CONTENTS

ACTIONS TAKEN AT SPRING MEETING
April 17-21, 1967

ELECTIONS - Loren D. Carlson was elected to the position of President-Elect. Harry D. Patton, who had been filling the unexpired term of K. S. Cole, was elected to a full four-year term on Council.

John R. Brobeck was elected to fill the unexpired term of Loren D. Carlson on Council.

All candidates nominated by Council were elected to membership.

All elections are effective July 1, 1967.

ABSTRACTS FOR 1968 SPRING MEETING - At the business meeting of Thursday, April 20, 1967, Council was instructed to determine the number of 10-minute papers to be presented at the Spring 1968 meeting in Atlantic City and to devise a non-selective system for keeping the number of papers presented within that limit. Accordingly, the following system will be used: The number of papers to be presented will be essentially the same as this year (approximately 850). Each abstract will be given a number as it is received. To reduce the number presented to 850, every n^{th} paper will be excluded from presentation. No sponsored abstracts will be accepted. A person's name can appear only once on the program. An APS regular, retired or honorary member must be one of the authors.

NOMINATING BALLOT FOR OFFICERS - The membership present at the Business Meeting voted to continue the system of mail nominating ballots used this year. The procedure is as follows: Instead of all nominations for President-Elect and Councilman coming from the floor on the first nominating ballot, nominations are made by mail prior to the meeting. Return cards are sent to all regular voting members. Persons receiving 10 or more votes are recorded on the first nominating slate. It is hoped that all regular members will utilize this mechanism for nominations.

FUTURE MEETINGS

1967 Fall - Howard Univ., Washington, D.C., August 21-25
1968 Spring - Atlantic City, N.J., April 15-20
1968 Fall - Cancelled
1968 IUPS - Washington, D.C., August 25-30
1969 Spring - Atlantic City, N.J., April 13-18
1969 Fall - Oklahoma State Univ., Stillwater and Univ. of Oklahoma Medical Center, Oklahoma City, September 1-5
1970 Spring - Atlantic City, N.J., April 12-17
1970 Fall - Indiana Univ., Bloomington, late August
1971 Spring - Chicago, Ill., April 11-16
1971 Fall - Univ. of Kansas, Lawrence and Kansas City
1972 Spring - Atlantic City, N.J., April 9-14

NOTICE OF SUBSCRIPTION PRICE CHANGE

Beginning with the January 1968 issue, the subscription price of Physiological Reviews will be $13.00 a year for members, and $15.00 a year for non-members for U.S. and Possessions; postage to Canada $1.00 per year extra; postage to other countries $1.50 per year extra. The journal will continue as a quarterly publication in one volume per calendar year. The cost per single issue will remain unchanged.

MEMBERSHIP STATUS

April 1, 1967

Active Members	2702
Retired Members	139
Honorary Members	18
Associate Members	207
	3066

SUSTAINING ASSOCIATES

Abbott Laboratories, Inc.
Ayerst Laboratories
Burroughs Wellcome & Co.
CIBA Pharmaceutical Products
E & M Instrument Co., Inc.
Gilford Instrument Laboratories
Gilson Medical Electronics
Grass Instrument Co.
Harvard Apparatus Co.
Hoffman-LaRoche Laboratories
Lakeside Laboratories
Eli Lilly & Co.
Merck Sharp & Dohme Laboratories
The Norwich Pharmacal Co.
Chas. Pfizer & Co.
Phipps & Bird, Inc.
Riker Laboratories, Inc.
A. H. Robins Co.
Sherman Laboratories
Smith Kline & French Laboratories
The Squibb Institute
The Upjohn Co.
Warner-Lambert Research Institute
Wyeth Laboratories

DEATHS SINCE FALL MEETING 1966

George R. Crisler - 9/26/66
Joseph Doupe - 8/27/66
Ardrey W. Downs - 7/10/66
Joseph A. Dye - 12/17/66
Warren J. Gross - 10/17/66
F. G. Hall - 2/19/67
Philip B. Hawk - 9/13/66
Roger H. Helmendach - 3/7/66
Bruno Kisch - 8/12/66
Carlos Martinez - 8/24/66
W. C. Nungesser - 9/2/66
Jane A. Russell - 3/12/67
Samuel I. Yamada - 11/25/66

50-YEAR MEMBERS

Walter C. Alvarez
Samuel Amberg
Aaron Arkin
George A. Baitsell
Olaf Bergeim
Harold C. Bradley
Thorne M. Carpenter
Percy M. Dawson
George Fahr
Mabel P. Fitzgerald
Maurice H. Givens
Charles M. Gruber
Addison Gulick
Frank A. Hartman
Charles L. Hess
Harold L. Higgins
Paul E. Howe
Andrew C. Ivy
Dennis E. Jackson
Edward C. Kendall
Benjamin Kramer
Henry Laurens
Edward Lodholz
David Marine
Jesse F. McClendon
Franklin C. McLean
Frederick R. Miller
Victor H. K. Moorhouse
Sergius Morgulis
Eugene L. Opie

Julius M. Rogoff
George B. Roth
Andrew H. Ryan
Benjamin H. Schlomovitz
Charles D. Snyder
George H. Whipple
Rosalind Wulzen

NEWLY ELECTED MEMBERS

The following, nominated by Council, were elected to membership in the Society at the Spring meeting, 1967.

FULL MEMBERS

BADEER, Henry S.: Vis. Prof. Physiol., Downstate Med. Ctr., N.Y.
BEAMES, Calvin G., Jr.: Assoc. Prof. Physiol., Oklahoma State Univ.
BETHUNE, John E.: Assoc. Prof. Med., Univ. of Southern Calif.
BORTOFF, Alexander: Asst. Prof. Physiol., Upstate Med. Ctr., N.Y.
BROWN, Arthur M.: Asst. Prof. Physiol., Univ. of Utah
BROWN, John R.: Prof., Head Dept. Physiol. Hyg., Univ. of Toronto
BUCKINGHAM, Sue: Asst. Prof. Pediat., Columbia Univ., Coll. P & S
CHERNIACK, Neil S.: Asst. Prof. Med., Univ. of Illinois
DE FEO, Vincent J.: Assoc. Prof., Dept. Anat., Univ. of Hawaii
DeGRAFF, Arthur C., Jr.: Pul. Physiologist, Hartford Hosp., Conn.
DELANEY, John P.: Asst. Prof. Surg., Univ. Minnesota Hosps.
DOWNEY, John A.: Asst. Prof. Med., Columbia Univ., Coll. P & S
EGGER, Maurice D.: Asst. Prof. Anat., Yale Univ.
EMMERS, Raimond: Asst. Prof. Physiol., Columbia Univ., Coll. P & S
EWING, Larry L.: Assoc. Prof. Physiol., Oklahoma State Univ.
FANESTIL, Darrell D.: Asst. Prof. Med., Kansas Univ. Med. Ctr.
FOREMAN, Harry: Assoc. Prof. Sch. Public Health, Univ. Minnesota
FRIESINGER, Gottlieb C. II: Asst. Prof. Med., Johns Hopkins Hosp.
FRONEK, Arnost: Asst. Prof. Physiol., Bockus Res., Inst., Phila.
GALA, Richard R.: Asst. Prof. Physiol., Boston Univ.
GESTELAND, Robert C.: Assoc. Prof. Biol., Northwestern Univ.
GLAUSER, Elinor M.: Asst. Prof. Pharmacol., Temple Univ.
GLAUSER, Stanley C.: Assoc. Prof. Molecular Pharmacol., Temple Univ.
GORDIS, Enoch: Assoc. Prof., Rockefeller Univ.
GREENBERG, Michael J.: Assoc. Prof. Biol., Florida State Univ.
HAMILTON, Robert W., Jr.: Res. Physiologist, Union Carbide Corp.
HEIM, Louise M.: Asst. Res. Specialist Bur. Biol. Res., Rutgers Univ.
HIRSCH, Henry R.: Asst. Prof. Physiol. Biophys., Univ. Kentucky
HOOD, William B.: Res. Assoc. Med., Harvard Sch. Public Health
HUTTENLOCHER, Peter R.: Asst. Prof. Pediat., Yale Univ.
JENNINGS, Donald B.: Asst. Prof. Physiol., Queen's Univ., Canada
JEWETT, Don L.: Asst. Prof. Physiol., Univ. California, S.F.
JOLLEY, Weldon B.: Assoc. Prof. Physiol., Loma Linda Univ.
KAMINER, Benjamin: Independ. Invest., Marine Biol. Lab., Woods Hole
KARREMAN, George: Assoc. Prof. Physiol., Univ. of Pennsylvania
KETCHEL, Melvin M.: Assoc. Prof. Physiol., Tufts Univ.
KEZDI, Paul: Dir. Res., Cox Coronary Heart Inst., Kettering, Ohio
KOLDER, Hansjoerg: Assoc. Prof. Physiol., Emory Univ.
KRAICER, Jacob: Asst. Prof. Physiol., Queen's Univ., Canada
KUSANO, Kiyoshi: Asst. Prof. Psychol., Indiana Univ. Med. Ctr.
LARSEN, Joseph R.: Assoc. Prof. Entomology, Univ. of Illinois
LAVER, Myron B.: Assoc. Anesthesiol., Massachusetts Gen. Hosp.
LENTINI, Eugene A.: Asst. Prof. Physiol., Medical Coll. Virginia

