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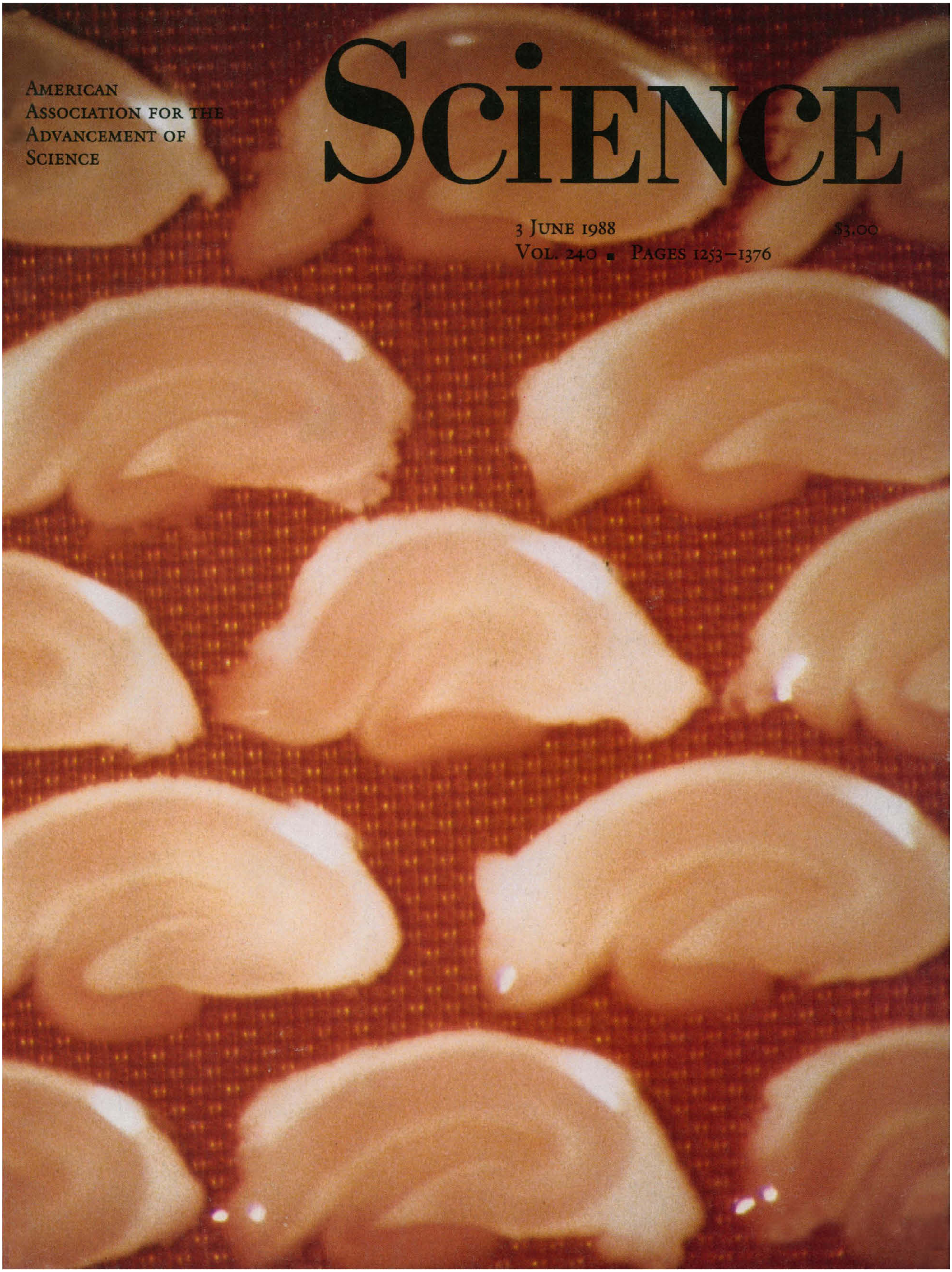

