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THE MATHEMATICIAN'S ART OF WORK

BY J. E. LITTLEWOOD

I WILL BEGIN by saying, with a double motive, that there are a lot of queer people in the world. I remember a report of a man who was three times saved from drowning in a day, bathed once more and *was* drowned. The same year there was the case of a man, whom I think of as having spent his life in the British Museum, who conceived the idea of a seaside holiday, had himself rowed out, dived overboard, and being unable to swim, was drowned.

A former pupil began brilliantly; he took a pure research post after his Ph.D. under me, and had 6 years of research. The work became dull though copious, and finally ended, and when I then met him he was on the point of a nervous breakdown. I then discovered that he had worked continuously for the 6 years for 365 and a-quarter days a year. If he had done the work in the reverse order he would have been a Fellow of the Royal Society.

Shortly before World War I the psychologist, Boris Sidis, subjected his son to a theory of education. By the age of 19 the boy had become outstanding in a number of subjects. According to the theory no strain was involved, and in fact the boy did not obviously overwork and was also good at athletics. Some time after the war, when he was about 30, he was met by visitors from England. He held an ill-paid post with unexacting duties, refused to be promoted, and said that his object in life was never to have to *think* again.

These are awful examples. On the other hand, there are successfully creative people with strange methods of work. I know of a man who works only two days a week, of one who can work only in a cabaret, of one who has a wine-bottle by his desk. The economist, Marshall, though he had been through the mill of the Cambridge Mathematical Tripos and was second Wrangler, could not, or at any rate did not, work in later life for more than fifteen minutes at a stretch.

There are two morals to all this. If a young man feels he is not at home in the world, or that his instincts of how to work are abnormal, there is no reason for him to worry unduly. On the other hand he would be wise to find out what the usual methods are and give them a prolonged trial (less than a month is no good at all) before finally committing himself. There can be powerful illusions on such points, which I will come to later.

Creativity

At the lowest level there is an element of creativity in much ordinary conversation. We do not think

what we are going to say and then say it, the experience is subjectively simple, and what is said emerges from the subconscious into the conscious. Long experience has established a working liaison between the two, but if it fails, one becomes "tongue-tied."

At the other extreme of creativity, there are the "great" creations, of something totally new and unexpected, and also of great importance, and seminal. We should all feel that the difference is one of kind and not of degree. (If I may frivolously digress, do you know the question: is the difference between a difference of degree and a difference of kind a difference of degree or a difference of kind? The *answer,* of course, is elementary.)

Much lies between the extremes. In any new form of mental activity, however man-made, the niche fills with people whose capacity is many orders of magnitude above the average. It has been said that we use only a small part of our brains; these facts are perhaps evidence for the idea. Let us run over some cases.

Oscar Wilde could cast his eyes down the pages of a novel, and in five minutes pass an examination on the contents.

The fantastic performances of musical prodigies and calculating boys are well-known. They have an intense interest in their game to the exclusion of all else, but the facts would be incredible if they did not happen. The calculators split into above average intelligence and below. The former lose interest when they realize that anyone can get his results slowly by routine methods; they reach their peak at about the age of 4. Gauss was a case of this, though he did do a good deal of numerical calculation throughout his life: possibly he found in it a relaxation like that provided today by crosswords; but Gauss was a law to himself. A contemporary of Gauss, Däse, was of low intelligence, kept his capacity all his life, and was actually employed by Gauss to make factor-tables. Bidder, himself a highly intelligent case, had a daughter with a rather different faculty, but one out of all relation with ordinary people. She knew the current 707 digits for π, could begin at any point and read them off *either forwards or backwards.* She was studied by philosophers and psychologists in Cambridge, but she was quite unable to explain how she did it.

Computer theory has thrown up a class with suitable gifts, and they are not necessarily very good at mathematics. There is a class, not apparently very distinguished intellectually, which – as a recent experiment showed – can do difficult crossword puzzles with almost complete certainty and in an incredibly short time.

There are people who can learn a new language in a week, but most adults are poor linguists. Children, on the other hand, if suitably exposed, can be fluently trilingual by the age of six (more than three languages creates confusion). I don't know how to place this difference, but clearly this is the right way to be trilingual.

None of all this is highly creative. But, still between the extremes, there is the army of people very gifted but short of genius. Though the importance of their creations falls short of the highest, I think the psychology involved is pretty much the same. A *sine qua non* is an intense conscious curiosity about the subject, with a craving to exercise the mind in it, quite like physical hunger. Love of truth – and all that – may co-exist, but I deny that it is the driving force. (To digress on physical analogies, a "hunch" – an idea for which one can give no reason – seems analogous to smell.) Given the strong drive, it communicates itself in some form to the subconscious, which does all the real work, and would seem to be always on duty. Lacking the drive, one sticks. I have tried to learn mathematics outside my fields of interest; after any interval I had to begin all over again.

The pungent, aphoristic style of the eminent mathematician, J. E. Littlewood – of Trinity College, Cambridge University – defies imitation or description. As he himself has said in his A Mathematician's Miscellany, *"The vast majority of English adjectives do not possess the quality they denote; the adjective 'red' is not red: some, however, do possess it; e.g. the adjective 'adjectival.' Call the first kind heterological, the second homological." Dr. Littlewood is replete with honors such as the Royal Medal, the Sylvester Medal, the Copley Medal of the Royal Society, the De Morgan Medal, and the Senior Berwick Prize of the London Mathematical Society. He gave these remarks in a somewhat different form at the University in May.*

Four Phases

It is usual to distinguish four phases in creation: preparation, incubation, illumination, and verification, or working out. For myself I regard the last as within the range of any competent practitioner, given the illumination.

Preparation is largely conscious, and anyhow *directed* by the conscious. The essential problem has to be stripped of accidentals and brought clearly into view; all relevant knowledge surveyed; possible analogues pondered. It should be kept constantly before the mind during intervals of other work. This last is advice from Newton.

Incubation is the work of the subconscious during the waiting time, which may be several years. Illumination, which can happen in a fraction of a second, is the emergence of the creative idea into the conscious. This almost always occurs when the mind is in a state of relaxation, and engaged lightly with ordinary matters. Helmholtz's ideas usually came to him when he was walking in hilly country. There is a lot to be said for walking during rest periods, unpopular as the idea may be. Incidentally the relaxed activity of shaving can be a fruitful source of minor ideas; I used to postpone it, when possible, till after a period of work. Illumination implies some mysterious rapport between the subconscious and the conscious, otherwise emergence could not happen. What rings the bell at the right moment?

I recently had an odd and vivid experience. I had been struggling for two months to prove a result I was pretty sure was true. When I was walking up a Swiss mountain, fully occupied by the effort, a very odd device emerged – so odd that, though it worked, I could not grasp the resulting proof as a whole. But not only so; I had a sense that my subconscious was saying, "Are you *never* going to do it, confound you; try this."

. . . the relaxed activity of shaving can be a fruitful source of minor ideas; I used to postpone it, when possible, till after a period of work.

My description so far has been appropriate to science or mathematics, one single idea. In the case of a symphony, incubation would be a more continuous process and many separate illuminations would be called for. And then the final miracle of a great symphony is the welding into an organic whole.

Beethoven's notebooks show that – with some remote objective vaguely in view – he would start with deliberate crudities, and approach the final work through blunders and repeated alterations. A recent surprise has been that the apparently completely spontaneous Dvořák was a quite similar case.

Some Anecdotes

Kekulé's Benzene ring came in a dream. It is proverbial that sleep alters thoughts and decisions, but I believe high creation in dreams is very rare. William James used to have what seemed vitally important ideas in dreams, but always forgot them on waking. He decided to write down such dreams, and succeeded in doing so on the next occasion. In the morning he read: "Higamus hogamus, woman is monogamous; Hogamus higamus, man is polyga-

mous." It is not too bad: it has both form and content.

MENDELEEV was a conscientious Professor of Chemistry with the urge to do the utmost for his pupils. He collected together likenesses of elements and tried to number them helpfully so as to be mnemonics. The final upshot was the Periodic Law.

LOBACHEVSKI had to teach Geometry; and began by an intensive critical study of Euclid, acting as devil's advocate. This approach to the anomalous parallel axiom resulted in his non-Euclidean Geometry.

M. RIESZ had conceived a beautiful collection of theorems. He could prove them all if he could only prove a very special and innocent-looking case of one of them. Specifically: if $f(z) = u + iv$ is regular in $|z| \leq 1$ and $f(0) = 0$ then we are to have

$$\int_{-\pi}^{\pi} |v|^4 d\theta \leq A \int_{-\pi}^{\pi} |u|^4 d\theta.$$

One day, having to give an examination, he was playing about with $\int_{-\pi}^{\pi} f^4 d\theta$ instead of the familiar $\int_{-\pi}^{\pi} |f|^4 d\theta$.