LINDSAY, Hugh A.: Assoc. Prof. Physiol., West Virginia Univ. Med. Ctr.
LONG, James F.: Asst. Prof. Physiol., Albany Medical College
LOWENSTEIN, Leah M.: Assoc. Med., Harvard Med. Sch.
MALVEN, Paul V.: Asst. Prof. Animal Sci., Purdue Univ.
McCARTHY, John L.: Assoc. Prof. Biol., Southern Methodist Univ.
MICHAEL, Ernest D., Jr.: Assoc. Prof., Inst. Environ. Stress, Univ. California
MOIR, Thomas W.: Asst. Prof. Med., Western Reserve Univ.
MORLOCK, Noel L.: Spec. Fellow Neurosurg., Univ. of Washington
MORSE, Russell W.: Res. Asst. Prof. Physiol. & Biophys., Univ. of Washington
MOTOYAMA, Etsuro K.: Asst. Prof. Anesthesiol. & Pediat., Yale Univ.
MULLENAX, Charles H.: Physiopathologist, Agr. Sci., Rockefeller Fndn.
NELSON, Leonard: Assoc. Prof. Physiol., Emory Univ.
NEWSOM, Bernard D.: Sr. Staff Sci., Gen. Dynamics Convair
PAPAVASILIOU, Paul S.: Assoc. Scientist, Brookhaven National Lab.
PARKER, Harold R.: Asst. Prof. Physiol., Univ. California, Davis
PINKERSON, Alan L.: Instr., Physiol. & Biophys., Georgetown Univ.
QUAY, Wilbur B.: Assoc. Prof. Zool., Univ. California, Berkeley
RABINOWITZ, David: Asst. Prof. Med., Johns Hopkins Hosp.
REITER, Russel J.: Exptl. Endocrinologist, USA Edgewood Arsenal Res. Labs.
RICHARDSON, David W.: Assoc. Prof. Med., Medical Coll. Virginia
SANDBERG, Avery A.: Dept. Head, Roswell Park Memorial Inst.
SCHANNE, Otto F.: Asst. Prof. Biophys., Univ. Sherbrooke, Canada
SHEPHARD, Roy J.: Prof. Applied Physiol., Univ. of Toronto
SPEHLMANN, Christian R.: Asst. Prof. Neurol. & Psychol., Northwestern Med. Sch.
STAHLMAN, Mildred: Assoc. Prof. Pediat., Vanderbilt Univ.
STEGALL, Hugh F.: Res. Med. Officer, USAF, Brooks AFB, Texas
STEPHENS, Grover C.: Prof. Biol. Sci., Univ. California, Irvine
SULLIVAN, Louis W.: Asst. Prof. Med., New Jersey Coll. Med.
TALBOT, Richard B.: Prof., Head, Physiol.-Pharmacol., Univ. of Georgia
THIEDE, Frederick C.: Res. Staff, Life Sci., North American Aviation
THILENIUS, Otto G.: Asst. Prof. Pediat. & Physiol., Univ. of Chicago
VELASCO, Marcos: Fellow, Neurol. Surg., Johns Hopkins Hosp.
VERNADAKIS, Antonia: Asst. Res. Physiol. II, Univ. California, Berkeley
WELCH, Keasley: Prof., Chrmn, Div. Neurosurg., Univ. Colorado Med. Ctr
WILL, Donald H.: Assoc. Prof. Physiol., Colorado State Univ.
WILLIAMS, John F., Jr.: Asst. Prof. Med., Indiana Univ.
WOLDRING, Sabbo: Principal Sci. Cancer Res., Roswell Park Mem. Inst.
ZUBER, Bert L.: Asst. Prof. Physiol., Univ. of Illinois

ASSOCIATE MEMBERS

BALDWIN, Bernell E.: Instr. Physiol., Loma Linda Univ.
BALDWIN, Marjorie V.: Res. Assoc., Physiol. & Biophys., Loma Linda Univ.
EGGE, Alfred S.: Asst. Res. Physiol., Univ. California, S. F.
FIFE, William P.: Asst. Chief, USAF Sch. Aerospace Med.
HAZELWOOD, Carlton F.: Instr. Physiol., Pediat. Res., Baylor Univ.
HILDEBRANDT, Jacob: Asst. Prof. Physiol., West Virginia Univ.
HILDEBRANDT, Judith R.: Asst. Prof. Physiol., West Virginia Univ.
LENTZ, Patrick E.: Predoct. Fellow, Physiol., Marquette Univ.
LOGIC, Joseph R.: Instr. Med., Univ. of Kentucky
WISE, William C.: NIH Predoct. Fellow, Physiol., Univ. Kentucky
WURSTER, Robert D.: Grad. Student, Physiol., Loyola Univ., Chicago

1966 FISCAL REPORTS

SOCIETY OPERATING FUND

INCOME

Regular Membership Dues		$38,970
Associate Membership Dues		999
Sustaining Associates		6,750
Interest on Savings Accounts		3,934
Reimbursement from Federation Spring Meeting		14,506
Reimbursement from Grants, etc. (overhead)		1,135
Fall Meeting (net)		1,088
Course for Physicians (net)		2,758
Sale of Laboratory Experiments		154
Councilman's Tour (net)		92
Sale of Back Issues of Physiology for Physicians		592
Miscellaneous Income		218
	Total Income	71,196

EXPENSES

Salaries and Benefits		$19,039
Hotel and Travel		2,881
Addressing, Mailing & Shipping		1,479
Telephone		177
Printing		700
Supplies & Equipment		177
Rent		4,734
Dues to Federation		15,744
Dues to AIBS		750
Dues to AAAS		20
Dues to Natl. Soc. Med. Res.		250
IUPS News Letter		500
Revision of Lab. Experiments		1,458
Bowditch Lecture		500
Miscellaneous Expenses		67
APS Business Office (SOF share)		13,297
	Total Expenses	61,773

Excess of Income over Expenses	9,423
Amount in Savings as of Dec. 31, 1966	$84,091

PUBLICATION OPERATING FUND

INCOME

Subscriptions		$306,581
Sale of Reprints (net)		57,439
Sale of Back & Single Issues		9,951
Advertizing (net)		15,926
Page and Article Charges		81,309
Author Alterations		931
Interest on Short Term Investments		4,419
Refund from Federation Redactory Services		3,887
Miscellaneous Income		192
	Total Income	480,635

EXPENSES

Salaries and Benefits		$122,298
Section Editors Expenses		10,927
Printing & Engraving		277,798
Supplies & Equipment		1,522
Addressing, Mailing & Shipping		45,142
Telephone		1,366
Hotel & Travel		4,862
Repairs & Maintenance		103
Rent		11,625
Miscellaneous Expenses		334
APS Business Office (POF share)		53,185
		529,162
Assigned to Special Publications		(4,240)
	Total Expenses	524,922
Excess of Income over/(under) Expenses		(44,287)

PUBLICATION CONTINGENCY AND RESERVE FUND

Balance Dec. 31, 1965	$701,957
Gain on Sale of Securities	17,009
Dividends and Interest Paid to APS	(22,635)
Interest Earned on Short Term Investment	(651)
Balance Dec. 30, 1966	$718,966

JULIAN TOBIAS MEMORIAL LECTURE

Roger W. Sperry, one of the world's leading authorities on the functioning of the human brain, delivered the second annual Julian Tobias Memorial Lecture at The University of Chicago on Friday, April 14.

