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PHYSICS, BIOPHYSICS, AND THE STUDY OF VISION

BY H. KEFFER HARTLINE

On October 12 in Cleveland, Professor Haldan Keffer Hartline received the annual Albert A. Michelson Award at the Case Institute of Technology. The Award, which includes a grant of $5,000 and a plaque, was given to Professor Hartline in recognition of his "noteworthy research on the sense organs and how they relate the behavior of animals to their physical environment and especially for classical discoveries in the physics and biology of visual perception."

The Michelson Award, one of the major international awards given in the field of science and engineering, is named in memory of the first professor of physics at Case and America's first Nobel laureate in the sciences. Its purpose is "To honor the individual chosen for his significant contribution to knowledge and the welfare of mankind. . . ."

The following is the address delivered by Dr. Hartline at the Award dinner attended by 800 friends of the Case Institute.

OPTICS, AS ITS very name implies, arose from a curiosity as to how we see. As the science of light, it could not have been otherwise. Optics as a part of modern physics has gone far beyond this origin, and Michelson's own work is an instance of the depths to which it probes the nature of our universe. The study of vision, based on the biophysics of the eye and the nervous system it serves, also has gone far beyond its beginnings, and with its related sciences probes the nature of our beings.

From antiquity, man has been curious about how he sees. And this question was one of the first to be examined by the emergent science of the Renaissance. Kepler, taking time from his pioneering work in astronomy, applied his mathematical genius to the subject of vision. Available to him was only a meager and inaccurate knowledge of the anatomy of the eye, yet he came to a correct interpretation of the nature of the image formed on the retina, and therewith founded the science of optics. After him, optics as a branch of physical science flourished — and flourishes today. With it, the lens-maker's art developed into a robust technology, yielding a wealth of optical instruments for the benefit of all branches of science. Its derivative, spectroscopy, yielded our modern physics of atomic structure. Astronomy depends on it; it generated photography, an art as well as a science. It has gone far beyond its beginnings — but it needs no eulogy from anyone.

Turned back upon its original subject, optics provides the physiologist and the physician with a clear and accurate understanding of the eye as an optical instrument. Physiological optics — a branch of biophysics in its most rigorous sense — developed steadily after Kepler and reached its culmination in the work of Hermann von Helmholtz. Physicists claim Helmholtz as a physicist; physiologists claim him as one of their number, for he was the pupil of a famous physiologist and early in his career made his mark by measuring the velocity of the nerve impulse. But, above all, physiologists claim him for his great contribution to the understanding of hearing and vision. The experimental psychologists claim him for these same reasons, and with justice, for he was a

master in utilizing his own senses in the study of these two great sensory systems.

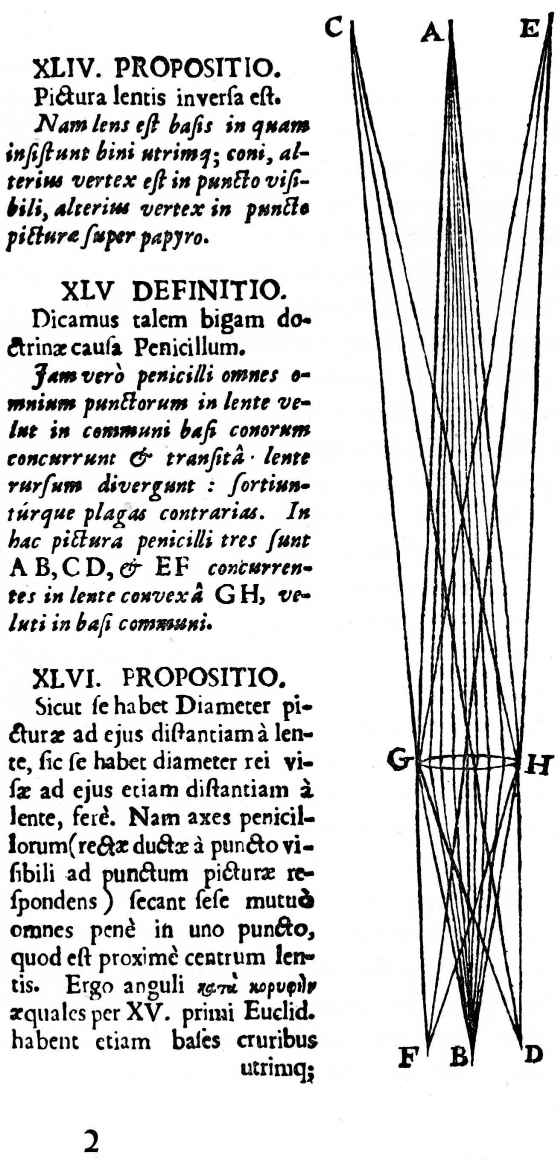
Helmholtz invented and used ingenious instruments for the objective study of the eye; he also used subjective observations critically and effectively — his own and those of others.

Psychophysics

Ideally at least, scientific procedure follows a universal pattern: the thoughtfully posed question, the controlled observation, the tentative hypothesis, the testing experiment, and so on. Our own personal visual experience can be subjected to such procedure. How bright a light can we see, against what specified background? How fine a pattern can we resolve? What colors can we distinguish? What mixtures of color look alike, and how and by how much must they be changed to look different? Starting from everyday experience, such questions become more and more sophisticated; as one seemingly simple property of our vision is studied, a dozen complexities are uncovered; one answer breeds a horde of new queries. Theories rise and fall — some are foolish, some stand the test of time well. Understanding increases, if slowly. This is a familiar story in all branches of science, but "psychophysical" studies of sensory experience seem to have an intimate appeal, and the questions and answers seem especially personal. Anyone can understand the strong aesthetic appeal of color, whether in a landscape, a painting, a butterfly's wing (one of Michelson's interests, you will remember), or a spectrum in a laboratory. Add to this the elegance of the laws of color mixture, for example, and it is easy to understand why the names of so many physicists appear in the literature of color vision — Newton, Thomas Young, Maxwell, Helmholtz — down to the present day. Even the less vivid branches have their appeal: the psychophysics of vision plays an important role in modern biology. It is a basic part of psychology, it is applied by the ophthalmologist and the engineer, its methods can be extended to the study of animal behavior. And the physiologist, seeking to elucidate fundamental mechanisms, must refer to it to pose the questions he ultimately hopes to answer when he has discovered those mechanisms.

Tunica Retina

What, indeed, are the fundamental mechanisms of vision? How do we see? I do not propose to discuss the nature of subjective experience — that philosophic morass has no bottom. Better to rephrase the question or — for scientific discussion — to redefine "vision" and "seeing" in terms of overt responses. Certainly, as we have just noted, the first step in the elucidation of visual mechanisms was that taken by Kepler, and those who followed him, when the laws

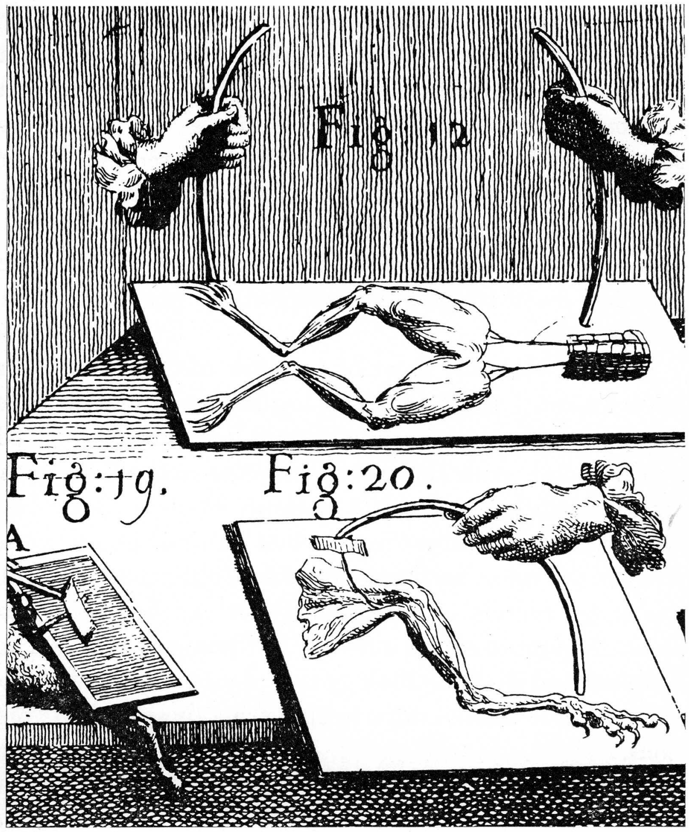

XLIV. PROPOSITIO.
Pictura lentis inversa est.
Nam lens est basis in quam insistunt bini utrimq; coni, alterius vertex est in puncto visibili, alterius vertex in puncto picturæ super papyro.

