

The Biological Basis of Behavior: An Old Field with New Momentum

The *Biological Basis of Behavior*, one of the newest FAS undergraduate majors, is hardly a stranger to scholars in the arts and sciences.

While its popularity may be a product of the past decade, the study itself is at least as old as Darwin—some would even say Aristotle. At Pennsylvania many scholars in such departments as biology, psychology and anthropology, as well as in the Schools of Medicine and Veterinary Medicine, have been studying how animals and man behave. About 10 years ago, students became interested in the field and began creating their own majors; by last year, one quarter of the students with individualized majors were working in this area.

The study of the biological basis of behavior has also been gathering momentum among scholars and the general public during the past decade. In 1973 the Nobel Prize in Medicine and Physiology was awarded to three of the field's pioneers—Lorenz, Tinbergen and von Frisch. Across the country over 100 graduate programs have been established under such names as sociobiology, ethology or psychobiology. At the same time books such as Konrad Lorenz's *On Aggression*, Desmond Morris' *The Naked Ape*, Edward O. Wilson's *Sociobiology: The New Synthesis* have been making an impact on a broader audience.

"We had tried for years to get a major together and would always say, 'Gee, isn't it a shame,'" says Professor of Psychology Norman Adler, who is chairman of the new major. Describing the process of creating the program, he says, "We decided first of all that we should have broad representation from all over the University. The faculty involved in our major are from the medical school, from the veterinary school and from FAS—in psychology, biology and anthropology. And that in itself was an achievement."

After a year of meetings, an interdisciplinary faculty committee presented a proposal for the new major. It was approved by the FAS Committee on Instruction last spring.

Thirty students have enrolled in the program already. According to Dr. Adler, it is a natural for students interested in the life sciences who want a liberal arts education.

"Given the present state of the twentieth century," he goes on, "I think it's very useful to have a view of the biological basis of behavior, including human behavior, because it impinges upon so many professions and so

much that goes on in the world. The rise, and I hope the fall, of mind-altering drugs, the question of biomedical ethics—that is who has the right to control behavior—are questions that a psychiatrist and a neurologist would face, but they're also questions that lawyers, and indeed the lay public, should be concerned with."

The major encompasses studies ranging from David Premack's work in teaching a chimpanzee to read to Eliot Stellar's studies of the factors controlling appetite. According to Dr. Adler, most of the work on the biological basis of behavior derives from one of two approaches. Scientists who take the mechanistic approach see behavior as the output of the body, particularly the nervous and endocrine systems, and ask just how these processes work. Other scientists view behavior as part of the organism's genetic equipment and are interested in how this behavior has evolved. While most colleges and universities have developed their programs in the biological basis of behavior along one line or the other, Pennsylvania's program includes both. To accommodate the many different points of view, the major has three areas of specialization: neural systems, the biological psychology of human organisms and social behavior and sociobiology.

Those specializing in neural systems look at how



the nervous system operates. An example of work in this category is Charles R. Gallistel's study plotting which neurons in the brain are stimulated during the phenomenon of self-stimulation—described on page 2 of this report.

The second area, the biological psychology of human organisms, deals with how behavior is controlled by the nervous system.

"A student who is interested purely in the nervous system would be very happy to take out a piece of the nervous system, put it in a dish, look at it under the microscope and record from it with no really direct connection to behavior. The kids majoring in the second area sometimes have an interest in physiology, but they're more concerned with large problems in behavior *per se*: what are the things going on in our bodies that cause us to eat, sleep and learn and that motivate us," notes Dr. Adler.

Thus that part of Dr. Gallistel's work that deals with memory formation falls into this second area. Paul Rozin's studies of food preferences, explained on page 3 are also examples of this category.

Social behavior and sociobiology, the final category, is concerned with how the organism behaves in groups, how this behavior relates to the ecology of the natural environment and how this behavior has evolved. W. John Smith's studies of communication among animals fit into this third category. Dr. Smith's work is described on page 5.

Students in the new major must specialize in one of these areas. In addition to six courses in their specialization, they must take 12 background courses in science.

"We really want the students to have more than a little taste of some interesting tidbits; we want them to be able to understand something in depth. And a knowledge of the science of behavior—or the biology of behavior—really requires a very good general scientific background," explains Dr. Adler.

While the requirements may be rigorous, students are given a lot of flexibility. In their areas of specialization they can take a wide variety of courses—in departments ranging from linguistics to anatomy—and from the veterinary and medical schools as well as from FAS. Another payoff for their hard work is the opportunity to become involved in research on their own. Some of the students explain their projects on page 6.