Dr. Sperry is currently Hixon Professor of Psychology at the California Institute of Technology, Pasadena.

The Julian Tobias Memorial Lectures were inaugurated at The University of Chicago last year to honor the late Dr. Julian M. Tobias, a Professor of Physiology at the University who died in April 1964.

This year's lecture was entitled "Some Behavioral Effects of Surgical Disconnection of the Cerebral Hemispheres."

Dwight J. Ingle. Professor and Chairman of the Department of Physiology at The University of Chicago, said of the lecturer:

"Like Dr. Tobias, Professor Sperry has done outstanding work in neurophysiology. Much of our current thinking about the neural bases of the mind is based on Professor Sperry's original contributions."

A native of Hartford, Connecticut, Sperry received the B. A. degree in 1935 and the M. A. in 1937 from Oberlin College. After receiving the Ph. D. from the University of Chicago in 1941, he joined the faculty of Harvard University, where he remained until 1946. In 1946, he was named an Assistant Professor of Anatomy at The University of Chicago, and, in 1952, he became Chief of the Section of Developmental Neurology at the National Institute of Neural Diseases, Bethesda, Maryland. In 1954, he was appointed Hixon Professor of Psychology at the California Institute of Technology.

In 1954, Dr. Sperry received the Distinguished Alumnus Citation of Oberlin College. He is a fellow of the American Academy of Arts and Sciences and the American Association for the Advancement of Science. He is a member of the National Academy of Sciences, the American Physiological Society, the American Association of Anatomists, the American Psychological Association, and the American Society of Zoologists.

Dr. Sperry is the author of more than 70 research papers and seven chapters in scientific texts. He serves on the editorial boards of "Experimental Neurology" and "Neuropsychologia."

Last year's lecturer was Dr. Ralph W. Gerard, Dean of the Graduate Division of the University of California at Irvine.

FALL MEETING
HOWARD UNIVERSITY COLLEGE OF MEDICINE
WASHINGTON, D. C.
AUGUST 21-25, 1967

The 1967 REFRESHER COURSE will begin at 9:00 a.m. on Monday, August 21st in Cramton Auditorium at Howard University. The topic for discussion is "Intercellular Communication." Dr. Rachmiel Levine, Professor and Chairman, Department of Medicine, New York Medical College, and associates, will present three lectures during the morning session. Dr. David Potter, Dr. J. D. Sheridan, and Dr. C. R. Slater of the Department of Neurobiology, School of Medicine, Harvard University, will conduct the afternoon session beginning at 1:30 p.m. The lecture series will contrast chemical and electrical mechanisms and elaborate on appearance of post-synaptic potentials as well as review knowledge about transmitter agents. Ion mechanisms underlying chemical excitation and inhibition is the thesis of the afternoon discussion. Views related to presynaptic events include quantal release of transmitters and control of postsynaptic sensitivity by nerves.

The SYMPOSIA will include three very interesting subjects. Dr. W. C. Randall of Loyola University will discuss "Physiology Education" on Tuesday evening, August 22nd at 8:00 p.m. Friday morning, August 25th, will be devoted to consideration of "Neural Control of Body Salt and Water" by Joseph P. Gilmore, University of Virginia. Dr. Jere H. Mitchell, University of Texas, will present the closing lectures on "Effect of Vagal Efferent Stimulation on Mammalian Ventricular Function."

Dr. Peter F. Curran, Department of Biophysics, Harvard Medical School will give the 1967 BOWDITCH LECTURE on "Coupling Between Transport Processes in Intestines" at 1:00 p.m. on August 23rd in Cramton Auditorium.

Dr. Robert E. Forster will address the Society at the ANNUAL BANQUET in the Presidential Ballroom of the Statler Hilton Hotel on Thursday, August 24th. The reception will begin at 6:30 p.m. and will be followed by the Banquet at 7:30 p.m.

An attractive array of events and activities are planned beginning with the Welcome Reception in the Home Economics Building Living Room at 10:00 a.m. on Tuesday August 22nd. The Thursday afternoon sightseeing tour will include the John F. Kennedy gravesite, the Washington and Lincoln Memorials, Tomb of the Unknown Soldier and the U.S. Capitol Building. Tour of the National Gallery of Art begins on Wednesday, August 23rd at 10:00 a.m., and an Embassy Tour is planned for the afternoon.

The "early bird" White House Tour will begin promptly at 8:00 a.m. on Thursday, August 24th. This comprehensive tour through the White House will be limited to 300 persons.

The social activity calendar is to be climaxed Friday August 25th with the 1:30 p.m. Potomac River Cruise to Mount Vernon with a twohour visit on the historic Mt. Vernon grounds. The boat will return to the pier at 6:30 p.m.

Limited housing is available on the Howard University campus. These rooms are not air-conditioned. Arrangements have been made with the selected hotels in central downtown Washington with guaranteed rates as requested if reservations are made on the special form provided on or before August 5th.

Chartered buses will transport persons from the hotels to the campus and return. This shuttle service will operate on schedules to be announced.

Registration begins at 8:00 a.m. on Monday August 21st and will continue through Thursday August 24th at 5:00 p.m.

NOTICE

The Society has on hand an excess number of copies of the following publications. We wish to reduce our inventory and offer the following at a special price.

The History of the American Physiological Society - Third Quarter Century, 1937-1962 - W. O. Fenn, 1963. Original price $4.95. Sale price $2.50.

Some Founders of Physiology - C. D. Leake, 1956. Original price $3.00. Sale price $1.50.

PRESIDENT-ELECT TOUR

R. W. BERLINER

The Council of the Society was kind enough to ask me to undertake the very pleasant responsibility of visiting Society members in Mexico. The majority of our members in Mexico are located in Mexico City and it was possible to meet many of them during a week spent there in mid-February. The major centers of physiological work are located at the National Institute of Cardiology, the Department of Physiology of the Faculty of Medicine, University of Mexico, and at the Institute of Advanced Studies of the National Polytechnic Institute. I had an opportunity to visit each of these institutions and to acquire at least a superficial familiarity with the work that was being done.

At the Institute of Cardiology the work combines basic and clinical activities in a fashion not unlike that of the institution with which I am affiliated. I was struck with the uniformly high quality of the work. The enthusiastic staff and the excellent facilities are a reflection of the foresight of its founder, Dr. Ignacio Chavez, and of the skill of its former and present directors Dr. Arturo Rosenblueth and Dr. Manuel Vaquero. I am indebted to the Institute and particularly to Dr. Herman Villarreal, head of its Laboratory of Nephrology, for their unstinting hospitality.

The Department of Physiology, Faculty of Medicine, University of Mexico, seemed to be doing excellent physiological work, under its chairman, Dr. Alonso de la Florida, successor to Dr. J. J. Izquierdo, now Professor Emeritus, despite what by North American standards would be considered an overwhelming teaching load with well over 1000 students in each class.

The work at the Institute of Advanced Studies, IPN, is largely neurophysiological reflecting the major interest of its director, Dr. Arturo Rosenblueth, well-known to Americans from his many years in Cambridge.

The Mexican Society of Physiological Sciences is still small enough to represent biochemistry and pharmacology as well as physiology, a circumstance calculated to arouse nostalgia in some of our oldest members. The president of the Society, Dr. Efrain G. Pardo, is a pharmacologist. Socities of biochemistry and pharmacology have been organized, but the three groups meet jointly. The abstracts of last year's meeting indicate the contents of some 64 papers of high quality which, relative to the problems faced by the Federation, should have been scheduled without difficulty.