XLV DEFINITIO.
Dicamus talem bigam doctrinæ causa Penicillum.
Jam verò penicilli omnes omnium punctorum in lente velut in communi basi conorum concurrunt & transitâ lente rursum divergunt : sortiunturque plagas contrarias. In hac pictura penicilli tres sunt A B, C D, *&* E F *concurrentes in lente convexâ* G H, *veluti in basi communi.*

XLVI. PROPOSITIO.
Sicut se habet Diameter picturæ ad ejus distantiam à lente, sic se habet diameter rei visæ ad ejus etiam distantiam à lente, ferè. Nam axes penicillorum (rectæ ductæ à puncto visibili ad punctum picturæ respondens) secant sese mutuò omnes penè in uno puncto, quod est proximè centrum lentis. Ergo anguli κατὰ κορυφὴν æquales per XV. primi Euclid. habent etiam bases cruribus utrimq;

2

Divergent and convergent cones and rays in Kepler's "Dioptrics," London, 1653.



Luigi Galvani (LEFT); *details from Galvani's "De Viribus Electricitatis in Motu Musculari,"* 1792 (RIGHT).

of optics were invoked to explain the formation of the retinal image. But what next?

Do not the Rays of Light in falling upon the bottom of the Eye excite Vibrations in the *Tunica Retina?* Which Vibrations, being propagated along the solid Fibres of the optick Nerves into the Brain, cause the Sense of seeing.

This phrasing of Newton's is not especially acceptable to us today, but the sense of his question is clear.

Modern biology had barely begun in Newton's day. Since then the structure and development of the eye have been studied by anatomists and embryologists, and in painstaking detail by histologists armed with the powerful microscopes that applied optics has given them. And nowadays, a new offspring of optics — electron optics — has yielded the electron microscope to probe still more deeply into the ultrafine structure of the receptors and nerve cells that comprise the "*tunica retina.*"

Very different and equally valuable are the contributions of chemistry. Over a hundred years ago it was noticed that a frog's retina, freshly removed from its eye in dim light, had a pinkish tinge which faded in bright light. Thus was discovered "visual purple," the first of the visual pigments. These pigments, packed in the visual receptor cells, give them their sensitivity to light and enable them to initiate the visual process. Thanks to modern biochemistry the properties of the visual pigments are now known in considerable detail, and a firm basis exists for understanding the first step in the photoreceptor process: the excitation of the visual cell by light.

If I were a chemist, I would dwell at length on this topic of visual photochemistry, for it is a fascinating story, and no more important chapter exists in the study of vision. The story would undoubtedly unfold effortlessly from this beginning, if the next steps in the visual process were known. But I fear that it will take more than chemistry in any narrow sense to provide the links between the initial photochemical events in the visual pigment and the con-

sequent excitation of the receptor cell. A cell is a complexly organized physical system; its chemical machinery is subject to the restraints of intricate molecular arrangements that constitute the fine structure of living systems. And the visual receptor cell is no exception in intricacy of structure, as the electron microscope so vividly reveals. About all we can say at present is that, somehow, the initial photochemical event triggers the receptor and generates nervous action.

Even if we knew more of receptor mechanisms than we do, I think that our logical, step-by-step inquiry into the visual process would be interrupted at this point, with the words "nervous action." A visual organ must translate patterns of light and shade and color and movement into patterns of activity in the retina and optic nerve and ultimately in the visual centers of the brain. What can be said about the nature of this activity, and how can it be detected and studied? Biology and physics are once again in close collaboration in answering these questions.

Animal Electricity

It was some two hundred years ago that Galvani, as we all know, hung some freshly prepared frog's legs by brass hooks on an iron balcony rail, and noticed that they twitched whenever the flesh came in contact with the iron. He attributed this to "animal electricity." He was wrong in this particular instance, and it was his antagonist Volta who proved right in attributing the electricity to the dissimilar metals, moistened by the tissue juices. Volta, with his voltaic pile – forerunner of the electric battery – produced electricity without the benefit of living tissues, and with it opened the modern chapter on the physics of electricity.

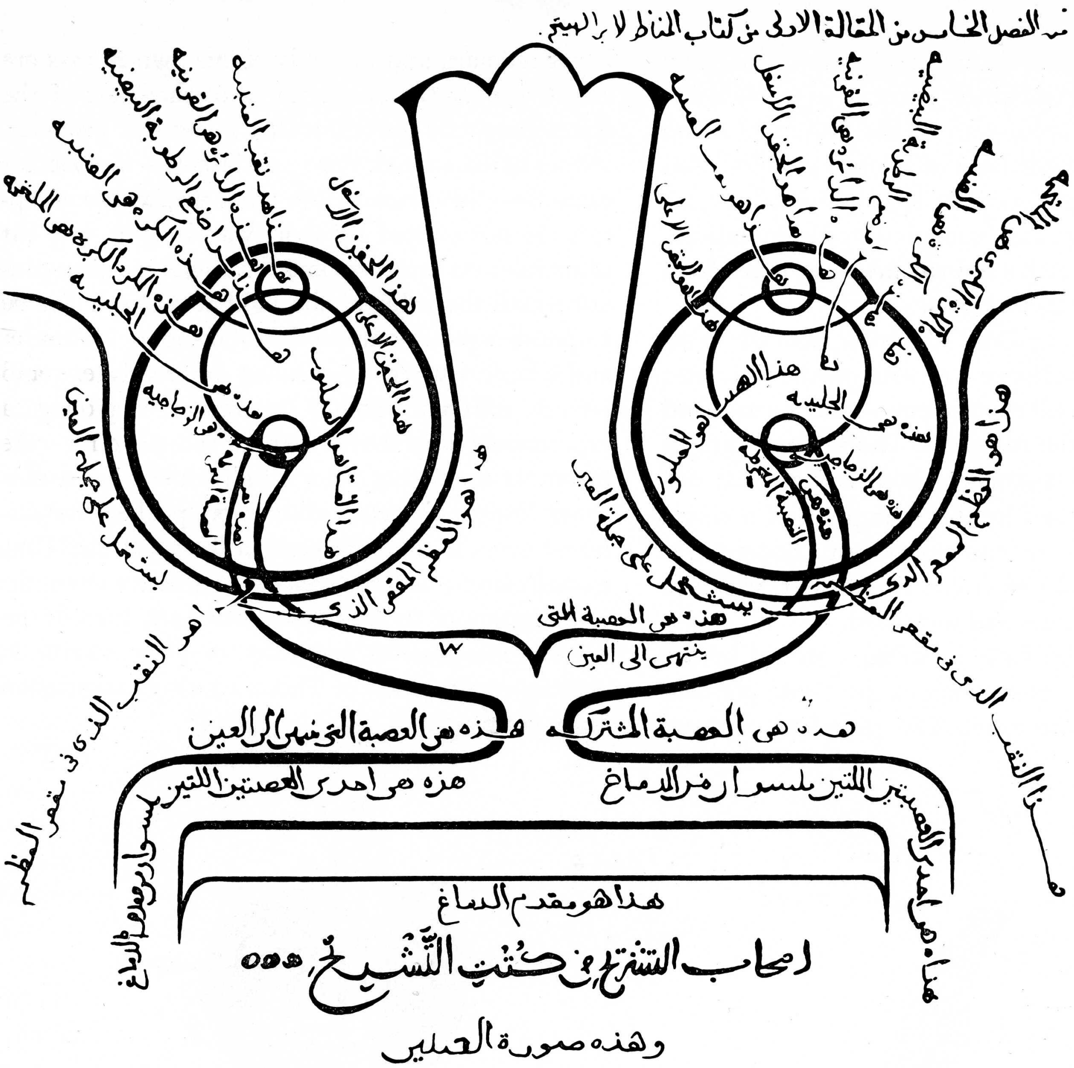
But Galvani was not entirely mistaken, and other experiments of his did indeed concern "animal electricity." We now recognize bio-electric phenomena as an inevitable and universal feature of cellular activity, at least in irritable tissues. Gland, muscle, nerve; the heart, the brain, the ear, the retina – all exhibit electric changes when they go into action. And a variety of extraordinary fishes, by specialized electric organs, can deliver a substantial "wallop" to stun their prey, or by subtler shocks to probe their surroundings.