This gives $\int_{-\pi}^{\pi} v^4 d\theta = -\int_{-\pi}^{\pi} u^4 d\theta + 6\int_{-\pi}^{\pi} u^2 v^2 d\theta.$

Using Cauchy's inequality on the least provocation was second nature to him. Doing this and changing the *minus* into a *plus* to fit higher indices, he had

$$\int_{-\pi}^{\pi} v^4 d\theta \leq \int_{-\pi}^{\pi} u^4 d\theta + 6\left(\int_{-\pi}^{\pi} u^4 d\theta \int_{-\pi}^{\pi} v^4 d\theta\right)^{\frac{1}{2}},$$

and saw his proof staring him in the face.

A possible moral of the last three instances is that teaching activities may pay off in pure research.

In passing, I firmly believe that research should be offset by a certain amount of teaching, if only as a change from the agony of research. The trouble, however, I freely admit, is that in practice you get either no teaching, or else far too much.

ERASMUS DARWIN held that every so often you should try a damn-fool experiment. He played the trombone to his tulips. This particular result was, in fact, negative. But other incredibly impudent ideas have succeeded. An Italian physicist had rigged up two screens and transmitted electric impulses from one to the other. If he had spoken to one of the screens he would have invented the telephone, but with his sound physical sense he of course did nothing of the kind. The phonograph and telephone are surely most impudent ideas.

Erasmus Darwin held that every so often you should try a damn-fool experiment. He played the trombone to his tulips.

There is a superb example, which I have described as the most impudent idea in Mathematics, with very important consequences; it is too technical for this paper, but you will find it discussed on pages 20-23 of my *Mathematician's Miscellany.*

On Being a Mathematician

There is much to be said for being a mathematician. To begin with, he has to be completely honest in his work, not from any superior morality, but because he simply cannot get away with a fake. It has been cruelly said of arts dons, especially in Oxford, that they believe there is a polemical answer to everything; nothing is really *true,* and in controversy the object is to prove your opponent a fool. We escape all this. Further, the arts man is always on duty as a great mind; if he drops a brick, as we say in England, it reverberates down the years. After an honest day's work a mathematician goes off duty.

Mathematics is very hard work, and dons tend to be above the average in health and vigor. Below a certain threshold a man cracks up; but above it, hard mental work *makes* for health and vigor (also — on much historical evidence throughout the ages — for longevity). I have noticed lately that when I am working really hard I wake round about 5:30 a.m., ready and eager to start; if I am slack, I sleep till I am called. I mentioned this to a psychological doctor, who said it was now a known phenomenon.

There is one drawback to a mathematical life. The experimentalist, having spent the day looking for the leak, has had a complete mental rest. A mathematician's normal day contains hours of close concentration, and leaves him jaded by the evening. To appreciate something of high aesthetic quality needs close attention, easy to the unfatigued; but a strain for the fatigued mathematician. (Music seems a happy exception to this.) This is why we tend to relax either on mild nonfiction like biographies, or — to be crude, and to the derision of arts people — on trash. There is, of course, good trash and bad trash.

THE HIGHER MENTAL ACTIVITIES are pretty tough and resilient, but it is a devastating experience if the drive does stop, and a long holiday is the only hope. Some people do lose it in their forties, and can only stop. In England they are a source of Vice-Chancellors.

MINOR DEPRESSIONS will occur, and most of a mathematician's life is spent in frustration, punctuated with rare inspirations. A beginner can't expect quick results; if they are quick they are pretty sure to be poor.

To digress on this point, the ideal line for a supervisor with a really promising man is to give him two subjects: one, ambitious; the other, one that the supervisor can judge to be adequate for a Ph.D. (even if he has to do the thing himself first).

When one has finished a substantial paper there is commonly a mood in which it seems that there is really nothing in it. Do not worry, later on you will be thinking "at least I could do something good *then.*" At the end of a particularly long and exacting work there can be a strange melancholy. This, however, is romantic, and mildly pleasant, like some other melancholies.

Research Strategy

With a good deal of diffidence I will try to give some practical advice about research and the strategy it calls for. In the first place research work is of a different order from the "learning" process of pre-research education (essential as that is). The latter can easily be rote-memory, with little associative power: on the other hand, after a month's immersion in research the mind knows its problem much as one's tongue knows the inside of one's mouth. You must also acquire the art of "thinking vaguely," an elusive idea I can't elaborate in short form. After what I have said earlier, it is inevitable that I should stress the importance of giving the subconscious every chance. There should be relaxed periods during the working day, profitably, I say, spent in walking.

HOURS A DAY AND DAYS A WEEK On days free from research, and apart from regular holidays, I recommend four hours a day or at most five, with breaks about every hour (for walks perhaps). If you don't have breaks you unconsciously acquire the habit of slowing down. Preparation of lectures counts more or less as research work for this purpose. On days with teaching duties, I can only say, be careful not to overdo the research. The strain of lecturing, by the way, can be lightened if you apply the golfing maxim: "don't press." It is, of course, hard not to. Don't spend tired periods on proof correction, or work that needs alertness; you make several shots at an emendation that you would do in one when fresh. Even in making a fair copy one is on the *qui vive* for possible changes.

Either work all out or rest completely. It is too easy, when rather tired, to fritter a whole day away with the intention of working but never getting

properly down to it. This is pure waste, nothing is done, *and* you have had no rest or relaxation. I said "work all out": speed of associative thought is, I believe, important in creative work; another elusive idea, with which my psychological doctor agrees.

For a week without teaching duties – and here I think I am preaching to the converted – I believe in one afternoon and the following day off. The day off need not necessarily be Sunday, but that has a restful atmosphere of general relaxation, church bells in the distance, other people going to church, and so on. The day, however, should stay the same one of the week; this establishes a rhythm, and you begin relaxing at lunch time the day before.

At one time I used to work 7 days a week (apart, of course, from 3-week chunks of holidays). I experimented during a Long Vacation with a Sunday off, and presently began to notice that ideas had a way of coming on Mondays. I also planned to celebrate the arrival of a decent idea by taking the rest of that day off. And then ideas began coming also on Tuesday.

Morning versus evening Before World War I it was usual in Cambridge to do our main work at night, 9:30 to 2:00 or later. Time goes rapidly – one has a whiskey and soda at 11:30 and another later – and work *seems* to go well and easily. By comparison the morning seems bleak and work a greater effort. I am sure all this is one of the many powerful illusions about creative work. When put out of action by a severe concussion in 1918, I consulted Henry Head, an eminent psychologist, and known for wise hunches as a doctor. The traditional prescription was complete rest, but he told me to work as soon as I felt like it (I had leave of absence) and as much as I felt up to, *but* – only in the morning. After a month or two I discovered, that, for me at least, morning work was far the better. I now never work after 6:30 p.m.

Warming up Most people need half an hour or so before being able to concentrate fully. I once came across some wise advice on this, and have taken it. The natural impulse towards the end of a day's work is to finish the immediate job: this is of course right if stopping would mean doing work all over again. But try to end in the middle of something; in a job of writing out, stop in the middle of a sentence. The usual recipe for warming-up is to run over the latter part of the previous day's work; this dodge is a further improvement.

Before coming to the subject of holidays I will say something about the various symptoms of overwork. I have wrongly disregarded them in the past; so doubtless others do too. One symptom can be muscular trouble. I once got into a vicious circle of feet painful enough to prevent exercise. I went to a masseuse who had the reputation of being a bit of a crank outside her work; she said my trouble was due to mental overwork. I am afraid I laughed, but I found she was perfectly right.

An ominous symptom is an obsession with the *importance* of work, and filling every moment to that end. The most infallible symptom is the anxiety dream. One struggles tensely all night with a pseudo-problem – possibly with some odd relation to one's current job – and wakes in the morning quite unrefreshed.

Holidays A governing principle is that 3 weeks, exactly 21 days – the period is curiously precise – is enough for recovery from the severest mental fatigue provided there is nothing actually pathological. This is expert opinion and my experience agrees entirely, even to the point that, e.g., 19 is not enough. Further, 3 weeks is more or less essential for much milder fatigue. So the prescription is 3-weeks holiday at the beginning of each vacation. It is vital, however, that it should be absolutely unbroken, whatever the temptation or provocation.

I believe there is a seasonal effect in mental activity, the trough coming about the middle or end of March. The academic year is surely involved, but there is probably a climatic factor. If this question is to be studied – and I think it should be – moments of high inspiration are far too rare and sporadic for statistics, but we could fall back on chess, bridge, and particularly crosswords, as tests of alertness and minor creation. My own evidence comes from a period of about 10 years when I played a form of two-pack patience, or solitaire, involving a very high element of skill. My curve of successes showed a general rise, with an unmistakable seasonal effect, a trough at the end of March. There was one anomaly, a March with a positive peak. I then recalled that I had taken a sabbatical term's leave from January through March, skiing in Switzerland.