Membership in the American Physiological Society is still held by only a relatively small number of Mexicans. One has the impression that a considerable number of others possess the qualifications. Discussion of this subject revealed that membership is kept down by the relatively high cost of Society dues as well as the difficulty and expense of attending the Society's meetings.

STATUS OF RESEARCH IN PHYSIOLOGY

(Certain of the training committees of non-government consultants which advise the National Institute of General Medical Sciences have been asked to undertake an advisory function of broader scope than the routine evaluation of training grant requests. In an attempt to assist the staff of the Institute in the guidance of program development, each such committee will generate annually a working paper describing the status of research in its particular field. The first attempt at this task has resulted in some broad definitions of the scope and meaning of the various fields involved. The paper which appears below is such a working paper formulated by the Physiology Training Committee in 1966. It is being published here on the strong recommendation of a number of Society members who are not members of the Physiology Training Committee. It should be regarded as a joint expression of current opinion by the Committee members listed at the conclusion of the article and since it is an advisory report does not necessarily reflect Institute attitude or policy. The Committee hopes that it will be interesting and helpful to you.)

INTRODUCTION - THE SCOPE OF PHYSIOLOGY

Physiology is the science of life processes. These processes occur in microbes, plants, animals and man, but relevance to the programs of the National Institute of General Medical Sciences requires that "physiology" must be oriented toward the physiology of man, and of other organisms which contribute to a general scientific picture basic to human life. Among other sciences, physiology stands out by its richness and diversity; by the multitude of viewpoints it allows in the study of its subject; by its colorful heritage and history, and its broad contacts with other sciences and the humanities; by the directness of its practical application, which immediately relate to human life and health, and by the profound way in which the understanding of the human body and its behavior is fundamental to all problems affecting man and his society. If it is true that, after the explorations of the earth and physical nature, man is the next frontier, it is obvious that physiology is the most crucial science of the future. It is already the foundation of medicine, and of applied and technological fields concerned with man's performance and environment.

In part, physiology is well-prepared for this present and future challenge, in part less so; this report will analyze areas of strength and weakness, and will consider means for continuing the former while correcting the latter. Physiology is not the only science dealing with all of these challenges. Psychology and psychiatry deal with man's mind, and are thus of profound personal and social importance; but they have less easily defined or developed scientific criteria, and greatly depend upon physiology for finding a solid foundation. Microbiology, besides dealing with the biology of microbes, also has much to contribute to the mastery over human illness; with pathology, it supplements physiology in supporting medicine. Anatomy, in describing the structure of the human body, is in turn basic to physiology, but its classical descriptions have largely been laid down by earlier generations, and its current research efforts, apart from a flowering of ultrastructure research with sub-microscopic techniques, are usually of a physiological nature. Biochemistry which has split off from physiology by specialization toward the analysis of the chemical manifestations of body function, has, reinforced by the influence exerted by pure chemistry, reached a period of great productivity which, however, will have to return to physiology the strategic initiative of its functional elaboration. Genetics deals with the hereditary facets of life; it shares with biochemistry (and particularly with what is now called molecular biology) the elucidation of the mechanism of hereditary information transfer, and with physiology the investigations of the development of functional and behavioral patterns in the body. All these sciences vie with each other in the study of human nature, and have alternated through phases of greater or lesser rewards for their efforts.

Physiology may have swayed less during these cycles, and may have maintained a stable course of pursuit both as a pure science and as a starting point for applied research. It is our opinion that physiology is on the threshold of its greatest epoch, both because of the possibilities that are resulting from the scientific picture of the age, and because of the social implications of unprecedented scope that may result from its development and seem likely to be demanded by the problems of humanity of the future.

Our previous allusion to the strength of physiology referred in part to the magnitude of its task. It also recognized the existence of a sizeable number of physiologists qualified to conduct research and teaching in their science and its applications. But reference was also made to its weakness. This weakness derives in part from the scientific requirements imposed upon its practitioners - requirements which are more diversified than in the case of any other science. Already the present generation of physiologists is unevenly prepared for this challenge. Our severe concern is for the requirements of the future, and we are very profoundly interested in the problems of adequate training to provide the needed manpower for sustained excellence. While all scientific training faces increasing difficulty because of the information explosion, physiology in particular sees its difficulties compounded by the need for a broad preparation in mathematics, physics and chemistry, as well as in its biological sister - and background sciences and at least to some extent in medicine and other applied areas. These extraordinary needs merely reflect the many-splendored content of our science, and must be considered in our planning for the future.

LEVELS OF PHYSIOLOGICAL ORGANIZATION

The course of scientific investigation, as it developed in our culture, is reductionist or analytical; one attempts to understand a phenomenon in terms of its simplest cause or mechanisms. The accomplishments of contemporary science attest to the success of this approach, yet at the same time its shortcomings turn up. The reduction of problems, of entities or complex phenomena, to their next-simplest units explains much, yet at the same time diverts from an understanding of their total nature. According to a comparison overly familiar to the student of elementary philosophy, the entity and meaning of a painting are lost in the chemical analysis of its pigments, and the road to their resynthesis is long and not necessarily possible.

We do not need to belabor the point; the comparison is crude at best, yet not altogether untrue. Reduction and analysis in science leads to profound penetration, and yet at the same time to a loss of the insight into the whole. Perhaps uniquely among all sciences, physiology, through the nature of its problems and its inquiry, has a built-in protection against one-sided simplification since physiology works simultaneously on different levels of complexity. Although individual specialists may be at home in one of these levels, in preference to others, the science as a whole is typified by extending over a range from the simplest to the most highly organized and by the obligatory interaction between these levels: analysis toward the lower, synthesis toward the higher orders of organization.

With each step toward analysis, the physiologist increasingly uses the viewpoints of chemistry and physics, and in much of his daily work he may be indistinguishable from the biochemist or regard himself as a biophysicist. But with each step toward complexity, the possibilities of interaction increase tremendously. Interestingly, the increasing use of mathematics appears at all levels simultaneously. Toward the extreme of elementary resolution, its use goes hand in hand with the advanced physics and chemistry being applied, and also purely biologically the simplifying reduction of phenomena encourages their fundamental mathematical formulation. Toward the opposite extreme, the existing complexities and interactions themselves require a mathematical treatment of their own, and are finding analogies with mathematical advances being made by studies of complex non-living systems. All this together contributes to physiology, and the viewing together of all these requirements reminds us of the long and arduous future of physiology as the only science of such scope and balance.

1. Molecular Physiology and Cellular Mechanisms

The introduction of the term "molecular" in biology in this century is of recent date, yet the term "molecular physiology" (1950) has for some time found less resonance in scientific circles and in the public eye than "molecular biology" which in the last decade has explosively developed new findings on the chemical basis of protein - and nucleic acid synthesis and the mechanism of heredity. There are sure signs however, that molecular physiology is poised for a period of equally intense growth which will be of tremendous importance for the understanding of the mechanisms of vital phenomena. It will have to go at its task with the full impact of all relevant areas in thermodynamics, macromolecular physics and chemistry, and with a considerable use of the results of molecular biology already gained or still to be obtained.

Among the great problems it is facing is the general fact that living cells maintain electrolyte compositions which differ from those in their surrounding media. This fact goes hand in hand with the specific needs or preferences of many enzymes for certain ions, and thus with fundamental features of the regulation of metabolism: the control of the energy flux through the cell, as well as the regulation of biosynthetic processes. These differential distributions do not only apply to the cell versus its medium, but also are found between one cell compartment and another. Such localized distributions are based upon distinct morphological structures, and membranes of sub-microscopic thickness delimit those compartments as well as the whole cells themselves. The physiology of active membrane transport, already in a very productive stage of investigation, deals with the biophysical mechanisms whereby these distributions are effected, and, by extension, also with the numerous cases in which special instances of the transport of ionic or non-ionic substances are elevated to special functions for their own sake, in the form of secretion or absorption serving the uptake of food or the maintenance of constant body composition.

Furthermore, many of the membranes separating different electrolyte solutions in living cells are endowed with a capability which still eludes our understanding in physicochemical terms: the membranes are labile in their selective permeability properties, and by a disturbance called "excitation" give rise to an ionic flux which as a self-propagated phenomenon excites the next membrane region and so constitutes a conducted impulse. This process of propagated excitation constitutes an example of a general, characteristic, and unique feature of the interest and orientation of physiology. It is a process of importance throughout the whole realm of multicellular animals.