But it is in the special study of the nervous system that bio-electric phenomena most persistently force themselves upon the biologist's attention. The analysis of these phenomena by the application of basic principles of physics and physical chemistry has furnished a partial answer to our question: "What is the nature of nervous action?" It is a complex cellular process, to be sure, but one essential feature of it is the generation of voltages and the flow of electric currents in and about the nerve cells and their filamentous extensions. When a region of a nerve fiber is excited, local electric currents, like eddies, carry the excitation to adjacent regions of the fiber, stimulating them in turn almost explosively to set up their current eddies. Thus a disturbance, the nerve impulse, eats its way rapidly along the fiber. Its powers temporarily disturbed, the fiber recovers quickly and can transmit another impulse – and another, and then another, as long as the original source of excitation persists. Trains of discrete nerve impulses constitute the basic signals that are transmitted over the nerves and fiber pathways from receptors to brain, from nerve center to nerve center, from motor nucleus or ganglion to muscle or gland.

The nature of the nerve impulse, how it arises and how it influences and controls the activities of the cells it reaches, are matters that are now beginning to be well understood. As always, new understanding breeds new questions: basic biophysics and biochemistry still have an enormous task before them to specify the detailed molecular and ionic mechanisms that underlie the grosser cellular phenomena.

Nerve Cell

Because nervous action has an essential electrical component, and because electrical instruments can be so sensitive and so versatile, the physiologist is able to explore the intimate workings of the individual units of the nervous system. He can, with amplifier and oscillograph, and loudspeaker too, "listen in" on the traffic of signals that control the organism's activities. The functional unit of the nervous system is the nerve cell, and even if its basic mechanisms are not yet fully understood in terms of physics and chemistry, its activity can be recorded, and the functional relations of individual nerve cells to one another and to the cells they control can be explored. This unitary analysis of nervous function



The oldest extant pictorial representation of the complete human visual system and its relationship to the brain. From the Arabic original of the "Kitāb al-manāẓir," or "Book of Optics," by Ibn al-Haitham, or Alhazen (A.D. 965-1039) ms no. 3212 in the Faith Library, Istanbul.

began in Adrian's laboratory in Cambridge, England, almost forty years ago. Adrian and Bronk were the first to dissect a single fiber from a nerve trunk, and record the trains of impulses coursing along it. Many workers, by isolating individual units one by one out of the seemingly jumbled traffic of thousands, have been able to piece together a clear picture of nervous function in many instances in almost all branches of neurophysiology.

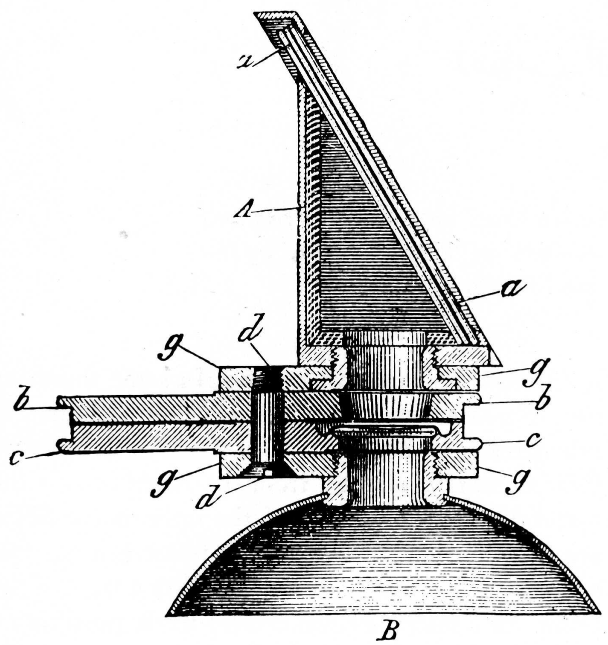
Unitary Basis

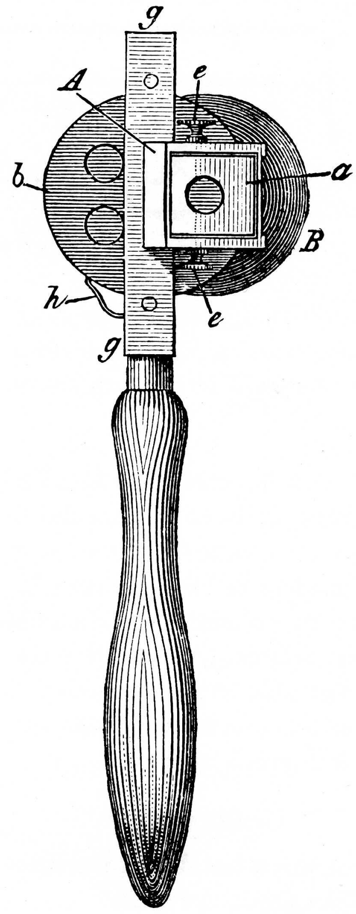
The study of vision has shared the benefits of this unitary analysis. Optic nerve fiber responses have been recorded in many animals. In some these are the responses of the primary photoreceptors, in others they are the responses of retinal cells deriving their excitation directly from the receptors. In the vertebrate eye, responses of the optic nerve fibers are complex and diverse, for the retina is a nervous center and the optic nerve is in reality a tract of the brain. Fine microelectrodes have made possible an extensive study of the activity of single nerve cells in the retina, and more recently, in the visual centers of the brain itself. Thus the unitary basis of visual function is being analyzed at all levels in the nervous system.

The present-day study of vision proceeds on many fronts, using many methods. Those of us who engage in it are largely indifferent to the origins of those methods, or what our kind of science is called. But each one's work, of course, is conditioned by his tastes and training, and hampered by his limitations. I can here only sketch a few salient areas, taken from the work of many laboratories.

Many of the properties of vision familiar to us from common experience — or with greater exactness from psychophysical experiments — may be ascribed to properties of the receptors. The faintest flash of light we can see comprises about 100 quanta; one retinal rod is excited by the absorption of a single quantum, though several rods must cooperate to reach the threshold of vision. As a result, vision in dim light is indistinct and uncertain.

The limits of the visible spectrum are set by the receptors — by the absorption of the visual pigment they contain, to be exact. The receptors of many lower animals, and the rods of our own retinas are sensitive over the entire range of that part of the electromagnetic spectrum that is, by this property, visible to the animal. For some insects — the bee, for example — this extends into what we, whose receptors are not excited by short wavelengths, call the ultraviolet. As far as we know, a single receptor cannot signal the color of the light it receives, for its response depends only on the total energy it absorbs, and it has no way of responding differently to qualitatively different stimuli. But recent, very elegant experiments have shown that our retinal cones — the receptors mediating color — individually have narrower limits of spectral absorption, peaking for different cones in different parts of the spectrum. Thus a small sample of cones can, by the relative strengths of excitation of its individual members, furnish the sensory information necessary to color vision, in striking confirmation of Thomas Young's suggestion many years ago.





Ophthalmoscope developed by von Helmholtz. From "Handbuch der Physiologischen Optik," Leipzig, 1909. Essentially the same instrument is in use today.

Our eyes function over an enormous range of intensities — from dim starlight to the brightest sunshine. True, our retinas possess two sets of receptors — rods and cones — to cover this range. But a single receptor, at least in many lower animals, can by itself cover a substantial range — a millionfold at least — signaling different intensity levels by the different rates at which it discharges nerve impulses. Yet each receptor can respond by a transient frequency change to a quick fluctuation of intensity of only a few percent.

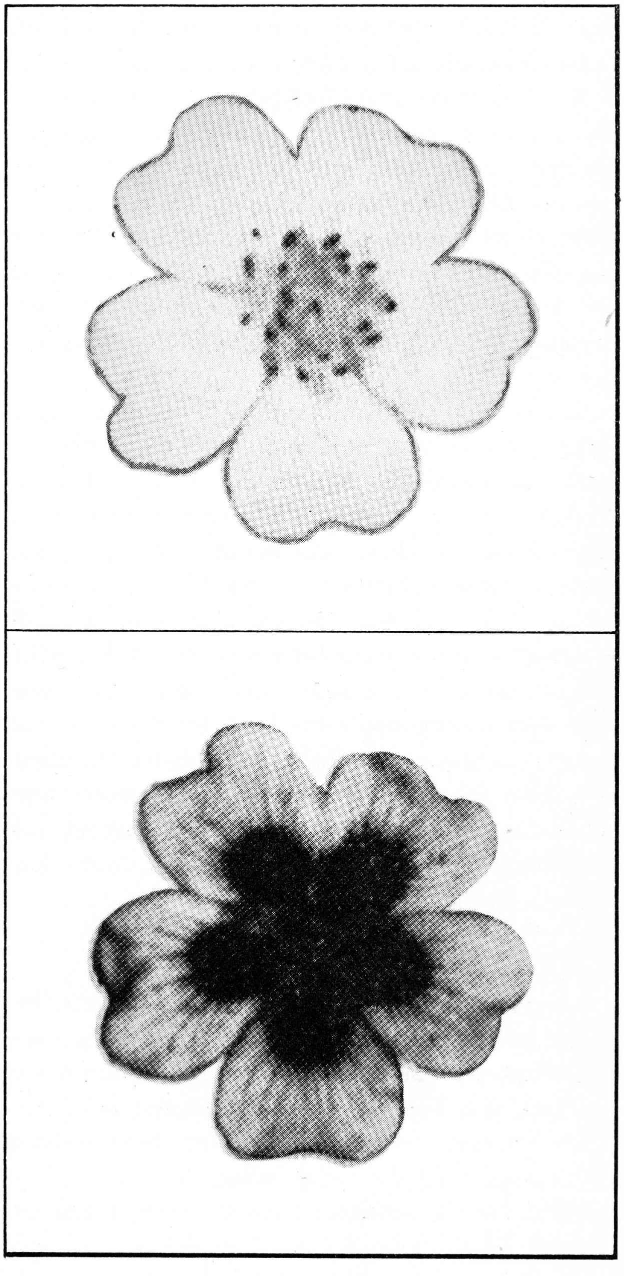
These and many other properties of visual receptors spur our efforts to understand more fully the fundamental mechanisms of photoreception.