Holiday activities For many people these are highbrow: visits to Italian art galleries, a tour of Greece, and so on. I admire them, but do not share

their tastes. I have an intense interest in music, but this does not need travel. I began skiing at 40 and rock-climbing at 43: these activities renewed my youth. They give the most complete relaxation possible for mental work, and I believe they enlarge one's personality. Simple walking in mountains is very good. So is golf.

FOOD, TOBACCO, ALCOHOL Do not work within two hours of a substantial meal; blood cannot be in two places at once. I was once trapped into cold salmon at 6:30 p.m., immediately followed by a lecture, which I had had to leave largely to the spur of the moment. The lecture was confused and I was poisoned for a week afterwards. I should have starved.

On tobacco my bleak advice is: no smoking till the day's work is over. There is much to be said against regular smoking: you are merely normal when smoking and miserable when not. I was converted from the heaviest possible smoking (16 pipes and 4 cigars a day) by Henry Head. He had the 1918 flu, followed by lack of tobacco on his ship and at his destination; an interval of 4 or 5 weeks. He decided to try giving it up for good. He then found that a heavy paper he was writing was finished in, he said, a third of the time it would have taken before. I sighed, succeeded in the struggle for abstinence, and I fully agreed with his estimate. I said speed was important; smoking is its enemy.

Alcohol is a depressant or sedative, not a stimulant, in spite of the illusion of champagne. It has a very valuable function in *stopping* thinking at the end of the day's work, a thing which many workers find indispensable. It has been said that, for this reason, Beethoven's posthumous quartets were paid for by cirrhosis of the liver. A permissible use is to mitigate the boredom of long routine calculations, or making a final draft. But then there must be a final check.

TEA AND COFFEE These are admirable, with no later reaction. They are usually considered to be rather mild in the way of stimulants; but since most of us never have the experience of being without them, it is possible that their virtue is underestimated.

. . . stimulants do exist; but they should be used . . . only in a crisis. And there is the problem of knowing what is *a crisis.*

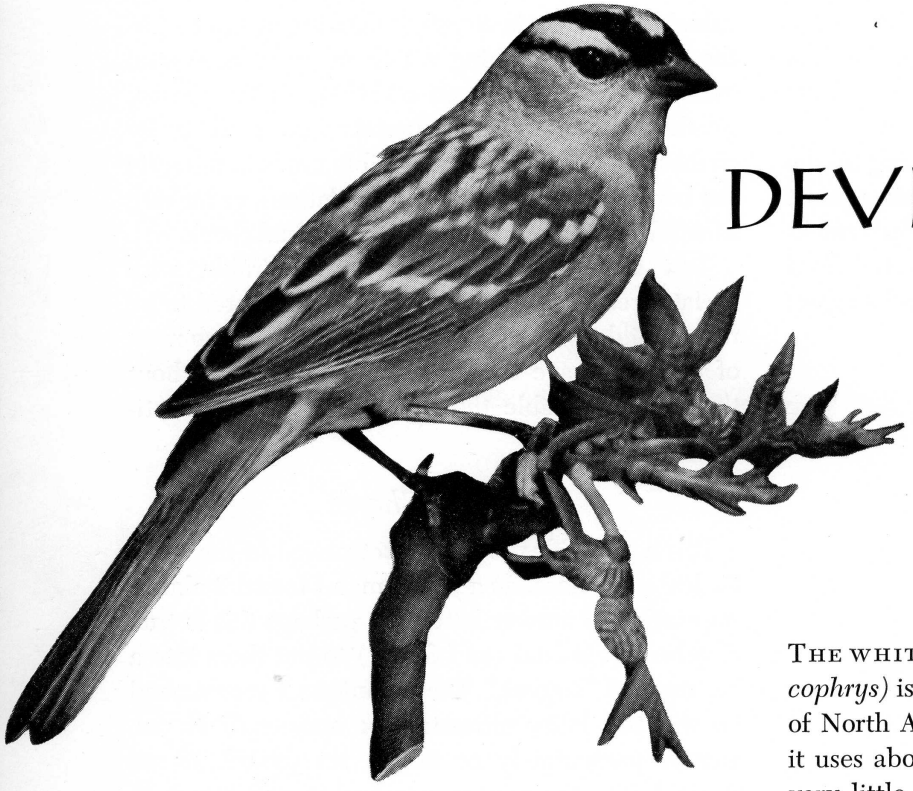
Routine Chores

It is a good idea to keep a set period in the week to deal with these. As a young man I found it almost impossible to answer letters, so perhaps this is true of others. It is fatal (as I found) to put them into a file marked "Urgent." The technique I recommend is: will this letter ultimately be answered? If yes, answer immediately or in the set period. If no, straight into the wastepaper basket and forget it. This needs *knowing* oneself, a very important thing in many ways: not everyone does. There is a true story of an English clergyman offered a Colonial Bishopric. An inquiring visitor was told by the daughter of the house: "Father is in the study praying for guidance, Mother is upstairs packing."

DRUGS I can envisage a future in which stimulant drugs could raise mental activity for a set period of work, and relaxing ones give a suitable compensating period, perhaps of actual sleep. The present is a time of transition; stimulants do exist; but they should be used only with the greatest care and only in a crisis. And there is the problem of knowing what *is* a crisis.

ACOUSTICAL INFLUENCES IN BIRDSONG DEVELOPMENT

BY PETER MARLER



Dr. Marler is Professor in The Rockefeller University, and his primary research interest is the developmental basis and physiology of animal communication. He presented this paper at a Research Colloquium that was held in Caspary Auditorium on March 3, under the auspices of the Faculty Committee on Lectures. Dr. Marler is also Senior Research Zoologist of the Institute for Research in Animal Behavior, which is conducted jointly by The New York Zoological Society and The Rockefeller University.

THE WHITE-CROWNED SPARROW *(Zonotrichia leucophrys)* is a small songbird, common in many parts of North America. In the course of an annual cycle it uses about seven different sounds, most of which vary little or not at all in different sections of the range. However, one vocalization – the breeding song of the male – varies widely from place to place to such an extent that it is known among ornithologists as a classical illustration of birdsong "dialects." Once an individual male white-crown becomes adult, it employs a single basic song pattern. Roger Tory Peterson describes it as several plaintive whistles followed by a husky trill. This is repeated many thousands of times, with only minor variations, in the course of a breeding season. A comparison of the songs of males living in the same area reveals that they have many characters in common, particularly in the detailed syllabic structure in the second part of the song. Extension of the comparison to birds in

other areas shows striking and consistent differences, which can appear over quite small distances and are stable from year to year (see illustration, page 10).

By studying responses of both wild and captive birds to playbacks of recorded songs, Dr. Marilyn Milligan and Dr. Jared Verner, working at Berkeley, found that white-crowned sparrows react more strongly to songs of their own species than to those of another, such as the song sparrow. According to a variety of measurements, both males and females are also more responsive to their own dialect than to recordings of another dialect of their own species. Having communicatory significance to the birds themselves, the dialects might favor the coherence of local populations, reducing the likelihood of movement of birds from one breeding area to another. They might even be a first step toward the divergence of local populations and, ultimately, toward speciation. To assess the likelihood that dialects are a sign of incipient speciation we need to know more about their ontogeny.

Dialect Development

What is the developmental basis of these song dialects? One possibility is that they represent genetic differences among populations. There is evidence that variation in the structure of singing behavior in some domesticated birds is determined genetically. On the other hand, these dialect differences appear over very short distances, which are hardly effective barriers for animals as mobile as birds. The available evidence suggests that the variations are, in fact, phenotypic, and that the dialects are transmitted from generation to generation by tradition, young birds learning from adults. The development of song in this bird represents a most unusual example of lability in the structure of natural motor patterns, paralleling in some respects the way in which human children learn to speak from hearing the voices of adults.

In experiments on animal learning, most attention is ordinarily given to the role of experience in determining the kinds of environmental stimuli to which an animal will respond. The role of experience in the development of motor patterns is usually studied with the focus on the frequency, completeness, or orientation with which an action is performed; rarely is the focus on the detailed structure of motor patterns – rarely, that is, outside studies of the development of speech and manual skills in man. Patterns of motor activity are, in fact, less labile than the sensory systems that control behavior, as a necessary result of the constraints imposed by the related skeletal, muscular, and neural equipment. Embryologists have demonstrated that the growth patterns of this equipment are largely controlled by endogenous processes. It is particularly rare to find that the detailed structure of natural patterns of behavior is determined by environmental influences. In this sense, the type of song development in such birds as the white-crowned sparrow is unusual, and offers an opportunity to explore the interplay of genetic and environmental determinants of behavioral development.

