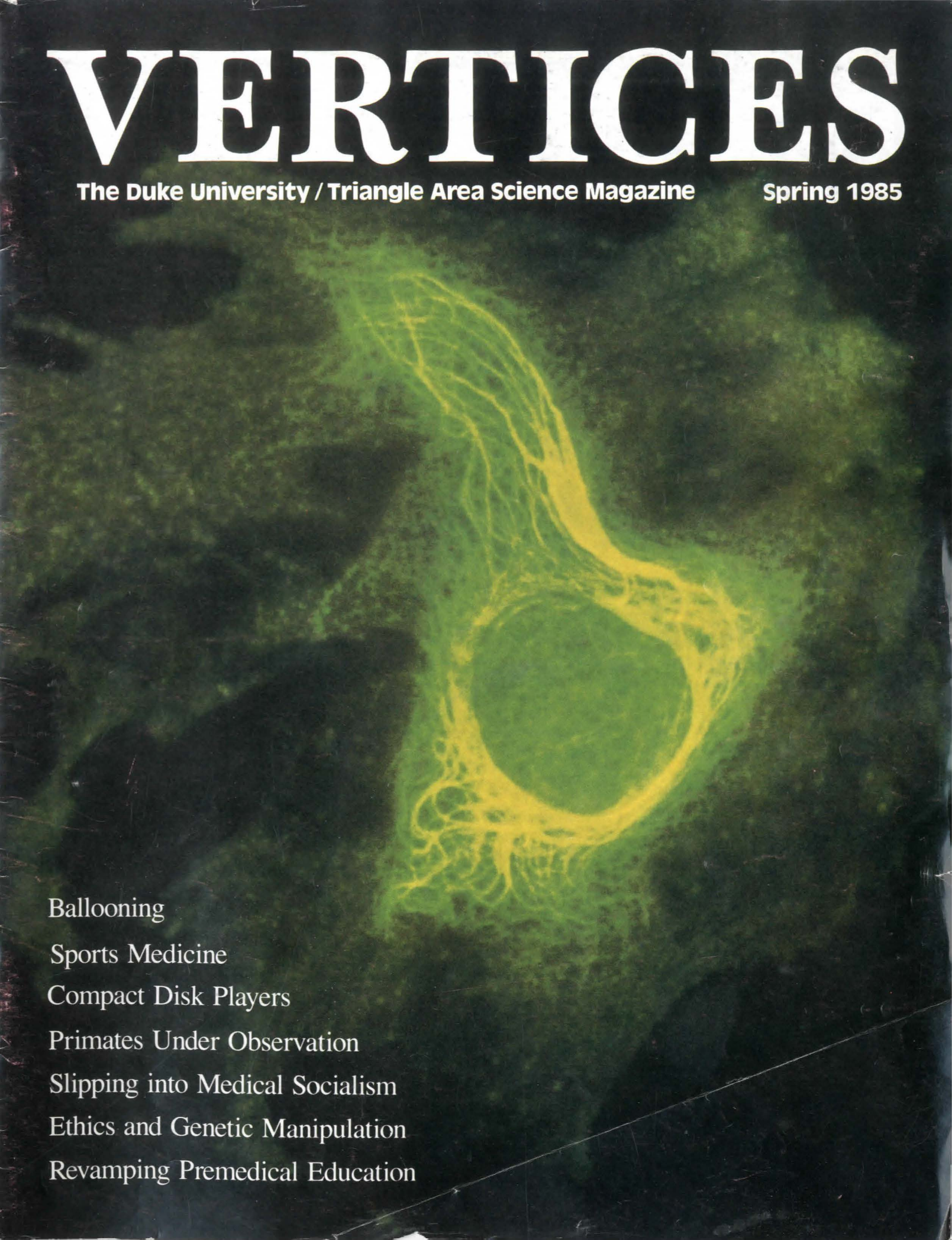
VERTICES

The Duke University / Triangle Area Science Magazine Spring 1985



Ballooning

Sports Medicine

Compact Disk Players

Primates Under Observation

Slipping into Medical Socialism

Ethics and Genetic Manipulation

Revamping Premedical Education

VERTICES

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from the editor

Every year on the same day that most people celebrate Christmas, my grandfather also celebrates his birthday. I remember how old he is during most of the year by subtracting two from the last two digits of the year; he has seen 83 years outside the womb this last Christmas. He is neither physically nor mentally debilitated, and so I listen to him when he talks because I want to, not because I'm polite or want to ease my conscience by letting the old guy ramble and acting like I'm listening. His brain is an amazing thing to pick.

He was born in a world that had czars, Prussia, and horse-drawn carriages. He has lived to see a communist Russia, a divided Germany, and space shuttles. Of course, the world's countries have always been changing, but this century's technological changes represented by the leap from carriages to shuttles have no comparable precedent in history. My grandfather lives in a world where a person must be careful not to wear his pacemaker near a microwave oven, or not to place floppy disks next to the phone with which he can dial directly to a house in a suburb of Tokyo, or not to provoke the Russians and cause us to blow up the world with pinpoint accuracy with ten times more nuclear weapons than necessary for the job.

Somehow my grandfather hasn't lost his marbles by living in a world that bears no resemblance to that of his youth. Even the vegetables he grows in his garden are different, being products of genetic manipulation or hybridization. He does often wonder out loud whether I will see as many changes as he has. If technology progresses at the same rate as it has for the last 83 years, I can't imagine the world in which I'll celebrate my eighty-third birthday. With advances in information transfer, for example, perhaps printed matter will become obsolete, and magazines like *VERTICES* may be art forms, as antediluvian as calligraphy is now.

Until that time comes, though, *VERTICES* should be an established and valuable form of information transfer. This is the second issue of *VERTICES*, in existence because of the dedication of students and moral support by administrators at Duke, as well as by the financial support of advertisers in the Triangle area. The purpose of our magazine is to bring our readers closer to an understanding of the technological advances that are changing the way we live. By understanding the implications of these advances, we will be better able to control the course of our human destiny.

Happy birthday, Grandpa.

R. Steven White

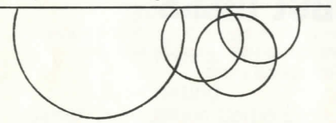
Ballooning

Dodds Meddock has settled in North Carolina after touching down in almost every continent

Steven White

Playboy paid Dodds Meddock and his company $45,000 for one which included a fitted galley, platinum-inlay crystal glasses, computerized telephone service, and a VCR. The $45,000 product can withstand maximum impact without breaking. Although the chain of Playboy Pubs it was designed to promote six years ago didn't fly, Playboy's hot air balloon has graced the skies over London, Atlantic City, and other major cities sporting Playboy Clubs.

Meddock, who in 1983 gave up the challenges of running the largest manufacturer of lighter-than-air craft in the world, leads a relatively calm existence as business manager of Duke's zoology department. Before 1983, though, he followed his avocation with a passion, having established Balloon Works with his partner, Tracy Barnes, in Statesville, North Carolina in 1972. Only months away from finishing a Ph.D. in philosophy at the University of Illinois, opportunity knocked and Meddock founded the company, along with Barnes. He and Barnes before had shared in a very lucrative part-time enterprise, hiring out their store-bought balloon and their ballooning skills for fairs, grand openings, and balloon races.



A sphere has the smallest surface to unit volume ratio of any container. However, in the case of balloons, stress on the envelop varies directly with the air pressure inside the balloon, and the fabric must be thick enough to withstand this stress. The necessary thickness varies with the square of the diameter of the balloon. Often, for high altitude balloons in which weight must be minimized, bundles of smaller balloons are used instead of a single large one. For example, while the total surface area of eight smaller balloons with the same total volume as a single one is twice that of the single balloon, the total stress is only one-fourth as great. Therefore, the total fabric weight of the eight balloons is half that of the single balloon.

Opposite: *Meddock and his balloon opened the British-American Festival at Duke in June 1984, shown here in front of the Duke chapel.*

Meddock and Barnes rode their company through some hard times initially, but they "built a better mousetrap," a specialized high-output burner for balloons, and it paid off. Until that time, balloons were filled with either gas, such as helium or hydrogen, or hot air. Unless passing through Zurzach, Switzerland where the hydrogen is free in a public park, or Augsburg, West Germany where a balloon-full costs about $20, you may have to pay about $250 for a fill-up. United States insurance companies wouldn't insure your balloon, however, since hydrogen is very flammable and visions of the Hindenburg at Lakehurst burn brightly in their memories. Gas balloons in the states use non-flammable helium. A fill-up, unless at a helium wellhead, costs nearly $2,500. Considering such balloons cost $45-50,000 and up, the helium cost is similar to paying one-ninth the price of a car for the gas to fill its tank.

Not only are gas balloons expensive to operate, but control of their altitude is limited. Opening a simple 18-inch valve in the top of the perfectly spherical balloon and allowing helium to escape causes the balloon to lose altitude. Throwing sandbag ballast overboard causes it to rise. At some point, the gas or sandbags run out and the flight is over.

Most hot air balloons use a burner to heat air to fill the balloon. By adding more hot air the balloon rises, while letting the air cool or releasing some hot air causes it to sink. Meddock and Barnes developed a high output burner which blasts propane-fired hot air into the balloon for two seconds every two minutes. These balloons can cost from $15-25,000, but the cost of the fuel to fill the three or four 10-gallon propane tanks is perhaps $10 per tank. At its peak, Balloon Works was manufacturing nearly 300 of its balloons per year.

The sun can be used to heat air and serve as a third, more environmentally ideal source of lift power. In the early 1970's Meddock and other members of the International Explorers Society, which includes Thor Heyerdahl, were contracted by the Peruvian government to build a low altitude balloon as part of its tourist trade development. Tourists had been renting taxis and driving around Peru's Atacoma desert to see the acre-size drawings on the Plains of Nazza, made famous in *Chariots of the Gods*. Tourists were unable to see the drawings in their entirety and were destroying the drawings with tire tracks. Meddock and the other members designed a solar-heated hot air balloon, the Icarus, which tourists could ride and see entire drawings without destroying them. The Peruvian government, being unstable, did not complete their desert drawing preservation plans. Though the Icarus flew several times, it is not currently being used and taxis are still driving over the drawings.

Meddock found that not only does North Carolina's weather suit ballooners' needs, but the state's long tradition of textile and fine furniture industries has made it a prime balloon manufacturing area. Although the 85 people who worked for the Balloon Works did not initially have the specific skills necessary to make the gas-holding envelop or the carriages, they did have a feel for quality craftsmanship. The envelop is a cut-and-sewn product, and for the more decorative balloons production can be quite an elaborate operation. For his chateau in France, Malcom Forbes contracted for a balloon depicting six Greek myths of flight on a background patterned after the Tem-

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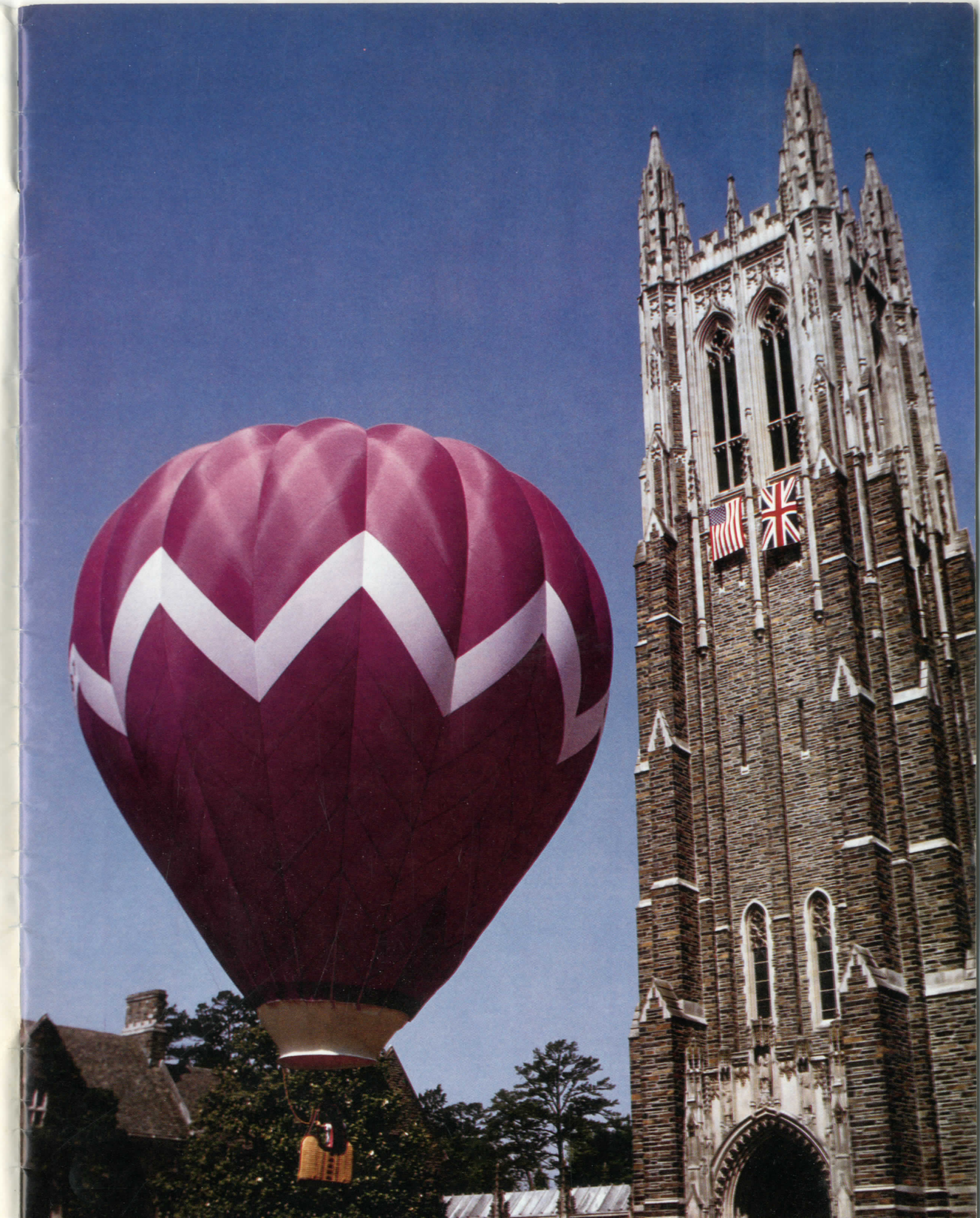


Primates

The Duke Primate Center serves as a refuge for endangered species

April Pulley

Snow covered the ground as I walked down the path between the cages. Parting the ice-covered bamboo, I looked through the foliage into the outdoor, wire cages. My gaze was met by the unflinching stare of a ring-tailed lemur munching on a banana. Short grey and white fur covered a primate body about the size of a raccoon. The animal's striped tail and black and white coloring made it look even more like a raccoon.