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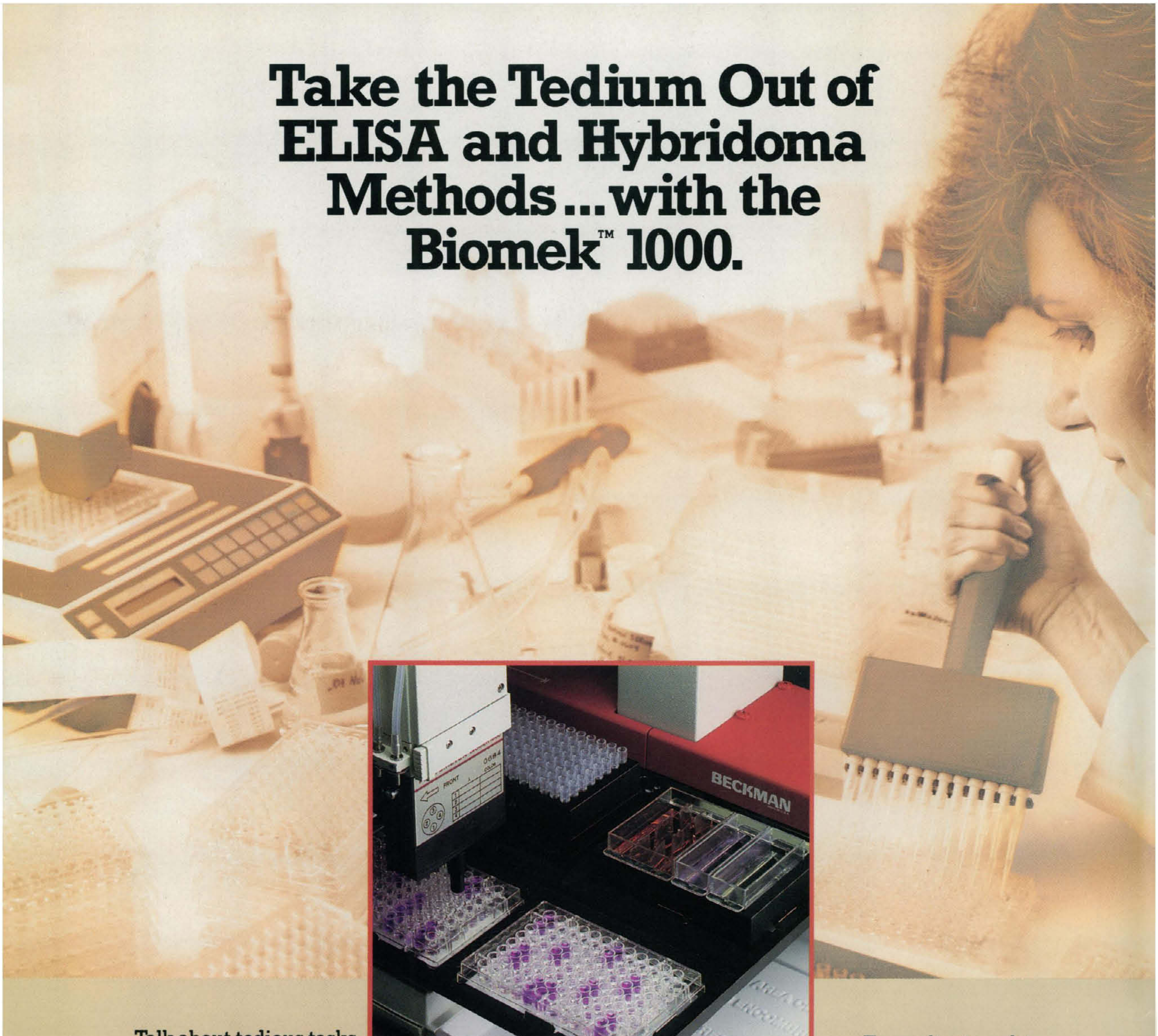

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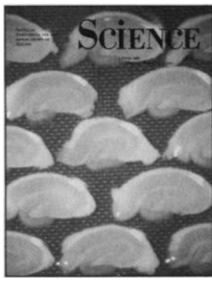
■ The American Association for the Advancement of Science was founded in 1848 and incorporated in 1874. Its objects are to further the work of scientists, to facilitate cooperation among them, to foster scientific freedom and responsibility, to improve the effectiveness of science in the promotion of human welfare, and to increase public understanding and appreciation of the importance and promise of the methods of science in human progress.



COVER Rat hippocampal slices supported on a nylon mesh laid over a polyethylene sheet in one compartment of a dual, linear flow, incubation and recording chamber. The 5-hour-old transverse slices (0.4 millimeter thick, 5 to 6 millimeters long, and 2 to 3 millimeters wide) are perfused with artificial cerebrospinal fluid and oxygenated with a humidified gas mixture of 95% oxygen and 5% carbon dioxide. See page 1326. [Robert D. Acland, School of Medicine, University of Louisville, Louisville, KY 40292]

Reports

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This Week in SCIENCE

Pacific turbulence

THE El Niño–Southern Oscillation (ENSO) is an irregular self-sustaining cycle of alternating warm and cool water episodes in the Pacific Ocean; despite reference to the baby (El Niño), powerful weather effects can be produced that sometimes have disastrous biologic consequences (page 1293). ENSO is governed by a natural oscillator that couples several ocean and atmosphere phenomena—the sea surface temperature, the surface wind stress, and the thickness of the ocean's warm upper layer of water. Each parameter shows its own quasi-periodicity but all are interrelated; together they maintain an oscillation with a 3- to 5-year periodicity. Graham and White provide a review and a new synthesis of numerical models and field observations of ENSO and emphasize the importance to the ENSO oscillator of wave motions in the ocean. Rossby waves travel slowly from east to west (taking, depending on latitude, from 9 months to 4 years to cross the Pacific basin); at the Pacific's western boundaries, faster moving Kelvin waves are reflected back toward the equator to reinitiate the cycle. Prospects for forecasting El Niño events continue to improve as more is understood about the interplay of ocean and atmosphere dynamics.