But vision is more than photoreception. An image is the first requirement for pattern vision; a pattern is seen by comparing intensities and hues in different parts of the image. By such comparison, from the wealth of sensory information generated by all the receptors, features of the pattern that are relevant to particular visual responses must, somehow, be extracted by the nervous system. This is a complex process that begins in the retina itself, at the level of the very receptors that gauge the image and generate the elementary nervous signals.

One part of this truly neural process simply sums the signals over a small retinal area; another averages rapid fluctuations over short intervals of time — as when we fuse motion pictures or the television image. Other processes are more concerned with differences and changes, and with gradients of brightness. Even in primitive eyes, the receptor units in the retinal mosaic are not independent light sensors, but interact with one another.

One example of retinal interaction is a simple mechanism of mutual inhibition which serves to enhance contrast and accentuate lines and contours. In our own common experience we recognize the effectiveness of the line drawing, and are quick to appreciate the artist's skillful use of contrast in shade and hue. A hundred years ago, a great physicist, Ernst Mach, investigated contrast effects in human vision, and correctly ascribed them to inhibitory interaction in the retina, which we now study by our more direct methods.

In the vertebrate retina increasing complexity and more extensive interaction are the rule. This is no surprise, for histology and embryology both tell us



In the photograph at top, taken with yellow light, the flower appears almost featureless as seen by the human eye. In the photograph below, taken with ultraviolet light, the identical flower shows well-marked honey guides seen by the bee, but invisible to the human eye. From "Blumenfarben, wie sie die Bienen Sehen", by K. Daumer.

that the retina is a layer of brain tissue, spread thinly over the densely packed mosaic of receptors. From the receptors the retinal nerve cells take the sensory messages translated from the patterns of light in the retinal image, and subject them to the first steps of what today we would call "data processing." Some cells discharge impulses in their optic nerve fibers in response only to light, others only to shadow, some only to fluctuations of intensity, or movements of contours. Antagonistic responses elicited by complementary colors have been described. There are reports of fibers that discharge only for curved contours, or only to black moving spots. Such kinds of response must be synthesized from the patterns of receptor activity by processes that depend on neural organization and interaction in ways as yet not understood.

In the brain are even more hierarchies of organization, and even greater complexities are being revealed as the cellular units in the visual centers are studied. Various features of the retinal information are extracted by nerve cells in different regions and various patterns of response synthesized by them for use by still other neurons. Orientation of contours is detected, and color is further analyzed. Many individual cells receive inputs from both eyes; somehow they must provide the basis for the binocular gauging of distance. In the brain, moreover, information from the visual apparatus must interact with that from other sense organs, in ways that are just beginning to be studied: the faculty of vision does not operate alone.

Summary

I began with a review of the obvious relation between optics, a branch of physics, and optics, a science applied to the study of vision. Electrical science, I noted, also has served visual science well. And other sciences — physical chemistry, biochemistry, psychology — supply basic principles as well as methods for the analysis of visual function. Indeed, it is one of the compensations of this narrow specialty that so many diverse fields illuminate it; only one's own limitations restrict the view.

The last portion of my discussion, you will have noted, had a different tone from the first. There was less of basic mechanisms, more of relations between acting components; less of elemental action, more of organized interaction; less of analysis, more of synthesis. Less, perhaps, of physics and chemistry, more of biology. Physics and chemistry must be there, of course — a solid foundation; units of action must be understood before the interactions can be appreciated; analysis is still unfinished. But the problem of organization is the dominant concern of those of us who are neurophysiologists, and we must deal with it largely by ourselves. Help we must have — other sciences of course are concerned with organization, whether of elementary particles or of atoms in molecules; principles found valid in one kind of inquiry can often be applied in another. And it is the business of mathematics to deal with abstract relationships, if we can but learn to use it as effectively as we should.

Technical aids are abundant in neurophysiology, and will continue to be of crucial importance, not only in the deeper analysis of cellular mechanisms but in this difficult field of functional organization. Recording is readily done from one nerve cell, and from two or even three interacting units without too much difficulty. But beyond this the study of the patterns of activity of even a small number of interdependent elements can become quite a formidable technical problem. Computers are becoming enormously useful in such studies, of course, and methods will develop for processing and reducing the mountains of tedious numbers they generate. But I suspect that the basic problem will remain: how to think about complex organization, how to develop useful general principles.

However our study of vision may develop, it is certain that increasingly diverse scientific disciplines will be brought to bear on it. This makes it an interesting and exciting specialty for one who has grown up in it. But it places a burden upon the beginning student, however vigorous and enthusiastic he may be. This is a concern no scientist as teacher can escape. How can we help our students gain professional competence — not just superficial familiarity — in so many pertinent fields? And how can this be done without swamping them in detailed specialization, risking the destruction of creative imagination? Our specialty is not unique in this matter; for all branches of science, it is a serious concern. And it is a concern not only for beginners but for all of us in all stages of our careers.

WEST AFRICAN SCULPTURE

BY ROBERT GOLDWATER

On the lower level of Caspary Auditorium, a group of sculptures from western African nations is on display, and the exhibit will continue into December. These works are on loan from the permanent collection of The Museum of Primitive Art. Dr. Goldwater, who is Chairman of the Administrative Committee of the Museum and Professor of Art History at New York University, is the author of a number of books on Africa, including "Traditional Art of the African Nations," "Bambara Sculpture from the Western Sudan," and "Senufo Sculpture from West Africa," published by The Museum of Primitive Art. This article, adapted from these writings, describes some of the sculptures of two of the tribes represented in the exhibit.

On the continent of Africa a group of nations has emerged. The rest of the world has become accustomed to think of them as the new nations of Africa – they are so recently organized so recently independent. And so they are in the limited sense of geographical identity and political structure.

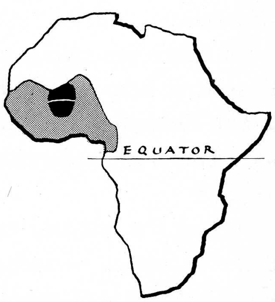
But in another, more profound sense these nations are far from new, or even recent arrivals. Socially, culturally, aesthetically, their peoples have a long and intricate history. Since for the most part that history has been orally transmitted, we know only a portion, probably only a small portion of the complex of its traditions and development. Some few specific dates have been recorded by travelers from abroad such as the eyewitness reports of Ibn Battuta from the 14th century or the Portuguese chroniclers of the 15th century; others, more ancient, have been revealed by archaeology (for example, the Nok excavations of Bernard Fagg), which has told us enough so that we may be sure that further investigations will tell us much more; some oral histories are apparently chronologically accurate. But there are not many such temporally pin-pointed facts, and their scarcity has perhaps given them an undue importance, compared to the vast totality of African cultural history.

We can infer the quality of this history from what we know of the nature of the recent past. The many cultural traditions of Africa, in all their distinction and variety, the ordering of their social structure, the intricacy and sharpness of their religious beliefs, the wealth of their oral traditions – all these can only have evolved in the course of a long, complex, and thoughtful history.

The plastic arts of Africa are a manifestation of this cultural history, the one perhaps best known to the world in general, and they carry its evidence within themselves. Their skilled technique has a di-

The Bambara are in the northern section of solid black area, the Senufo in the southern section.

Other West African peoples represented in the exhibition.