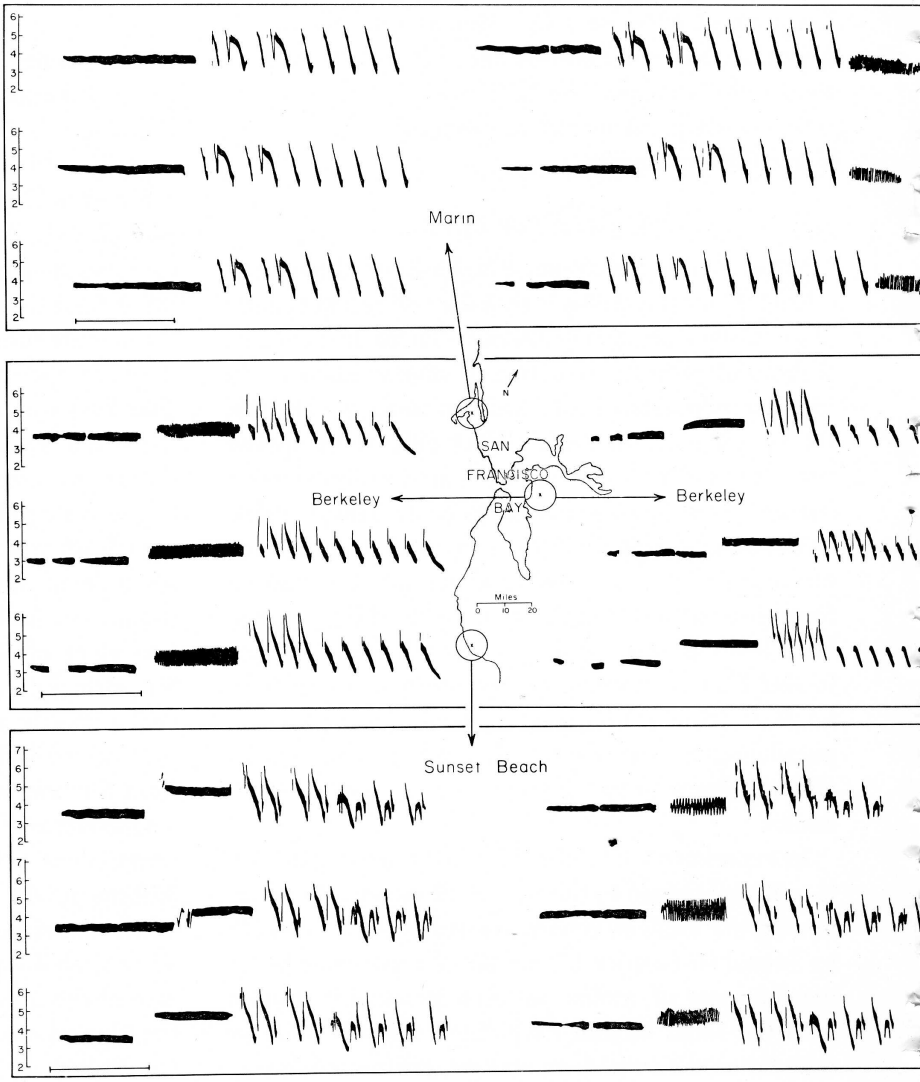
Songs of Isolates

The parents of a white-crowned sparrow normally feed it for about a month, just less than two weeks in the nest and the rest of the time out of it. In the experiments to be described here, birds are taken from the nest within a few days after hatching and are raised by hand in virtual acoustical isolation. Special chambers insulate the animal from any external noises other than those generated by a ventilation fan and the sounds audible through the chamber doors when they are opened for feeding and cleaning purposes. The bird can, of course, hear the sounds it makes itself. If a male is kept continuously under such conditions, its testes will enlarge in the spring and it will begin to sing more or less on schedule. Knowing the area from which the bird came, we can specify in some detail what its normal pattern of development should be. As far as can be determined by the rate and vigor of its singing, the motivation is normal. Surprisingly, sound spectrograms of the songs reveal a grossly abnormal pattern. Evidently some aspect of our isolation treatment diverts development from the normal pathway.

One cause of the abnormality could be the lack of companions, which need not necessarily be adults. Siblings might provide some form of mutual stimulation that is necessary for normal song development. To explore this possibility, we raised nine males from several different areas in group isolation in a large, soundproof room. Each bird was in a separate cage, free to look at its companions and to hear them. All of the birds developed well-defined song patterns in

the course of the following year. None bore any detailed resemblance to the home dialect, nor could any consistent differences be seen among the song patterns of birds taken from three different areas. In fact, the three birds that came the closest to sharing a similar pattern were each from a different area. Here, as with the songs produced in individual isolation, the patterns fell quite outside the range of those to be found in wild white-crowns. The songs consistently lacked the typical syllabic trill at the end of the song. Nevertheless, there was a suggestion of normality in the tonal quality of the whistles, a point to which I will return later.

I should point out that in neither of these experiments on group and individual isolates were the birds actually raised in true isolation. They were exposed to natural song while they were in the egg and during their first few days of life as nestlings. Although they are highly altricial at birth, it is conceivable that acoustical experience at this time might have some effect on song development – a possibility we are exploring by raising birds under foster parents. One small experiment seems to indicate that very early acoustical experience is irrelevant. A bird was taken from the nest at three days of age and for five days was exposed to normal song through a loud



Sound spectrograms of songs of 18 male white-crowned sparrows from three localities in the San Francisco Bay area. The detailed syllabic structure of the second part of the song varies little within an area but is consistently different between populations. The introductory or terminal whistles and vibrati show more individual variability. The time marker at bottom left in each panel indicates 0.5 second and the vertical scale is marked in kilocycles per second.

speaker. This "training" song was a different dialect from that in the bird's home area. The bird developed an abnormal song with no sign that the early training had had an effect.

Effects of Training

In our first attempt to train older birds with recorded song, we took nets out into the field and captured young birds at about three months of age. After aging and sexing, the young males were placed in acoustical chambers and exposed to recordings of a song pattern other than their home dialect. This experience was given to different birds at different periods during the following year. The experiment was attractive because it bypassed the considerable labor of raising the young birds by hand. In most cases, the birds developed normal home dialects. Only those birds trained soon after they were brought into the laboratory showed any deviation from the normal pattern, and even they failed to correspond in detail to the training song. If learning from adults was involved in song development, it must have occurred before the birds were captured. The results point to a period between about one week and two months of age as the time when acoustical experience is critical for normal song development.

We then took two males from wild nests, one at five and one at ten days of age, and placed them in individual isolation. Both were trained with recordings of a normal white-crowned sparrow song, which was given for four minutes each day over a period of three weeks. One bird was trained from one to four weeks of age, the other from five to eight weeks of age. In the subsequent year they both produced an adequate copy of this training song. It seems, then, that the dialect patterns are transmitted from generation to generation by learning, young birds acquiring the pattern from adults. Acoustical experience after the age of about 100 days apparently has little affect, at least on birds already trained during the sensitive period. The development of song in this species is thus labile to some extent, and the next question is: are there limits on the kind of song pattern the bird can be taught? The experiment just described was, in fact, a little more complex than I have indicated. Although the two birds were trained with a normal song of the species, each of them also heard recordings of another species for the same period of time. For one bird, the alien songs were those of a member of the same genus, Harris sparrow, which has a rather simpler song than the white-crown. For the other bird, the recordings were of the song sparrow, a member of another genus, and with a more complex song. In neither case did the alien song have any apparent effects on development.

There is a suggestion here of a most interesting phenomenon – a predisposition to learn certain sound patterns rather than others. What would happen if a white-crown heard only songs of another species and none of its own? To attempt to answer that question, we raised three males in individual isolation and exposed them to recordings of song sparrow songs for four minutes per day from the 7th to the 28th days. Several months later they began to sing, and the patterns were quite abnormal, although there was no detectable correspondence to the song sparrow training song. That is, recordings of the alien species were not imitated, and failed to establish subsequent development in a normal path. It begins to appear that when the young male is acquiring the species song from the first to about the fifth weeks of life, his learning is highly selective. On further reflection, one can see a need for such selectivity, for white-crowned sparrows and song sparrows live close together in the same habitat, and young birds would be just as likely to hear songs of one species as the other.