As conducted in neural networks, it coordinates the various parts of the animal body; in nervous systems of higher development and specialization, it forms the code and informational message for more complicated interactions. It is the mechanism of operation in the sense organs whereby influences such as light or sound are transduced into the neural language; it is the basis of triggering used by cells of effector organs to cause them to give rise to the mechanical and chemical responses upon which all physiological outputs, whether secretion, locomotion, speech, writing or other reactions, are based.

The essence of the process is that it constitutes a reversible change of state of the cellular membranes in which it occurs. What is it that changes? Why does it change? What reverses the change? How is the change controlled? What external influences can modify this capacity for reversible change? From the analytic point of view it is imperative that we learn more about the physical and chemical nature of these living membranes so that we can properly evaluate the degree to which such fundamentally important processes are vulnerable to interference by abnormal conditions.

Many other examples of change of state at the subcellular or molecular level might be cited as areas requiring persistent effort. The study of the mechanisms of muscular contraction is advancing greatly, in terms of the energetics and the molecular events in the chemomechanical transduction process. Yet, further challenges are waiting. On the one hand, the complete molecular biophysical elucidation of the events has barely begun, and will advance only with great effort since much of the required physicochemical knowledge will have to be generated while advancing and the linkage between excitatory and transducing phenomena also is a problem without precedent. Practically any physiological problem will eventually reach an analysis at this level, be it concerned with the modification of cardiac contractility by autonomic stimulation, or with the mode of action of a hormone upon its target organ. Such problems coming from a higher level of functional organization will immediately require a resynthesis back to their original level, one of the warranties of the balance among the levels in physiology.

These analytical investigations penetrate deeply and require instrumentation unfamiliar to the physiologist of the recent past and even the present. The use of ultracentrifugation, light scattering, circular dichroism, and many other physiochemical tools is entering into physiological laboratories dealing with the substrates of vital mechanisms, and it can be foreseen that other techniques, such as those of infrared spectroscopy, electron spin resonance, or X-ray diffraction will join in. Methodology for cellular electrical potential detections and for special mechanical and heat measurements are already available at considerable levels of sophistication. The electron microscope will be as generally important to the physiologist as it is now to the ultrastructure researcher in the fields of cytology or virology, and will also pose requirements upon application of radioautography or specific localization of substances.

We must anticipate a great demand in physiology departments, for advanced equipment and for space to put, operate and maintain it; and, in many instances, for its design and construction. These parts of physiology departments will appear rather different and will be regarded by many as "biophysical." This should not be a source of concern. The term "biophysics" does not denote a homogeneous group of interests necessarily aside from and different from the interests of the physiologist in the physical nature of biological processes any more than the term "biochemistry" denies the appropriateness of the interest of the physiologist in the chemical nature of biological process.

In summary, interest in "molecular physiology" is justifiable; it is intense; it should be continuously encouraged.

2. Embryonic Development and the Differentiation of Physiological Mechanisms

This is not a generally recognized entity among physiological specialties, yet it is wise to signal its probable emergence. The overwhelming multitude of patterns of function and interrelation in the adult organism becomes even more astonishing if it is realized that this multitude, in a short span of time, develops by itself from a nearly unformed germinal cell, in a series of processes whereby not only different kinds of cells assume their specialized functional characteristics and all the specialized organizations these are based on, but all super-cellular arrangements fall into space and develop the correct connections among themselves and in relation to others. The staggering scope of these problems must be obvious to anyone selecting the genesis of any one functional system for a moment of contemplation. No systematic branch of such developmental physiology has yet emerged, yet the first signs begin to appear.

The investigations of nerve growth factors; the indications of humoral substances regulating tissue differentiation and organ growth; the development of differing contractile proteins and enzymes in muscles depending upon the innervation; all such problems, which will form a link between classical organ physiology and the results of the molecular genetics and biochemistry of the present era, will, with but little vision and foresight, be recognized as forming the impetus to a whole new subdivision of our science, one of immense importance not only for our scientific understanding of the growth, maturation and decline of the body, but also of the genesis of organic diseases which are nothing but faults in the fabric of this developmental process. The specific character of this future branch, and its material needs, cannot yet be predicted. Any budding interest in this area is deserving of careful attention and encouragement toward excellence.

3. Organic Function

Less attention will be given to a characterization of this category than to some others. This category represents the core of classical physiology, and has been a well-established field for some time. The physiology of the heart and the circulatory system, of the lungs and of respiration, of muscular movement, of the gastrointestinal, renal and other systems, all are typical parts of physiology as contained in the textbooks for good and lasting reasons; they are the first line of description, the structure of daily used basic knowledge, of immediate and constant need in medicine, surgery, and all other areas of application. It is and will remain the bulk of the teaching material, whether it is an area of active research or not.

But it still is a research area too! For example, the question how the heart regulates its contractile force and its output has only recently become subject of appropriate investigation; major facets of the mechanisms operative in blood pressure regulation, and of the regional distribution of blood in relation to individual body functions are only now finding decisive view points, or methods suitable for their correct measurement. The perceptive functions of eye and ear, and of the neglected senses, such as olfaction; the nature and regulation of gastrointestinal secretory, absorptive and digestive functions; the growth and maintenance of connective tissue or bone; all these, and other functions are subject to investigations leading often to a total reformulation of the concepts of previous periods. The whole physiology of reproduction, of the birth process, of the harmonious limitation of the growth of organs, of transplantation and compatibility of tissues from different individuals, of stress and anxiety and their effects upon organic function, and other broad areas are still in their infancy. And all these areas are of the most direct practical applicability in relation to medicine and surgery, or in the understanding of the individual body and its relation to its surroundings and to society, both in ideal and in extremely practical connections.

We are aware of opinions prevalent in other sciences to the effect that this part of physiology (identified with physiology at large) is closed, and is now a dead science; we are aware of unfavorable and indeed disastrous decisions in regard to the staffing and structure of medical schools that have been based upon this opinion. We can only reply that such opinions and actions are based upon gross and irresponsible ignorance.

It is understood, of course, that the renaissance of this rich section of physiology will not simply retrace the work of previous generations. New viewpoints are continuously generated, more chemistry of considerable relevance is known; and newer techniques are available, often allowing only now for the first time the appropriate measurement or observation of the phenomena in question. Classical organ physiology, while long pursued with merit and brilliance within the limits of the technical possibilities formerly available, is only now beginning to reach its full scope. At the same time, the integrations of research at this level into the study of regulation and control at higher levels of complexity, and on the other hand the pursuit of the mechanisms or organ function into the molecular realm, connect organ physiology with other forms of physiological inquiry. Many will still choose to work mainly at the organ level, whether on purely scientific questions or on the resulting application to the understanding and treatment of disease; or the solution of applied problems posed by the urban, technological or cosmic environment; or the guidance of problems in population control or resulting from improved health and longevity. They will, however, need the training and the advanced facilities to pursue their goals with the standards of quality now possible and required.

The support of research and training activities in this area should certainly be continued, if only because of the immediate relevance to the practical problems of medicine and surgery. The most evident danger lies in the direction of the dissipation of the resources for support through the funding of research efforts which are less than excellent in terms of need, imagination, quantitation, and orientation toward clearly defined analytic or synthetic goals. It is in this area of organ physiology where simple, non-quantitative, unsophisticated, descriptive efforts are no longer justifiable. It is in this area where the demands for quality should be most strenuously applied.

4. Principles of Regulation and Control

Here we enter into the area of the mechanisms whereby the diverse body functions are coordinated and regulated to proceed at the right intensity or sequence, and the constancy of the body is maintained in response to varying influences. "The essence of physiology is regulation. It is this concern with 'purposeful' system responses which distinguishes physiology from biophysics and biochemistry." This regulation is largely effected by means of two classes of interacting mechanisms: the hormonal and the nervous. Both classes have in common the attribute that they make use of the effects of one organ or organ system upon another, and indeed much of neuro- or endocrine physiology is hard to distinguish from the previously described category of organ physiology. However, in both instances there is the need to consider also the broader aspects of regulation and control, and in this area particularly the recently developed branches of applied mathematics are beginning to have considerable impact. It is here also that computer techniques are of particular prominence, and elements of information and control theory provide means for considering interrelations from a generalizing theoretical viewpoint.