Adrenergic receptors: structure and function

CHIMERIC genes are helping to clarify how structure and function are related in adrenergic receptors (page 1310). Both α_2 and β_2 receptors bind various agonists and antagonists and both bind G proteins; however, when the β_2 receptor binds a G protein, the enzyme adenylyl cyclase is stimulated, but, when the α_2 receptors couple with G proteins, enzyme activity is inhibited. Because the α_2 and β_2 adrenergic receptors both have seven membrane-spanning domains, a panel of patchwork receptors could be produced from various combinations of genes encoding domains of the two receptors. The ability of each chimera to bind with agonists and antagonists and to activate adenylyl cyclase in association with G protein binding was then evaluated and correlated with the domains making up the chimera. Kobilka *et al.* point out that a number of hormones, neurotransmitters, and drug receptors have structures that are homologous to those of the adrenergic receptors and that structure-function relations in these molecules might also be studied by constructing chimeras. This method is superior to mutagenesis and to cleavage analyses, in both of which loss of function rather than the acquisition of a new activity serves as the end point.

Plate subduction into the earth

A subducting oceanic tectonic plate apparently experiences significant deformation as it penetrates into the mantle of the earth at a subduction zone (page 1317). The rate of deformation or the strain rate of subducting slabs has been calculated from the magnitudes of deep earthquakes that have occurred in slabs at mantle depths of 75 to 175 kilometers. The slab strain rate turns out to be not much smaller than the strain rate of the surrounding mantle into which it is descending. Thus, subducting slabs are neither rigid nor strong. Bevis suggests that there may not be a barrier to subduction at 680 kilometers, an important seismic discontinuity in the mantle, because such a barrier would cause the weak slabs to buckle, and buckling is not evident.

Finding mates with good scents

AN explanation is at hand for the observation that, normally, inbred male mice choose to mate with female mice who have different tissue histocompatibility types (called H-2) than their own: the males are choosing a "non-self" partner and this is a negative response to their early family experiences (page 1331). Litters of newborn mice were separated from their mothers and raised by foster parents; the genetic composition of the biologic and the foster parents differed only in the H-2 genetic region. At maturity, the fostered males (uncharacteristically for inbred mice) showed marked preferences for females of their own H-2 type rather than for the non-self choice that was the same as that of their foster parents. These experiments of Yamazaki *et al.* indicate that early chemosensory imprinting—the smell of the foster parents or siblings—directly guides the choice of a mate, probably helping the male mouse avoid mating with his closest kin.

AIDS incubation periods

FOR two AIDS risk groups, the incubation periods—the time from infection with HIV-1 (the AIDS virus) to diagnosis of the disease AIDS—have been determined, and they are very similar (page 1333). An 8.2-year incubation period was previously calculated for adults who had acquired AIDS through blood transfusions, but it has been unclear whether this figure would apply to other groups as well. Using serum data from a cohort of 84 homosexual and bisexual men, Lui *et al.* have developed a model from which an incubation period of 7.8 years for the homosexual-bisexual risk group was calculated; of all the adult AIDS cases in the United States, 74% occur among individuals in this risk group. All of the men in the cohort had developed serum antibodies to HIV-1 within 12 months of having had a negative blood test. Although the year of seropositivity in the homosexual-bisexual group was used as a proxy for the year during which exposure to the virus occurred (because the exact date of exposure to the virus could not be directly known), the true incubation period is not likely to be off by greater than 12 months; it is known from studies of adults who have contracted AIDS through blood transfusions that sera usually become positive for HIV-1 antibody within a few months of exposure to the virus.