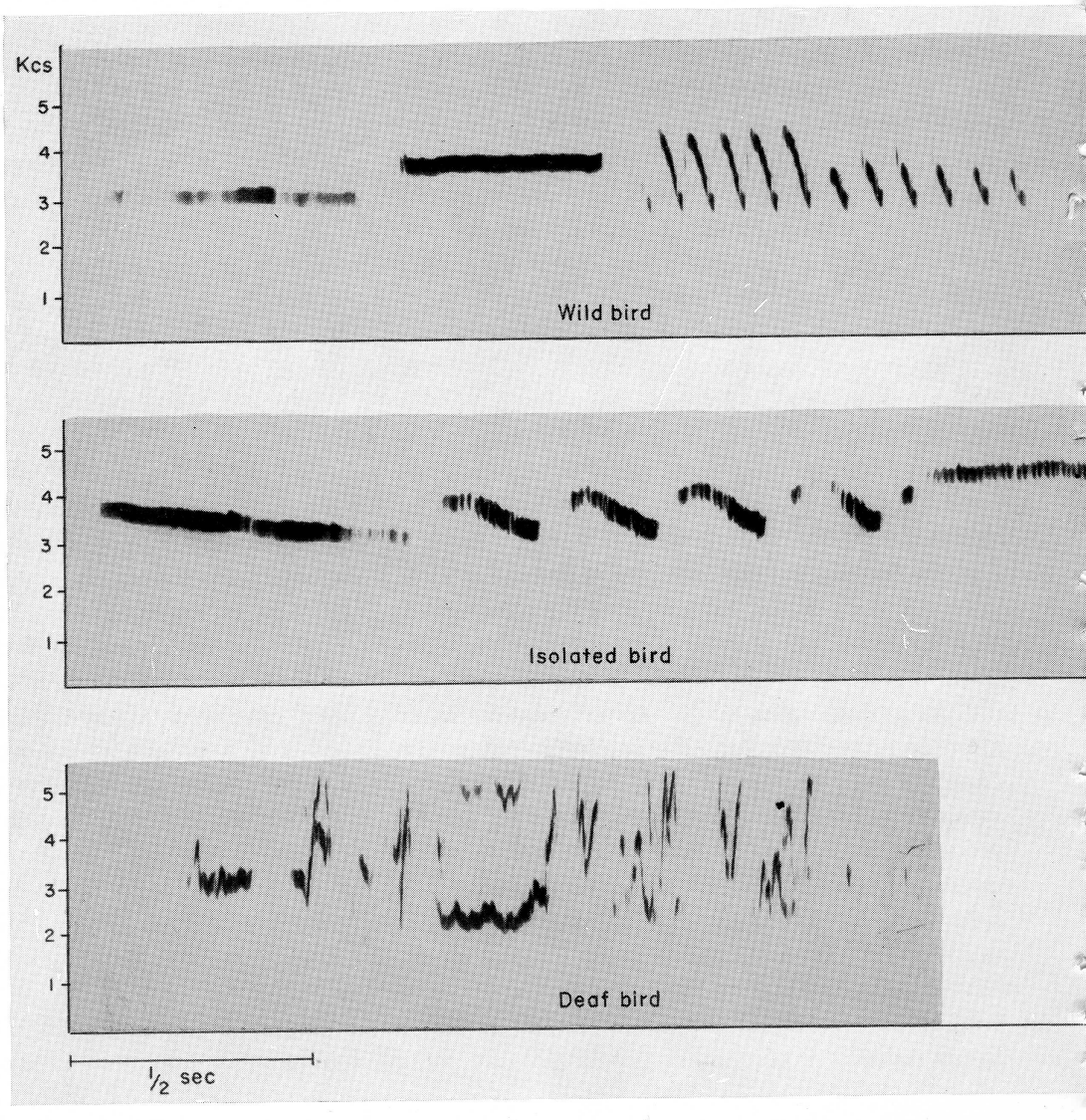
Deafness and Song

How, then, is this selectivity imposed? It could be on the motor side, if a syrinx is so designed that it can produce only certain types of sound. However, detailed comparison of syringeal structure fails to reveal any differences; in fact, the structure of the syrinx is a conservative trait among songbirds and is used extensively by systematists only at the higher levels of taxonomic classification. Moreover, the sequence of events in the white-crowned sparrow seems to preclude such a possibility. As singing usually starts only some months after learning has taken place, it seems more likely that the selectivity is imposed on the sensory side. Experiments on the effects of deafening on singing behavior also seem to imply a sensory mechanism.

The ability to hear sounds from the environment is obviously important in song development. What

about a bird's ability to hear its own voice? In our laboratory in Berkeley, Dr. Masakazu Konishi, now at Princeton, explored the effects of surgical deafening upon the vocal behavior of a variety of birds. Some species deafened at an early age develop a quite normal vocal repertoire. Chickens are one example, and Dr. Fernando Nottebohm, now with us at the Rockefeller, has found that doves are another. In some songbirds, however, deafening produces abnormal development, and the effect on the white-crowned sparrow is particularly interesting. If a bird is deafened after it has been trained to a normal song but before it has itself begun to sing, it develops a song pattern that lacks any sign that the training was effective and that is even more abnormal than the song of an untrained bird raised in isolation. The sound is almost mechanical, or insect-like, lacking even the normal tonal quality of the whistle portion of the song that an isolated bird produces. An essentially similar song will develop if an untrained bird is deafened before it has sung.

Evidently a young bird that has heard the normal song but not yet begun to sing must be able to hear its own voice if it is subsequently to translate the memory of that song into motor activity. This suggests that the learning generates some kind of auditory template with which the auditory feedback from vocalization is matched at some later time. The contrast between song patterns of a deaf bird and an isolated bird implies that even a naive individual has



Comparison among normal, isolated, and deaf birds.

a crude kind of sensory template. This template, perhaps with genetically determined characteristics, may also suffice at an earlier stage to restrict song learning to species-specific sounds. We may think of the template itself becoming sharpened and more specific as a result of the learning. Without training, genetic control by the template of the naive bird predominates; the control is not exerted directly on motor output from the central nervous system, but indirectly by sensory feedback generated during motor activity.

Birdsong and Human Speech

There are some gross parallels with speech development in human children. For instance, as I have mentioned, the white-crowned sparrow has a predisposition to learn some sound patterns rather than others. Several recent workers, approaching the study of human speech from different viewpoints, have felt the need to postulate an innate predisposition to use certain grammatical constructions, thus invoking concepts that are not unrelated to those proposed here. There is another parallel. Deaf children obviously have great difficulty in learning to speak, but a person who can already speak before deafening suffers much less speech impairment. The same is true of the birds. Konishi found that an adult white-crown deafened when already in song shows only slight abnormality of the motor pattern. In the course of weeks or months there is a slight, gradual drift away from the original pattern, but it never goes as far as the extreme abnormality observed in birds deafened early. What is the mechanism by which the motor pattern of song, dependent on acoustical feedback for its development, becomes independent of this feedback once the motor pattern is established? Does some other feedback pathway, such as proprioception, take over, or is the central nervous system capable of generating a pattern without any detailed feedback?

We have seen, then, two functions for the bird's ability to hear its voice: to realize a previously learned sound pattern as singing activity and to translate a pre-existing sensory pattern into motor activity. An appreciation of these effects illuminates, in turn, another old problem. Song does not appear suddenly but, at least in some species, develops over a period of days or weeks, often with a series of transitional stages that are different enough from the final product to merit the term subsong. To some observers, the bird sounds as though it is practicing, although others have doubted that subsong has functional significance. Dr. Nottebohm has used the deafening technique to explore this problem in the European chaffinch. He reasoned that if experience is accruing as a result of subsong performance, the deafening of individual males after varying periods of subsong and song practice should result in the subsequent production of more-or-less organized songs. The prediction was verified; the birds deafened earliest produced a song consisting of virtually unstructured noise, while those deafened later came closer to a natural song. It may even be that experience of the very earliest vocalizations contributes to all subsequent activity, a possibility that offers a considerable area for exploration.

With environmental influences on song development so many and varied, the likelihood that dialects are a sign of incipient speciation seems remote. Certainly, no morphological differences have been found among birds in the different dialect areas. Nevertheless, it is hard to avoid the conviction that song dialects are in some way involved with maintaining the coherence of local populations. Even though the song is learned, the learning occurs while the young are still in the area of birth. The stability of the dialects in nature suggests that little exchange of individuals between populations occurs after the song patterns have been acquired. We know that both males and females respond most strongly to recordings of their own dialect. If males are more likely to settle in an area where their dialect is heard, and if females are more likely to mate with a male from their own dialect area, some tendency toward inbreeding within a local population would inevitably follow. This would occur even though the behavior pattern primarily responsible is under environmental rather than genetic control. If it exists, what could be the significance of a mechanism favoring inbreeding in local populations? Perhaps there are physiological adaptations to local conditions that have yet to be discovered, adaptations so subtle that they do not bring visible morphological changes in their train. Meanwhile, it seems advisable to leave open the possibility of a relationship between song dialects and the genetic constitution of populations.