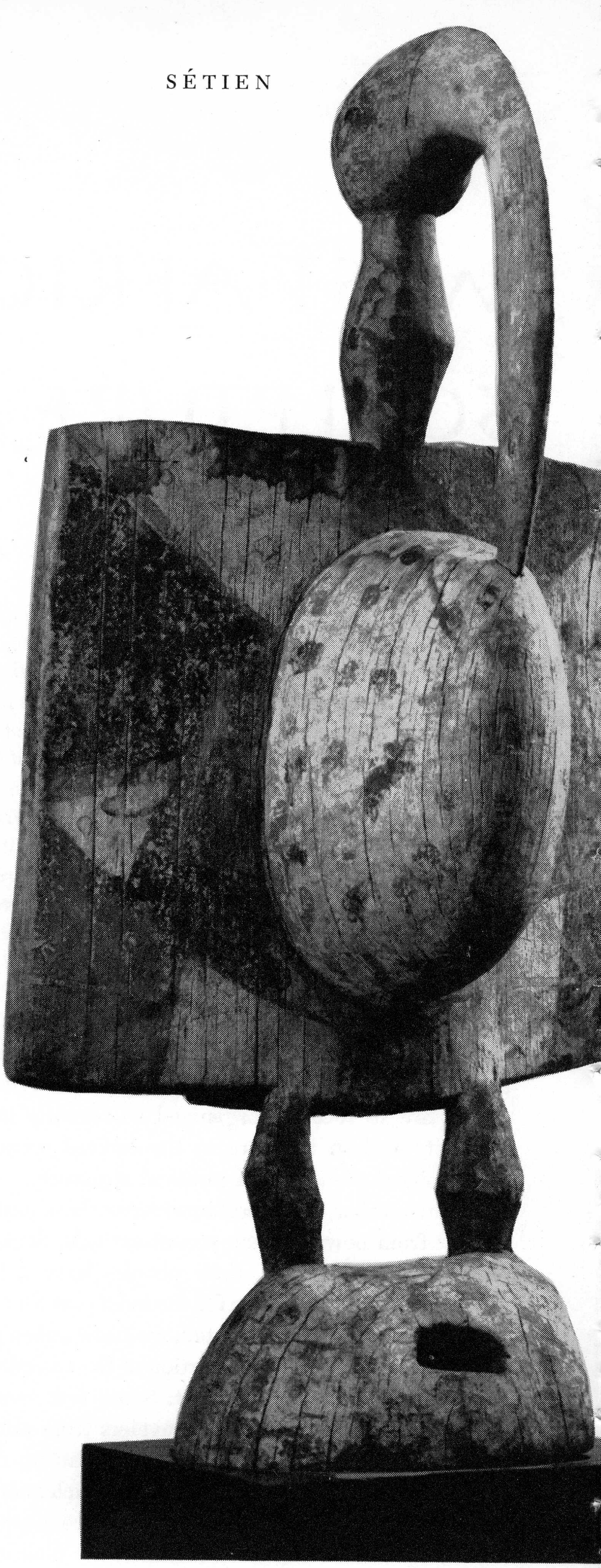
rectness that comes from an almost intuitive use of established methods, passed on and gradually perfected. Their styles are as various as the cultures that have developed them, since they embody and externalize them. Because the cultural unit has been the "tribe" (which may number many hundreds of thousands of persons and so is perhaps better referred to as a people), and the art reflects this unit, any one of today's nations has been the home of many styles. If these styles are distinct and recognizable, they are also related, and have influenced and borrowed from each other. Neither immutable nor isolated, yet clearly formed and individual, they are like the arts of the city-states of Italy — Florence, Siena, or Bologna — each having its separate style (marginally affected by trade and travel), and all the product of related vision.

The traditional arts of Africa's nations are then, in their own right, old arts. This remains true even though because of the perishable materials so widely employed only a minority of the works known to us are of any great historical age. Function, whether symbolic or magic, was paramount, and antiquity as such had little meaning for the original intention of these arts.

Yet there are two senses in which African art as illustrated here from the sculptures now on display at The Rockefeller Institute may be said to be new: one stems from understanding, the other from knowledge.

During the last few years we have come to know of the existence of hitherto unsuspected styles and of a whole wide range of individual works — some of

SÉTIEN



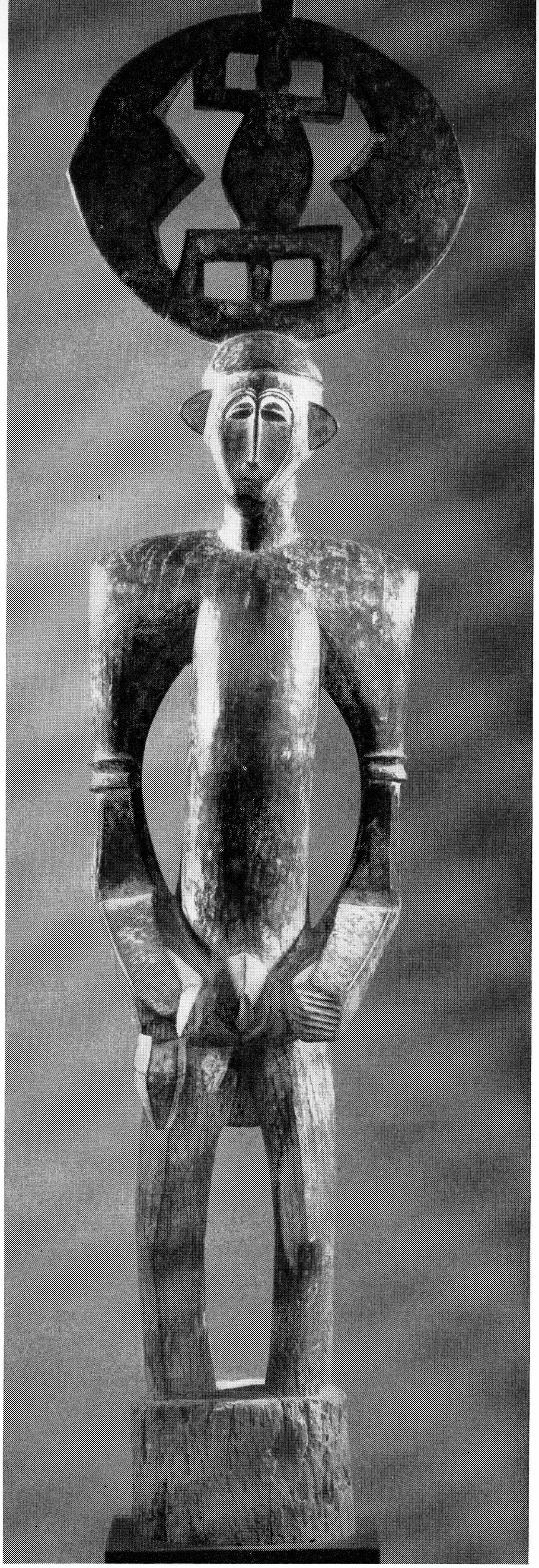
them masterpieces. In a few instances these are in fact recent styles; in most, however, it is our knowledge, rather than the works, which is new. The total impact has been a new realization of the richness and variety of African sculpture.

The relation of African art to modern Western art and important instances of strong influence are by now familiar, such as Modigliani, Picasso, Braque, and Schmidt-Rottluff. Both anthropologists and artists played a role in first seeing and then collecting, but it was crucially the freer vision propagated by the painters and sculptors that permitted the modern eye to receive the shock and impact of an unfamiliar art. This new appreciation was highly subjective, yet it was an indispensable step in the direction of the more objective, more understanding enjoyment that has become widespread in the last few years. Thus, for Americans and Europeans African art has entered a new phase – new, that is, for them. It is one which, because it is now based on a maturity of vision to match the maturity of the art, will continue and grow.

Senufo

The Senufo people, which are represented at the Institute by six sculptures, live in the northern Ivory Coast and southern parts of Mali and Upper Volta. Numbering nearly one million, they are divided into some twenty-five sub-tribes. The Senufo are an agricultural people whose religious and social organization is largely built around an initiation society called Lô to which every male must belong, beginning in adolescence and passing through several grades. At each stage, performance of appropriate rituals (known only to members of the society) which have mythological references, ensures the continued harmony of the people within the universe. Most Senufo sculpture functions in the context of these Lô rituals.

For example, the ancestor figures on heavy bases (called DEBLÉ in the secret language of the Lô society) are employed in memorial services for the dead. The arms of the figure and its base are its functional parts, since during the ceremonial rites the young initiates in file, hold these statues by the arms and pound the earth in a slow rhythm. This is an appeal to the ancestors to take part in the rites and also a way of ridding the earth of its impurities and thus



ensuring its fertility. The rhythmic processions of the deblé are accompanied by the sounds of drums, gourd rattles, and a heavy wooden trumpet which amplifies the words of the funeral chants recited in the secret language of the Lô society.