Endocrinology itself has developed fruitfully and extensively, but there are no signs that its activity is coming to a plateau. Here too, as in other parts of physiology, there will be much progress on different levels of complexity. Although the field continues on the descriptive and experimental level as before, much progress is beginning to be made in the elucidation of the cellular and molecular mechanisms whereby hormones exert their actions. This field will advance to the extent that molecular physiology itself advances. In the biochemistry of cell metabolism, incidentally, much profound understanding of control principles is being reached on the basis of allosteric mechanisms and of feedback control in multienzyme pathways, and these advances are likely to contribute considerably to the elucidation of hormonal mechanisms as well as of their cellular control functions.

Hormonal effects will continue to be recognized as pervading every part of the body, and their further study will considerably affect not only the understanding of a variety of body functions, but also such areas as developmental and behavioral physiology. And, of course, the applications of the field are considerable, in the interpretation and treatment of disease, the phases of development of the body, and practical matters such as the control of fertility. In all of these, much deeper knowledge is needed than is now available, for the rational use of hormones or for the appreciation of long-term effects; the latter aspect is particularly important for the application of oral contraception, which involves a severe change in the endocrine periodicity of the body, of which the indirect effects may be profound.

On the other end of the scale, the theory of feedback control is beginning to be applied to endocrine systems. Such theoretical treatments are not limited to hormonal interrelations, but are being applied to other complex functional systems where non-linear, distributed, multi-dimensional, multi-loop control systems are involved. An important example is given by the cardiovascular system wherein regulation is based upon neural and non-neural inputs. To "understand" such a system means that the dynamic behavior of each component in isolation must be quantitatively described, the nature of their coupling explored, and a synthesis accomplished which yields the behavior of the intact system. Such a procedure has recently been dignified by the term "systems analysis", but the general principles are as old as science itself. What is new is that modern instrumentation, data processing, and computational techniques make such a procedure feasible for complex biological systems.

To enter meaningfully into synthesis, component descriptions must be dynamic, quantitative, and provide meaningful "isomorphic parameters." This means that many of our classical component descriptions must be recast. This is beginning to be done for the mechanical properties of blood vessels, the basic mechanical properties of heart muscle and their manifestations in the operation of the intact ventricle, the peculiar properties of the micro-circulation, the detailed "transfer functions" of various baro- and chemoceptor systems, the nature of the manipulation of cardiac and circuit parameters by neural and humoral signals, etc. As this information becomes available, it is incorporated into synthetic mathematical models whose behavior can be explored with large scale computers.

Such synthetic systems provide both a summary of our current quantitative understanding and an indication of deficiencies. In the modern context, this is the only form that real understanding of complex system can take. This has obvious implications for the training of future physiologists who must provide such understanding as well as of future physicians who must apply it, for it is in this form of understanding which must provide the basis of any real satisfactory component prothesis (e.g. artificial heart) introduced into a complex multiloop system, and for any really satisfactory characterization of the alterations induced by disease.

What has been said of the cardiovascular system can be said equally well of the respiratory system for they are both components of a single gas transport system. To really understand these either in health or disease, one must understand both in the sense referred to above. Indeed one could say that every organ and organ system with which the physiologist deals needs to be re-examined and re-described in this modern context of "understanding."

Our understanding of the mechanical responses of complicated mechanical systems such as those of the chest-lung is at present limited both by inadequate information of the local stress and strain relationship and by our lack of knowledge about how best to describe the rheological properties of the parenchyma and surface films involved. An understanding of these properties seem vital to a proper understanding of cause and results relationships in obstructive lung disease.

Such theoretical analyses have likewise begun to contribute to the understanding of the nervous system. It has been recognized since the turn of the century that individual nerve cells, in isolation, could exert no useful function. Whatever functional capabilities are possessed by an organism because it has a brain originate from the ways in which nerve cells can influence other nerve cells and thus eventually, control gland and muscle cells. Hence, interactions between nerve cells lie at the basis of brain function. The important strides which have occurred in the past few years are related to the processes and mechanisms which underlie nerve cell interactions. It is now possible to understand how this interaction occurs, how many forms of interactions there are, and what the final results of these interactions will be. It is now known that secretion from a nerve terminal may alter the excitability of another nerve cell in such a way as to cause it to generate new nerve impulses, or in such a way as to prevent it from generating new nerve impulses.

It is further known that the secretion from one nerve terminal may influence the secretory capabilities of other nerve terminals.

The signs of these interactions are now known and can be recognized with a high degree of reliability. This sort of information is indispensable for the complete basic understanding of brain function; it constitutes a description of the degrees of freedom available in a nerve-cell network for functional relations between the elements of the net. Without this information the knowledge of the structure of the network is essentially useless.

In addition to this information about basic processes, important progress has also been made in the understanding of the meaning of the rhythmic, repetitive discharges of nerve impulses which characterize the behavior of nerve cells in networks. In essence, it may now be said that neuronal interactions are governed by a coded sequence of nerve impulses in which intensity variations are expressed in the form of changes in temporal pattern. It is now possible in a number of instances to relate the frequency of nerve impulses to the magnitude of both stimulus and response.

These items of information, about how the pieces fit together functionally, constitute the foundation upon which our understanding of the brain must be built. Without this knowledge about how the pieces work together it is impossible to contemplate understanding the whole. It seems time now to begin the next steps toward making use of new-found knowledge. To understand the characteristics of these new steps, however, it is essential to look at the past for a few moments. Our information about interneuronal relationships has been gathered under circumstances which differ importantly from those which pertain to normal brain function. The usual experimentation condition has involved maintaining the input impulses to nerve cells at the lowest possible constant level in order to eliminate uncontrolled influences on the nerve cell under study. In this condition, nerve impulses have been artificially generated in selected nerve fibers and delivered in isolation to the cells under observation. Thus the experimental design has been productive because it dealt with highly controlled and, at the same time, highly artificial conditions. Now that this approach has paid off, it is necessary to begin to make our experiments more complex.

The next step will be to develop new experimental designs which enable us to work in more normal circumstances. We can devise experiments in which nerve impulses are generated normally, in trains of varying frequency. We can, with present techniques, examine the patterns of reaction in the brain which are the result of the introduction of these trains of nerve impulses which are produced by normal external events. In short, it is now time to think about learning how the brain reacts to presentation of common simple problems requiring normal adaptive reactions. Given the basic processes, identified under abnormal experimental circumstances, it is reasonable to expect to learn more about brain function under conditions in which the brain is doing things it was designed to do.

In this framework, neurophysiologists are not without theoretical and technical support from other sciences. The theoretical developments in both linear and non-linear systems analysis constitute powerful tools which hold out the only real hope for developing an understanding of the behavior of the brain. When one considers that systems as complex as the modern jet aircraft and missiles have been completely simulated before construction was even begun, it seems reasonable to expect that there are lessons to be learned about brain function through the use of similar treatments. Certainly, the term generally applied to the brain and spinal cord - namely, the central nervous system, - obligates us to examine its behavior as a system rather than restricting our view of it as a set of parts associated through some mysterious inter-linkage. For these reasons, quantitative analysis and application of control theory seem to be the inevitable steps toward the future.

Since this aspect of physiology - the understanding of control and regulation - constitutes, in a sense, the ultimate goal of the science, it follows that every effort should be made to support steps in this direction. To be sure, the analytical efforts must precede the successful synthetic efforts. Nevertheless, attempts at synthesis are mandatory in many instances in order to identify the qualities and characteristics of the needed analyses. In many situations it is necessary for a synthesis to fail before it is possible to determine what critical information still needs to be acquired. Thus, the analytic and synthetic approaches to physiology interact and reverberate in a mutual reinforcement which demands continuous effort in both directions.