DEDICATION OF GASSER HALL

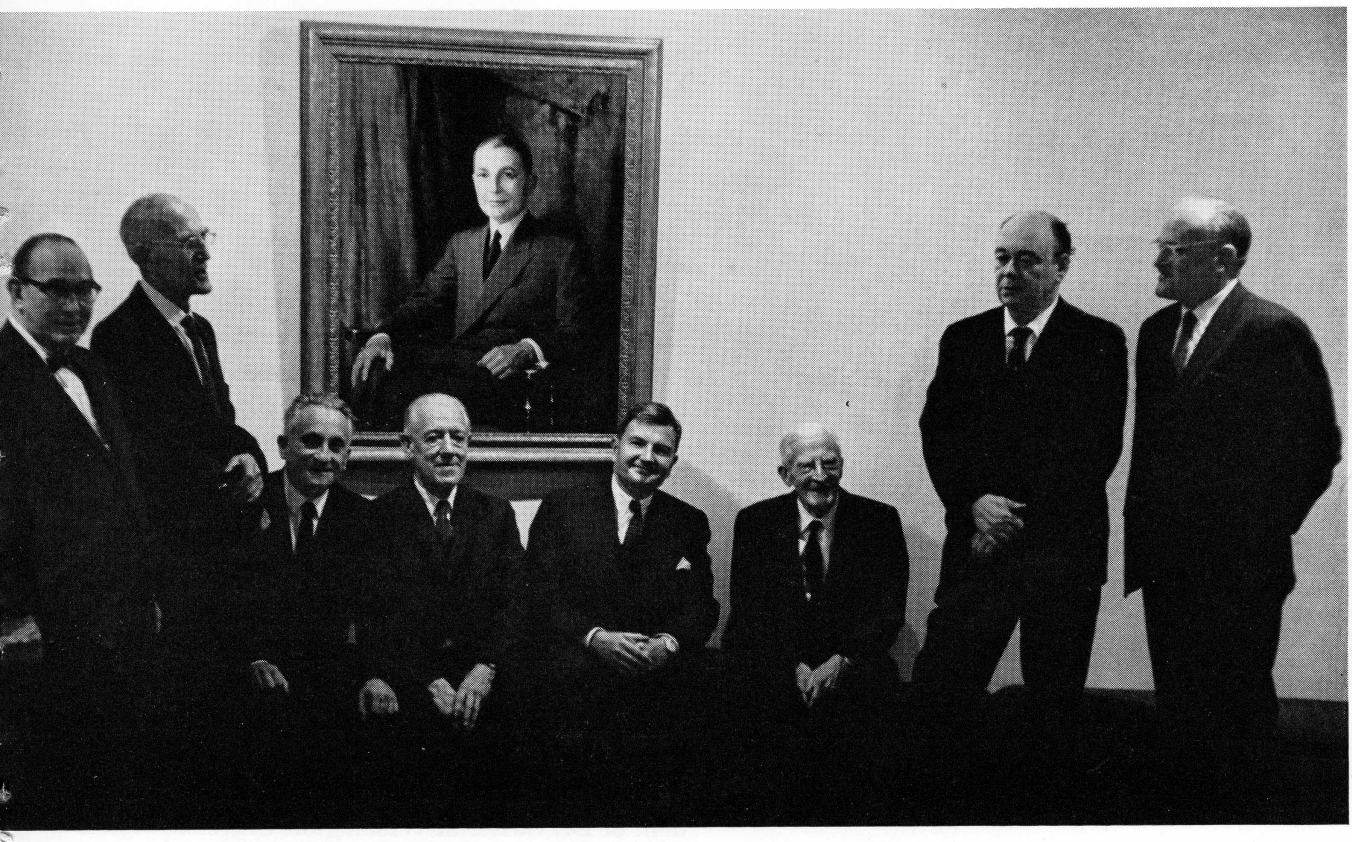
COLLEAGUES, students, and friends of Herbert Spencer Gasser gathered from France, England, and many parts of the United States on Wednesday afternoon, October 18, to express appreciation for the work of a physiologist who opened a new era of neurological research. The occasion was the dedication of Herbert S. Gasser Hall on the campus of the institution which Dr. Gasser served with distinction as Director from 1935 to 1953.

The dedication exercises in Caspary Auditorium were opened by President Bronk who said: "During the four years since Herbert Gasser's death the Trustees of The Rockefeller University and I have considered how we could express our gratitude to him for his devoted service to science and to our institution. To inscribe his name on a building in which science would be furthered would have pleased him, and that we are doing today. But he would have abhorred a program of eulogies in praise of him as a person; he was a modest man. Because he admired exacting scientific standards, he would have valued our approval of his notable achievements in research. And so we have asked eight who knew him best as their colleague and teacher to talk of the significance of his career in science. As they do so, notable qualities of his admirable character will be revealed.

Herbert Gasser at his desk in 1942

"I knew him best, for I lived with him in his home and he in ours with my family for much of each of twenty-five years. Because of that, I should trespass on the sacred ground of close friendship if I were to speak with the emotion that I feel. But this I must say in gratitude to him: he gave selfless affection and noble example to my wife and me and my sons who loved him as a father; he enriched our family of which we were privileged to call him one."

A warm tribute then followed from Lord Adrian of Cambridge, Trustee Emeritus of The Rockefeller University: "Gasser was a man of exceptional learning and technical ability, as well as a man of great sensitivity and kindness." He added, "I can still recall the excitement which I felt on reading his paper with Newcomer published in 1921 with the title, 'Physiological Action Currents in the Phrenic Nerve, An Application of the Thermionic Vacuum Tube to Neurophysiology." This paper opened the floodgates to the whole new era of electrophysiology. It was soon followed by a succession of papers by Erlanger and Gasser describing experiments made not only with thermionic amplification to magnify the action potential, but with the Braun tube – the cathode ray oscillograph – to record its exact time course as well. It was a combination that gave full play to Gasser's demand for quantitative accuracy. And as we all know, it made possible the classification of nerve fibers, which was the main object of Gasser's work. I



Speakers gather in Gasser Hall after the reception LEFT TO RIGHT *Professor Lorente de Nó, Dr. George H. Bishop, Professor Ali Monnier, President Bronk, David Rockefeller, Chairman of the Board of Trustees, Lord Adrian of Cambridge, Trustee Emeritus, Professor David Lloyd, and Professor Francis O. Schmitt. The oil portrait is by Robert Oliver Skemp.*

think he enjoyed really accurate data, and was satisfied that he had helped to provide them for one line of physiology. His measurements had added to natural knowledge and would outlast the theories that might be based on them."

Dr. George H. Bishop was an early colleague at Washington University, a life-long correspondent, and one of Gasser's friends. Said he: "Gasser laid the foundation for practically all the main-line study of the fine structure and organization of the central nervous system, as well as the periphery." And Dr. Bishop concluded, "We might say that Dr. Gasser laid down for neurophysiology something like Mendeleev's table of the elements for chemistry. Chemists are still working on Mendeleev's table today, as we are working on fibrocellular relationships."

Appropriately, Dr. Joseph C. Hinsey, Director Emeritus of the New York Hospital-Cornell Medical Center, followed Dr. Bishop on the program. For Dr. Hinsey was also a close friend of Gasser on the campus of Washington University, and later joined him at Cornell University Medical College and succeeded him as Professor of Physiology there. He knew Dr. Gasser to be "shy and modest in his relations with his associates; he was intensely interested in the welfare of those about him. He was a scholar in the best tradition, and his interests knew no boundaries. Whatever he undertook, he did with meticulous care and utmost devotion – whether it was an experiment in the laboratory, student teaching, administrative duties, or a conference with his colleagues. He continued as a laboratory benchworker until nearly the end. What he and his colleagues have done has shaped the destiny of biological science in this century."

Professors Monnier, Lloyd, Marler, and Mr. Rockefeller

Another of Dr. Gasser's friends at Washington University was a brilliant young neuroanatomist whom he later brought to the Rockefeller, Professor Lorente de Nó. When he decided to become an electrophysiologist, Dr. Lorente de Nó related, "I did some experiments on the central nervous system at the Central Institute for the Deaf in St. Louis, and the results were very interesting and very complex. So I came to New York to consult Gasser. As a proof of the thoroughness with which he studied all problems, let me say that we spent in his office, in Cornell Medical College, from two o'clock in the afternoon to past seven o'clock. There were five hours of discussion of those experimental results of mine."

Professor Ali Monnier of the University of Paris paid his tribute with charm and affection, for he had known Gasser during thirty years in this country and in France. "Perhaps Gasser's scientific foresight and judgment," he speculated, "were based upon his vast and diverse culture. Every domain of human endeavor activated his attention: the rise and fall of former civilizations and art in all of its manifestations elicited comments of which only his closest friends were to appreciate the profundity and brilliance. I remember with particular delight the truly exciting discussions he often had with my wife, Andrée, on French literature and our medieval cathedrals. They did not always have the same views by far, but Gasser's opinions were always based on a profound knowledge of the subject, expressed with elegance, clarity, and often with a special and pleasant kind of humor."