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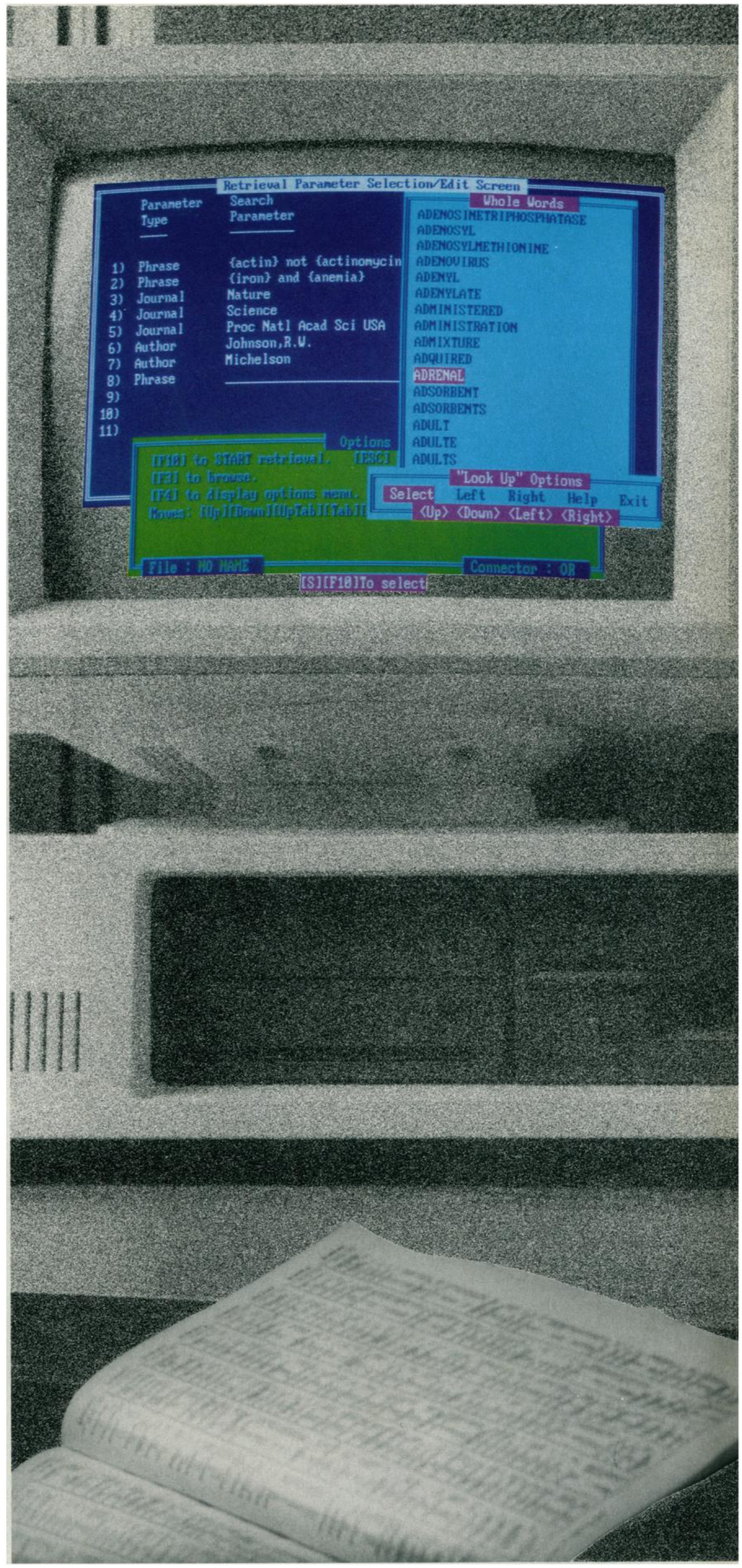

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Random Samples

Einstein once said, "Science can progress on the basis of error as long as it is not trivial." Farraday was once asked by a colleague, "Is Professor X always wrong?" "He's not that consistent," replied Farraday. Once when Philip Handler was chairman of the National Science Board and was defending the budget of the National Science Foundation, a hostile senator said, "I hear you biochemists want to adulterate bread by adding vitamin B to it. If the good Lord had wanted vitamin B in bread he would have put it there." Handler responded, "The good Lord did put vitamin B in bread. It was man who took it out in order to make white bread. The scientists who want to put it back are doing God's work." The NSF appropriation passed.

These vignettes are not the hard stuff of new scientific experiments or theories on which major scientific progress is based, but they are vignettes illustrating the processes and illuminating the people who create it. In this issue of *Science* we introduce a new feature in which incidents similar to those described above will be recorded (see page 1279). It will include testimony before Congress, quotations of scientists and of nonscientists about science, philosophical observations, and historical events. It is intended, like stroboscopic flashes, to highlight the insight and amusement that become visible transiently in the onward march of science. This column will be researched and written by Gregory Byrne, who will welcome your contributions.

One particular type of contribution will satisfy two needs. *Science* is deluged with requests to report prizes, obituaries, and promotions. We report little in this regard, not because the items are unimportant, but because to do a good job would require pages of sleep-inducing facts. Specialty journals can do this for one discipline, but *Science* covers the entire range of disciplines and there are innumerable prizes. If we wish to be fair to all disciplines, we would soon be swamped. However, anecdotes from award ceremonies frequently reveal little-known facts about how important discoveries were made or how scientific careers were formed. These and other amusing insights tell a great deal about the policies and history of science. *Science* readers should find that reporting of such information is worthier of space than a dry recital of the awards, promotions, and deaths. Those who provide us with interesting stories will be in the happy situation of giving our readers some ideas to ponder.

