acidify and on cells whose pH has been clamped at physiological level (to block any fluctuations in intracellular pH that may be caused by the UV irradiation). Any difference in apoptotic rate will be indicative of whether or not intracellular acidification is necessary for apoptosis. Both of these experiments will lend insight into the function and significance of intracellular pH changes in apoptosis.

Mazon Creek-Type Fossils from the Pennsylvanian of the Arkansas River Valley

Heather Stottman
Faculty Mentor: Ben Waggoner

Fossil-bearing siderite concretions are best known from the Mazon Creek Formation (Pennsylvanian: Westphalian) in northeastern Illinois. The Mazon Creek assemblage includes two basic assemblages: the Braidwood assemblage, dominated by terrestrial plants and non-marine animals; and the Essex assemblage of aquatic organisms from varying salinity levels. Fossil-bearing siderite concretions occur in the Pennsylvanian of other states, such as Oklahoma and Missouri. We present a report on fossil-bearing concretions in the Pennsylvanian coal-bearing strata of the western Arkansas River Valley. Most of the fossils are plants, including probable seed ferns; the predominant invertebrates are clams. The assemblage is much more like that of the Braidwood assemblage of Mazon Creek and that of eastern Oklahoma than the concretionary biota described from coeval rocks of western

Missouri, which contains several Essex-type taxa. These fossils should prove useful in paleoecological reconstructions of the southern margin of Laurentia in the Pennsylvanian.

Chemistry

Cation-Pi Interactions Between DNA Bases and Cations

Lindsay Lewis and Brian Hill
Faculty Mentor: Lori Isom

DNA bending is important in signaling for the transcription of certain genes, for the repair of mutations, and is important for the proper functioning of the immune system. The bends in DNA have been attributed to two mechanisms; the interactions between the DNA bases themselves and the interactions between the bases and hydrated metal ions. The purpose of this research is to study the latter. The interactions between the rings of DNA bases and hydrated metal ions, otherwise known as cation-pi interactions, will be studied through the analysis of X-Ray Crystallography data. Understanding the mechanisms of DNA deformity will give insight into the mechanisms of cancer development and thus can lead to the prevention and treatment of cancer.

Investigating the Interaction Between Mg^{2+} and the Crystal Dehydrating Agent MPD and its Role in DNA Bending

Julie Maris and Candice Means
Faculty Mentor: Lori Isom

We are studying the interaction between MPD and magnesium ions (Mg^{2+}). We are currently investigating the role of Mg^{2+} ions in DNA bending. Discrepancies concerning DNA bending exist between results obtained from X-ray crystallographic and solution studies. X-ray crystallographic studies suggest that DNA is primarily unbent while solution studies have produced evidence of DNA bending. One explanation of this discrepancy involves the hypothesis that the crystal dehydrating agent MPD added to all crystals during growth affects DNA bending. Solution studies have been conducted which support this conclusion. Our research focuses on explaining the mechanism by which MPD affects DNA bending. We believe that ion binding can induce bends in DNA and that MPD interacts with Mg^{2+} ions, sequestering them away from the DNA thereby decreasing its

curvature. We are currently using UV spectroscopy to investigate the interaction between MPD and Mg^{2+}. A color transition from pink to blue occurs when the indicator Eriochrome Black T becomes unbound to Mg^{2+}. We are attempting to quantify the interaction strength between Mg^{2+} and MPD by competing with EBT for MPD binding. The color transition indicates the stripping of Mg^{2+} away from EBT by MPD.

Modeling of A–B Step Polymerizations

Charity Washam
Faculty Mentors: Danny Arrigo and Richard Tarkka

Statistical models of step polymerization processes do not account for precipitation of chains that exceed some limiting molecular weight. The objective of this study was to develop a model, based on differential equations, that describes such a process. We used the accepted general form of the differential equation, which describes the kinetics of formation of each individual polymer, to generate a set of equations that describes the populations of each individual chain. We discovered that those equations do not provide the necessary materials balance. A second drawback is that the rates of reactivity of each species are assumed equal. We propose a new model that overcomes these limitations. The present work focuses on the question of material balance where a comparative study of the numerical solutions of the two models is presented.

Computer Science

Automated Parked Vehicle Surveillance

Josh Hight
Faculty Mentor: Chenyi Hu

Our research studies an automated surveillance system using a single fixed camera. Our automated surveillance system will ultimately monitor a vehicle in a parking lot environment to detect unwanted activity against that vehicle, such as unusual and frequent interaction from humans or other objects, damage caused by other vehicles, and excessive loitering.