All the lemurs stayed above ground level. Because lemurs normally live in tropical rain forests, snow is probably a shocking sight. Like Floridians seeing their first snowfall, the lemurs did not know quite what to do.

Since those animals ignored me, I moved toward the next cage which contained white ruffed lemurs. Most were intelligently staying in the heated nesting box, but one leaped onto the cage wire in front of my face. I was not certain who was the observer and who was the observed. Keeping scientific objectivity is not easy when a human-like hand is thrust through cage bars toward you. The hand is the most startlingly human feature of the lemurs. Even though these animals at the Duke Primate Center are only distantly related to man, their hands, faces, and body expressions are very human.

Some nocturnal animals, such as tarsiers, eat mostly insects and lizards. Their cages are reminiscent of tropical rain forests, and as I stepped into one, the warm, moist air and the sound of crickets surrounded me. I watched a lizard crawl up a nearby wall. Suddenly, in the red light, I saw two huge yellow saucer eyes staring at me. As my eyes adjusted to the light, I realized that the large eyes were in a mouse-sized body. This primate seemed more closely related to mice than men.

Containing the world's largest collection of lemurs and other prosimians, the Duke Primate Center is dedicated to researching primates and establishing a breeding colony of prosimians. Seventy percent of the animals housed at the center are endangered species. Lemurs are prosimians found on the island of Madagascar, off the east coast of Africa. Other animals at the center, such as tarsiers, lorises, and galagos, are found in Asia, Africa, and some small Asian islands. Coming from tropical rain forests to North Carolina, these animals have had to make quite an adjustment.

> Keeping scientific objectivity isn't easy when a human-like hand is thrust through cage bars toward you.

Located in the Duke forest, the primate center is designed to give the animals the most natural habitat possible. Most of the animals live with family groups in spacious cages. A special grant from World Wildlife USA financed the construction of two natural habitat areas which enclose eleven acres of Duke forest. These areas enable the animals to roam quite freely. Consequently, scientists can carry out much more effective behavioral research. Because of successful breeding attempts, more grants and contributions are needed to provide large cages for some animals. Galagos, cat-size primates that look like small black bears, are presently housed in cages inside a trailer—they are waiting for space in larger cages.

The population of the primate center was built up by careful breeding of prosimians and capture from the wild. The center was begun at Yale in 1958 by John Buettner-Janusch, and when he transferred to Duke to teach in 1966 he brought the lemurs. The current director, Dr. Elwyn Simons, became chief in 1977.

Lemurs in the outdoor enclosures are fed bananas and other fruits. The animals also gather sweet gum leaves, crabapples, mushrooms, and clover. Poison ivy even suits their tastes. Researchers, such as Dr. Kenneth Glander and Jorg Ganzhorn, have studied how prosimians taste chemical toxins in leaves. In the outdoor habitat, lemurs have left toothmarks in poisonous toadstools, seeming to have tasted the toadstools and then left them alone. According to Simons, "This has great implications for conservation. If the animals are re-introduced into a place not quite like their normal habitat, they will not eat poisonous plants."

The primate center provides an excellent opportunity for graduate and undergraduate research projects. Pat Wright, a Ph.D. candidate, is studying the sound production and social system of the tarsier. Her project is one of the many research efforts at the center. Behavioral studies are conducted on many of the primates. Dr. Kay Izzard, for example, is studying reproduction in galagos. Dan Gebo, an anthropology graduate student, is studying foot structure in prosimians. By travelling to museums in Kenya and Germany, studying Duke's extensive fossil collection, and observing living prosimians, he is learning about primate locomotion. Another anthropology graduate student, Joe Macedonia, uses a movie camera to automatically sample one lemur species' behavior at certain time intervals.

Graduate students come from other countries to study the primates. Peter Kappeler, from the University of Tuebinger in Germany, is observing the reproductive behavior of *Lemur coronatus*. Only twenty of these endangered lemurs are in captivity in the world, and ten are at Duke's center. These ten are not reproducing very successfully, however, and Kappeler is studying them here and will return to Germany to study the successfully reproducing colony there. He hopes to discover why the Duke primates are not breeding well.

Undergraduate students also work at the primate center. The students in Glander's primate behavior class conduct research projects for a major portion of their grade. Susan Murray, a junior majoring in anthropology, and Bruce Higinbothom, a junior majoring in biology, are studying handedness in *Hapalemur griseus*. Some students opt for a semester-long independent study. David Meyers, a senior majoring in zoology, spent the fall studying the mating behavior of certain lemurs in the outdoor enclosure.

From left, Dr. Ross MacPhee, Elwyn Simons, and Prithijit Chatrath with a Paleopropithecus skeleton.

Dr. Elwyn Simons

Pictures of fossils, African statues, and straw depictions of lemurs decorate Dr. Elwyn Simons' office. As I waited to interview him, I wondered what a world famous paleontologist would look like. From behind a grey beard and under a cap, his sharp eyes peered. Immediately his energy struck me. A month ago he was in Egypt; tomorrow he will be galavanting off to South Africa for an anthropological conference celebrating Raymond Dart's discovery of the Tong Child skull sixty years ago.

Famous for his discovery of Aegyptopithecus in 1966, Simons leads yearly paleontological expeditions to the Fayum area of Egypt. He invented a special process to harvest the wealth of fossils from the desert sand. His expedition picks up the fossils which are sticking out of the sand. After collecting and cataloging them, he and the other researchers get out their brooms and sweep away the desert sand. Although sweeping up the desert may sound like a fruitless venture, it has uncovered significant Oligocene fossil finds. The Fayum is the only area that has fossils from the Oligocene, 35 million years ago. After sweeping up the sand and carrying it away in baskets, the researchers leave the job to the desert wind. During the rest of the year, when the researchers are away, the wind carves away the sand and exposes a new crop of fossils.

Dr. Peter Klopfer

A pregnant Lemur catta *at the Duke Primate Center.*

None of the research at the center hurts the animals. Only blood samples or other tests which do not harm the animal can be done. According to Dr. Jonathan Pollock, research at the primate center is "behavioral and physiological but not surgical. We engage in a variety of research directions, but with a general theme of finding out more about unknown animals, tracing evolutionary relationships and studying reproductive behavior."

Reproductive behavior is a primary concern because the center is trying to build a breeding colony of animals. They have had excellent success with most species. The first ruffed lemur birth in captivity in forty years took place at Duke's center, and the only slender loris colony in the U.S. is kept there, with seven lorises having been born in the last two years.

Simons explained the reasons for establishing a breeding colony of prosimians. In Madagascar and other parts of Africa, slash-and-burn agriculture destroys the tropical habitat of lemurs. "Wherever I've been in Madagascar, I can see they have been hacking down the forest. Every year in the world a piece of the land the size of France is destroyed. Ninety percent of the original forest is already destroyed."

Once a tropical rain forest is cut down, it is very difficult to restore. "The tragedy of slash-and-burn agriculture is that when you do this and then grow crops for a while, the fertility is depleted and subsistence farmers must move on," Simons said. Some reforestation has been attempted in Madagascar; however, the trees which have been used are not native types which can be used by the birds, mammals, and insects. According to Simons, "Once primary forest is cut down, it can't be brought back without generations of work."

> "The people who want to return animals to the wild are turning them in the wrong direction. They need to be rescued to captivity."

"It's not only the problem of saving lemurs," he added. "The forest is also a resource for the people." The problem seems to lie in education and resource management. If the land is denuded, the erosion and loss of soil fertility could create a barren land. "The forests of Ethiopia were once fertile like those of Madagascar. But how do you tell people that are starving not to hunt an animal or cut the forest because of conservation?"

How, then, can the lemurs, which come only from the island of Madagascar, be saved? According to Simons, the answer lies in captive conservation, in which a captive breeding colony is established in order to preserve the species. "Father David's deer," he cites, "has survived only in captivity for the last 200 years. But some people are stuck back in the nineteenth century. They do not like to see the animals confined—but it's not a primordial world. Even the last haunts of the mountain gorillas are constantly being assailed by poachers. The people who want to return animals from captivity to the wild are turning the animals in the wrong direction. They need to be rescued to captivity."

On the optimistic side, most prosimians are fairly easy to breed in captivity. Because they are small, it is fairly inexpensive to feed them and put them in quite large cages. As Simons admits, "Captive conservation is a pitifully small effort, but manageable."

He emphasized that libraries conserve rare books because of the knowledge they contain. "The animals and plants of the tropical forests contain knowledge that we may need." Simons explained that many disease-controlling substances have been found in rare plants. "If the forests had been destroyed first, that bit of knowledge would have been lost."

"Since man is a social animal himself, it's interesting to study other social animals than ourselves. That's part of the endless fascination of the animal world." Simons calls the work at the primate center part of "the growing interest in animal rights—the ultimate right of a species not to be driven extinct."

Education

How can physicians learn the humanistic side of health care?

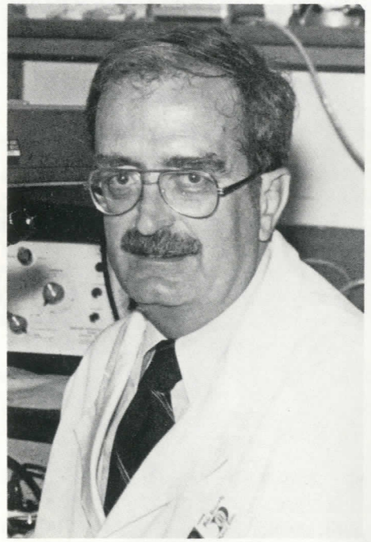
Dr. Wendell Rosse

In the United States the education of the physician is divided by current convention into two parts: "premedical," undergraduate experience and professional medical school training. These parts have been separated in such a way that admission to a medical school is dependent upon successful completion of a number of premedical courses. The curriculum of the medical school part is, within limits, uniform from school to school. There is no consensus, however, about the desirable premedical curriculum; both its objective and the curriculum required to achieve that objective are the subject of controversy.

There is, in general, a prescribed set of premedical courses which are prerequisites to admission to medical school. These usually encompass biology, inorganic chemistry, organic chemistry, and physics. Occasionally a course in higher methematics, usually calculus, is required, and sometimes, though rarely, a foreign language. Although the prescribed science courses appear to be relevant to medical education, in their actual content, they often are not. The biology course is generally concerned with the details of lower, often invertebrate, biology. The chemistry courses are geared more to the chemical engineer than to the student of human biology.

The remainder of the undergraduate education of the student of medicine is largely left up to the student himself. (I use the masculine pronouns for convenience, realizing that one-third of all medical students are women.) In most instances, he must select a major in which he must take a predominant number of courses, and most choose a major in science. They do this for several reasons. In the first place, the prescribed premedical courses usually may be used in fulfilling the requirements of the major. Second, many students believe that good grades in science courses improve their chances of admission to medical school. Others think that such courses will put them "one leg up" once they are in medical school. Finally, of course, others have a sincere interest in science they wish to pursue.

Is this sort of premedical curriculum the best education for preparation for being a physician? Because of the many prescribed and recommended courses, many premedical students are unable to or discouraged from taking a wide variety of other courses. Usually they may take the minimal requirements in the humanities, and seldom take significant courses in history, social sciences, and least of all, philosophy. In sum, they do not get a liberal education.



Dr. Wendell Rosse, Chief of Hemotology/ Oncology at the Duke Medical Center.

The question is: Is a liberal education of any use to the student of medicine? And, if it is, how can it be attained within the prescribed requirements for medical school admission?

What is a "liberal education?" A liberal education is one which ranges as widely as possible in terms of subject matter. It comprehends the breadth and variety of human knowledge. The nature of man, his works, his world, and his place in that world are explored. It need not have a practical end other than the education of the student; knowledge is its own end.

Many educators feel that a liberal education should be the primary objective of all undergraduate education because it prepares the student to appreciate the world he lives in. Hutchins of the University of Chicago, Stringfellow of St. John's College, and many others advocate a liberal education as the primary curriculum for all college students. In fact, most colleges require that subjects in each of the major areas (humanities, sciences, social sciences) must be taken. However, these courses are often of such narrow scope that they fail to give the student a true appreciation of a liberal education. For instance, the course designated to fulfill a history requirement may be "Russia: 1905-1919" which is certainly interesting but inadequate for giving the student a sense of the panoply of human history.

They seldom take significant courses in history, social sciences, and, least of all, philosophy. In sum, they do not get a liberal education.

If college is the end of an education that must prepare the student in some practical way, such as electrical engineering or the teaching of history, then the concept and practice of the major may have some validity, even though its fulfillment may erode the time given to a liberal education. However, college is not the end of education for the student of medicine. Medical school provides the practical education needed to practice medicine. Thus, the premedical student, perhaps more than other students, has the opportunity to use his undergraduate years for a liberal education.

Furthermore, it is particularly important for the student of medicine to get a liberal education. His entire professional career will center of dealing with people and their problems. He will do this much better if he has an understanding and appreciation of the nature of man and his world. Knowledge and appreciation of the works of man makes each human more cherished and valuable. The physician should know the elements of the organization of society in order to be able to understand his role and the role of his patients in that society. With knowledge of the nature of philosophy, the physician would be better prepared to deal with the ethical and philosophical decisions so common in the practice of medicine. Thus, for practical reasons, the physician should have a liberal education.

One element of understanding the medical problem of a patient is understanding his history—what has happened to the patient up to the time he sees the physician. Although few physicians realize it, the precess of constructing the history of a patient is the same as that of writing of history of nations and societies. The historian gathers data from a number of sources, evaluates and collates that data, and eventually constructs an hypothesis to explain a given event. The physician should do the same thing in his approach to the history of each patient. Often the patient is the main source of data, so much so that physicians often say "the patient was a poor historian" to explain why they, the physicians (the real "historians"), were unable to construct a reasonable view of the patient's past. Data from a number of sources (charts, family members, other physicians, etc.) must be used to construct a history that, in the end, includes an hypothesis about what it is that has made the patient as he is. To do this, the physician draws not from his medical school training, but from the skills and knowledge he gained in the liberal part of his education.