Among the most pervasive representations in the repertory of Senufo sculpture is a bird with a small round head bare of plumage, a long beak, prominent belly, and rectangular wings, that stands in the suggestion of a human pose. This bird, the hornbill, or SÉTIEN, appears as a "totemic" crest on the top of many face masks, and is placed between the horns of animal helmet masks; it decorates the covers of ointment boxes and is carved in relief on the sculptured doors.

According to Senufo belief, the hornbill along with the chameleon, the tortoise, the serpent, and the crocodile, also shown frequently—was one of the first five living creatures and was the first to be killed for food. In its allegoric form, with its long beak touching, or almost touching its swollen belly it suggests the male and female components of increase, symbolizing the continuity of the whole community.

These large birds play their own part in the ceremonies of the Lô society when, heavy as they are, they are carried on the heads of members taking part in the rituals, symbols of the living forces of the universe. This explains why the base of many of these sculptures is hollowed out underneath so that it may fit like a cap on the head of the wearer.

Firespitter

The FIRESPITTER masks, on the other hand, function in a ritual organized by one of the several secret societies outside the Lô—a ritual organized to destroy "soul-eating witches." They get their name because sparks of burning tinder are blown out through the jaws. The "firespitters," like the other helmet masks, are worn nearly horizontally over the head with a costume that completely covers the body.

Almost all of the several kinds of helmet masks, including the "firespitters," are characterized by a broken, bristling silhouette made up of an assortment of jaws, teeth, ears, and horns put together on a large scale and executed with vigor. These masks are intended to be taken in at a single glance. They are meant to impress, to terrify. And this is, in fact, their

FIRESPITTER

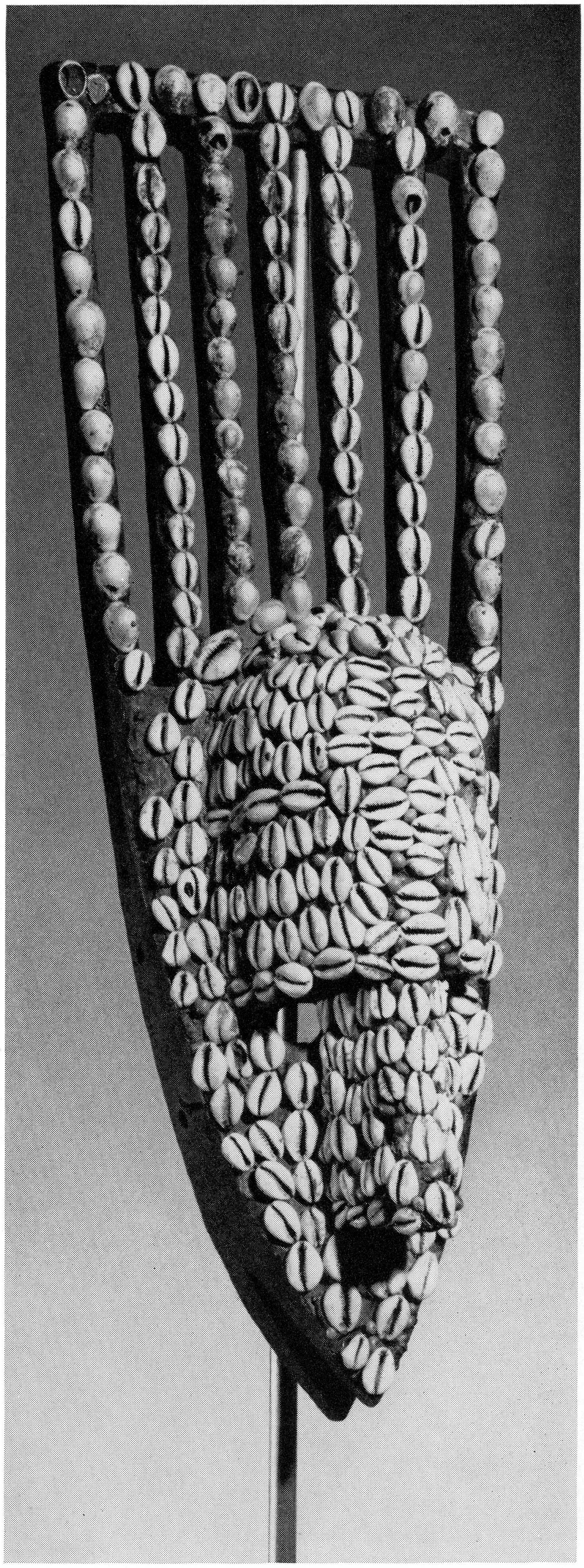
functional role. Although each of the parts is drawn directly from nature, they are not to be found together in the natural world. The most common of the animal masks, whose prominent features are its single muzzle and long horns, can include iconographic details taken from the buffalo, the wart hog, the crocodile, and the antelope in its large parts, plus small representations of a chameleon and a bird, sometimes even a snake. It would seem correct to say that this sort of additive compositional imagination is more characteristic of Senufo art than of other African styles.

Bambara

The habitat of the Bambara peoples, who are the neighbors to the north of the Senufo, lies within the area of a large V described by the lower course of the Senegal River and that of the Niger. Both the religious life and the social structure of the Bambara people are based upon fraternal groups or societies. The beliefs of these societies—their dogma, their symbols and their rituals—are all related to an organized and detailed body of cosmological theory and oral tradition fused in a mythology that is at once cosmogony and history, and that pervades all religious thought and social behavior. Some of the initiation procedures and cult practices of the secret societies are closely guarded (particularly from women), but the rites are also important festivals that attract general attention and may be observed by spectators. The secret societies serve a double purpose. Since everyone in the community belongs, almost from birth on, to one or another of them (and, if he can afford it, to several) they are important forces of social organization, binding whole village populations together in a sort of universal brotherhood and giving them a relation to the gods as well.

Bambara religion, in general, is concerned with increase. As a consequence, its most important rites are directed toward aiding and controlling the fertility of nature (and by, and for, sympathetic association, human fertility). It is for the observances of these societies that the Bambara fashion their works of art, above all, their masks and figures.

Among the most interesting of the Bambara masks are those of the N'TOMO. This society organizes much



N'TOMO

of the life of the boys of the tribe up until the time of circumcision when, as men, they enter the other societies. The Bambara say that the N'tomo is "the mother of the wanzo of the uncircumcised," that is, its power, which resides in its ritual objects (including its mask and its musical instruments) is the collected evil power (wanzo) of all the uncircumcised, a power which at the time of circumcision is transferred from them to the society, leaving them free and fertile adults.

Antelope

The best known of all Bambara sculptures, and among the most widely appreciated of all African sculptures, is the ANTELOPE HEADPIECE. Sculpture antelopes are the property and dance equipment of the associations of the young men of each village. Each age group or *soli* (issue of the same circumcision ceremony at which they leave the N'tomo) constitutes a *flamobolo,* and three such groups make up a *flan ton.* The antelopes belong to the *flan ton* of the younger men which bridge the gap from childhood to manhood, socially and sexually.

These young men's agricultural groups employ the antelope headpieces in dances carried out just before the rainy season or when, during the dry season, a new field is cleared. On such occasions the antelopes which are worn attached to a basket-cap, accompany the members out to the field and supervise the work. After their return to the village, the wearers of the mask execute a dance accompanied by an orchestra of drums and watched by the whole population. When the society members of two neighboring villages have a hoeing contest, the winners don the cap and costume and carry out the ritual.

It is sometimes suggested that the various styles of the sculptured antelopes stem from differences among the several antelopes of the region, such as the roan, the kob, and the gazelle. However this may have been at some distant starting point (and even in origin it seems unlikely), the extremes of stylization should make it abundantly clear that such naturalistic differences are not the determining factors in the artistic result, but rather the slow growth of an inventive tradition which serves as a base and spur for the imagination of the individual artists.

ANTELOPE HEADPIECE

MEDAL OF FREEDOM TO PRESIDENT BRONK

PRESIDENT DETLEV BRONK has received the Presidential Medal of Freedom which is the Nation's highest civilian honor. As President Johnson conferred the Medal in White House ceremonies on September 14th, he said of Dr. Bronk: "Scientist and leader of scholars, his vision and untiring efforts have advanced science education and helped forge an enduring link between Government and the scientific community."

In the presence of several hundred leaders of government and national affairs who were gathered in the East Room, President Johnson opened the ceremonies by saying: "What America is to be, America will be, because of our trust in and of the individual and of his capacity for excellence. Only those who doubt the individual can be dubious of America's survival and success in this century of contest. This belief is mine. It was this conviction that led President Kennedy to the establishment of the Medal of Freedom as our highest civilian honor for outstanding individuals — citizens who share an extra measure of individual excellence in the mainstream of our well being and our advancement. On the talents of such citizens rests the future of our American civilization, for it is from the genius of the few that we enrich the greatness of the many.