Concludes Norman Adler, "It's a truly interdisciplinary major and that's good for both the faculty, the University and the students. It combines elements of FAS, the veterinary school and the medical school, and therefore, I think, is unique. It's also a good general education. I feel that after four years in this major, a student will not only be equipped to become a professional in a certain field, but will be educated in a well-defined area of scholarship. That's the goal of a university education."

Tracking the Pathway to Learning



Charles R. Gallistel, Professor of Psychology

Speculation as to how we learn has been intense for over 100 years, and while learning theories abound, there is still little concrete knowledge of the process of learning—how our nervous system takes a transient signal and turns it into a memory, or permanent change, in the brain.

To understand this process Professor of Psychology Charles R. Gallistel is trying to find the neural pathway that leads to memory. Fortunately, a fairly dramatic occurrence called the phenomenon of self-stimulation of the brain is well suited to studying this problem. Scientists have found that if they excite the neural tissue in a certain tract of an animal's brain and turn the controls of the stimulator over to the animal, the animal becomes so excited that it continues to stimulate its own brain to the exclusion of everything else—eating, sleeping, drinking—for as long as two days.

"Obviously something about the signal that the stimulation produced in the nervous system has been encoded by the nervous system into a memory of some kind. It's been put in its library," explains Dr. Gallistel.

Not only does the phenomenon involve memory, but it is so powerful—enough to exclude virtually all other activity—that it is convenient for experimental purposes.

So Dr. Gallistel reasons, "If you could strip away all the neural systems whose excitation is irrelevant to this phenomenon and just find the pathway that was carrying the relevant signal, you could follow that pathway, and somewhere you ought to bump smack into this memory process."

This psychologist is now tracking the neural pathway in two ways. In one set of experiments, he is plotting just which neurons are excited during the self-stimulation phenomenon. In another set of experiments, he is trying to pinpoint which neurons, from among all of those stimulated, lead to memory.

Until recently, seeing which neurons are excited at any given moment was an overwhelmingly tedious and time-consuming task. Scientists like Dr. Gallistel stuck a fine micro-electrode into each neuron to see if it was active.

"It's an enormous fishing expedition. It's very good about telling you exactly what one individual neuron is doing, but a very poor technique for giving you a picture of what all the neurons are up to."

The process has been greatly simplified by a technique called 2-deoxyglucose autoradiography, which Penn neurologist Martin Reivich helped develop, and which is revolutionizing functional neuroanatomy, the study of the parts of the

brain that are activated in different behavioral conditions.

This technique takes advantage of the fact that when neurons transmit impulses, they produce the necessary energy by burning glucose. As the neural cells absorb glucose for this process, they take in a chemically mutilated form of glucose called 2-deoxyglucose, which does not burn but remains in the cells. If a radioactive form of 2-deoxyglucose is used, the radiation given off from a particular area of the nervous system is proportionate to the concentration of the 2-deoxyglucose in that area. Thus, the more active an area was during the time when the 2-deoxyglucose was being taken up by the cells of the body, the greater its concentration of 2-deoxyglucose.

Drs. Gallistel, Reivich and their collaborators inject rats with radioactive 2-deoxyglucose, let them electrically stimulate their brain while the 2-deoxyglucose is being taken into the cells, kill them, section their brains and place the sections on X-ray film. After several days' exposure, the film shows images of the sections. The neural systems that were excited in the self-stimulation appear unusually dark.

"One of the great advantages of being at a large university like Penn is that there are a lot of people doing a lot of interesting things that intersect with what you're doing. And when I discovered that Reivich was doing this, I went running across the campus suggesting that we collaborate, because this technique is ready-made for my problem," says Dr. Gallistel.

In his second line of investigation, Dr. Gallistel is distinguishing the neurons that mediate the self-stimulation phenomenon from those that are excited by the stimulation but play no role in the self-stimulation phenomenon itself.

He is looking for what he calls a signature, a set of distinguishing characteristics that will set the neurons mediating the self-stimulation phenomenon apart from all the other neurons. Following an approach that has enjoyed its greatest success in sensory system psychophysics, he is studying the ways various parameters of the stimulation trade off against one another. For example, a decrease in the intensity of an electrical pulse reduces its ability to excite a neuron, but this may be compensated by increasing the duration of the pulse. While this is true for all neurons, the increase in pulse duration required to offset a given decrease in intensity varies from one kind of neuron to another. If Dr. Gallistel can figure out just what this relationship is for neurons at work in the self-stimulation phenomenon, he can pinpoint them and, he hopes, follow them to memory.