The physician must often express himself in writing and in speech, as when writing the patient's history or giving a more formal presentation about a patient or scientific matters. He certainly is not trained to do this in medical school; it is the role of the liberal education to teach the student an appreciation

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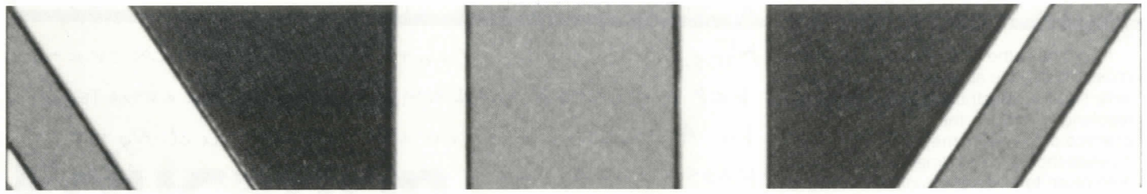


Socialized systems

The health care systems in Britain and the United States may not be as different as some people would like

Laurie Burton

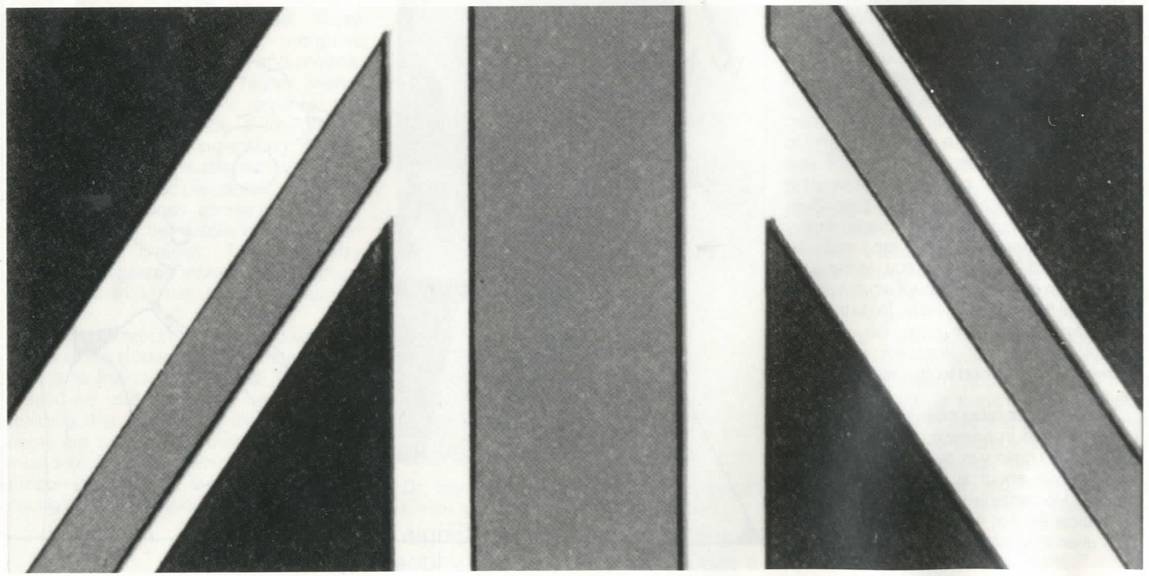
The problem is the same everywhere: how to deliver health care to millions of people. The solutions vary from country to country. The health care systems of Great Britain and the United States are often compared, usually starting with the assumption that Britain has socialized medicine and the U.S. does not. But the fact is that both countries are using socialized medicine, and using it widely.

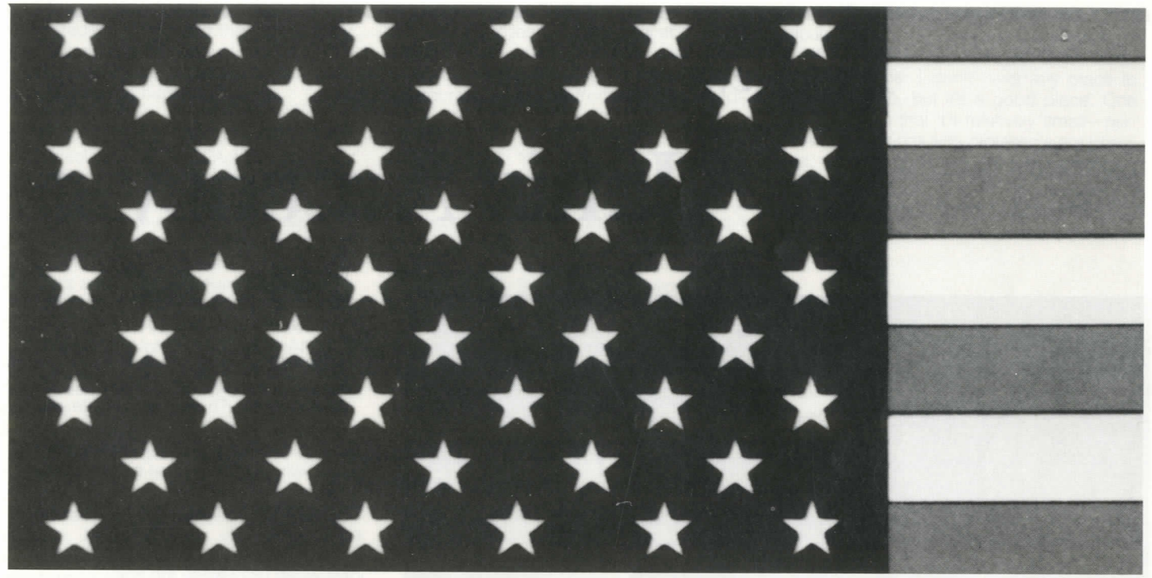
Recent figures say that U.S. per capita health expenditures exceed $1,400 per year. If health care costs seem exhorbitant already, they are predicted to continue rising unless some major changes in health care delivery are made. To avoid escalating costs, more Americans may start to take advantage of alternate types of health care, Health Maintenance Organizations (HMO's) in particular. Also, as health care costs become less affordable for a greater number of citizens, the federal government may take on a larger role in financing health care and may use diagnostic-related groupings to control how much doctors and hospitals can charge patients. In addition, health care may have to be rationed to some extent in this country to get medical costs under control, a practice the British have been using for decades.

What sort of health care is available for British citizens? First and foremost is the British National Health Service, funded by tax revenues and of which every citizen is a member. The link between the NHS and the public is the general practitioner (GP) who is on salary and is assigned to a district. Most citizens go to the GP nearest to them, but may choose any GP within their district.

A British citizen sees his GP for whatever ailment he has, whether it be a sore throat, backache, anxiety attack, or yearly physical. If the GP is unable to diagnose or treat the problem he refers the patient to a specialist. While the GP is very accessible, it may take months before a specialist is able to see a patient. Urgent cases are seen immediately, but to be considered urgent the patient's condition must be life-threatening.

Under the NHS no one is denied care for financial reasons, nor does anyone receive preference or better quality care because of





The doctor wishes to keep his patients healthy since he is on salary, and the healthier everyone is, the less work he has to do to earn it.

financial status. For college students, children, senior citizens, and needy persons, all health care under the NHS is free, including visits to the doctor and dentist, medication, surgery, and hospitalization. For the working population, doctor's visits and surgery are free, but there are small fees for medication and dental work.

Not every British citizen relies fully on the NHS for health care needs. Some may opt for private medical care, hospitals, or health insurance. The main impetus for choosing the private route seems to be to obtain prompt care. Since the NHS operates on a limited budget, patients not requiring urgent care often must wait for treatment or surgery. There are reports of patients waiting six years to be admitted to a hospital for elective surgery. As British economist Michael Lee describes, the difference between private medicine and NHS medicine is that "the private patient pays to avoid waiting; the NHS patient waits to avoid paying."

Socialized medicine is defined as "medical and hospital services for the members of a class or population, administered by an organized group and paid for from funds obtained usually by assessments, philanthropy, or taxation." The NHS would certainly fall under this definition, but so would two American health services administered by the federal government, the IHS and OCHAMPUS. The IHS, or Indian Health Service, provides care for American Indians and Alaska natives. The Office for the Civilian Health and Medical Program of the Uniformed Services provides care for families of those in the armed forces. Both are financed by federal tax revenues and operate essentially like the NHS but for those specific groups only.

Health maintenance organizations are private health services and are fairly recent additions to American health care. An HMO member pays a set fee in advance in return for various unlimited medical services, including visits to a physician. Since financial barriers to receiving care are removed, there is an emphasis on prevention. Patients are likely to visit their doctor immediately after suspecting something is wrong because they are not charged for the visits. It is completely in the wishes of the doctor to keep his patients healthy since he is on salary, and the healthier everyone is, the less work he has to do to earn it.

Reports have been made of HMO's serving their subscribers more cheaply and effectively than matched fee-for-service populations, and for such reasons, HMO's are growing in popularity. Only weeks ago a California-based HMO opened offices in Raleigh, North Carolina, and the firm has plans to come to Durham in a matter of months.

Despite HMO's, the IHS, and OCHAMPUS, most of the health care delivery in the U.S. is fee-for-service. Few people can afford to pay such fees directly out of their pockets. One of the major parties footing the bill for health care expenses is the federal government, through its Medicare and Medicaid programs. Medicare enables people 65 and older to be insured for medical and hospital services for a monthly premium of $15.50. Medicaid, on the other hand, subsidizes the medical expenses of needy people; a doctors visit, for example, would cost the patient only two dollars.

How much are Americans paying for medical care? Eleven percent of the U.S. gross national product currently goes toward health care expenses. Dr. William Schwartz, an expert on health policy issues, predicts that health care costs can be expected to continue to escalate primarily because of technological innovations. New diagnostic tools, therapeutic devices, and surgical procedures improve the quality and length of life, but often replace cheaper methods of treatment.

With health care costs continually increasing, this country has two alternatives. One is to leave the present system as it is and accept ever-rising costs. In the words of Schwartz, "It is not engraved in stone that we as a society can't continue to increase the fraction of gross national product invested in health care from the current level to 15 or 20 percent." The other alternative is to attempt to control rising costs, and an effective way to do so is to ration health care.

In Great Britain, where the NHS has rationed health care since its

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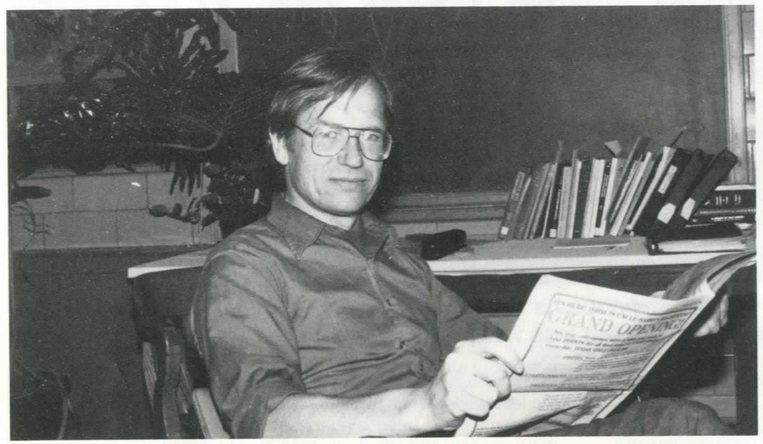
Why are malpractice suits so uncommon in Britain, where health care is rationed and patients sometimes denied potentially beneficial therapy?

Interview:

Janis Antonovics



Dr. Janis Antonovics

Terry Habacker

Along with more than 100 other students, many with their noses pointed towards medical school, I took Genetics 180 last fall. Dr. Janis Antonovics, one of the two instructors for the course, would occassionally set aside his lecture notes and for a few moments follow a tangent on such topics as Dukies, science, and research. He seemed to have definite opinions about education, and the pursuit of a science education in particular. One reason that I was so excited about being involved in Vertices *was that I felt that many students majoring in the sciences were missing a multitude of opportunities. Having never interviewed anyone before, for example, it took me months to find the nerve to approach Dr. Antonovics. What follows is a summary of our discussion.*

VERTICES: What is your role at Duke?

Antonovics: I'm basically an ecological geneticist. In other words, I'm interested in the impact of genetics on ecological processes. The area of research that I cover is looking at mechanisms of evolutionary change in populations and examining how genetic differences amongst individuals influence their ecological success.

My current research is based on a very simple question: Why do organisms produce variable progeny? There are tremendous costs to variation, thus there must be advantages which outweigh these costs. Males, for instance, are created for variability. Females which produced only females would double their fecundity. It is rather teleological to explain variability by saying it is a phenomenon which is desirable because it results in evolution.

VERTICES: How can you answer this question?

Antonovics: Well, what we're doing is generating variable progeny from seeds of plants and generating uniform progeny through cloning. Then, we put them out in nature.

VERTICES: How long will this research take? two years?

Antonovics: Each experiment takes two years, or perhaps four considering preparation, etc. There are organisms which reproduce faster, but you can't work with animals. Cloning is much harder and if you put them out in the field . . .

VERTICES: . . . you lose them. So far, what have your studies demonstrated?

Antonovics: That there is quite an advantage to variability. Why? We're not quite sure. There is an avoidance of predatism, essentially like an immune system to pathogens.

VERTICES: Have others studied this question?

Antonovics: I think I'm not being immodest when I say we're the first.

VERTICES: The Genetics Program itself is unique, isn't it?

Antonovics: The program is an interdisciplinary conglomerate—it incorporates people from the medical center as well as those of the school of Arts and Sciences. Membership is by vote. It is essentially a group of people who identify themselves as geneticists, held together by seminars, research interactions, and grants. Our main thrust has been toward the graduate education in genetics, but we're hoping to attract undergrads who may be interested in genetics but are not mathematically inclined. We're reviewing the curriculum; people are interested in genetics and its implications, but not necessarily the nitty-gritty.

VERTICES: It seems that if students took an intro course earlier in their careers, they could take upper-level genetics. You've mentioned this before in a more general sense with reference to the typical pre-med route.

Antonovics: I suppose that one criticism of the pre-med route is that students often believe they must take the required, broad, basic science course immediately. Another criticism is that students don't consider other options—at least, not in a positive sense. It's a shame if students take their education at Duke as goal-oriented. Many pre-meds are narrowing their opportunities.

VERTICES: This brings up other issues . . .

Antonovics: Yes, because they attempt to take the prerequisites within the first two years, they don't develop other interests. It would be to their advantage to specialize in something other than medicine.

VERTICES: How?

Antonovics: Seek out a professor and work on an independent study— basic research or a historical study. It's a shame when students beginning their senior year have not yet had a 200-level course.

VERTICES: The pre-med is too often geared toward a high GPA.

Antonovics: Yes, and we who judge records—for scholarships, for instance—are not interested in a high GPA if all a student's courses are 100-level or below. It is often these students who are upset about the lack of intellectual atmosphere. These students have a mediocre attitude toward Duke, and it's not completely the fault of Duke. It's a problem of course selection.

VERTICES: Do you encourage focusing on one subject as a prospective career?

Antonovics: Not to the extreme. I think being career-oriented is a mistake. Any undergraduate who comes to Duke is not going tobe on the streets after four years. Being overly tense is foolish.

VERTICES: Regarding research, you've mentioned that students neglect the plant kingdom.