"All Americans are proud, as I am proud, to salute today the great Americans here before me. Their lives and their works have made freedom stronger for all of us in our time. They are creators; we are the beneficiaries."

The twenty-nine Americans then honored in addition to President Bronk, included Dean Acheson, former Secretary of State; Aaron Copland, composer; Walter Disney; T. S. Eliot, poet and critic; John W. Gardner, President of the Carnegie Corporation; John L. Lewis, labor leader; Walter Lippmann; Alfred Lunt and Lynn Fontanne; Carl Sandburg and John Steinbeck, authors; Carl Vinson, veteran Congressman; and Thomas J. Watson, statesman of business.

At a State Department reception for the recipients of the award held later in the day, Under Secretary of State George W. Ball, Chairman of the Awards Committee, said: "We have come here today in praise of greatness — to express our respect for an extraordinary company of men and women who have been selected by the President of the United States as deserving the highest tribute of their countrymen.

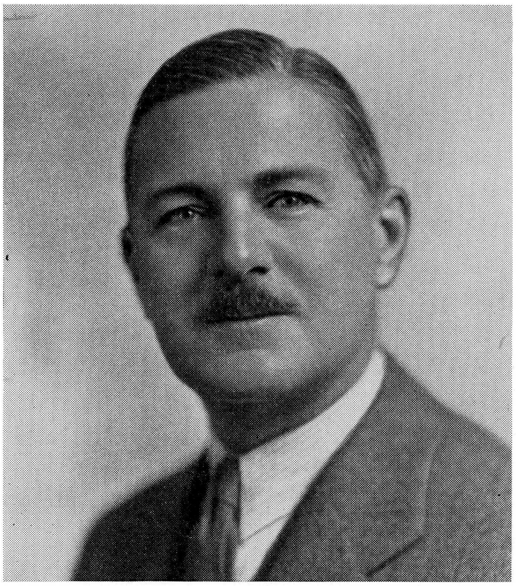
"Represented on this roll of honor are rich and varied talents. Each of this proud company pursues the truth in his own way — in politics and the arts, in business and labor, in medicine, in education, journalism, science, and theology. Each works in the medium of his own discipline. Each speaks in the language of his special craft.

"Yet there is a common quality in the uncommon achievements that we celebrate here today — the quality of excellence. Each of our guests has attained distinction in a separate field of endeavor, but all have impressed on their chosen tasks the unmistakable mark of greatness."

The Presidential Medal of Freedom awarded to Dr. Bronk

ALPHONSE RAYMOND DOCHEZ

1882-1964



Dr. Alphonse Raymond Dochez, John E. Borne Emeritus Professor of Medical and Surgical Research at Columbia University College of Physicians and Surgeons and Trustee Emeritus of The Rockefeller Institute, died on June 30, 1964, at the age of 82. Dr. Dochez, who is perhaps best known for his discovery of an antitoxin for scarlet fever, began his research career at the Institute more than half a century ago and served as a member of its Board of Trustees for over twenty years.

Dr. Dochez was born in 1882 in San Francisco, the son of Louis and Josephine Dochez. In 1899 he made the journey eastward to The Johns Hopkins and upon his graduation went on to the Hopkins Medical School from which he received the M.D. degree in 1907. On graduation from the Hopkins, he was given a Rockefeller Institute Fellowship in the laboratory of Dr. William G. MacCallum of the Hopkins who had been his Professor of Pathology at medical school. In the fall of that year, Dr. Dochez came to the Institute as a Fellow in Pathology to work with Dr. Eugene Opie who was then studying the spinal fluid as a part of Dr. Simon Flexner's program to develop a serum for spinal meningitis. Dr. Dochez credited this early association with Dr. Opie with kindling his interest in medical research. When Dr. Opie left the Institute in 1910, Dr. Dochez was appointed bacteriologist in the newly completed hospital and it was there that he began the investigations of bacterial and viral infections that were to form his life's work. He served as Assistant Resident Physician in the Hospital from 1910 to 1914 and as Associate Resident Physician from 1914 to 1917.

Dr. Dochez's first major research program was a study of the organism responsible for lobar pneumonia. By the end of 1912, his work had led to the development of a serum effective against one type of pneumonia and had inaugurated a series of investigations on the pneumococcus that were to become a major part of the Institute's research program in later years. He and Oswald T. Avery first described the so-called soluble specific substances of pneumococci which were found to occur in human exudates of individuals suffering from acute lobar pneumonia. This work of Dr. Dochez together with Avery, led to the discovery that these substances were bacterial polysaccharides which conferred type specificity upon the various pneumococci. Later in turn, this discovery led to the isolation of these substances by Avery and Michael Heidelberger and brought about a whole new concept of the field of microbiological immunity. Dr. Dochez interrupted his work in 1917 to enlist in the Army Medical Corps which he left in 1919 with the rank of Major.

After the war, with Dr. Walter Palmer, Dr. Dochez returned to The Johns Hopkins University as Associate Professor of Medicine. During the two years he remained there, he was able to show that scarlet fever was caused by the hemolytic streptococcus, an organism with which he had become familiar during the war. In 1921 Dr. Palmer accepted an appointment as Professor of Medicine at Columbia's College of Physicians and Surgeons and persuaded his colleague to return to New York with him. Dr. Dochez was Associate Professor of Medicine at Columbia from 1921 to 1924, the year in which he was able to announce that after six years of study he had de-

veloped an antitoxin effective against scarlet fever.

In 1925 Dr. Dochez became a full Professor at Columbia and in 1939 just before the outbreak of World War II he was appointed to the newly-endowed John E. Borne Professorship of Medical and Surgical Research and shortly afterwards became Professor of Bacteriology and head of the Department. During this period he resumed his work on respiratory infections, particularly the common cold. In 1934, with Gerald Shibley and Yale Kneeland, Dr. Dochez was able to transmit colds to chimpanzees with filtrates from the throat washings of infected human beings, and subsequently the trio was able to develop a vaccine which protected the chimpanzees from infection with this virus. In addition to being an investigator and a teacher, Dr. Dochez was also a distinguished clinician and was a holder of the Kober Medal of the Association of American Physicians.

During World War II, Dr. Dochez served as a member of the Armed Forces Epidemiological Board and also on the Committee on Medical Research of the Office of Scientific Research and Development. He received the United States Medal of Merit for his contributions to medical research during World War II.

Dr. Dochez, a handsome bachelor, bon vivant, and expert golfer, was almost as much in demand in New York social circles as in scientific ones. His great interest was his work, however, and he would spend hours stretched on the sofa in his office lost in thought or would talk far into the night with any available colleagues. Associates of Dr. Avery, with whom he shared bachelor quarters for many years, recall that he frequently arrived at his laboratories inspired and exhausted by a long night of discussion.

Dr. Dochez became Professor Emeritus of Columbia in 1949 and also retired from active research at this time but maintained a lively interest in new developments in the field, devoting his time to reading and to sharing his wide experience with other physicians and investigators. He served as a member of the Corporation of the Institute from 1935 to 1959 when he was elected a member Emeritus. He was a member of the Board's Committee on Research where he commanded wide respect for his penetrating views and informed opinions on the work of others as well as his great personal contributions to medical research.

A Rockefeller Institute Hospital group photographed in May 1915. From left to right: (FIRST ROW) *Alfred Einstein Cohn, Rufus Cole, Alphonse Raymond Dochez, Oswald Theodore Avery:* (SECOND ROW) *unidentified, Mariam Vinograd-Villchur, unidentified, Donald Dexter VanSlyke;* (THIRD ROW) *Frederick Madison Allen, Walter Walker Palmer, unidentified, Ernest Goodrich Stillman.*

HEART AWARD TO DR. LANCEFIELD

ON OCTOBER 23, Professor Rebecca C. Lancefield received the 1964 Research Achievement Award of the American Heart Association. The award, consisting of an illuminated scroll and a $1,000 honorarium, is given in recognition of distinguished accomplishment in the cardiovascular field. It was presented to Dr. Lancefield by Dr. John J. Sampson, President of the American Heart Association, at the opening of the Association's 40th Annual Meeting in Atlantic City.

Dr. Lancefield has received wide recognition for her work on the classification of the streptococci; subdivisions of these organisms are universally referred to as the Lancefield groups. In her early work she established that the streptococcal organisms pathogenic for man share a common antigen, and so can be distinguished from those that are usually harmful only for other animals or are saprophytes. She also demonstrated that these so-called group A streptococci can be subdivided into more than fifty types on the basis of another antigen, the M protein. This protein, her investigations have shown, not only determines the production of specific protective antibodies for each subtype but also is responsible for the virulence of the organism. The effect of the M antigen on pathogenicity appears to depend on its ability to prevent ingestion and destruction of the streptococci by host phagocytes. Antibody to the particular M antigen reverses this effect. Recently in reinvestigating a group of patients whose streptococci infections had been studied earlier in the course of her work, Dr. Lancefield found that type specific antibody can persist for as long as thirty years.