We have named the page "Random Samples." The dictionary defines "random" as "without definite aim, direction, rule or method, haphazard" and "sample" as "a part of anything shown as evidence of the quality of the whole." An individual anecdote is not evidence in science, and the items on this page will be collected with no large goal or message in mind. But often facts collected with one aim in mind can turn out to be useful in an unexpected connection. Space does not allow coverage of all the awards, all the testimony before Congress, or all the incidential items that occur each week. But if we are random enough, and our samples are representative, a picture of some of the fun and humanity of science may serendipitously emerge.

To believers in fairy tales, the good guys always win and the winners are always good guys. In the real world, including science, that is not always true. Some very important discoveries have been made by individuals whom one might not want to invite to dinner. And some extremely nice people just do not end up in the winner's circle. Character, however, is not irrelevant, since individuals who are generous with advice and materials to colleagues accelerate science by helping others, sometimes at sacrifice to their own advancement. The press is great at exposing unpleasant character flaws, but the person who is willing to play by the rules instead of cutting corners frequently gets short shrift. Scientists' attitudes, however, to new opportunities for inquiry, their insights into future directions of science, their eloquence in testimony before Congress, and their memories of how certain discoveries were made can provide insight, inspiration, or warning to others who are practitioners of the art. In some cases they may affect the research effort of the scientist in the laboratory. In other cases they may provide an epigram that will be useful to those trying to communicate more effectively with the public. Felicity in language and novelty in ideas deserve recognition whenever they occur. Those who notice such events should send them to us so that others may also enjoy and profit from the experience.—

DANIEL E. KOSHLAND, JR.

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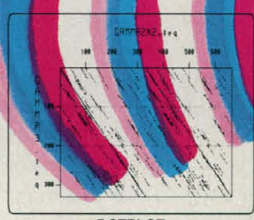

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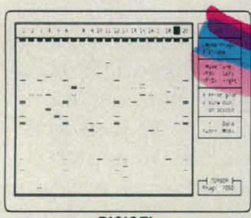

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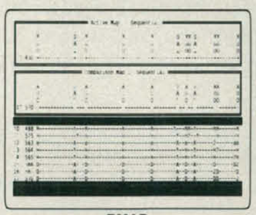

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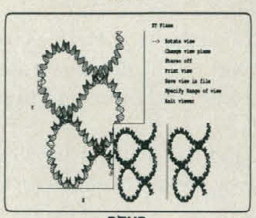

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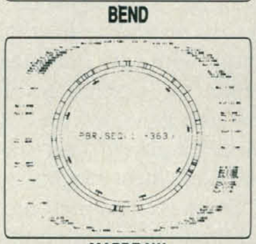

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The Constrained Curve

The Constrained Curve

The geometric path traced by a robot arm is independent of time. Now a mathematician at the General Motors Research Laboratories has devised a simple, innovative way to relate the path to time so that the machine can track the path and meet specific performance objectives without exceeding its physical operating limits.

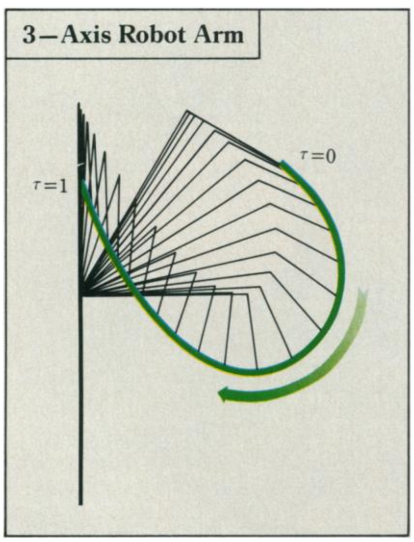


Figure 1: Schematic diagram of a 3-axis robot tracing a path in 3-space.

Figure 2: Results for Figure 1 path. I: Plot of the change of variables, t=h(τ). II, III, and IV: Normalized velocity, torque, and rate of change of acceleration for the waist, shoulder, and elbow (for any variable, a value of ±1 indicates operation at a limit).

Industrial robot arms are very good at repeating a well defined motion with a high degree of accuracy. A robot with a welding tool, a paint sprayer, or a grasping device at its tip can weld in the right spot, spray a precise pattern, or locate a part in a given place time after time.