Antonovics: Yes, the botanical side of research. Perhaps, more importantly, the agricultural aspects of research. There's a whole world out there which the incoming freshmen who watches, uh, what are those t.v. programs?

VERTICES: St. Elsewhere, and . . .

Antonovics: There are so many doctor programs, you never see human disasters of the farm. I suppose that's too quaint. Unfortunately, it seems to be a forgotten area, and with N.C. State so close, there is opportunity to learn a great deal about agriculture as an undergrad or to consider a master's program. I don't think we need to discourage students from entering medicine; you can't deny that it's an interesting profession.

VERTICES: Yes, but it isn't *the* profession.

Antonovics: Exactly! My mother was a dentist and she wanted me to be a dentist. I thought it would be boring to study one organism.

VERTICES: So, what would you advise incoming freshmen who are interested in science to do?

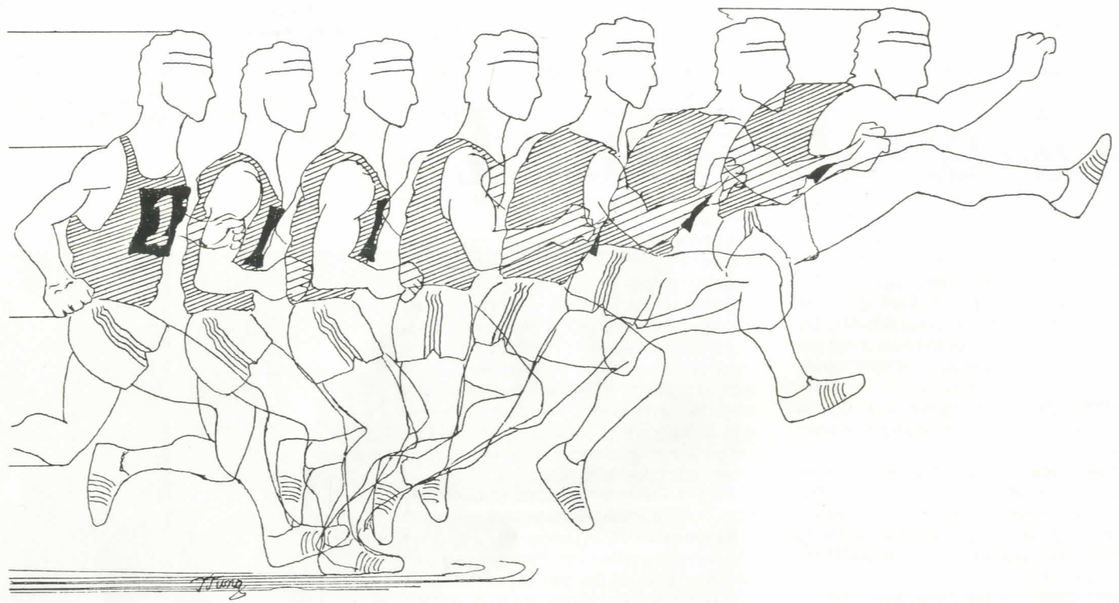
Antonovics: Take the science courses which he finds interesting, but take courses in other areas as well. He should become involved in his major, become acquainted with professors. Consider medicine, but consider also basic sciences and agricultural research or the integration of public policy and the sciences. One can pursue research or go into industry.

VERTICES: Why do some students shy from research other than medical research?

Antonovics: I don't know why they don't consider the alternatives. Perhaps it's a lack of imagination on the part of parents. A lot of it is just pop-sociology. It's true—there's nothing so desperate as when you're ill. Graduate school is difficult, there are no salary guarantees. It's almost impossible to predict the next "hot topic," although there's growing interest in plants at the molecular level.

VERTICES: How do you feel about Duke.

Antonovics: I don't have any place to compare it to, but it's a good place. One advantage is that it's relatively small—personal interactions with professors are possible, even though the system does not promote them.



Body rebuilding

High-tech rehabilitation is bringing athletes back into action

Tom Romary

Orthopedic surgeon Stan James was not the only teary-eyed spectator of Joan Benoit's victory in the women's Olympic marathon last summer. With James, sports fans across America rejoiced in the triumph of a remarkable dedicated athlete. Yet, James felt especially proud of Benoit's accomplishment. Without the doctor's victory in the operating room just 18 days befor the Olympic trials, Benoit would never have made the squad.

The new technology in sports medicine was as much a factor in her gold run as her own determination. Call it a miracle? Perhaps, but as modern sports medicine and orthopedic science accelerate into the 1990's, the scene will become less miraculous and more common.

The driving force behind the recent advances in orthopedics has been the athletes themselves. The need for expedient repair and recovery of injured joints has escalated the research into the biomechanics of human joints, as well as the development of new operative and rehabilitation techniques. The arthroscopic surgery used to remove a one-inch strand of cartilage in Benoit's knee, for example, has only been available since the late 1970's. The arthroscope, a microscope-like viewing device, enables surgeons to accurately diagnose damage to an injured knee without opening the joint. Today, approximately 90 percent of all knee surgery in the U.S. involves the use of the arthroscope. As new methods and devices are developed, athletes whose careers might have been ruined a decade ago are now likely to be back on the playing field in as little as a week's time.

At Duke University's Sports Medicine Orthopedic Rehabilitation Center (DUSMOR), injured triangle-area athletes are the fortunate recipients of such high-tech rehabilitation. Functioning primarily as a post-operative rehabilitation facility, DUSMOR personel work closely with Duke Medical Center's orthopedics division. "We use an accelerated method to rehabilitate our athletes," says Debbie Harned, physical therapist at DUSMOR. "The main idea is to get the athlete back into action before such adverse effects as muscle atrophy becomes a factor."

Today, most orthopedic specialists stress the importance of motion-aided healing. "In the past, patients were allowed to sit back and lick their wounds," says Ross Rich, Physician Assistant at DUSMOR. "Now we realize the importance of mobilizing the injured joint as soon as possible." According to William Glancy, Jr., of the University of Wisconsin's sports medicine division, "more detailed knowledge of the adverse changes that occur in muscle has led to the concept of early functional rehabilitation in order to limit the deleterious effect that immobilization has on muscle, ligament, and articular cartilage." Muscle atrophy is one common effect of such immobilization. There are cases, of course, such as after major ligament repair in the knee, where it is impossible to mobilize immediately. "In such cases, other aids, such as electrical muscle stimulation, can be implemented," according to Rich.

The techniques and machines used at the center are described as "state-of-the-art." Indeed, the entire therapy program developed by Harned and Rich is just that. "Our staff offers an individualized, sport-specific or job-specific program with full attention to medical considerations," says Rich. "This is a long-term program which seeks to restore the patient to the previous level of activity."

The attention given to the center's patients is especially individualized. Patients observe their progress towards recovery via the quantitative records kept on their daily performances. Harned suggests that the awareness of one's progress makes the rehabilitation process much easier and, in many cases, more effective. Terri LaSalle, a student assistant to Harned and Rich, has also observed that an encouraging voice to patients is an integral part of successful physical therapy. According to Dr. Steven Scott of the Mayo Clinic, "treatment of the psychological problems of the injured athlete is one of the most important consideration in rehabilitation. The psychological preparation of an athlete to return to a sporting event is as important as the retraining of physical skills."

The therapeutic machines used at the center reflect the recent accomplishments in modern sports medicine research. The Ariel computerized leg exerciser, for example, enables patients with injured or surgically repaired knee to view their progress grapically on a video monitor. The machine looks like a typical leg-extension exerciser except that ther are no weights and there is a computer terminal aside of it. It can be programmed to operate on the isokinetic principle in which the lever arm will move at a constatn pre-programmed velocity and no faster. The leg exerts force on the lever arm throughout the range of motion, and generates maximum torque possible at the preset velocity. In other words, the lever arm will push back with a force matching that applied to it by the leg as long as the leg moves the lever arm at the preset velocity.

The machine's functions vary from measuring the average range of motion obtained in a series of repetitions to measuring the relative strengths of the legs' quadriceps and hamstrings, all of which are displayed graphically. The patient may be asked to exert a certain level of output per repetition or to maintain a fixed level of output per repetition for as many repetitions as possible (a measure of fatigue). Thus, patients with surgically repaired knee may improve their range of motion, increase muscle strength, reduce muscle atrophy, and improve endurance depending on which function is used.

Other therapeutic devices used at DUSMOR include a tilt board platform used to increase the ankle's rotational flexibility. The biomechanical ankle disk, manufactured by Biomedical Proportionates, Inc., helps increase the strength of the ankle muscles and aids in redeveloping coordination. The elliptical platform rests on a ball and rotates when one foot is set on it. The device is designed such that the malleolar axis of the ankle, the axis about which the ankle rotates, is aligned with the rocking rotation center of the platform. Patients with ankle injuries often perform the exercise on the disk with their eyes closed in order to further develop their coordination during therapy.

> "In the past, injured athletes were allowed to sit back and lick their wounds."

For injuries receiving post-operative knee rehabilitation, such as for a tibial plateau fracture, a continuous passive motion device may be implemented. The device repetitively extends and flexes the knee throughout a prescribed range of motion. It operates very slowly and may be used while the patient is asleep. Continuous passive motion is usually used soon after injury and subsequent surgery once the athlete has obtained a reasonable level of comfort. According to studies done at the Mayo Clinic, early joint movement aids in healing of tendons and ligaments and prevents contractures when it is done in a controlled and nonstressful manner. Such passive motion exercising of the joint is often followed by static or isometric strengthening. "The amount of stretching needed to improve the range of motion is related to the duration of the stretch, the temperature of the tissue, and the forces applied," according to Scott. The use of the continuous passive motion machine is in accordance with the DUSMOR staff's view of sports injury rehabilitation technique: begin exercise as soon as possible.

As soon as the isometric and passive exercising is complete, the athlete may proceed to more dynamic forms of exercise, such as on the computerized exerciser to build strength and endurance. The final approach to full sport-specific recovery aims at regaining and refining coordination skills.

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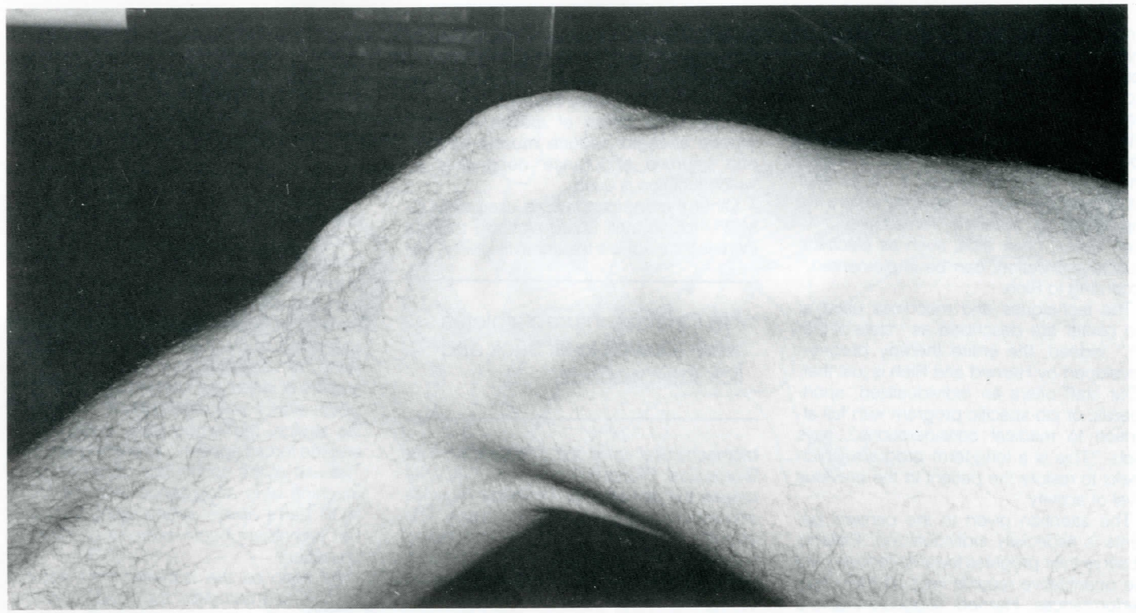

Biomechanics

The often-injured knee is perhaps the most complicated joint in an athlete's body

Tom Romary

More than 400 sports medicine clinics exist in the U.S. today, and many, like DUSMOR, conduct experimental research into rehabilitation methods. Most of the research in sports medicine focuses on the biomechanics of the knee joint. It is the most commonly injured joint in sports since so many sports present hazards to the knee.

Specifically, injury to the cruciate ligaments of the knee, both anterior and posterior, presents the most controversial and complex problem to surgeons and therapists alike. There is no standard to dictate when an operation is necessary and which surgical technique should be used. There is a trend, however, towards establishing more concrete clinical test results to enable the clinician to make more accurate diagnoses, according to William Clancy, Jr., of the University of Wisconsin sports medicine division. The development of sophisticated testing devices by bioengineers has made available more detailed knowledge of the function of the muscle cells after injury and surgery and after rehabilitation. Together with a better understanding of the multidirectional laxity and instability that may occur after knee ligament injury, "we have added significantly to our knowledge of the knee joint, increased our clinical acumen, and facilitated our surgical treatment and rehabilitation," says Clancy.

The cruciate ligaments are considered by most orthopedic physicians to be the main stabilizers of the knee joint. Other static ligaments and the posterior capsule are all extra-articular (outside the knee cavity) stabilizers, according to Dr. Simonet and Simm of the Mayo clinic. A major dynamic stabilizer in the joint is the quadriceps muscle which is attached via the patellar (kneecap) tendon. The quadriceps work with the hamstrings in providing dynamic stability.

The roles that the anterior (ACL) and posterior (PCL) cruciate ligaments play in functional knee stability are many and varied. The ACL acts as the primary restraint to anterior displacement of the tibia on the femur, providing 86 percent of the total resisting force to such partial dislocation. The remaining 14 percent of this resistive force is supplied by the surrounding extra-articular stabilizers. The PCL, whose tensile strength is twice that of the anterior cruciate, provides 95 percent of the total force resisting posterior displacement of the tibia.

The ACL is responsible for the prevention of hyperextension of the knee. Only after the ACL has been severed or severely weakened does the PCL check against hyperextension. The ACL acts also as a secondary rotary stabilizer of the joint; a deficient ACL thus could result in increases internal rotation of the tibia during both flexion and extension of the knee joint.

The key to understanding rotational instability, however, is found in the PCL. "When the PCL is intact," explains Simonet, "rotational instability occurs around the posterior cruciate axis; when the PCL is injured, straight instabilities in one plane occur."