Typing of the streptococci as developed in this country by Dr. Lancefield and in England by Dr. Frederick Griffith has led directly to greatly increased scientific knowledge about this major group of infectious organisms. This has made it possible to establish routes of spread for epidemiological studies and also, to some extent, to associate particular organisms with particular diseases. For example, certain streptococci now known to be responsible for acute nephritis and one single group has been found to cause rheumatic fever.

Dr. Lancefield comes from a southern family but because of her father's Army career was born in Fort Wadsworth, New York. She was graduated from Wellesley College in 1916 and received the A.M. and Ph.D. degrees from Columbia University. Her association with The Rockefeller Institute began during her days as a graduate student. In 1922, she became a permanent member of the staff. She was appointed Member and Professor in 1958.

Dr. Lancefield had her first introduction to the Streptococcus in her work with O. T. Avery and A. R. Dochez on strains isolated from a severe epidemic in military camps during World War I. This study, published in 1919, involved the demonstration of several serological types among the epidemic strains and was the initial step in her series of now classical investigations.

Dr. Lancefield has served as President of the Society of American Bacteriologists and of the American Association of Immunologists. In 1960, she received the T. Duckett Jones Memorial Award of the Helen Hay Whitney Foundation. Earlier this year Professor Lancefield was appointed an Honorary Member of the Pathological Society of Great Britain and Ireland.

Dr. Weiss Retires as Emeritus Professor

PROFESSOR PAUL A. WEISS, who retired from the faculty of the Institute at the close of this academic year, has accepted the position of Professor and Dean of the University of Texas Graduate School of Biomedical Sciences at Houston.

Dr. Weiss, who has been with the Institute since 1954, has specialized in problems of growth, differentiation, and organization of tissues. He was born and educated in Vienna, receiving the Ph.D. degree from the University of Vienna, and did research in various European countries, in part as a Fellow of The Rockefeller Foundation. Prior to coming to the Institute, Dr. Weiss was Professor of Zoology at the University of Chicago.

During World War II, Dr. Weiss was in charge of a broad government program on nerve repair. In this capacity, he was responsible for the evolution of improved techniques to promote the regeneration of shattered nerve and muscle tissue, a scientific contribution that won him the Army-Navy citation for outstanding merit.

In his studies of the morphology and organization of cells and tissues, Dr. Weiss was always conscious not only of the scientific implications of his observations but also of the intrinsic beauty of these structures. According to Dr. Weiss, it was Dr. Bronk's broad vision of a synthesis of the humanities and science that drew him to the Institute and it is this spirit that he will carry with him to his new post.

Dr. Weiss will be Professor Emeritus of the Institute and will also continue to maintain a laboratory here. His appointment in Texas took effect on October 1.

Institute Concerts

THE CURRENT SEASON of music at The Rockefeller Institute was inaugurated on October 7 with a performance by the Borodin Quartet. This distinguished ensemble, which was on its first trip to the United States, played only at Carnegie Hall and Caspary Auditorium during its brief stay in New York City. Harold C. Schonberg, *New York Times* music critic, described the quartet's performance as "a perpetual delight," saying "Refinement and precision mark their playing — that and scrupulous musicianship." Dr. P. A. T. Levene of The Rockefeller Institute was a graduate of The Royal Military Academy of Medicine and Surgery in St. Petersburg, where his professor of chemistry was Aleksandr Porfirevich Borodin, for whom the quartet is named. Borodin was acquainted with the Russian chemist Mendeleev and the German chemist Erlenmeyer.

The second program of the season, held on October 28, featured the well-known harpsichordist, Albert Fuller, who played selections from Couperin, Handel, Rameau, and Scarlatti. The Institute concerts are arranged by Professor Theodore Shedlovsky.

News and Notes

DURING THE month of October, Professor Richard Shope spent several weeks in California as Regents' Lecturer at the University of California at Davis. Dr. Shope gave a series of lectures and seminars on viruses and virus-induced tumors.

Dr. Maclyn McCarty served from March to July as Chairman of the Microbiology Panel of the Wooldridge Committee which was organized under the Office of Science and Technology at the White House to study the operations of the National Institutes of Health. A report on the findings of the Committee is forthcoming.

On September 28, Professor Loren Eiseley received an honorary Doctor of Literature degree from Brown University, honoring him as "a penetrating investigator and a lucid expositor, as specialist and generalist, as scientist and humanist."

In October, Dr. Jules Hirsch visited the Hebrew University in Israel where he was the guest of Olga and Yechezkiel Stein who were at the Institute as guest investigators several years ago. While he was there, he gave a seminar on his studies on human adipose tissue. In the course of the same trip, Dr. Hirsch also visited Cambridge where he spoke on lipid chromatography.

Dr. Frederick Dodge, Jr., who was graduated from the Institute in 1963, and a Research Associate during 1963-1964, has now become an Affiliate in Dr. Hartline's laboratory. He will also be working

at the IBM Thomas J. Watson Research Center in Yorktown Heights, New York, as a Research Staff Member in the Applied Mathematics Division, and as a Consultant on Biological Problems.

Three investigators from The Rockefeller Institute, Doctors Philip A. D'Alesandro, George J. Jackson, and Stuart M. Krassner, gave invited papers at the First International Congress of Parasitology. The meeting was held in Rome from September 21 to September 26.

Dr. Vincent du Vigneaud, a Trustee of The Rockefeller Institute, and Professor of Biochemistry at Cornell University Medical College, was awarded the Pirquet Medal on October 14. The medal, which was presented at the annual Clemens von Pirquet Meeting at the New York Academy of Medicine, was given to Dr. du Vigneaud for his "contributions to the health of humanity." On this same occasion, Dr. du Vigneaud received a scroll "in recognition of his outstanding scientific achievement" and an honorary membership in the Pirquet Society of Clinical Medicine, an American Association organized by medical graduates of Central European Universities.

During September and October, the Institute was host to a number of national and international organizations, including the New York State Science Advisory Council, the Corporate Associates of the American Institute of Physics, and the American Council on Education. Also, on October 19, Dr. Gerald M. Edelman addressed a group of thirteen foreign naval medical officers comprising the current class in "United States Medicine for Foreign Officers" at the U. S. Navy Medical School in Bethesda. Dr. Edelman spoke on the purposes and accomplishments of the graduate program at the Institute. Captain John R. Stover, Jr., MC, USN, was in charge of the group which included representatives from Italy, Brazil, Spain, Nationalist China, Korea, Germany, Iran, Greece, South Vietnam, the Dominican Republic, Argentina, and the Netherlands.

Dr. John B. Nelson received a special plaque and citation in September from the American College of Laboratory Animal Medicine. The College was recently established to encourage the training of veterinarians in the care of laboratory animals and to certify qualified veterinarians as competent in this specialized field. The plaque was given Dr. Nelson, whose interest in the pathology of laboratory animals dates back to his early associations with Dr. Theobald Smith, in "sincere appreciation for his many outstanding contributions in laboratory medicine." The plaque was presented to Dr. Nelson at the Griffin Award Banquet of the Fifteenth Annual Meeting of the Animal Care Panel held at the New York Hilton from September 21 to September 25. Guest speaker at the dinner was Professor René J. Dubos who spoke on "Infectious Health." Dr. Dubos was introduced by Dr. Howard A. Schneider, who at the Friday morning session of the meetings, Dr. Schneider presented a paper prepared jointly by himself and Mr. George Collins, Supervisor of the Institute's Animal House.

ILLUSTRATIONS

THE COVER PHOTOGRAPH shows an antelope headdress used by the Bambaras in ceremonies and dances. Carved in wood and mounted on a grass cap, this is one of the pieces of West African sculpture exhibited on the lower level of Caspary Auditorium.

COVER and PAGES 10-14 sculpture photographs by Charles Uht, courtesy of The Museum of Primitive Art, New York. Group photograph PAGE 10 by Sam Vandivert. PAGE 2 courtesy of The New York Public Library. PAGE 3 portrait from *Collezione Delle Opera Edite ed Inedite, Luigi Galvani*, Bologna, 1841, courtesy the Burndy Library, Norwalk, Conn.; details from Galvani's *De Viribus*, 1792 ed, The Rockefeller Institute Library. PAGE 5 *The Retina* by S. L. Polyak, 1941, courtesy of The University of Chicago Press. PAGE 6 The Rockefeller Institute Library. PAGE 7 *Zeitschrift für vergleich. Physiologie.*, Vol. 41:54, 1958. PAGES 15, 16, and 18 The Rockefeller Institute Illustration Service.