This untiring precision makes robots valuable in a quality-oriented manufacturing process such as the assembly of an automobile. That's why General Motors has installed so many robotic manipulators in its plants, and why GM is intent on developing technology and software to use these machines to their best advantage.

When a robot is to apply sealant to a windshield opening, or move a part from one point to another, its tip is positioned at points along a fixed geometric path, always maintaining the orientation needed to perform the task.

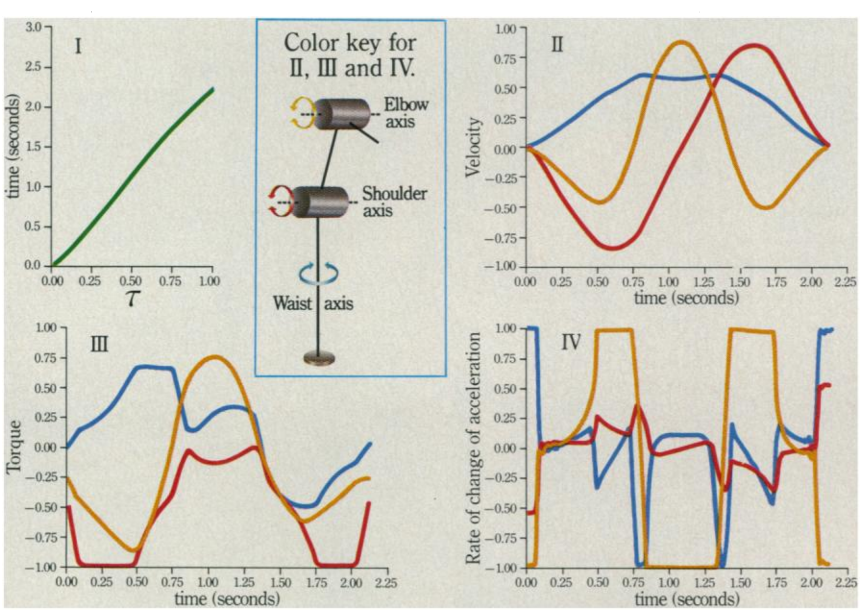
Mathematically, tip position along the path can be described as a function of a one-dimensional position parameter τ that ranges from 0 to 1 as the path evolves from beginning to end. Actually, for a robot having three joints, Figure 1 for example, tip position is determined by a set of three functions of τ, one for each joint of the arm. Each separate joint function relates a specific angle of rotation, θ, about that joint axis to a given value of τ.

To get the robot to perform a task, however, its computer controller must associate each point on the path with some value of time—in effect telling the robot to be in position A at a certain time, position B at another time, and so on, throughout the path.

Establishing an appropriate correspondence between time and the path position parameter is an important prerequisite to actually controlling the robot to follow the path.

Dr. Samuel Marin, a mathematician at General Motors Research Laboratories, has devised an effective and efficient means of computing the required correspondence. His work addresses productivity concerns. Dr. Marin's objective is to make cycle time (the time it takes the robot to trace the path from beginning to end) as small as possible, yet to respect at all times the physical operating limits of the robot.

Dr. Marin noted that by seeking a correspondence that gives time explicitly in terms of the path position parameter, $t=h(\tau)$, the problem's character changes. It appears not so closely associated with control theory, where the problem has also been studied, but more like a problem of nonlinear optimization.



Setting $g(\tau)=h'(\tau)$, the derivative of h with respect to τ, allowed Dr. Marin to pose the minimum time problem in the following way: minimize $\int_0^1 g(\tau)\, d\tau$, subject to some constraints dictated by the physical operating limits of the robot mechanism. These limits on the robot—limits on velocity, acceleration or torque, and on rate of change of acceleration (Fig. 2)—can all be formulated as differential inequality constraints and are all expressible in terms of the unknown function $g(\tau)$, as: $g(\tau) \geq G(\tau, g, g', g'')\ \tau \in [0,1]$.

If the problem could be discretized, making it in some sense finite, it could be put on a computer and solved numerically. So Dr. Marin replaced the unknown function with a piecewise cubic approximation.

This allows the search for the unknown function to be confined to a class of functions that are completely characterized by a finite number of coefficients in a B-spline series.

He similarly discretized the constraints, replacing the infinite set of constraints with a finite dimensional subset that could be dealt with numerically.

He completed the formulation of the discrete problem by incorporating a grid-refinement strategy. Now the problem's dimension could be gradually increased to better approximate the continuous case.

What resulted was a classic nonlinear optimization problem, a finite dimensional problem in which it remained only to find the coefficients of the B-splines while satisfying the constraints.

A monotonicity property of this problem coupled with properties of the approximation method suggests that the simple technique of cyclic coordinate descent might best provide a solution.