The anterior cruciate ligament runs from the posterior part of the knee to the tibia in front. It is composed of three bundles of fiber: the antermodial, the intermediate, and the posterolateral. "Each of the bundles has a specific function contributing to the stability of the knee," explain Drs. Rovere and Adair of Wake Forest's sports medicine unit. The anteromedial grouping primarily supplies anterolateral stability. Severing this bundle, which is taut in flexion and extension, will result in anterior dislocation of the tibia. The posterolateral bundle provides posterolateral stability, and its loss is difficult to assess clinically, according to the Wake doctors. As a whole, the ACL decreases in tension from full extension to large flexion angles, although there may be some increase in tension at the greatest degree of flexion. Biomechanically, the ACL will elongate by 57 percent of its resting length before ultimately failing. Large amounts of plastic deformation will have occured before this, however.

The posterior cruciate ligament, which runs from the front to the posterior section of the knee, consists of anterolateral and posteromedial bundles. As a whole, the ligament increases in tension with inward rotations. Unlike the ACL, "the posterior cruciate receives no protection from the collateral ligaments," say Munich doctors Worth and Jager, against posterior dislocation of the tibia.

While injury of the PCL is less common than that of the ACL in sports, its deficiency results in a feeling of instability, especially when making sharp turns, especially common in tennis and soccer. Acl ruptures are very common in sports such as skiing. Often, the high stiffness of modern ski boots cause the tibia to be pushed forward or the knee hyperextended when skiers land offbalance from a jump or mogul. The result is an anterior cruciate tear.

The treatment of injured cruciate ligaments has improved dramatically in the last decade. Arthroscopy, for example, enables doctors to determine the precise cause of knee instability or pain without opening the entire knee. Ideal for the athlete since it provides quick and accurate diagnosis of intra-articular (within the knee cavity) damage, arthroscopy does have limitations. It is rarely used to perform repair work in the knee, and simply cannot be used to reconstruct ligaments. However, because it does provide a quick diagnosis, reconstructive surgery, if necessary, can be performed immediately after injury and rehabilitation begun soon after this.

The decision to surgically repair a ruptured cruciate is a major one. For the nonathlete, the patient's age and daily activity must be considered to determine if such a major reconstruction is necessary. For most athletes, however, surgery is chosen if instability in the knee exists. As Clancy explains, "the reports that those with severe functional instability have a high probability of developing significant early traumatic arthritis have led to a more aggressive surgical approach." Most orthopedic physicians feel that surgery is needed to correct severe instability. In PCL injuries, researchers have realized that severe degenerative disease of the joint can result if left untreated. Such realizations have been the impetus for further advancement of knee joint surgery techniques.

Surgical methods for cruciate repair range from using tendons to using artificial substitutions as replacements for the ruptured ligament. One method, the Slocum procedure, involves a transplant of the pes anserinus flexors. The flexors become powerful tibial internal rotators resisting external rotation. This method is used for anterior rotary instability due to a cruciate tear. Other methods include the O'Donoghue procedure, in which the entire medial capsule and ligamentous mass from the patient's tibia is detached and advanced anteriorly in order to regain stability. Such repairs are termed "extra-articular" since they utilize ligamentous materials outside of the knee joint.

Intra-articular substitutions involve the tendons or ligaments which are a part of the complex knee joint. "In essence," describes Rovere, "nearly all intra-articular anterior cruciate ligament reconstructions involve off-setting a piece of tendon or ligament from the anatomic site of the cruciate ligament." Numerous substances have been used with varied successes in the past, including the patellar tendon and the iliotibial band.

In using the patellar tendon, a drill hole in the tibia is necessary. The tendon is passed through the drill hole and then intra-articularly. This method has a success rate of 70 to 90 percent. The use of artificial ligaments is still in the developmental stages, and, generally, has not been promising. One substitution, however, has proven itself as a viable candidate for future operations. The

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Ethics and DNA

As the potential benefits of genetic engineering increase, so do the ethical considerations

Neil Kalin

In 1953 Watson and Crick elucidated the structure of DNA, the complex double-stranded molecule which governs human heredity. DNA carries the genetic information which influences nearly all physical characteristics including sex, eye color, and hair color, as well as whether or not one possesses a genetic disease such as hemophilia or muscular dystrophy.

With the exception of identical twins, each of us possesses a unique DNA code sequence and therefore a unique set of characteristics. Darwin's theory of natural selection explains that variety within a species allows it to survive the threats of a changing environment. Different DNA sequences confer different physical characteristics which in turn determine survival ability.

In the 1970's scientists learned how to manipulate bacterial DNA so as to change only selected regions of it. This technology is commonly referred to as "genetic engineering," and DNA manipulated in this fashion is known as "recombinant" DNA. One of the greatest advances in genetic engineering is that geneticists have been able to induce bacterial organisms to produce proteins for which the gene sequence is known. For example, in July of 1984 Eli Lily began to manufacture Humulin, a synthetic human insulin used by diabetics. It was produced by bacterial organisms which were made to contain the gene for human insulin. Humulin is much purer than other types of synthetic insulin and can be produced more cheaply. Interferon and human growth hormone have also been produced using genetically engineered organisms. Theoretically, any protein could be produced in this manner, and in the future these techniques may be used to manufacture vaccines and chemicals.

More recently researchers have begun to apply recombinant DNA technology to humans. Some of the research has centered on finding genetic "probes." A probe is an isolated DNA sequence which binds to selected genes.

Huntington's disease, for example,is a fatal neurological disorder that is genetically determined. It is not manifested until after age thirty and is currently untreatable. Researchers at various institutions across the nation, including Duke, have been searching for the gene which causes the disease. One group has developed a probe which identifies DNA very near the gene, and eventually a probe for the gene itself may be developed. Huntington's is not the only disease which is being investigated; the team at Duke is also working on probes for myotonic muscular dystrophy, Duchenne muscular dystrophy, and amyotropic lateral sclerosis.

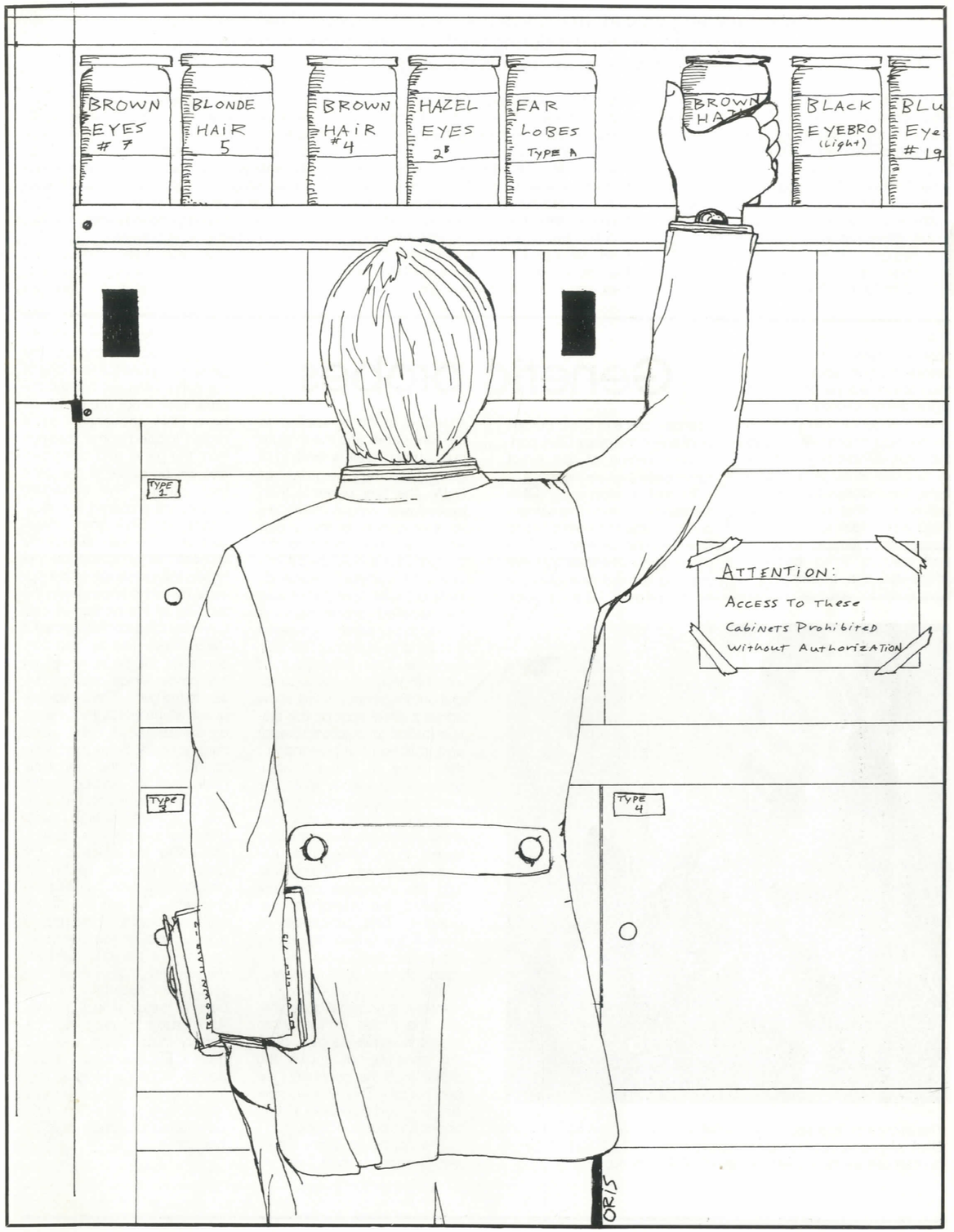
Probes can also be used to screen unborn fetuses for genetic diseases. Since it is not possible to safely obtain fetal blood for a DNA sample, DNA is obtained by amniocentesis or chorion biopsy. Amniocentesis involves taking a sample of the amniotic fluid which surrounds the embryo. This sample contains copies of the fetus' DNA which can then be analysed. First, the DNA can be stained and examined for gross defects such as abnormal chromosome number. An abnormality of this sort usually results in a lethal birth defect such as Down's syndrome.

As probes are developed, it will become possible to detect disease-causing genes. Amniocentesis is limited in that it cannot be performed until the fourteenth week of pregnancy, and results from DNA analysis are not available until the seventeenth week. Chorion biopsy, on the other hand, allows a sample of fetal DNA to be obtained as early as the sixth week.

Once a defect has been detected, another possible application of genetic engineering is treatment of diseases by gene therapy. Gene therapy involves inserting the correct DNA sequence for a given gene into cells of a person who has a genetic disease, essentially curing the disease. Though it has not yet been successfully performed on humans, tests done with animals have been successful. Further research may make gene therapy a reality for humans, but the application of this technique is quite far in the future. The problem is that not only must the correct gene be inserted but it must also be regulated. If it produces too much or too little of its product, then the abnormality will not be corrected.

Successful gene therapy would cure the individual cells, but germ cells (sperm or eggs) would not be altered. Since these cells would continue to possess the abnormal gene, the individual's future children would risk inheriting the disease. It may someday become possible to alter the genetic complement of sperm and egg cells, or of fertilized eggs, so that all of an individual's body cells will possess the correct gene.

At this point in time, some of the steps in the series which would be neccessary to effect the gene therapy have been achieved. Still, complete gene therapy in adults may not be possible since there are too many cells into which correct genes would have to be inserted. The insertion can only be done to a small number of cells, such as a newly fertilized embryo. However, at the embryo stage the defect is not yet known. In order to get to DNA from the embryo for probe analysis, the embryo must be accessible. This can be achieved by fertilizing the egg outside of the woman's body.



This screening procedure mimics the natural process of twinning, but one of the embryos will die during testing. Does preventing a genetic defect justify creating then destroying a human embryo?

In 1978 external fertilization proved possible when Louise Brown, the world's first test-tube baby, was born. The procedure involved combining a sample of the male's sperm and female's egg in a petri dish. After fertilization occured, the young embryo was implanted in the uterus where it continued to develop normally. The technique, known as *in vitro* (in glass) fertilization, has been improved greatly since 1978 and has allowed hundreds of previously infertile couples to have children. There are over sixty *in vitro* clinics in the United States, including one at Duke. Since its opening in 1983 the Duke clinic has achieved ten pregnancies and one birth.

In vitro fertilization makes prenatal gene therapy a possibility. The embryo's DNA can be screened and any abnormal genes corrected before the embryo is implanted.

A sample of fetal DNA must therefore be taken for analysis. At early stages (two or four cells) there is not enough DNA to extract and examine. Even if such a minute quantity could be examined, its removal would kill the embryo. The solution would be to make a copy of the embryo's DNA for testing, then implant the correct gene into the embryo. In animals it is possible to duplicate an embryo; in 1984 twin colts were born after reseachers surgically divided an *in vitro* fertilized egg and implanted the embryos into two different mares.

Although it has never been done, such a procedure could be performed in humans. The ethical considerations in this case are difficult: the procedure mimics the natural process of twinning but testing will necessarily kill one of the embryos. It must be decided if the ends (preventing a prenatal defect) justify the means (creating then destroying a human embryo). Once a doctor has two embryos, the development of one would have to be arrested until tests on the first one can be completed.

Researchers in Australia have managed to store embryos by freezing them. When frozen, the embryo ceases to grow and divide and thus its development is halted. It can be stored indefinitely and later thawed and implanted. Freezing apparently does no damage to the embryo, although if it is stored for prolonged periods of time the effects of radiation in the environment could accumulate and cause genetic damage. The technique of embryo storage is quite new and thus far the University of Southern California *in vitro* clinic is the only place in the United States where human embryos have been frozen.

This type of genetic engineering is not currently possible. Although it may be possible to duplicate embryos, freeze them, and screen for defects, it may not be possible to insert genes to effect a cure. Only further research will prove if prenatal gene therapy can be a reality. Even if this type of intervention were possible, many people might consider it unethical. At present the National Institute of Health (NIH) has imposed a moratorium on research with human embryos, and guidelines governing research in this area will certainly be established.

Before further guidelines can be established, though, much thought and discussion concerning the ethics of genetic intervention is necessary. Genetic intervention is novel and it is feared by many. Some feel that it is an intervention in the natural order of things and therefore should be outlawed. However in a way, health care also interferes with the natural order; it allows survival to individuals who might otherwise die if not treated. If humans felt morally bound not to intervene in nature, then many people who are alive today would not be. To some extent, Darwin's theory of natural selection does not hold in the human world, for we can manipulate our environment and compensate for our deleterious characteristics. The exploitation and development of genetic technology offers promise for the future. If research in this area is determined to be unethical then we lose one of the greatest potentials ever in the prevention and treatment of disease.