Thus, Dr. Gallistel's current experiments are designed to find out exactly how much of an increase in current intensity is needed to offset exactly what decrease in such parameters as pulse duration, pulse frequency and train duration.

"That kind of experiment, which sounds like about the dullest sort of quantitative plowing along one can imagine, is, I believe, the only good way we have of tackling this signature question."

As he takes on these problems in the neurobiology of learning, Dr. Gallistel is completing a book called *The Organization of Action*, whose subject is how behavior is actually produced. He is also writing a textbook on physiological psychology with Norman Adler and has recently completed a book with his wife, Professor of Psychology Rochel Gelman, called *The Child's Understanding of Number*.

How does he do it all?

"I mostly hang my head in despair!" he replies with a grin.

The Psychology of Chili Peppers

Why do people set their mouths afire with chili peppers when even an indiscriminate rat knows better?

Paul Rozin, chairman of the Department of Psychology, has been wondering about that too. He has been considering this as part of a broader study of what makes us come to like foods that are initially distasteful and how we come to avoid eating things that have nutritional value. These questions are particularly interesting for him because these food preferences set us apart from other animals.

Early in his career Dr. Rozin studied food selection in animals, then became interested in reading acquisition in children. He traces his renewed interest in food preferences to his wife Elisabeth's *The Flavor Principle Cookbook*. This book defines basic flavors that characterize the food of a culture, like tomatoes and chili peppers in Mexico or ginger root and soy sauce in China.

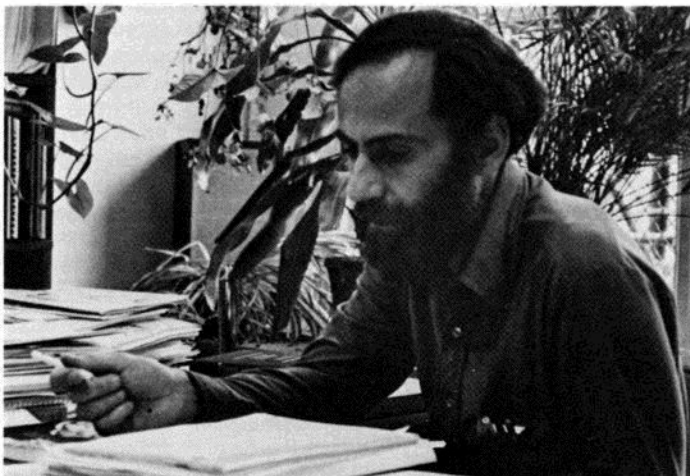
It was the chili peppers that stopped Dr. Rozin. Why do people like chili peppers, he kept asking, particularly when children and animals don't?

"The reason I'm interested in it psychologically is that we don't have a single theory that could explain how someone can get to like a food. Now that may sound absurd, but it's true," says Dr. Rozin.

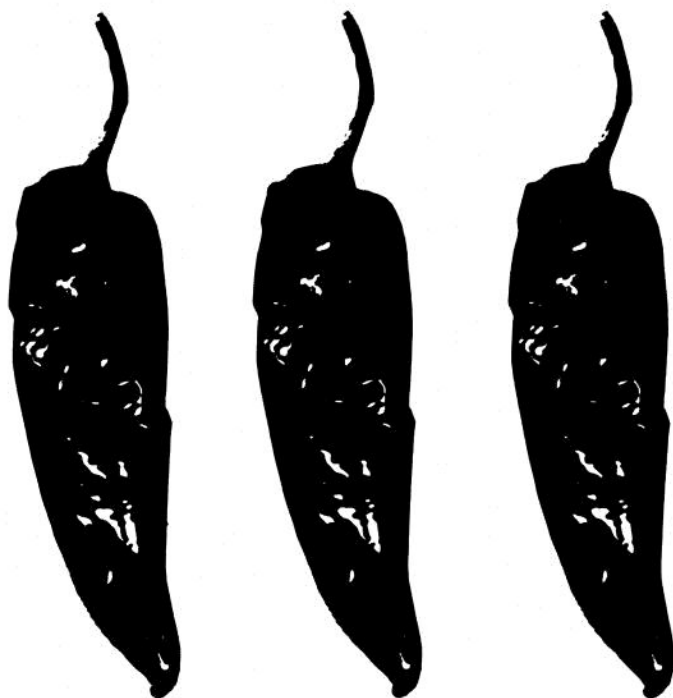
After Dr. Rozin tried to get rats to like chili peppers, and failed, he set off for a village near Oaxaca, Mexico, to study chilis in a cultural context. In this aspect of his work, he is looking at how the Mexican villagers use different chili peppers and when and how their children learn to like them.