An automated surveillance system consists of three components: object detection, tracking, and classification. That is, a surveillance system must be able to recognize important objects, follow their movement, and determine what the object is. A fourth component is implied in automated surveillance—one in which the data gathered from the first components is analyzed. Serving as the high-level logic of the system, this component utilizes artificial intelligence algorithms to make conclusions from the data. We believe this component is the most important and will focus our research on it.

We employ a simple thresholded background subtraction function to detect moving objects. Each object is then classified into one of three categories: human, vehicle, or other, based on its dispersedness. Tracking and analysis components have yet to be implemented.

Object detection and classification components have yielded satisfactory results, despite some limitations. For example, the background subtraction-based object detection algorithm fails in environments of greatly varying brightness. Dispersedness data is mostly accurate, although it produces minor incorrect results at times.

Further refinement of the dispersedness function will soon be done, in hopes of tweaking results. The tracking subsystem will be developed in the near future as well. Planning and design of the analysis component will begin shortly.

Studying Artificial Intelligence with a Thinking Computer Checkers Player

William Holdcraft, Glen Massingill, and Kenneth Priest
Faculty Mentor: Chenyi Hu

Computers today have much more processing power and data storage than the human brain. If we can give them thought, they can accomplish many tasks faster and even better than us. The study of Artificial intelligence (A.I.) is directed at programming a computer to think. A.I. has many applications in today's world.

One of the most common fields of development and testing for A.I. is gaming. Games tend to be less complex than real world problems, thus they provide an easier starting point for development of new ideas and A.I. solutions that may later be adapted to real world problems. In dealing with computer programs that play games like chess and checkers, one particular question arises. With much more processing power and storage, why don't computer players significantly out perform the best human players? This question has been the motivation for our research of computer chess and checkers players.

Throughout our research we have noticed that in most previous implementations, computers have been programmed to generate a search tree of all possible moves. The idea is to know the outcome of all moves by looking ahead to every possible move that can be made after each move. Although theoretically the entire search tree can be generated, for games like chess and checkers the tree is still much too large to be generated in a reasonable amount of time. So the basic algorithm used previously involved generating the search tree to a certain depth and then evaluating the state of the boards on the deepest level. Based on the relative values given to those boards the computer would then make it's move.

Humans that play the game using this method rarely play higher than a novice level. So our next question was how do humans play? During the course of our research we found that humans have many layers to their playing styles and thought patterns. We decided to focus on one component that was particularly interesting. Rather than using a look ahead technique, advanced human players determine what moves to make based on the arrangement of just a few pieces on the board. They have stored thousands of patterns in their head and have a feel for the outcome of each move for a given pattern. So when an advanced human player looks at the board they look at chunks of pieces searching for known patterns. At this

point we wanted to know if having the computer play in this manner could allow it out think the best human and computer players. So our approach was to generate a database of patterns and when it was the computer's turn to play it would search these patterns and make a move based on the patterns found. We decided to give a value to each pattern so the computer would know which move to choose when more than one pattern was found.

We plan to extensively optimize the way we search the board for patterns to keep thinking time to a minimum. We would also like our program to have the computer itself recognize and store new patterns during games so that it would continue to learn and improve throughout every game it played. The computer will also recognize when a move associated with a pattern has risks and store warnings about what to look for before making a move based on that pattern. Indeed, the study of this project will provide us insights of constructing knowledge-based agents in artificial intelligence to give these agents knowledge about their world, and reasoning about their possible courses of action.

Mathematics and Mathematics Education

Nonclassical Symmetries of Evolutionary Partial Differential Equations and Compatibility

Regan Beckham
Faculty Mentor: Danny Arrigo

The determining equations for the nonclassical reductions of a general nthth order evolutionary partial differential equations is considered. It is shown that requiring compatibility with a first order quasilinear partial differential equation, the determining equations are obtained. Burgers' equation and the KdV equation serve as examples illustrating how compatibility leads quickly and easily to the determining equations for their nonclassical symmetries

Symmetry Analysis of a Generalized KdV Equation

Jesse Pratt
Faculty Mentor: Danny Arrigo

Several physical phenomena are modeled using nonlinear partial differential equations. One of the more popular types of these equations is the Korteweg-de Vries (KdV) equation, that is used to model shallow water waves. This research is to consider the symmetry analysis of a generalized form of the KdV equation. Symmetry analysis is one of the most powerful techniques available for obtaining solutions of nonlinear PDEs. There are two methods of symmetry analysis: the classical and nonclassical methods. The nonclassical method is typically much harder to perform than the classical method, however it has led to new exact solutions not obtained by the classical method. The goal of this project is to determine whether or not the nonclassical method will give rise to new solutions for this general class of KdV equation.