Genetic probes

A probe is too small to be seen by itself, but it can be detected when labelled with a radioactive isotope. In order to signal the presence of a certain DNA sequence the labelled probe must chemically bind to the DNA sample being tested. In its usual form, as a double helix, the probe is bound to itself and cannot bind to anything else. Heating the probe upsets its chemical structure and causes it to become single-stranded. In this form it can bind to another single-stranded piece of DNA, but will bind only if the other DNA contains a region of the exact same base pair sequence.

To test someone, a DNA sample is needed. This sample can be extracted from a blood sample. The sample DNA is made single-stranded by heating and is fixed to a piece of filter paper. The single-stranded probe is applied to the filter paper and the mixture is incubated to allow binding of complementary regions of DNA. The filter paper is then treated with various chemicals so that copies of the probe which are not bound to the sample DNA are washed away. The DNA sample remains attached to the filter paper and the labelled probe remains bound to the sample wherever the gene is present. The filter paper is then photographed with film that is sensitive to radiation. Radioactivity will show up as a white spot on the picture (called an autoradiograph) and indicates the presence of the probe. If the autoradiograph has any white spots, the probe has bound to a complementary sequence and the individual has the disease being tested. If no white spots appear, the probe did not bind and the individual does not possess the abnormal sequence. This procedure is used if the probe represents the exact gene which is responsible for a certain disease. If the gene abnormality is known it is possible to synthesize the probe working from the gene sequence itself, but if the gene is not known the probe must be generated experimentally. This involves constructing and screening a number of candidate probes.

The candidate probes consist of short, unique DNA sequences taken from the chromosome which carries the gene. It is possible that one of the candidates will contain the gene itself. If not, the probe will be a DNA sequence from a region located some distance from the gene, and some probes will be closer to the gene than others. The candidate probes are prepared and incubated with DNA from individuals who are known to have the disease. A concordance between the presence of the disease (which is known) and the binding of the probe (as indicated by the autoradiograph) is determined. The highest concordance will be achieved by the probe which resides closest to the gene. The candidate probe which yields the greatest concordance can be used diagnostically. Since this probe might not be the abnormal gene itself its binding to the sample being tested indicates only that there is a high probability that the gene is present. The nearer the probe is to the gene the greater will be the correlation between DNA samples which contain the abnormal gene and the presence of a white spot on the autoradiograph. If a person is already manifesting the disease, the probe can ascertain that the basis of the disease is genetic. Additionally, the diagnostic capability of genetic probes is of great utility if a person is suspected to be carrying a gene for a disease which is not manifested until later in life, or if parents wish to screen their unborn child.

The arrows on this segment of DNA show the points at which the DNA strand is replicating (magnification = 25,000x). A single human cell will have over six feet of DNA in its nucleus.

Genetic advantage

The relative value of a given characteristic is determined by the constraints of a specific environment. The genetically determined disorder sickle-cell anemia provides a good illustration of this principle. In its homozygous form (i.e. an individual has inherited the sickle-cell gene from both parents) the gene greatly reduces the ability of the red blood cells to carry oxygen. This results in anemia. When the gene is present in heterozygous form (i.e. the individual has inherited the gene from only one parent) the person will not be anemic, but will be endowed with a resistance to malaria. In environments where malaria is a threat, such as in Africa, heterozygous (resistant) individuals have a survival advantage relative to homozygous (anemic) individuals as well as individuals who do not carry the sickle-cell gene at all and are not resistant to malaria. In the United States, where malaria is not a significant threat, individuals who are heterozygous have no advantage, while those who are homozygous are anemic. In this environment the gene may confer a disadvantage or may have no effect, but in no cases does it confer an advantage. In general, as long as a given characteristic is not lethal, it is of itself neither good nor bad. Its relative value can be determined only with respect to a specific environment. As the environment changes the relative value of a characteristic is subject to change.

If a species lacks the genetic potential for variety, then as its environment changes the species may well become outmoded and probably go extinct. The major exception is man. Humans are unique in that to a great extent we can compensate for many of our deleterious characteristics. For example, hemophiliacs have a gene abnormality which makes them deficient in certain factors that are necessary to clot blood. Their blood takes significantly longer to clot than does the blood of normal individuals and they are at a much greater risk of bleeding to death from a cut. Before treatment was possible the majority of hemophiliacs died young, usually before having children. Treatment involves giving doses of the substances that they cannot produce. This is not a cure for they remain unable to produce the necessary factors. One way to effect a cure would be to alter their DNA. It is not yet possible to alter the genetic make-up of humans, though much success has been achieved with bacterial organisms.

Compact disks

Lasers and microprocessors are producing distortion-free music for the stereo world

Ted Alyea

Dave English

The home stereo has been the layman's link to the revolution in electronics and computing. The first advances in message transmission were incorporated into the receiver, and recently magnetic information storage has become manifest in tape recording. Most recently, the successful attempt to improve on information storage devices for computers has been adapted to the stereo industry in the form of laser-read disks. A single 12-inch disk for computer use, the form which should be commercially available towards the end of 1985, could store all of the information in 10,000 years worth of *Scientific American* magazines. Thirty of them could store Duke's Perkins Library collection of over 14 million books.

A compact disk, or CD, resembles a conventional vinyl album except that the information on the CD is stored digitally, or in pieces. Other recording devices store information in analog, or continuous form. A compact disk is about 4.25 inches in diameter, consisting of a thin metal layer overlaid by a glass or plastic later, and surrounded by a protective acrylic layer. The tracks on a CD are read from the inside toward the outside, opposite that of a vinyl record. A laser scans the tracks of the CD and retrieves the musical information stored there. The information is then processed, filtered, and finally converted to usuable form for amplification.

Previously, sound had always been recorded in some analog form, whether it be on the grooves of a record or the varying magnetic fields of reel-to-reel, cassette, and other magnetic tapes. Since any sound can be exactly represented by a single constantly changing wave, the easiest way to record this sound has been to duplicate the shape of the wave in plastic or in a magnetic medium. Analog recording was the most obvious solution to the problem of recording sound, and has therefore been the standard of the industry since inception.

Unfortunately, analog recording has a whole host of problems. The first major problem is sound quality deterioration during duplication. Whenever an analog recording is copied, the copy is slightly different from the original. Since analog sounds have no standard forms, error correction or detection is not possible. With repeated copying, the deterioration accumulates, making distortion audible. This problem is similar to that encountered when one tries to xerox a copy of a copy—each copy becoming progressively worse than the last.

The second major problem is sound quality deterioration due to damage or wear to the recording medium. If a record groove is scratched, or part of a magnetic tape demagnetized, the stereo system has no way

of detecting the flaw and subsequently cannot correct or ignore the errors. To minimize this problem, an entire ancillary industry has developed, selling tape cleaners, tape head demagnetizers, record cleaning fluids, static removers, and needle cleaning kits.

The solution to these deterioration problems is to store the musical information in digital rather than analog form. If sounds can be stored as a sequence of digits, then there would be no gradual deterioration due to duplication since digits would be read from the original and written on the copy in pristine form. Digital recordings are also less susceptible to bad playback from handling damage since any unreadable or obscured sections may be ignored or filled in by interpolation to eliminate audible errors. At their best, CD's can ignore all dust and any fingerprints on a disk and give a playback exactly identical to the playback of a clean disk.

Why didn't digital recordings and CD's become popular earlier? Unfortunately, while there are many advantages to digital recording, there is one significant problem which has only been solved in the last few years—the speed of information processing. To record a pitch of 20,000 Hertz (the highest sound that the average human can hear) digitally, a minimum of 40,000 sampling points per second must be taken, converted into digital levels, and recorded. To play back the pitch, a minimum of 40,000 digital levels would have to be read, converted to analog levels, filtered, and output at a perfectly steady rate every second. Until the advent of microprocessors, there was no way to handle the flow of this volume of information. With the simultaneous development of relatively simple scanning lasers, the hardware became available for development of laser disks.

After much experimentation, the current processing design used in CD systems was developed and standardized. During recording onto the disks, a writing laser burns a pattern of holes, called pits, into the underside of the glass or plastic layer. The metal coating fills in these pits and covers the base. When the disk is scanned from the top side, the pits appear as a series of raised bumps,while the spaces not pitted are read as flat spaces. The presence or absence of a pit represents a 0 or a 1, respectively. Sixteen of these locations in a row are grouped together to hold enough information to record one digital level (16-bit linear pulse code modulation). The 16-bit groupings can be formed into 65,536 (2^{16}) different patterns, and each pattern can represent a digital level.

A digital level is equivalent to the amplitude of the sound wave at the point in the wave's cycle which the digital level is representing. The upper boundaries of a series of these digital levels form the outline of a sound wave.

The laser scans the tracks and through techniques of optical refraction and reflection determines, without ever touching the track, whether it is scanning a pit or a flat space. Every time sixteen pits are read, they are processed by error-checking devices, reconstructed to analog levels, chained together, and sent out as a fully-reconstructed analog signal.

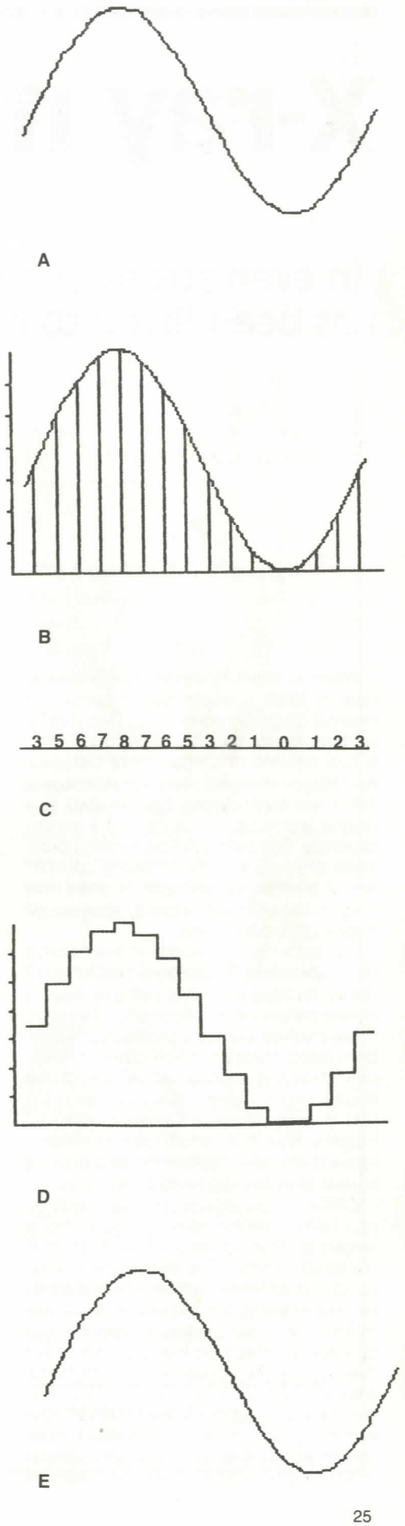
The processing rate of the CD system is enormous. The playback rate of the optical laser is 1,411,200 bits, or pits, per second. To read this much data accurately, the CD must spit at a precise speed to pass exactly the same number of bits per second under the laser. The spinning rate required to achieve this depends on how far out from the middle of the disk the laser is reading. A set of complicated circuitry is devoted exclusively to keeping the disk spinning at the correct speed, which varies from 200 rpm at the outside of the disk to 500 rpm in the middle. The tracks, or rows of pits, on a CD are spaced only 1.6 thousandths of a millimeter apart, this width being the minimum to insure accuracy. For a 4.25-inch disk, this corresponds to a maximum of 75 minutes of playing time, well over the duration of most single albums. The Sony Corporation once demonstrated a 12-inch disk with a playing time of 14 hours, a length of time of limited usefulness for the stereo industry.

The compact disk players produce essentially no background noise and no distortion. Since the laser causes no disk wear and dust and fingerprints are ignored, the thousandth playing of the CD sounds the same as the first. Compact disks eliminate the need for the music purists to spend extra time scrupulously cleaning recordings and equipment to get optimum sound.

The laser, with a lifetime of approximately 5,000 hours of playing time, can presently be replaced when it burns out for under $100. Since the laser contains the only moving parts on the system, replacement of the laser is a complete system overhaul.

Which brand is best, and what price range is reasonable? Unlike analog audio components which have completely different circuit layouts from brand to brand and therefore slightly different sound production, compact disks players are so rigidly formatted and standardized that all manufacturers use effectively the same layout for the laser playback system. Combined with the fact that this new digital technology surpasses in accuracy what the ear can detect, the various brands of CD players sound indistinguishable from one another.

*A sound wave is a continuous wave (**A**) and is usually recorded as such by analog devices. A compact disk recorder, however, only takes points along the wave and assigns them sound level values relative to each other (**B**). These levels (**C**) are recorded in binary form in 16-bit codes on the compact disk. A compact disk player can then read the codes, reconstruct an outline of the original sound wave (**D**), and smooth the curve to reproduce the original wave (**E**).*



X-ray microscopy

An even stronger looking glass has been lifted to the microscopic world

Justin Wu

When Wilhelm Roentgen discovered x-rays in 1895, a whole new dimension of medical diagnosis opened up. Decades later, the development of the electron microscope ushered in a new era of biological microscopy. In recent years, the marriage of these two technologies has resulted in a unique technique called contact x-ray microscopy. Combining the penetrating properties of x-rays with the resolving capabilities of electron microscopes, it offers new insights into cells, with exciting applications in biology and medicine.