At the same time he is considering four theories of why we eat chilis and other bitter, burned, irritating or initially distasteful food. One explanation he has already ruled out is that after people have eaten a great deal of a distasteful food, their receptors become less sensitive to the distasteful quality. In the case of chili peppers, the theory goes, they burn less once you get used to them. Dr. Rozin's findings show that this just isn't true. Chili lovers find them just as fiery as non-chili lovers; they just like the fire.

A second abandoned theory is that the distasteful food makes people feel good in some way. While the case might be made for the mellowing quality of wine or the energy ascribed to coffee, lovers of chili peppers do not make this claim, according to Dr. Rozin.



Paul Rozin, Professor and Chairman of Psychology.



At the moment Dr. Rozin is testing a variation of the opponent process theory, developed by Richard Solomon, Penn professor of psychology. Dr. Solomon has shown that whenever an organism is thrown out of emotional balance, the body will generate the opposite emotion to cancel the original one and return the body to neutral. When the same stimulus is introduced over and over again and produces the same emotion, the opponent response is often strengthened to the point where the organism does not even feel the original emotion.

Taking this theory one step further, Dr. Rozin is asking whether the body may generate such a strong opponent response that it eventually becomes the dominant response. Thus, we feel pleasure from a stimulus that originally made us feel displeasure. To find out, Paul Rozin is feeding chilis to people in his lab and recording the way their responses vary as they eat more and more of the peppers.

One as yet untested theory is what Dr. Rozin calls benign masochism. Chilis, he postulates, are to our taste buds what roller coasters are to our equilibrium. Both begin as negative sensations and eventually become pleasurable because of the risk involved.

"I call it the masochism of everyday life," says Dr. Rozin. "People in their normal dealings with the world get to enjoy these danger signals, or negative experiences, and the reason is that they discover that in these individual cases these negative responses are not really dangerous."

How does this inscrutable human propensity relate to the biological basis of behavior?

"I'm interested in how our biological heritage affects what we do," he explains. "We're omnivorous animals like rats, and omnivorous animals in general have a tendency to explore new foods."

Trying new foods is a risky business, Dr. Rozin continues. Returning to his wife's flavor principle, he conjectures that one function of flavoring may be to label

foods as safe to eat. Ironically, then, the fiery chili pepper may offer its supporters great comfort.

Paul Rozin is also interested in identifying the adaptive value of individual foods. What advantages do chili peppers offer to one quarter of the world's adult population who eat these little red or green vegetables? Chilis do contain vitamins A and C, he notes. They might also be valuable because they stimulate salivation and thus help people digest fairly bland, starchy diets.

Dr. Rozin is working with graduate student April Fallon on the flip side of the problem: how people develop aversions. As the first step in their study, they have defined four categories of substances with nutritional value that we don't eat. The first, distasteful food, is comprised of things that have an unpleasant taste or smell, like quinine water, coffee or chili peppers. The second includes foods that may well be harmful, like wild mushrooms. Inappropriate substances are the third category, which includes things that we don't object to eating, like grass, but don't view as food. The final category, and the one they find most interesting, is disgust items, like insects or rotten things in our culture. We don't eat these substances because we have learned not to eat them and to be repulsed by them. Disgust items vary from one culture to another.

"By the time they're six years old, children are pretty much members of the culture with the general aversions of people in the culture," explains Dr. Rozin. He hopes to document what kids won't eat and where and when they get these ideas.

To study these questions, Paul Rozin plans to observe children both in the United States and in Mexico. In this work Dr. Rozin, who was the first to receive a joint Ph.D. in biology and psychology from Harvard, is drawing together psychology, biology and anthropology to study the biological basis of behavior.

Translating the Language of the Animal Kingdom

Biologist W. John Smith's laboratories are the woods of Delaware County, the jungles of Panama and the landscapes of the Philadelphia Zoo, where he works as a translator for the animal kingdom. The languages that interest him include the dance of the honeybee, the howl of a wolf, the raised fist of a human and the color changes of a fish. . . any act that is specialized to provide information.

Describing his work, Dr. Smith says, "I've tried to compare the ways in which quite diverse animals signal and find the commonality, to see what sorts of features are basic to the evolution of signal behavior."

This work led in 1977 to the publication of *The Behavior of Communicating*, in which Dr. Smith develops a theoretical structure for signaling (or display) behavior and reviews the work of the many ethologists who have studied these forms of communication. The book, now in its second printing, had been in the making since, as a graduate student, he used signaling behavior as a tool to see evolutionary relationships.