Professor David Lloyd then spoke with appreciation and pungency of Dr. Gasser's work on the spinal cord – which was in fact a brief period of approximately five out of the fifty years of his overall scientific endeavor. "But in Dr. Gasser's brief encounter with the spinal cord," Dr. Lloyd stated, "he was certainly a pioneer and he made the intellectual caldron boil concerning studies within the central nervous system, as it still does today as the result of his researches." And concerning his use of the English language: "He was the perfectionist, demanding from himself and from others, clarity. Although, without sacrificing clarity, he could turn a fine phrase."

Professor Francis O. Schmitt, who had been a student of Dr. Gasser at Washington University and is now Director of the Neurosciences Research Program at Massachusetts Institute of Technology, said, "I would not have anyone suppose that Gasser was a superficial reductionist. Quite the contrary, he was well aware of the role of emergent characteristics in systems as complex as the nervous system, not to say the brain or the whole man. He once said, 'Why not confess to deeper satisfaction in the sense of service to humanity, to medical science, as sufficient reason for doing research?' Such were the qualities of his mind and spirit, that the deeper satisfactions never blunted his passionate drive compounded by the thrill of scientific exploration, the search for truth, and an abiding sense of purpose and direction."

At the age of 32 Gasser was appointed Professor of Pharmacology in Washington University and thereby hangs a tale that was told by Abraham Flexner. When that powerful catalyst of medical progress was negotiating support by The Rockefeller Foundation for full-time teaching and research at Washington University Medical School, Dean Nathaniel Allison gave a dinner for the display of the excellence of his faculty. Seeing youthful Gasser, straightforward Flexner queried the Dean: "What are you doing? Making

freshmen full professors?" Acute judge of promise in young scholars that he was, Flexner then asked Gasser: "How would you like to go to Europe for two years on a Rockefeller fellowship and learn some languages?" He knew full well that Gasser, with his restless mind, would return with more than knowledge of foreign languages and cultures.

Go he did, and there he had the good fortune to work in London with A. V. Hill, the eminent physical physiologist. Recalling those early days, Professor Hill sent the following tribute:

"I am sorry indeed that I cannot join with Herbert Gasser's colleagues and admirers in dedicating the new laboratory in his name. I gather that those who speak will deal with his contributions to physiology and their present significance. I am proud to join them, *in absentia,* not only as one of Herbert's oldest friends, but particularly because, when we worked together in 1923-24, he made a fundamental contribution to a subject quite unlike any other subject on which he ever worked, on the developments of which many people are still busy.

"I think I met him first at an International Congress of Physiologists at Edinburgh in 1923. After the Congress the German physiologists, who for the first time since 1913 were able to attend, moved by the friendly reception they met, invited a token party of us to join in a Congress of German physiologists at Tübingen. There were Ernest Starling, Gasser, Cathcart and myself. It was a tremendous success, chiefly because of Starling; and I remember admiring Herbert for the gusto with which he spoke bad German, in an American accent, quite unaffected by the sort of embarrassment I felt in speaking even rather better German. He wanted to communicate and did, quite unconscious of himself. This is just a minor illustration of a kind of courage which made him totally disregard his physical disability. This he knew must be recognized by physiological colleagues and he never allowed it in the least to affect his behaviour. Ill health he often did have to allow for, but he learnt to manage it. All this he would not himself have counted as virtue, but others did. Courage is the unconditional basis of all virtue, and it was Herbert Gasser's quiet courage that allowed him to make so good use of the other intellectual and personal qualities which he possessed in such splendid measure.

"The problem that was engaging my mind when Herbert joined me after the Congress was that of the relation between speed of shortening and force exerted in muscular movement. This has many aspects but it is a fundamental property of every muscle. We explored it together in a cellar at University College, London, using isolated muscles. I was extremely busy then, having just taken charge of a large department of physiology (and having all the distractions of a Nobel Prize as well; the same distractions happened to him 22 years later). But we discussed it every morning 'and planned a new experiment of which, next day, Herbert would tell me the result. He worked with astonishing speed and skill with the simplest apparatus, and made a little mechanical lever (frequency 400 c/s) writing on a smoked drum to do many things for which one now uses refined electronic devices.

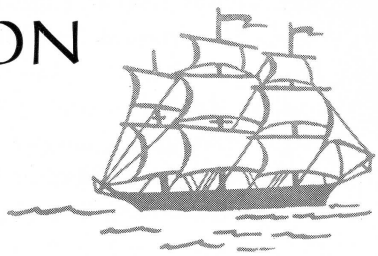
The fundamental mechanical response is shown to attain its maximum intensity quite early in contraction, long before the maximum tension is reached, and to pass off continuously thereafter.

"That was in *Proc. Roy. Soc.* B, 1924; and the investigation is still going on. The idea of the 'active state' (though not the name then) arose from it, and many other things. Herbert himself liked those experiments and referred to them in his autobiography (1964). I liked them too, though he made them. And Herbert used to recall how we avoided disturbance by putting a notice on the door: Danger; 100,000 ohms. It worked well in those days. Perhaps it might be tried in the new laboratory, in memory of him!"

Finally, David Rockefeller, Chairman of the Board of Trustees, told of his father's admiration and affection for Dr. Gasser during the eighteen years that he was Director and John D. Rockefeller, Jr. was President of the Board. And he told of how he himself had received kindly help and inspiration when he had joined the Board as a young man during the latter years of Dr. Gasser's time.

At the end of the afternoon there was an informal reception in Abby Aldrich Rockefeller Hall for the hundreds of friends of Gasser who were present, followed by inspection of the new laboratory building which bears his name, and the viewing of a display of historical books and papers on the theme, "From Galvani to Gasser."

GOVERNOR'S CONFERENCE ON OCEANOGRAPHY

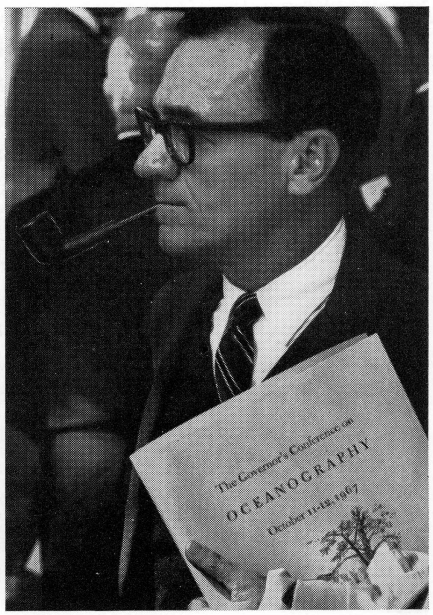


LEADERS OF SCIENCE, education, government, and industry met at the University for two days in October at the invitation of Governor Rockefeller, for New York State's first conference to survey the oceanographic activities, resources, and opportunities of New York and its neighbor states.

"We need more knowledge before the sea may yield her secrets to us. That is why this conference is of such consequence," affirmed Governor Rockefeller in his dinner address on Wednesday evening, October 12, in Welch Hall. "And the man I have asked to help prepare New York State's role in this vast undertaking as Chairman of this assembly and of its Steering Committee, is himself a pioneer in the furtherance of modern oceanography – Dr. Detlev W. Bronk, President of The Rockefeller University. Our present activity in oceanography probably owes as much to Dr. Bronk as to any other man, for as President of the National Academy of Sciences he established and vigorously supported the Academy Committee on Oceanography which stimulated the present-day development of oceanography in our country."

In opening the conference Dr. Bronk, the chairman, said:

"New York State institutions, public and private, have had a leading role in oceanographic research for years, but this conference is the first overall survey of activities in this region. Although our primary responsibility is to consider how New York State can participate most effectively in the Federal programs



for furtherance of oceanography, our opportunities are necessarily related to the activities of oceanographers everywhere. Our resources and activities are especially dependent on New Jersey, Connecticut, Rhode Island, Massachusetts, and Pennsylvania for with them we share the waters that bathe our shores. And so, desirably and of necessity, this conference is regional and international in scope."