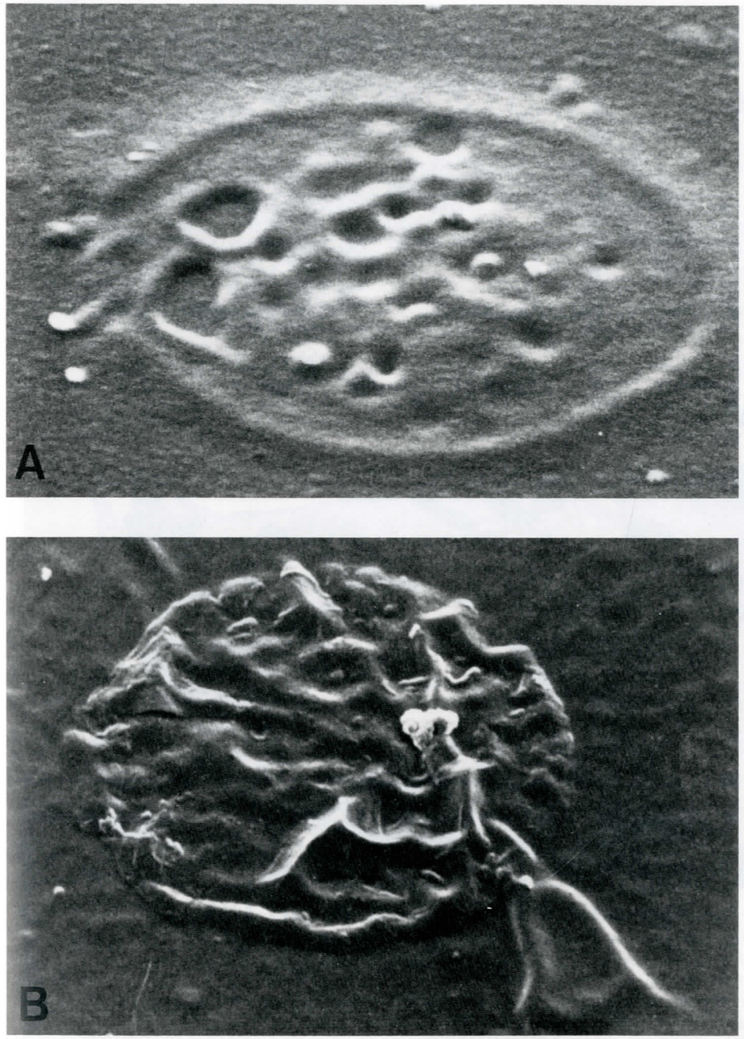
Contact x-ray microscopy evolved from a technique used in the computer chip industry to transfer circuit patterns from a master pattern onto a silicon chip. This technique involves a resist, a photosensitive carbon-based material, which covers the silicon chip and records an image of the master circuit pattern. Scientists from the IBM Watson Research Center in Yorktown Heights, New York, and a team of medical researchers have applied the idea of using a resist to examining living cells.

Contact x-ray microscopy uses "soft" x-rays (with wavelengths of 10 angstroms or longer) to form the image of a cell on an x-ray sensitive resist. The resist is then developed and examined under an electron microscope. Using this technique, structures as small as 5 nanometers in diameter can be resolved. Because the specimen is not directly examined under an electron microscope, contact x-ray microscopy has several advantages over conventional electron microscopy in biological studies. In order for electrons to provide a high-contrast image of a cell using transmission electron microscopy (TEM), the specimen must first be ultrathinly sliced, dehydrated, stained with electron-dense metals, and placed in a high vacuum chamber.

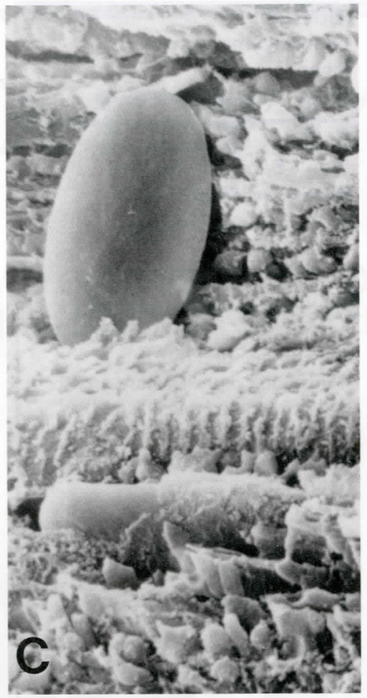
On the other hand, contact x-ray microscopy has the distinct advantage that the specimen can be in a relatively natural state. Due to the penetrating ability of x-rays, the specimens can be relatively thick. Because the wavelengths of x-rays used to image the specimen are between 24 and 43 nanometers, a region in which water absorbs much less radiation than proteins, the specimens can be hydrated and a good contrast image produced without staining. This technique can also yield unique information about the subcellular distribution of chemical elements within a cell by quantitatively analyzing their absorbnce or flourescence properties.

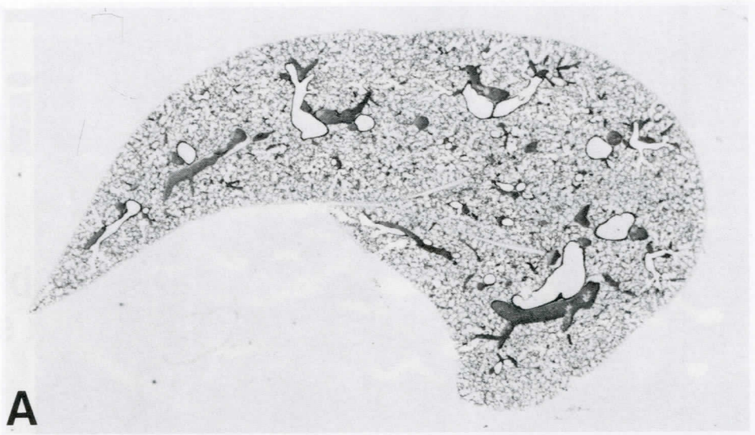
Human blood platelets, key factors in blood clotting, were the first cells to be studied using contact x-ray microscopy. Air-dried, whole mounts of platelets were chosen for study because they have been extensively studied by conventional electron microscopy. When the images produced by TEM and an x-ray resist were compared, striking differences in the amount and type of structural detail were evident. Pseudopods, the finger-like projections which platelets send out during clotting, appear to be fairly homogeneous when viewed by TEM. Internal cellular structures are more poorly defined, and there is no evidence of an internal network. The cell periphery is outlined by a prominent rim of dried protein. In contrast, x-ray resist/transmission electron micrographs show that the pseudopods actually contain a photon-absorbent core that intersects a rim of similar material lying just inside the cell's periphery. The x-ray images also reveal an internal cytoplasmic network of dark filaments that surrounds vacuoles and connects with structures called dense bodies. Contact x-ray microscopy is able to highlight cellular features undetectable in the TEM because many molecules, like phosphate, are much more distinguishable by their x-ray absorbing patterns than by their electron scattering properties.

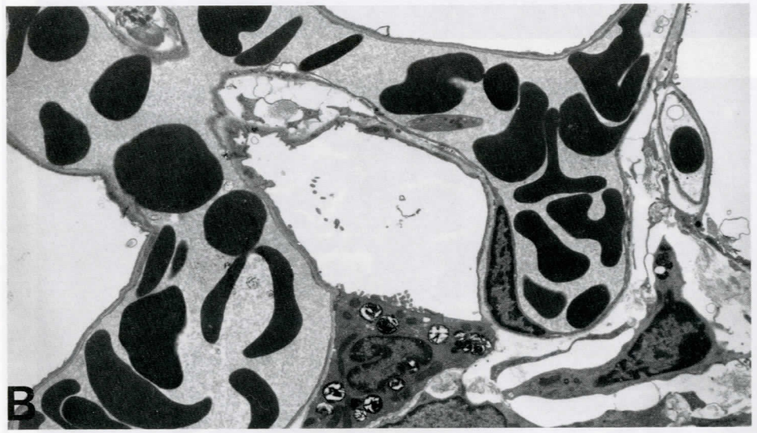
Recently, IBM has produced the first high magnification images of live platelets using a technique called flash x-ray microscopy. This technique uses a brief, intense flash of soft x-rays to expose the resist. Contact x-ray microscopy previously used x-ray sources that required exposure times ranging from several minutes to several hours, resulting in blurred images due to radiation-induced movement of the specimens. Although it was possible to examine wet specimens, air-dried whole mounts of dead platelets had to be chosen for the original studies in order to reduce exposure times. Now, using an imploding gas jet plasma as the x-ray source, a beam of x-rays can be produced that is intense enough to form resist images of hydrated specimens in one trillionth of a second periods. The short duration of the source is critical because it ensures that an accurate, non-blurred image of a live, wet specimen can be captured before the specimen dies of radiation exposure. For the first time, living cell processes that occur in less than one millionth of a second can be recorded and studied at



X-ray microscopy allows pictures to be taken of living cells. This can result in quite different pictures of the same type of cell, as in **A** *which shows a dead blood platelet and* **B** *which shows a live one. These pictures were obtained using contact x-ray microscopy in which x-rays pass through a platelet, make an image on an x-ray sensitive resist, and then a scanning electron micrograph taken of the resist.*







*The above cross-section (**A**) of a baby rat lung is magnified no more than 50x, while the single alveolar space (**B**) is magnified over 2,000x using thin-section transmission electron microscopy. Oxygen and carbon dioxide are exchanged across the walls of the alveolus and reach the red blood cells (dark and irregularly oblong) in the capillaries. The scanning electron micrograph of finch heart muscle (**C**) is nearly the same magnification, with an oval red blood cell situated in the fibers. All of these methods (prepared slides and transmission and scanning electron microscopy) require dead, chemically preserved specimens, unlike x-ray microscopy which can use living cells.*

high resolution.

Flash x-ray images of live, wet platelets have shown platelets in the process of extending their pseudopods. The absence of an elevated rim of dried protein, characteristic of air-dried platelets, proves that the cells were hydrated at the instant of exposure. New structures never before visualized by electron microscopy or contact x-ray microscopy of air-dried whole mounts include bubble-like structures at the base of the pseudopods and scattered throughout the platelets. The very high quality of these flash x-rays demonstrate that the technique can provide good contrast when the cell is covered by a layer of water as thick as one micrometer or more. This ability to examine cells in the presence of water is crucial for biological studies because practically all cell processes occur in an aqueous environment.

Flash x-ray microscopy has useful applications in medical as well as biological research. This technique enables blood disease researchers to make detailed studies of the interaction of platelets with their environment. An understanding of the actual mechanisms involved in blood clotting is important for the study of several blood diseases, including hemophilia, stroke, and some heart diseases. Most importantly, more detailed analyses of a wide variety of cell types are now possible using the eyes of flash x-ray microscopy.

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Devices such as the ankle disk are used at this stage in recovery. As Scott explains, "Neuromuscular reduction necessitates the development of proper mental awareness in the patient in order to develop coordinated movements gradually through repetitive exercises."

Most of the programs available at DUSMOR are geared toward the rehabilitation of injured knees, reflecting the fact in the sports world that this is the most commonly injured joint of the human body, and typically requires the most care in determining the proper therapy method. Orthopedic specialist Dr. Garrett of Duke's medical center keeps DUSMOR steadily supplied with athletes who need repair work on ligaments, cartilage, and tendons in the knees. While their conditions often require surgery, Triangle area athletes are fortunate enough to have in the area a modern, well-equiped facility with knowledgeable personel in the field of physical therapy and exercise physiology.

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use of freeze-dried fascia lata allografts have been used as a substitute for knee ligament reconstruction. Once the allografts are reconstituted with water, their tension does not vary significantly from that before they were freeze-dried.

The modern athlete has reason to feel more secure in the wake of sports medicine's accomplishments in the last decade. More research is being done in this field than ever before, and the result has been a deluge of new operative techniques, therapeutic devices, and prolonged athletic careers. The revolution, according to Dr. McElhaney of Duke's biomedical engineering department, will help to put the field in "a state of creative ferment," where paralyzed muscles will be allowed to move again, and artificial limbs will be used for body implants. Electrical stimulation will accelerate the healing of ligaments and tendons. The future should bring more success stories like those of Olympian Joan Benoit, as well as more durable athletes such as Gordie Howe and Phil Neikro.

The premedical student, perhaps more than other students, has the opportunity to use his undergraduate years for a liberal education.

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tion of language and the ability to use language elegantly.

Finally, in the most personal sense, the physician is an educated man or woman. Although comfortable with his professional expertise, the physician without a liberal education may concern himself, and others, about the narrowness of his outlook.

A few reformers would make a liberal education accessible to the physician. In the first place, some of the course requirements for admission to medical school could be changed. The need to know if a premedical student enjoys and has an aptitude for science could be assessed in two year-long courses, one in biological sciences and one in the physical sciences. These could be taken during the first two years of college. A third year of science, including statistics, experimental design, and a practicum in research could also be required in order to give the student a thorough understanding of the bases of scientific knowledge.

Preliminary admission to medical school, contingent only upon successful completion of the undergraduate curriculum, could be decided at the end of the second year of college. This is already being done on a limited scale at Duke and other places with success. Performance in the two science courses as well as the rest of the courses taken during those two years should give sufficient information about the interest and aptitude of the student for medicine. Provisions for the admission of "late bloomers" could easily be made.

Once the student has been admitted to medical school, the usual requirements for an undergraduate major could be removed; in practice, his major is medicine, to be fulfilled in medical school, and now the student is encouraged or required to take the broad spectrum of courses needed to lay the foundation of a liberal education.

Preliminary admission to medical school could be decided at the end of the second year.

Finally, the college must devise a curriculum that provides a liberal education. Courses which emphasize principles rather than pure facts, which are broad in scope rather than narrow, which teach how to learn rather than how to memorize, should be available. The environment of the education must stimulate and reinforce the educational process.

Even as students continue to be admitted to medical school at the end of four years of college, the "liberality" of undergraduate education could be used as a criterion of admission, in addition to grade point average and test scores. If students know that getting a liberal education is an important criterion for admission, those who do not presently seek it out for philosophical reasons would do so out of self-interest.

It would be complex to change the current systems. Nevertheless, if the value of a liberal education for the physician is clear, steps can and should be taken to make it easier for him to achieve it.

On 11 April 1980 Dodds Meddock became the first man to fly a balloon over the North Pole. Sponsored by Jensen, Meddock and his assistants stayed for four days at a weather station in the Northwest Territory. Six men serve six month tours of duty at the weather station, with their closest contact to civilization being Resolute Bay.

(from page 4)

ple of the Winds in Athens. Four people worked for five months designing, making transparencies, and eventually sewing together quilt-like the six panels, with 73 pieces of fabric per panel, creating images of Nike, Icarus, Hermes, Pegasus, and others. Similar artistic creations of the Balloon Works include Raggedy Ann, monarch butterfly, and gumball machine motifs.

The carriages, usually some style of wicker basket, benefit from the furniture craftsmanship in the area. They must be not only shock-absorbant and electrically nonconductive, but also beautiful. Although most carriages are open-air, some specialized ones are not, such as the Playboy balloon's carriage or those of high altitude balloons which must be enclosed to protect passengers from oxygen deprivation and cold.

Early in his life, Meddock had a passion for flying. He remembers watching airshows from his father's shoulders, who himself was a fixed-wing pilot. In his teens he built models and operated a war surplus gas balloon, and in college he joined a ballooning club.

Meddock has unwavering faith in the safety of ballooning. "I don't view the risks as being great" he says, claiming that in over 202 years of ballooning history there have been fewer that 200 casualties. And in the ectasy of riding in one: "The sensation differs from soaring, where you're penetrating the air and making some noise, even in a glider. In a balloon, you are moving with the wind, and feel stable and stationary as you move across the earth. There is no other way you can have the experience of gliding along and picking leaves from the tops of trees and watching deer run underneath."

Although it is possible to change altitude fairly easily in hot air balloons, possibilities for changing directions are much more limited. The wind does blow in different directions at different levels in the atmosphere, but target landing is still very challenging, and along with racing is "very rewarding on the international level."