"I became very much concerned with the fact that signaling behavior was not being properly addressed. There was no theoretical basis for understanding it," he explains.

At the time signals were seen as expressions of fear, aggression or sex. Scholars were asking about the motivational states of wolves who howl or birds who sing. No one was trying to find out what information they might be making available.

After receiving his Ph.D. in 1962, Dr. Smith decided to learn what he could about signals. In Panama and elsewhere in South America he watched animals signal. He also went to Europe to study with the traditional experts in the field. After this postdoctoral work, he came to Penn, where he has continued these studies.

He first considered the signal

behavior of several phylogenetic lineages of birds, then moved on to a colony of prairie dogs at the Philadelphia Zoo and from there to primates as well as other animal species.

One of the common features he has found is that most animals have very few signals—there are between 20 and 40 different signaling patterns in any one species. To carry on what may be rather complex social interactions, most animals supplement what they know from signals with environmental information and their understanding of the animal with whom they communicate.

He has discovered that most signals provide information about the communicator rather than the environment. Although a given signal might be performed on seeing or hearing a predator, it would not indicate that there was a predator around. This is because the animal would perform the same signal under many circumstances. For example, the high pitched sound that a bird might make when he was about to flee would be uttered when there is a hawk around, when he is losing a fight with another bird, or when his parents turn on him because he is demanding too much food. The high pitched sound always indicates that there is a good chance that the bird will flee, but there could be any number of reasons for the escape.

To an outsider the task of learning the signals of so many species of animals and then coming up with a theoretical framework to deal with them seems more impossible than learning Latin, Chinese, French, Greek and Arabic and then coming up with a theory of languages. And if the problem itself is overwhelming enough, Dr. Smith's experiments all take place in a natural, or nearly natural, setting.

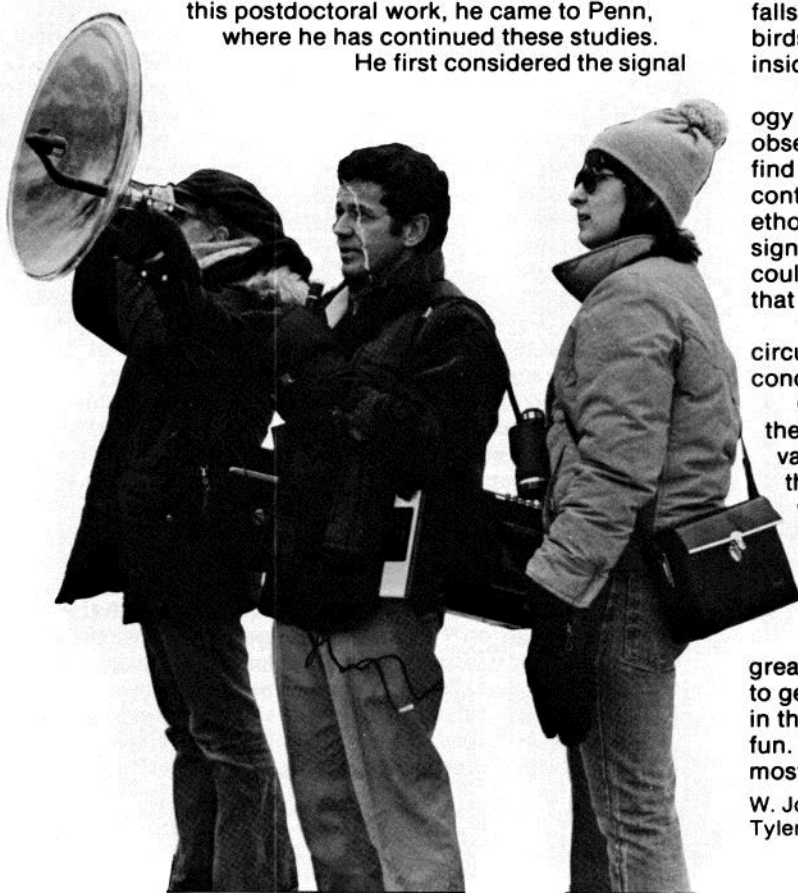
"Most scientists are fundamentally concerned with controlling events and limiting the amount of variation," says Dr. Smith. "That's a very difficult thing to manage when you're dealing with social behavior. If you put limits on it, it falls apart. The phenomenon goes away. Caging a couple of birds to study their interactions is like bringing a snowflake inside."