Program of The Governor's Conference on Oceanography

OCTOBER 11

MORNING

Opening Remarks by the Chairman: Detlev W. Bronk *President, The Rockefeller University*

Geophysical Oceanographic Studies at Lamont Geological Observatory: Maurice Ewing *Director* and J. Lamar Worzel *Associate Director Lamont Geological Observatory of Columbia University*

The Continental Shelf and Its Resources: Kenneth O. Emery *Senior Scientist, Woods Hole Oceanographic Institution*

Recent Geophysical Studies on Mid-Ocean Ridges: Manik Talwani *Senior Research Associate, Lamont Geological Observatory*

AFTERNOON

Moderator: The Honorable John W. Wydler *United States House of Representatives*

Research in the Life Sciences at Lamont Geological Observatory: Paul R. Burkholder *Chairman of Biology Programs, Lamont Geological Observatory*

Some Views on the Potential Food Resources of the Sea: John H. Ryther *Chairman of the Biology Department, Woods Hole Oceanographic Institution*

The New York Aquarium and the Osborn Laboratories of Marine Sciences as a Center for Marine Biological Research in New York City: Ross F. Nigrelli *Director, the New York Aquarium and the Osborn Laboratories of Marine Sciences*

A Marine Research Center Operated by a Consortium of Universities and Located "One Hundred Miles at Sea": John C. Baiardi *Vice Chancellor, Long Island University*

EVENING

Address by The Honorable Nelson A. Rockefeller, *Governor of the State of New York*

OCTOBER 12

MORNING

Moderator: Edwin A. Link *Link Group, General Precision Systems, Inc.*

Measurements of Ocean Currents: Nicholas P. Fofonoff *Senior Scientist, Woods Hole Oceanographic Institution*

The Main Effects of Form on Ship Motions in a Seaway: John P. Breslin, *Director, Davidson Laboratory, Stevens Institute of Technology*

The Use of the Deep Submersible ALVIN in Oceanography: William O. Rainnie, Jr. *Oceanographic Engineer, Woods Hole Oceanographic Institution, and Chief Pilot of the* ALVIN

History of the Ocean Basins Recorded in the Sediments: John I. Ewing *Senior Research Associate, Lamont Geological Observatory*

AFTERNOON

Moderator: Clifford C. Furnas *Chairman, Advisory Council for the Advancement of Industrial Research and Development*

The Economics of Marine Science: Noel B. McLean *Chairman of the Board, Edo Corporation*

Understanding and Forecasting Phenomena at the Air-Sea Interface: Willard J. Pierson, Jr. *Professor of Oceanography, New York University School of Engineering and Science*

Physical Oceanographic Studies at New York University: Gerhard Neumann *Professor of Oceanography, New York University School of Engineering and Science*

The Sea Grant Concept: Robert D. Wildman *Program Director for Sea Grant Projects, National Science Foundation*

THE ROCKEFELLER UNIVERSITY

NEWS

Royal Society of Arts Medal

PRINCE PHILIP, Duke of Edinburgh, presented the Benjamin Franklin Gold Medal of The Royal Society of Arts to President Bronk in London on October 30. In awarding the medal at the Society's annual dinner, Prince Philip, President of the Society, said that he did so in recognition of Dr. Bronk's many contributions to forwarding Anglo-American relations and to science for which Dr. Bronk had already been decorated with the Order of the British Empire, elected to The Royal Society of London, awarded honorary degrees from Cambridge, London, and Belfast, and elected to honorary membership in many British scientific societies. This is only the third time that the medal has been awarded to an American. Previous recipients were John Hay Whitney, then Ambassador to the United Kingdom, and Paul Mellon, President of the National Gallery of Art and philanthropist.

Academic Council

DURING THE PAST academic year, President Bronk requested a committee of the faculty to consult with him on the creation of a representative body that would advise the President on University-wide academic policies and on the development of the faculty. That committee and the President subsequently recommended to the University Senate that an Academic Council of nine members be elected by the Senate to meet monthly with the President who would serve as Chairman of the Council. This proposal was adopted by the Senate which has now elected the following nine members of the Council: George E. Palade, Vice Chairman (to serve until 1970); Frank Brink, Jr. (1970); Lyman C. Craig (1969); Mark Kac (1970); Henry G. Kunkel (1969); Neal E. Miller (1969); Alfred E. Mirsky (1968); Edward L. Tatum (1968); George E. Uhlenbeck (1968).

Prince Philip presenting the Benjamin Franklin Gold Medal to President Bronk

Karl Taylor Compton Gold Medal

THE AMERICAN INSTITUTE OF PHYSICS conferred its highest award, the Karl Taylor Compton Gold Medal, on Dr. Alan T. Waterman—first Director of the National Science Foundation 1951-1963 and honorary alumnus of Rockefeller—in Caspary Auditorium on October 2. Dr. Ralph A. Sawyer, Chairman of the Governing Board of the American Institute of Physics, is shown making the presentation. This was one of Dr. Waterman's last public appearances before his untimely death. The University conferred the degree of Doctor of Laws on Dr. Waterman in 1963.

New Students

Twenty-six new students have been accepted as candidates for the degree of Doctor of Philosophy:

ARTHUR P. ARNOLD, A.B. Grinnell College

JAMES K. BAKER, A.B. Princeton University

RICHARD S. BOCKMAN, B.A. The Johns Hopkins University
M.D. Yale University School of Medicine

FRANCOIS BOUVIER, D.E.S. University of Paris Faculty of Science

MICHAEL E. BRATMAN, B.A. Haverford College

DAVID E. BRILES, B.A. The University of Texas

JOHN R. BRINKLEY, A.B. Harvard College

PETER CHERBAS, A.B. Harvard College

DANIEL M. FARRELL, B.A. University of Chicago

FELIX T. HONG, B.M. National Taiwan University College of Medicine

MICHAEL JUBIEN, A.B. Dartmouth College

ROSS KIESTER, A.B. University of California, Berkeley

EUGENE M. KLEINBERG, B.S. Massachusetts Institute of Technology

NORA LESSER LAIKEN, B.S. University of Chicago

RONALD P. LARKIN, A.B. University of Missouri

PAUL B. LAZAROW, B.A. University of Chicago

MICHAEL LEVINE, B.S., M.S. Massachusetts Institute of Technology

EDWARD E. MAX, A.B. Harvard College

CYNTHIA REED NIST, B.A. University of Minnesota

JOHN G. PALFREY, JR., A.B. Harvard College

URS RUTISHAUSER, B.S. Brown University

ROBERT H. SCHOR, B.S. California Institute of Technology

AMOS B. SMITH III, B.S., M.S. Bucknell University

WALTER W. STEWART, A.B. Harvard College

JERROLD TANNENBAUM, A.B. Cornell University

JAY C. UNKELESS, A.B. University of California, Berkeley

"We shape our buildings, and afterwards our buildings shape us."

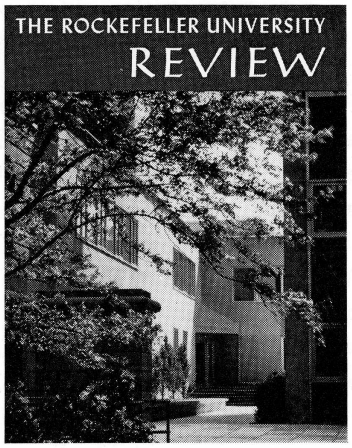
PROFESSOR RENÉ DUBOS delivered the major address at the plenary session of the Fifth International Federation of Gynecologists and Obstetricians in Sydney, Australia on September 28. Dr. Dubos had addressed The Research School of Social Sciences at the Australian National University in Canberra the week before, and also meetings of the Pathological and Microbiological Society and of the Medical School of the University of Melbourne.

"Man is not only a part of the environment; he is shaped by it," said Dr. Dubos. "All aspects of his physical and mental health are dependent on environmental health. The quality of human life reflects the characteristics of the technological and urban environment in which man develops and functions. Indeed, the ultimate ecological expression of human biology is that, genetically and phenotypically, man is being constantly transformed by the environment

in which he lives. Man becomes what he is in the very process of creating his ways of life." Dr. Dubos stressed the opportunities for developing an ecologic philosophy of biomedicine and an environment favorable to the germination of man's dormant potentialities: "The social standardization and regimentation resulting from the creeping monotony of technological culture, patterns of education, and mass communication, will make it progressively more difficult to exploit fully the biological richness of man. We must shun uniformity of surroundings as much as conformity in behavior, and make instead a deliberate effort to create as many diversified environments as possible. This may result in some loss of efficiency, but the more important goal is to provide the many kinds of soil that will permit the germination of the seeds now dormant in man's nature. Diversity of social environment constitutes a crucial aspect of functionalism, whether in the planning of cities, the design of dwellings, or the management of life.

"The conditioning of the physical and mental personality by the environment has of course long been recognized. Winston Churchill was aware of its importance for human life when he urged that the House of Commons, damaged by German bombs during the war, be rebuilt as exactly as possible in its original form instead of being replaced by a more efficient building. He feared that changing the physical appearance and organization of the House might alter the character of Parliamentary debates and therefore of English democracy. Winston Churchill's words in defense of the old House of Commons apply to all environmental influences: 'We shape our buildings, and afterwards our buildings shape us.'"

The message common to all Dr. Dubos' recent lectures was that we must learn to formulate social goals for science, instead of engaging more or less blindly in *ad hoc* developments and applications as is the present practice. We must not ask "Where are science and technology taking us?" but rather "How can we manage science and technology so that they help us get where we *want* to go?"



THE COVER shows the entrance to Gasser Hall, story on page 14 of this issue. The photograph is by Joseph Barnell.

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