The road to further accomplishments in this area will be long and arduous. The requirements for adequate training to enable the utilization of modern theory and techniques are severe and time-consuming. The tools of research in this area, the sophisticated measuring instruments and the aids to complex computations, are expensive. The experiments, carried out as they must be eventually on normal, intact, living systems, are difficult and progress slowly. Nevertheless, the goal is of sufficient importance to justify the relaxation of the restraints of time and money to support the development of excellence in training and research programs in this area. As they are now constituted, the Bio Engineering Programs are serving a useful function in helping engineers to prepare themselves to support the efforts of physiologists in these problems. But the level of physiological sophistication required is too high to expect the biologically oriented engineer to take the lead and direct the progress of research successfully. Consequently, it would be short-sighted to divert support and encouragement away from physiology itself.

PHYSIOLOGY AND THE AREAS OF ITS APPLICATIONS

The intimate relation between the progress of the development of a science and its applications has been mentioned at several points. Some general restatement may be in order, first of all, a reiteration that physiology is the most general and direct foundation of all of medicine. All diseases are functional disturbances, all treatments are functional interventions, and although specific instances may be more relevantly formulated in the parlance of biochemistry, pathology, pharmacology or microbiology, none of these medical sciences are as generally operational in the comprehension of a disease entity as is physiology. However, the applications of physiology are not limited to the management of disease as such. Human engineering is rapidly developing as a second outlet of physiological experience, and great strides will be made in the design of artificial organs and functional replacement as physiology is encouraged to extend beyond the limits of conventional medical applications.

PHYSIOLOGY AND PHYSIOLOGISTS

Our science is facing severe manpower problems, for two entirely different reasons. On the one hand, during the past decade, the brightest graduate students and postdoctoral trainees in the life sciences have usually been attracted to biochemistry and molecular biology. The considerable successes achieved in these sciences, and the promise of their continued dominance, combined with the persistent propaganda line that physiology is dead have had considerable impact upon the younger generation. On the other hand, some of the fault lays with us because too much training in physiology has continued to proceed along the prevailing pattern, providing a good introduction perhaps to classical physiology as such, but not always displaying sufficient cognizance of the emerging new physiologists in the cellular-molecular and in the systems directions. Thus, many younger physiologists are still insufficiently prepared in mathematics, physics and chemistry, and this gap is not always compensated by equivalent anatomical or medical knowledge.

We do not wish to exaggerate by saying that every young Ph.D. can be expected to master all major levels of physiological analysis with all the required supporting sciences. Yet, clearly, we will have to favor training programs in which a foundation is provided upon which the trainee can build in various directions, and in which the major lines of thought of all physiological levels are represented. We are confident that when such training is more widely available, and the newer directions of physiology see their results advertised in the popular press to the same extent as molecular biology has succeeded in doing, we will again compete successfully for the best young talent.

Some strong measures may have to be taken, for clearly the "new physiologist" cannot count on accomplishing his training and thesis research in the three or four post-baccalaureate years conventionally believed sufficient for the Ph.D. degree. To entice the best students into a longer course of training, somewhat higher training stipends may have to be offered than are customary in sciences requiring less extensive training. Besides classical physiology in its modern execution, which remains central and essential, instruction in biochemistry, molecular biology, and biological ultrastructure, in physics and physical chemistry, in basic mathematics, computer work and special mathematical theory, in electronics, and often in psychology and behavioral studies, will all be essential, and pose demands greatly in excess of those needed in biochemistry, microbiology or other more delimited biological areas. This will, further, not be possible without adequate faculty, and some foresighted policies will be needed for supplementary training of teaching and research physiologists in the form of special fellowships to support study in new areas.

It must also be realized that the faculty rosters of physiology departments will have to be enlarged proportionally more than those of other sciences. The days are past when a department was well balanced and sufficiently staffed with a few experts in circulation, respiration and gastrointestinal physiology, with perhaps an endocrinologist and one or two neurophysiologists added. All of these needs persist, but no group can at present and in the future be without additional specialists in the newer areas mentioned. A department without an electromicroscopist and biomathematical theoretician, with their expensive tools, would not be complete. Nor are the needs restricted to purely scientific physiology. As medical knowledge progresses, and disease entities are seen as specific abnormal physiological patterns, the interrelations between physiology and clinical departments will become such as to require the appointment of clinical physiologists (in whichever department) to deal with the interpretation of diagnostic features and the execution of advanced procedures such as cardiac catheterization, pulmonary function testing, dialysis procedures with artificial kidneys, the recording and interpreting of electroencephalograms, etc. The same functions will have to be fulfilled in regional and community hospitals in the context of increased medical care. In many instances, the persons responsible for these tasks will be internists, but additional physiological training will be required of them. These and other applied careers will in turn depend on sufficiently numerous academic physiologists in the University departments.

We do predict, therefore, that in the field of physiology the manpower needs are likely to increase more sharply than in most other sciences, and that the training requirements, due to the unusual breadth of the field, must be made higher than in sciences with more circumscribed contents. Besides this emphasis upon the training of Ph.D.'s or of M.D.'s (or D.V.M.'s) with supplementary scientific experience, it should also be understood that there is equal need for academically less advanced personnel: N.A. -physiologists for various technical performances (besides their place in school and junior college teaching), electronic and mechanical design engineers, biochemistry, or electronmicroscopy technicians, computer programmers, and supporting personnel in the managerial, editorial and data-processing fields. The need for competent assistants may deserve special mention, since our academic structure is progressing further toward a situation in which the best scientists - as should be - are placed in charge of departments, in which functions they then have to deal with so many administration distractions as to make their further work and scholarship well-nigh impossible.

SUMMARY AND RECOMMENDATIONS

1. Physiology as a pure science is of unusual scope and breadth, and has general and widespread contacts with applications in relation to medicine and to many relationships between man and his environment and society.

2. Although underestimated because of ignorance by many representatives of other sciences, physiology has a great past and present and an even greater future, even though the present and foreseeable manpower is insufficient for the needs.

3. Physiology works simultaneously on several levels of analysis, from the most penetrating analysis of molecular mechanisms to the most complex investigation of regulations and interactions. It is the primary science capable of obtaining a balance of analytical and of synthetic and holistic thought, and thus of reaching the philosophically most satisfying understanding of its problems.

4. In the field of molecular and cellular physiology, specific investigations may be hard to distinguish from efforts that could be called biochemical, biophysical, physiochemical or ultrastructural, but for the purpose and problematics of the work which are function oriented.

5. The field of organ function is the most classical area of physiology, but continues its investigations at a high level of activity and significance, with newer methods and viewpoints, and with the use of results contributed by its fundamental and clinical sister sciences. Organ physiology will flourish additionally by consideration of the embryological and genetic determination of the development of functional entities, and by constant interaction with both the lower and higher levels of investigative complexity. Organ physiology will remain the primary point of entry into the world of physiological problems, as well as the primary outlet for major categories of applications.

6. The most complex level of physiological research deals with the overall principles of regulation, integration and control, based upon both experimental work and mathematical theory. Here, too, applications of great scope begin to emerge, such as in the field of human engineering. These integrative features reach their highest manifestations in the study of the nervous system at all levels; from cellular function and "neurobiology", through classical neurophysiology in its modern forms, to systems analysis and the investigation of the highest manifestations of consciousness, behavior and the mental processes. This will remain physiology in its purest form, of the most essential significance for the understanding of human life.

7. Physiology departments (and others devoted to research and teaching of parts of the field) are in need of larger faculty rosters to provide specialist competence in the various aspects of physiology, and require greatly increased space assignments, instrument facilities, and techical staffing, than are now considered adequate.

8. Due to the richness and complexity of physiology and the fundamental difficulty of the subject matter, the demands upon the training of physiologists are the highest possible. Besides traditional physiology, training requires mathematics, physics, chemistry, biochemistry, histology and ultrastructure, and perhaps anatomy or psychology, as well as difficult technical areas of instrumentation, methodology and data processing. The training for the Ph.D. cannot be accomplished in 3-4

years, and the need for higher stipends in the terminal years may be essential.