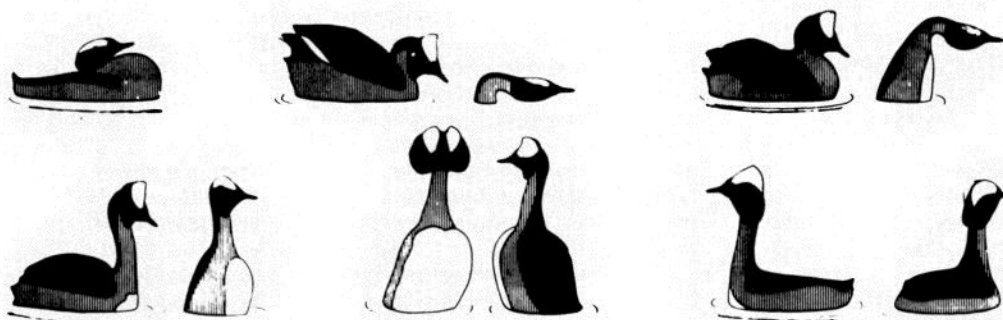
Thus, ethologists have come up with a special methodology to work within this enormous variety of conditions. They observe a phenomenon in nature, select it for study and then find natural settings in which most of the variables are controlled. To study a bird's high-pitched sound, the ethologists would find or develop a situation in which the signaling bird was out of sight and where the other birds could only hear his sound. They would also set up situations that would falsify their theory of the phenomenon.

"There is a lot going on in nature. You can select among circumstances to have your experiments run for you," concludes Dr. Smith.

Once ethologists learn what they can from one species, they compare that information with another species by varying just one of three sets of factors: the environment, the social structure or the evolutionary relationship. This way they can find out, for example, how much the environment affects the signaling pattern, how much the social structure (like monogamy or polygamy) affects the signaling pattern, or how much an animal's evolutionary lineage is responsible.

"It takes a rather different perspective, I guess, than a great deal of science, because the way in which one attempts to get control is very different, and the amount of uncertainty in this field is relatively high," observes Dr. Smith. "But it's fun. It is no less rigorous; certainly at least as challenging as most laboratory sciences. And I haven't got the personality to W. John Smith, Post-doctoral Fellow in Biology—bird-watching in Tyler Arboreum.





Behavior sequence in a courtship performance of horned grebes, beginning with display, then slowly rising to full height, moving together in a 'penguin dance performance', and finally swimming away.

sit around the laboratory. I'm a field person."

Since his book was published, John Smith has been studying three problems that will supply some missing links in the theories he set forth in his book. First he is looking at species that have a grammar for organizing vocal signals to learn what he can about grammar. He has already found out that you don't need nouns and verbs for a grammar. Indeed, certain birds have a fairly complicated grammar without these syntactical forms.

Another line of research deals with signal patterns that vary and grade into each other. Here he wants to find out how both the information and the physical form of the signals change. He is interested in the limits of information available by integrating signals, combining them and making signals simultaneously.

But probably the major focus of his future work is on social interactions, the system that the signals serve. He is setting up experiments year after year to study the nature of social life in a few species in order to learn about their relationships and the way signals support these relationships. In this work he takes his students to a weekly class at Tyler Arboretum in Delaware County, where they look at such birds as cardinals, mockingbirds and titmice. They watch to see how wintering groups form and define themselves, how chickadees throw out their young, how sparrows' head coloration varies by their ability to dominate; these observations will help W. John Smith understand how animals interact and use signals to do so.

The undergraduate program in the Biological Basis of Behavior developed in part because of the increasing numbers of students who over the past several years had designed individualized majors in this field. In the following articles, three of these early "psychobiology" majors discuss themselves and their academic experiences at Pennsylvania.

The Concept of Thirst Explored: S. Fluharty

I entered Pennsylvania as a pre-med, but after one semester I redirected my studies. My interest lies in research, not in a clinical practice, and more specifically, in research in physiological psychology. Acting upon that interest, I stayed on campus during January break to work on a volunteer basis in Biology Professor Alan Epstein's laboratory cleaning animal cages, and continued on during the spring term. I began reading books on ingestive behavior and asking questions of the graduate students and instructors working on the project. I also began writing to Dr. Epstein, who was away on leave that year, keeping him informed of progress in the lab and discussing my own ideas for future research. When Dr. Epstein returned, he asked me to stay and work for him on the project.

The project I began working on and from which my own research has sprung, is concerned with such physiological controls in mammals as feeding and drinking. Past research in this area concentrated on the brain on the assumption that the brain was the main mechanism controlling feeding behavior. Recent research, however, seems to indicate that

brain study is not as useful in understanding feeding as is hormonal study. Our work emphasizes hormonal controls and in particular, Angiotensin II. This is a hormone new to the study of ingestive behavior and is commonly called the "thirst hormone." Using rats as a model for humans, the main goal of the project is to discover how Angiotensin II fits into the concept of thirst.