"While not so effective in other applications, a cyclic coordinate descent-based algorithm appears to be exactly what is needed in this class of problems," notes Dr. Marin. "With modifications introduced to ensure that the iterates are strictly feasible, this method has consistently and rapidly solved the problem."

Working closely with mathematicians at Rensselaer Polytechnic Institute, Dr. Marin is confirming this method's utility. In comparisons so far with several widely used, general-purpose optimization codes, the special method consistently shows itself to be superior.

"My work in path parametrization is just part of the story here at GM," emphasizes Dr. Marin. "Many aspects of this problem's formulation are rooted in deeper concerns about how robots can be made to move faster and more accurately. These concerns originated in the work of Dr. Robert Goor, my colleague in the Mathematics Department, and have motivated several significant advances in robot control and trajectory planning.

"Until all the pieces are put together in a production system, it's difficult to gauge the full value of this work. However it will help reduce our manufacturing costs and will enhance our product quality."

THE MAN BEHIND THE WORK

Dr. Sam Marin is a Senior Staff Research Scientist in the Mathematics Department of the General Motors Research Laboratories. He is also the Manager of the Department's Mathematical Analysis and Computation Section.

Dr. Marin received his undergraduate degree in mathematics from St. Vincent College in Latrobe, Pennsylvania, and holds both an M.S. and a Ph. D. in that discipline from Carnegie-Mellon University. Between graduate degrees, Sam was an officer in the U.S. Navy, teaching mathematics at the Naval Nuclear Power School.

Since joining General Motors in 1978, Dr. Marin has pursued interests in numerical analysis and approximation. He has published research relating these areas to a variety of applications, including robotics, geometric curve design, and acoustics.

Sam is a member of the Society for Industrial and Applied Mathematics. He lives in Rochester Hills, Michigan, with his wife and two children.

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Evolutionary Physiology

New Directions in Ecological Physiology. MARTIN E. FEDER, ALBERT F. BENNETT, WARREN W. BURGGREN, and RAYMOND B. HUEY, Eds. Cambridge University Press, New York, 1988. x, 364 pp., illus. $49.50; paper, $19.95. Based on a symposium, Washington, DC, May 1986.

The ecological physiology of animals is a relatively new area of specialization. It can in part be traced to comparative physiology, but intellectually it is closely tied to natural history and studies of animal behavior. The classic study of thermoregulation of desert reptiles by R. B. Cowles and C. M. Bogert, published in 1944, showed that physiology could be related directly to the behavior of animals in the wild and that laboratory techniques could be taken into the field. Subsequently, the development of biophysical models of the mass and energy exchange of organisms has strongly influenced ecological physiology. The prominent role that terrestrial ectotherms, especially lizards, have played reflects the historical origins of the discipline as well as the conspicuous effects that interactions with the physical environment have on the minute-to-minute behavior of ectotherms.

Much work with birds and mammals had its origin in the pioneering studies of the allometry of energetics by S. Brody, F. R. G. Benedict, and M. Kleiber, and many studies of endotherms have emphasized those relationships in contexts somewhat different from those addressed in recent work with ectotherms. Plant physiological ecology has developed almost independently of work with animals, although biophysical modeling, which is now an important component of animal ecological physiology, originated with David M. Gates's studies of plants. These historical considerations help to explain the distribution of topics in this book: Plants are excluded, and the allometric approach to energetics that characterizes, for example, the work of Brian K. McNab is conspicuously absent.

At its best, ecological physiology has offered the opportunity to integrate specializations as diverse as physiology, ecology, morphology, behavior, and evolutionary biology. The most successful studies have combined reductionist and synthetic approaches to define both mechanisms and patterns. This perspective has allowed a diversity of information to be integrated into a coherent picture of how organisms work. For example, the differences in exercise physiology of lizards in the spectrum from widely foraging to sit-and-wait predators provides a context for interpreting parallel differences in body shape, color, predator avoidance mechanisms, diet, daily energy intake, and reproduction. This integrative approach provides insights that are not apparent from more restricted perspectives.

Of course, no discipline always realizes its potential, and ecological physiology has been no exception. The disparaging comment that ecological physiologists show that "organisms can live where they do live" has some foundation. Many studies have contributed only further examples of already well-documented phenomena. In an introduction, Albert F. Bennett suggests that one problem in ecological physiology has been its reliance on the study of novel organisms in novel environmental situations. That strategy was initially productive, but the fact of adaptation to specific environments has been so well documented that additional examples will contribute little to our understanding. Further progress will depend on asking new and more sophisticated questions.

New Directions in Ecological Physiology responds to this perception of stagnation by attempting to initiate a discussion of the questions, contexts, and goals that should define the future of the discipline. In 1986, 26 biologists—all senior, all male—assembled for three mornings of presentations and afternoons of discussion. The book is the product of that conference. As such, it is a social document as much as a scientific one, and many of the most interesting parts are to be found in the edited transcripts of discussions among the participants.