Exact Solutions to Approximate Equations

Casey Milford and Brandon Willis
Faculty Mentor: Danny Arrigo and Fred Hickling

Most current techniques used to approximate solutions to partial differential equations (PDEs) start with a given equation and provide an approximate solution using a variety of techniques. An alternate scheme for approximating solutions to an equation is to find an approximate equation for which exact solutions are known. We will use this alternate scheme to find solutions to Schrödinger's equation.

Until recently, there have been very few potentials for which exact solutions of Schrödinger's equation were known. Given the recent extension to this class of potentials, we have created and implemented an algorithm that approximates any given potential, $V(x)$, by intelligently manipulating members of the recently extended class of potentials. This will eliminate most of the error currently associated with approximate PDE solutions, by providing an approximate equation for which exact solutions are known.

The Effects of Normality Assumption Violations on the Student's T Test

Matt Flora
Faculty Mentor: George Bratton

The purpose of our research was to test the effect of sample size on hypothesis tests about population means. So we tested variations in sample size from the normal distribution and the exponential distribution using a Student's T test. This test depends heavily on the assumption of normality of the data. The exponential distribution will demonstrate what happens when we violate these assumptions. We studied effects on Type I and Type II Errors using a statistical package called Minitab to generate and test data from normal and exponential distributions. The method used for the Type I Error test was generating data at various sample sizes from the exponential distribution and testing against the true mean. The number of failed trials was compared to the expected number of failed trials if the data were from a normal distribution. For the Type II Error testing, the method used was to generate data from the two distributions at various sample sizes and at a mean of seven and test it at means of ten and four. Then, once the probabilities of Type II Error were tabulated, the results were compared and contrasted. Both

Errors strongly displayed the effect of violating the normality assumption at small sample sizes. After this we proposed a new test involving the gamma distribution. This test was run similarly to the Type I Error test only doing a gamma test rather than a Student's T test. This test proved to be more reliable for this data.

Algebra in Today's Standards-Based Curriculum

Lois E. Sancho
Faculty Mentor: Jean McGehee and Linda K. Griffith

"*In taking the position that algebra is for all, the NCTM is calling for a complete rethinking of what we might mean by algebra (1994). In effect, the NCTM is advocating that the notion of algebra be expanded to include a range of mathematical activity.*"

Mathematics curricula are broken down into five strands of emphasis. Traditionally, curricula for grades 1-8 has focused on one strand, Numbers, Property, and Operations (NPO). NCTM's position supports a balance between this strand and the other four strands: Patterns, Algebra, and Function (PAF); Geometry and Spatial Sense (GSS); Measurement (M); Data Analysis, Statistics, and Probability (DSP).

This study examines one school district's implementation of a Standards-based curriculum tailored to conform to grade-specific process standards set forth by the National Council of Teachers in Mathematics (NCTM), and accepted by the state of Arkansas. The specific focus of this study is on how the NPO and PAF strands progress through grades 1-8.

The effectiveness of the implementation is measured with criterion-referenced tests administered at each grade level. The limited scope, to date, appears to show the two strands in question to be well-balanced. Additionally, comparison of 146 of last year's eighth-grader's tests with their 7^{th} grade tests, has shown a marked improvement in their scores.

Physics and Astronomy

Symmetry Analysis of the Reduced Maxwell-Bloch Equations with a Permanent Dipole

Chad Fendt
Faculty Mentors: Stephen R. Addison and Danny Arrigo

The symmetries of the reduced Maxwell-Bloch (RMB) system with a permanent dipole are constructed. This analysis leads to a reduction of the RMB equations to a system of ODEs. Subsequent analysis of this system leads to a Jacobi elliptic equation. Solutions of this equation are then used to generate solutions of the RMB system, some of which exhibit soliton behavior. The symmetry analysis also leads to a transformation theorem that links different solutions of the RMB system.

Fabrication And Testing Of The Uca Fiber-Fed CCD Spectrograph

Allan Holloway
Faculty Mentor: Scott Austin

In order to obtain spectroscopic data for classical novae in outburst and Be stars, a fiber-fed spectrograph system was built for the UCA Observatory's 11-inch telescope. As many off-the-shelf components as possible were incorporated into the design of the system, including, the CCD camera, video camera for guiding, lenses, gratings, and optical fibers. A number of components and fixtures also had to be fabricated: the fiber-coupler/guiding assembly, fixtures for holding the optical elements, the comparison lamp assembly, and the base and enclosure for the spectrograph. The fabrication work was done between July 2002 and February 2003 using the UCA Physics and Astronomy Machine Shop. The ends of the optical fibers were also prepared and polished during the summer of 2002. Presented here is an overview of the construction of the spectrograph system, as well as initial calibration and testing data.