We stimulated the brain with chemicals through a process called stereotactic surgery. Angiotensin II is injected into the rat's brain through tubes placed at very precise spots known to be related to feeding behavior. This technique provides a very accurate means of mapping, three-dimensionally on a rat's skull, where and what is being stimulated without actually having to go into the animal's brain. We are trying to learn more about the critical physiological events that motivate the animal to get up to eat or drink, and then what makes him stop.

Interrelated as all behavior is, the more information we have in one area the better we will understand another. By learning what is normal behavior—why and what controls feeding—we will gain a better understanding of what causes abnormal behavior. Treatment for human diseases such as obesity, kidney problems and diabetes could benefit from increased information such as our study might provide. Although we have made tremendous gains in our studies of rat ingestive behavior, we are still a long way from applying what we have learned to humans.

Behavior Behind Food Preferences: M. Levin

I entered the University of Pennsylvania expecting to major in physics. After I took a freshman seminar on "appetites and feeding" given by Elisabeth and Paul Rozin, my academic orientation changed and I then designed my own major in nutritional psychology. My biggest problem in setting up a major sequence was selecting my courses: there were nearly 30 courses available. The program I finally devised contained courses in anthropology, psychology, calculus, biology and chemistry. My situation was further complicated by my acceptance into the University Scholars program; as a result, my senior year was spent taking mostly graduate courses. I now regret rushing through and foregoing such courses as marketing research, classical studies, philosophy and literature. I didn't realize I had missed these courses until I got to graduate school.

A second problem with my major was its isolation. I think it is a good idea to cull from a lot of different disciplines; it helps eliminate the intradisciplinary chauvinism that has been common in the past. However, my major was individual-

are rejected by most young children and animals and are accepted and even depended upon by some adults to the extent that some people carry hot sauce with them wherever they go because they cannot eat unless they have chili added to their food. I was interested in how this change from rejection of a food to preference for it came about.

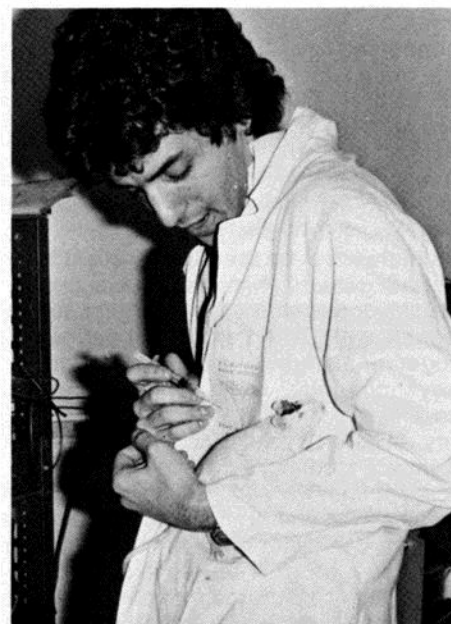
The effect of chili peppers on temperature regulation also interested me. Chili peppers are called "hot" and people respond to them the way they do to heat. I conducted one study in which I injected the major, active ingredient that makes chili peppers so hot into rats. The animals acted as if under an extreme heat condition. Under such a condition, rats begin "saliva spreading" to cool themselves, and they "prone extend," or spread themselves out, to increase the surface area exposed to the environment. If a lot of the chemical is injected within a short period of time, the animal loses all ability to regulate its body temperature; in essence, the mechanism being activated by the chemical is burned out. Although there are no major human diseases directly related to temperature, I believe it is critical to the study of



Steven Fluharty



Marcy Levin



Mitchell Blutt

ized and my courses scattered throughout the University. While my advisor, Paul Rozin, was always available, I did not have any contacts in the other departments with which I was involved. It would have been helpful to have had contacts in biology as well as in psychology, instead of encountering massive redtape every time I dealt with the administrative aspect of the program. What I missed even more was knowing other people in my major. Psychology majors know other psychology majors. The individualized nature of my major left me knowing very few fellow students involved in similar fields of study. I hope the new major program will eliminate many of these problems.

Although I had been working in the laboratory 10 to 15 hours a week during my sophomore and junior years, I did not begin doing my own research until my senior year.

My first study concerned the development of food preferences. I chose to work on chili peppers because they

any one system to learn as much as possible about all of them.