Following Bennett's introduction, the book is divided into three parts: Comparisons of Species and Populations, Interindividual Comparisons, and Interacting Physiological Systems. An opening chapter by George A. Bartholomew sets the historical scene. Interspecific comparisons have been the mainstay of ecological physiology, and Bartholomew (whose first- and second-generation students are represented among the participants) has been a pioneer in the field. Bartholomew is particularly associated with the recognition that animals in extreme environments are likely to provide the clearest examples of adaptive specialization. His fascinating chapter reviews the development of ecological physiology from a personal perspective and argues that interspecific comparisons do not yield trivial results when the species are chosen with an appreciation of their whole biology and when appropriate questions are asked.

The contrast between traditional and new directions is illustrated by the discussion following Bartholomew's presentation—evolutionary questions, some commentators suggest, are not usefully addressed by studies of novel species. Developing this theme in the next chapter, Martin E. Feder expands on the views presented by Bennett to suggest that enough is enough: "Ecological physiologists have assembled an enormous number of case studies that establish 'equilibrium' beyond any reasonable doubt," and further studies "will not appreciably augment the overwhelming mass of evidence already assembled to demonstrate 'equilibrium.' " Instead, Feder suggests that general questions can profitably be addressed. The most basic of these is whether individual variation in physiological characters is related to individual variation in Darwinian fitness. Feder's chapter proposes a significant reformulation of the perspective of ecological physiology, from an attempt to understand the biology of organisms to a way of asking questions about evolution. Most of the remaining chapters continue this theme, and the final chapter (also by Feder) concludes that "For me, the central question of organismal biology, and the one that expresses the essence of the potential new directions of ecological physiology, is, 'How can we explain the evolution of diverse complex organisms?' "

If we assume that this new direction is the right one (and not all ecological physiologists will accept that premise), how successful is it likely to be? Physiologists have long recognized the existence of individual variation in physiological characteristics, but, as Bennett points out, they have usually treated it as noise in the search for a mean value to characterize a species. In fact, that variation is the raw material of evolution. In this respect, evolutionary physiology is taking its cue from evolutionary morphology and the study of animal behavior, which came to similar realizations some time ago.

Can measurements of individual physiological variation be related to individual differences in Darwinian fitness as *New Directions* proposes? Productive attempts have originated with the observation of genetic variation and have pursued the significance of that variation at higher levels of biological organization. Most complete is the work of Ward Watt and his associates on the significance of genetic variation at the phosphoglucose isomerase locus of *Colias* butterflies. (Surprisingly, these studies are not represented in *New Directions*.) Watt has demonstrated mechanistic links that extend from the different functional properties of electromorphs of the enzyme through the flight times of male butterflies, and he has shown in the field that males with the isozymes that are predicted to be favored do, in fact, sire a disproportionately large number of broods. A similar approach to the functional significance of physiological variation is represented in *New Directions* in chapters by Richard K. Koehn (the leucine aminopeptidase locus of mussels) and Dennis A. Powers (the lactic dehydrogenase locus of killifish). Another approach to relating physiological variation to fitness rests on correlations of the multiple-locus heterozygosity of individuals with physiological characters such as metabolism and growth rate. Correlations of this sort have been reported for trees, grasses, invertebrates, and vertebrates. Their widespread occurrence is intriguing, but they do not suggest a mechanistic basis for a link between physiological variation and fitness.

Demonstrating an effect of any characteristic on fitness is difficult, and demonstrating an effect on evolution is harder still. Even the most successful studies have revealed stabilizing selection and thus cases in which evolution is *not* occurring. The goal of demonstrating a role for physiological variation in directional selection remains elusive. One of the difficulties we will encounter in attempting to establish a discipline of evolutionary physiology lies in the phenomena that ecological physiologists study. Complex functions do not readily lend themselves to genetic analysis. Sprint speed, endurance, oxygen consumption, salt or water flux, and temperature tolerance are the sorts of phenomena traditionally measured by ecological physiologists, and these characteristics are almost certainly controlled by multiple genetic loci.

Given the magnitude of the difficulties, is it realistic to hope to trace mechanistic links between heritable physiological variation and whole-organism performance under natural conditions and thereby demonstrate the importance of physiological variation for evolutionary biology? That goal is certainly not going to be achieved quickly, and a clear understanding of what we must accomplish is needed to avoid unproductive searches for simple answers to complex questions.

Attempts to relate individual physiological variation to fitness have focused so far on the middle levels of the chain of evidence, especially on the relationship of physiological characteristics to locomotor performance. From this point the links must be extended downward to tissue and molecular mechanisms and upward to the effects of variation in locomotion on fitness. A reduc-