"One of the most bizzare experiences you can have, and one which even few ballooners have had, is night flying." As Meddock describes it, "If you drift at 8,000 to 12,000 feet, and if there are few cities and only a few farmlights, and a few stars, you feel like you're in a sphere, in outer space. You can't tell the difference between the earthly and heavenly pinpoints of light." As when SCUBA diving at night or in dark water, it is difficult to tell which way is up.

But for the time being, at least, Meddock has settled down to a gentleman ballooner's lifestyle. He and his balloon did open the British American Festival at Duke in June of 1984. Still, he says, "ballooning and travelling aren't my wife's cup of tea, and my position here at Duke is ideal for my stage in life."

Abstracts

Classroom textbook science can often be dry and uninteresting, and although ideally labs are designed to give some hands-on experience, cookbook procedures can make them boring. For this reason, many undergraduate students have delved into their own scientific investigations. One of the primary purposes of VERTICES *is to report on new and interesting research being done in the Triangle area. However, not only Ph.D.'s and M.D.'s do interesting work. In the following pages are examples of what some undergraduate students have been able to do.*

An unhatched egg and a zoea stage crab larvae.

Beach orientation

Intertidal organisms are constantly subjected to environmental stresses caused by variations in tides, temperature, and salinity. Exposure at low tide can lead to desication or predation, while submersion during high tide might result in osmotic shock or death by drowning. Celestial cues, visual landmarks, and sun compassing are ways in which intertidal organisms are able to orient themselves in their environment. Behaviorial modifications, influenced by internal factors and environmental cues, help these organisms to adapt to their changing environment.

Beach slope and tidal changes are other physical factors which could provide directional cues. Slope as a possible guide for directed movement has not been extensively studied. The blue crab, *Callinectes sapidus*, has been found to combine slope and water surge to direct itself offshore. This behavior is thought to be used as an escape mechanism from predation, allowing the crabs to hide in the spartina marshgrass zone. The response of small crustaceans to slope is in part dependent on the dryness of the sand. Certain crustaceans, such as *Orchestoidea corniculata*, *Tylos punctatus*, and *O. californian*, move uphill on a wet slope, and the first two species move downhill on a dry slope. This result is expected if the animals are to remain close to the water's edge.

Another variable that may influence directed movement on slopes is endogenous tidal rhythmicity. I examined this potential response factor in *Uca pugilator*, the sand fiddler crab, at varying degrees of slope. Results from the experiments proved the existence of an endogenous rhythm which coincides with tidal changes. This important mechanism also aids the intertidal organism to orient on the beach slope.

Francine Donovan

Device to measure heart contraction

The contraction of a heart muscle cell is triggered by the movement of minute amounts of calcium into the cell; when the heart muscle relaxes, the calcium leaves the cell. Since both the amount of calcium moving across the cell membrane and the concentration of calcium inside the cell are very small, it is difficult to measure these quantities. For this reason, the strength of muscle contraction is often used as an indirect measure of intracellular calcium concentrations.

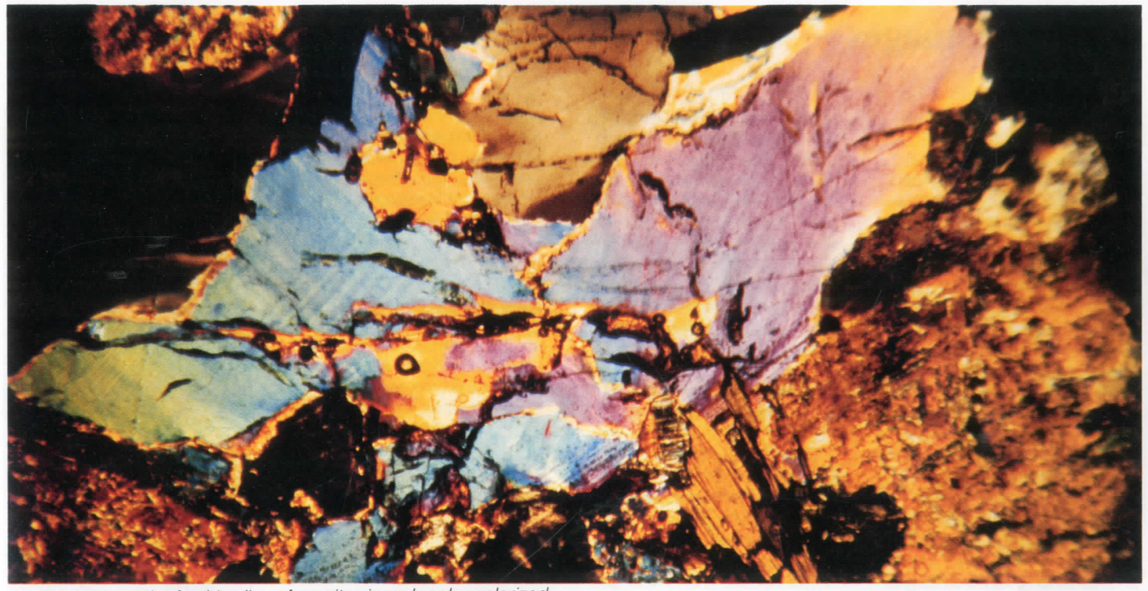
I have recently built a device that provides a measure of the strength of concentration of a cultured polystrand of heart muscle. This device analyses the video signal from a television camera which tracks the edge of the heart muscle as it beats.

Since many drugs used to treat heart disease affect the migration of calcium into muscle cells, this device can be used to investigate how these drugs work. Such research may help in developing new and better drugs to improve the treatment of heart disease.

Sanjay Desai

Abstracts

VERTICES *encourages submission of abstracts describing original undergraduate research projects. Any students interested in submitting an abstract should send a double-spaced, typed copy between 100 and 250 words to* VERTICES, Office of Student Activities, Bryan Center, Duke University, Durham, NC 27706.



A color petrograph of a thin slice of granite viewed under polarized light and magnified 37x.

Press rolls and petrography

Granite press rolls are used in paper factories to press water out of the paper. One of these rolls recently failed in service, killing one man and injuring two others. The probable causes for the failure were determined in the Failure Analysis Laboratory of the Department of Mechanical Engineering and Materials Science and in the geology department of Duke University. The failure was investigated by performing a detailed stress analysis of the press roll itself and then examining the granite by thin-sectioned petrography and scanning electron microscopy. Based upon results from these tests and citations in the rock mechanics literature, it appears that the failure of the granite press roll could be explained in terms of mechanical considerations of the press roll and crystallographic structure of the granite used.

Dennis Brickman

Glucagon and bile

The effects of the gastrointestinal hormone glucagon were studied in intact rats and in isolated perfused rat livers. In the intact rats, administration of glucagon was followed by a significant rise in bile flow. Results also suggested that the bile salt fraction of bile secretion was stimulated. However, in the isolated perfused rat liver, no stimulation of bile flow occured in response to glucagon. Since the isolated model tested for direct effects of glucagon within the liver, the overall results of the study suggest that glucagon acts at some site outside of the liver to produce its effects on increased bile flow.

David Spiegel

Abstracts

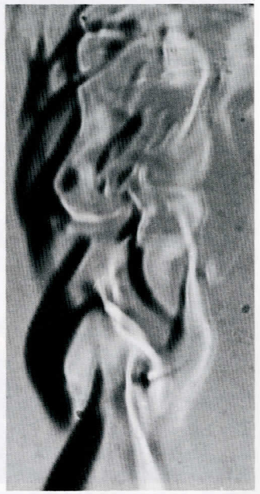
Schlieren images

Schlieren photography is a relatively simple technique which can be used to visualize density variations in a column of gas. For this reason it has become an important tool for use in the study of gas flow. Schlieren techniques are routinely applied in aeronautical engineering to study high velocity airflow patterns over surfaces. These techniques are also used to study heat transfer, combustion, and gas turbulence in an effort to make engines and automobiles more efficient. Recently, schlieren photography has been applied to the human body to investigate heat loss, respiration, perspiration, and metabolism. In general, any phenomenon that involves gas density variations can be analysed by using schlieren photography.

Schlieren photography makes use of the phenomenon that density gradients in a gas diffract light rays passing through the gas according to density. This diffraction causes variations in the brightness of light when it reaches an image plane, which in most cases is a photosensitive film. In this way, an image is formed in which variations in brightness depict gas density gradients in the light's path. These variations in brightness can easily be seen in the column of hot air rising from a flame.

The purpose of my project was to determine the feasibility of using schlieren photography to study pheromone release by female arctiid moths. When ready to mate, female moths release a chemical sex pheromone into the air for the purpose of attracting males. The pheromone is released in short, discrete pulses which may help males locate the female quickly and precisely. To fully understand the role played by these pulses, it is necessary to investigate the structure of the pheromone plume. Preliminary studies using acetone as a substitute for the pheromones suggest that the schlieren technique could easily be used to visualize the structure of pheromone plumes.

David Mott



Schlieren photography produces images of density variations in a column of gas.

Chemical cues for hatching

The release of larvae from certain female marine invertebrates is accompanied by abdominal pumping. Studies concerned with this response have demonstrated several reasons for this behavior. In the marine crab *Rhithropanopeus harrisii* the pumping action synchronizes the hatching process, causing all the larvae to be released together. Since the female crab must expose herself at her burrow's entrance during hatching, synchronized larval release allows this period of vulnerability to be as brief as possible.

Control over hatching appears to belong not to the female crab, but to the larvae themselves. Larval control over the pumping mechanism takes the from of a chemical cue which is released at the time of hatching. Initially, low concentrations of the chemical at the beginning of the hatching process induce the female to begin to pump. The pumping in turn causes further larval hatching which releases more of the pumping stimulant, causing even more vigorous pumping to occur. Thus, the chemical works in the form of a feedback cycle until all of the eggs which are ready have hatched.

Isolation of the chemical cue which causes abdomen pumping in *R. harrisii* have proved successful. Using a polyacrylate resin, I was able to extract the stimulant from larval hatch water. The chemical could then be eluted from the resin with methyl alcohol and purified further. Initial characterization of the chemical cue using proteases suggests it is probably a peptide.

David Mott

Abstracts

Biological timing for survival

So prevalent is the rhythmic nature of life on earth that we frequently tend to overlook the fundamental significance of many of the earth's rhythms. Tides ebb and flow, the sun rises and sets, the moon changes phase, and we go about our daily lives often without even bothering to notice. Yet, the earth's rhythms are known to induce biological rhythms in many plants and animals; the tulip opens its petals at first morning light and closes them as the sun fades below the horizon, the Canadian goose migrates south each winter, the blue crab releases its eggs according to the phase of the moon. Why? The persistence of biological rhythms in the laboratory, where the sun, the moon, the tides, and other major rhythms of the earth are absent, suggests that biological rhythms (biorhythms) are under the control of an endogenous (internal) timing mechanism called the biological clock. In marine organisms, coupling of biological rhythms to environmental rhythms may enable the individual to more fully utilize its fundamental niche through temporal adaptation to the cyclic parameters of its ambient environment.

The functional significance of biological clocks in crustaceans has been extensively demonstrated. To date, however, no rhythm studies have been done on the reproductive cycle of the grass shrimp *Palaemonetes pugio*, one of the most hardy and abundant organisms found in estuarine tidal marsh ecosystems. *P. pugio* is an ideal organism for biorhythm studies due to its broad distribution (from Massachusetts to the southern coast of Texas), its ability to tolerate wide fluctuations in salinity, temperature, and oxygen, and its adaptable food habits.

The purpose of my study was to investigate the correlation of larval release (egg-hatching) in *P. pugio* to: 1) the lunar phase, 2)the tidal cycle, and 3) the time of the solar day, with the ultimate goal of fostering new understanding of the functional significance of biological timing as a mechanism for increasing the survival chances of the larvae.

My findings indicate that *P. pugio* exhibits no long term reproductive rhythm correlated to the lunar phase and releases larvae in the lab one and one-half to three hours after the predicted time of nighttime high tide in the field on five consecutive nights, if held under constant conditions of light, temperature, and salinity. This finding indicates a circatidal (24 hours, 38 minutes) rhythm of larval release. Since larvae were only released in single bursts at night, there is also a circadian (24 hour) component of this circatidal rhythm. They exhibit a solar day rhythm in larval release if the egg-bearing females are maintained in the laboratory under a light/dark cycle without tides. I must note, however, that the data collected on the solar day rhythm were insufficient to draw any conclusions.

The significance of larval release rhythms of *P. pugio* needs to be more fully investigated. The absence of a lunar larval release rhythm indicates that it is not advantageous for *P. pugio* to release its larvae at any one particular phase of the moon. Why, then, does *P. pugio* release larvae soon after nighttime high tide? Perhaps nighttime larval release provides protection to the egg-laden females, as well as newly-hatched larvae, by making them less susceptible to visually-orienting predators. In addition, the release of larvae into the water column shortly after high tide, as the tide recedes, may be a mechanism for larval transport out of the estuary and may prevent stranding of larvae in anoxic mud or stagnant, low salinity pools.

It is feasible that in all organisms the capacity for rhythmic anticipatory response confers increased individual survival as well as increased genetic fitness by synchronizing the appropriate response at an advantageous place and time. Further biochronometry research should center around the concept of biological timing as an evolutionary adaptation to periodic fluctuations in the time structure of the earth's rhythms.

David Shreffler

Crabs detect sugars

The fiddler crab *Uca pugilator* is a semi-terrestrial crustacean which uses its chelae (claws) to obtain food. First, the crab probes the sand with its claws, using chemoreceptors on the chelae and legs to locate edible items such as diatoms, algae, protozoans, and other organic matter brought inshore by the tides. Then it uses its minor chelae to bring sand and food to its mouth region, and non-edible items such as sand and mud are removed from the mixture.

Previous studies have demonstrated that the fiddler crab uses a variety of factors to sort the edible items from the non-edible sand and mud. Certain amino acids, such as alanine, serine, and asparagine, appear to increase foraging activity. The foraging response is also increased by a variety of sugars, such as sucrose, maltose, glucose, and dextrin.

It is interesting to note that the only sugars to yield significant responses were sugars which contained a glucose ring, with higher responses from sugars with more than one ring. The response of *U. pugilator* to stimuli such as amino acids and sugars may be related to detection of glycoproteins and mucopolysaccharides secreted by the organisms upon which the crab feeds.

Eric Desman

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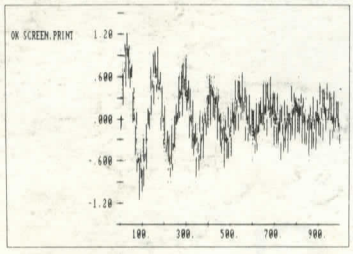

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