I spent two-and-a-half years studying temperature regulation both as an undergraduate and graduate student. My dissertation, however, is on quite a different topic, milk drinking and lactose intolerance. I first became interested in milk drinking because of Paul Rozin's course on appetites and aversions. I hadn't done the reading for a lecture on lactose intolerance. Dr. Rozin asked me, "Marcy, why do you think the enzyme (that breaks down milk sugar) goes away at the time of weaning?" Without any basis in fact, I answered, "Oh, it promotes weaning. Animals get sick after drinking milk and they don't want to nurse anymore." Dr. Rozin thought that was a very interesting idea. Since then, we have intermittently tested the hypothesis, and I now hope to develop it into a thesis.

A Look at Motivation through Electrical Stimulation: M. Blutt

During my freshman year, as I sat in Biology 102, I became fascinated by a lecture Norman Adler was giving on some of the neurophysiological aspects of behavior. Soon after, I responded to an ad in the Psychology Department for a laboratory assistant interested in gaining experience in research in the area of physiological psychology. The project, in electrical brain stimulation, seemed exciting and exotic and related to my own recently acquired interest in psychobiology. I volunteered and spent the first half of my sophomore year in the lab assisting a graduate student working for Randy Gallistel.

The project involved the implantation of electrodes in the brain of white, Norwegian rats. The desired placement of these electrodes is the medial forebrain bundles (MFB), a series of ascending and descending neural fibers running to and from an area of the brain known as the lateral hypothalamus. Past research had determined that these fibers are related to the so-called "pleasure center" of the brain and are involved with motivation, reward and perhaps emotion. The electrodes from the brain assembly are connected to a stimulator. This sends electrical currents to the brain which cause the nerve cells, or neurons, in that part of the brain to fire. The rat is thus stimulated. If the electrodes are properly placed, this stimulation seemingly rewards the animal; it rapidly learns to press a bar at the end of a runway to elicit the stimulation. The rat is, in essence, performing self-stimulating behavior. The project measured the quality of the reward by testing the frequency of bar presses, the animal's running speed in its quest to press the bar and certain general changes in the animal's behavior.

My internship on this project, along with a concurrent course with Dr. Adler, helped define my own interests. I put together an individualized major with Dr. Adler in the area of psychobiology, with a concentration on neurophysiology. I took several biology courses with Alan Epstein and continued my research in electrical brain stimulation with two independent studies. During my junior year, I took two physiological psychology seminars: one, with Jerre Levy, dealt with intelligence and brain evolution, and the other, with Eliot Stellar, dealt with brain functions and disorders.

Later, I took a course in perception with Edward Pugh. Dr. Adler encouraged me to integrate some courses from outside my immediate department to gain a more diverse understanding of behavior. I chose, among others, physical anthropology with Alan Mann, a philosophy course on Greek and Cartesian thought, a sociology course on deviant behavior, bio-statistics and a course in human sexuality. The number of courses related indirectly to my major is almost unlimited; I simply did not have time to take all the electives I would have liked.

I continued to work on the self-stimulation project with Dr. Gallistel. The research now included a neurotransmitter, which is a biochemical responsible for communication between nerve cells. Previous literature had indicated that at least one neurotransmitter, norendrenaline (or norepinephrine), was involved. Cholorpromazine (CPZ), a pharmacological agent, which blocks receptors for norendrenaline, was injected into the rats that had already been trained to self-stimulate. Our results confirmed that the blockage of norendrenaline receptors by CPZ weakened the self-stimulation behavior.

Investigators who had previously observed this result



Two undergraduates, Mark Boytim and Jeanne Flinn, implanting electrodes in the hypothalamus of a rat's brain.

had concluded that the self-stimulation ceased because the rat was no longer receiving the sensation of reward from the electrical stimulation. One possible argument against this conclusion is that fatigue causes the behavior change and not necessarily the absence of reward. Norendrenaline blockage is known to have depressant effects. It is very possible that the animal was still capable of receiving reward but was simply too sedated to actively seek it.

As a result of these considerations, I chose to introduce a second drug, metrazol. Metrazol is a general stimulant that probably acts without interfering with the norendrenaline blockage. My aim was to block the norendrenaline reception with CPZ, thus weakening the self-stimulation behavior. In addition, administering the metrazol would, I hoped, eliminate the fatigue effect of the CPZ and restore the animal's original level of activity without interfering with the norendrenaline blockage.

Unfortunately, my results were questionable. Preliminary results seemed to support the theory that norendrenaline is not necessary for the reward involved in self-stimulation; however, the statistical validity of these results is not yet complete. This research has been modified and presently is being continued in Dr. Gallistel's laboratory.

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