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THE THREE ELEMENT MODEL OF MUSCLE MECHANICS: ITS APPLICABILITY TO CARDIAC MUSCLE*

ALLAN J. BRADY

The subject of mechanical analogues of muscle has received considerable attention since the work of Blix (1). Thus, it may seem passé to belabor the subject further at this time. However, cardiac muscle has several unique physiological features which have either gone unrecognized or have been purposely avoided for the sake of simplicity. First, cardiac muscle cannot generally be tetanized, making steady state length-tension analyses impossible. Second, the onset of contractility in heart muscle is relatively slow (2). A simple quick stretch of the series elastic element soon after excitation does not reveal a constant high level of active state intensity. Thus, in order to properly study the cardiac active state more complex methods of maintaining the contractile element at controlled lengths must be found.

A third characteristic lies in the fact that a significant resting tension exists at muscle lengths where normal contractile tension is developed. In most studies of cardiac muscle mechanics experiments are conducted at relatively short muscle lengths in order to avoid the complication of resting tension. Consequently, little data exist in cardiac mechanics and energetics in the range of maximum force development and highest contractile efficiency.

A fourth distinctive feature appears from a number of papers published recently in which the passive nature of cardiac resting tension is challenged. Changes in diastolic compliance related to some inotropic states and problems in localizing all passive elasticity in extracellular elements have led to questions regarding the possible auto-regulation of cardiac resting tension.

It becomes apparent then that the complicating problems of resting elasticity must be faced. The objective of this discussion will be; 1) to show that useful information can be obtained from cardiac muscle at longer lengths, and 2) to review some of these data in terms of possible structural orientation of the mechanical elements. It should be emphasized at this point that we are considering muscle here as a simple system of three or perhaps four specific elements. Undoubtedly, a more realistic model would be one with distributed forces and elastic elements to account for the mechanical inhomogeneity of whole muscle. However, for the sake of simplicity and with the eventual goal of being able to clamp individual sarcomeres of cardiac muscle at controlled lengths, it is expedient to discuss these more simple analogues in terms of several ex-

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*Part of this work was done during the tenure of a Career Development Award from the NIH and supported by Grant #65G60 of the American Heart Association. Taken from the introductory remarks given at the session on Cardiac Muscle I at the 1967 Federation Meetings.

perimental procedures currently available to us.

Classical Models and Techniques

Following attempts by Weber [cited by Levin & Wyman (8)], Fick (3), and Blix (1) to characterize the mechanical and energetic behavior of muscle in terms of purely elastic and visco-elastic models, Levin and Wyman (8) described an undamped elastic component of active muscle in series with the visco-elastic contractile element proposed by Hill (5). By 1938 Hill preferred to characterize resting muscle elasticity, in effect, as an element in parallel with the contractile element since it was assumed that resting tension could be subtracted from total tension in order to measure active tension at long muscle lengths. In 1958 Jewell and Wilkie made a detailed study of muscle elasticity in terms of the Voigt and Maxwell models (Fig. 1) concluding a slight preference for the Maxwell model although the differentiation was not readily apparent.

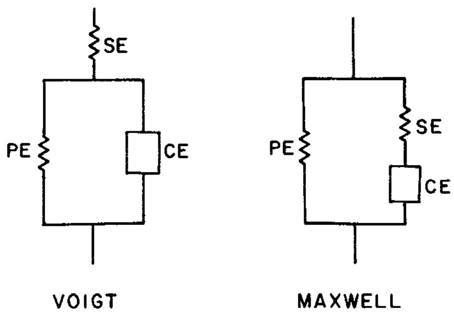


Fig. 1. Mechanical analogues of muscle. SE, series elastic element; PE, parallel elastic element; CE, contractile element.

In any case, it can be readily shown that muscle is composed of at least two types of elasticity, one peculiar to the resting muscle and another which appears upon excitation. Both are non-linear and of the form of a hard spring, i.e. their stiffness increases with extension. But how they might be arranged with respect to the force generating elements of the muscle would, in general, be impossible to tell from stress-strain data alone. For example, comparing the Voigt vs. the Maxwell model, it is apparent that analytically a system of springs and force generators could be selected for the Voigt model which would have the same overall mechanical impedance characteristics as the Maxwell model. However, the functional identity of these two models depends upon the assumption that its elements will support compressive as well as extensive forces. In a long thin muscle fiber it is unlikely that appreciable compressive forces can be sustained by the elastic elements. The contractile element (CE) is assumed to become highly damped upon activation so that it cannot change its length instantaneously. It becomes more resistant to stretch but will not support a compressive force, i.e. it goes slack upon release. Thus, in models of thin muscle strips all three elements are in effect shunted by mechanical rectifiers. This inability to support compressive forces makes the models at least conceptually differentiable.

The more common techniques involved in the mechanical analysis of these models are 1) small perturbations of length or force applied to the muscle during rest and activity 2) quick release of a muscle to zero tension or various loads at different times during a contraction 3) considerations of the time rate of change of force and length during the transition from isotonic to isometric contraction and vice versa. Other methods, such as controlled release, have been used, but these are more complex to interpret since they involve changes in CE length.

Small Rapid Stretches and Releases

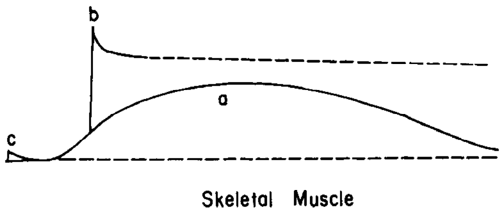
In the Voigt model resting tension is made up of two elastic elements in series. Activation of the muscle tends to make the parallel elastic (PE) element resistant to stretch, because of the damping effect of the now active CE. Small rapid extensions of the muscle at this time stretch only the series element which is shorter than the two rest elements combined. The muscle thus appears more resistant to stretch than in the resting state. In response to quick releases, the stretched series elastic (SE) element shortens progressively more with later releases, reflecting its extension by the CE; however, the contribution to overall shortening by the PE decreases because its length is progressively diminished by the shortening CE. Thus, the load-extension relation for small active forces is a series combination of the SE and PE elements, but with greater developed forces the contribution of the PE element decreases and the SE element tends to dominate. Also, it is apparent that the initial length of both series and parallel elements is directly related to the muscle length.

In the Maxwell model at rest, no force contribution of the series element is seen. During muscle activity perturbation of the muscle involves the two elastic elements in parallel. Again, an active muscle appears more resistant to stretch because the forces of the two sections sum. The initial length of the muscle controls only the initial length of the PE element. The rest length of the SE element is uninfluenced by muscle length since it is assumed that the resting CE is nonviscous and completely extensible.

Consider first the responses of passive and active skeletal and cardiac muscle to quick stretch (Fig. 2). At initial muscle lengths appropriate for maximum active tension development resting skeletal muscle shows little more than a small transient response to a stretch which when applied soon after the stimulus will reveal the full tetanic level of force development in the muscle. In cardiac muscle a similar stretch produces a large and slowly declining response in the resting muscle. In the active muscle little more than the twitch response at the new stretched length occurs. Thus, it is apparent that the functional relation of the elastic characteristics of resting and active muscle is different in the two muscles, but either the Voigt or Maxwell models would describe these responses.

Quick Release to Zero Tension and Various Loads

A second method of measuring muscle undamped elasticity used by Jewell and Wilkie (7) in skeletal muscle at least conceptually offers a



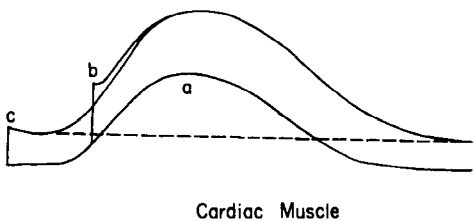


Fig.2. Contractile responses of muscle. a) unstretched response; b) response to a quick stretch after excitation; c) response to the same stretch before excitation. The lower dashed lines show the response in c but with no muscle stimulus.

means of differentiating the Voigt from the Maxwell models, if we assume that none of the elements will support a compressive force. In this method, (Fig. 3) a muscle which may be supporting resting tension is released to zero tension or a very light load at various times before and after excitation in successive contractions. An undamped shortening (ΔL) accompanies each fall in tension (ΔP) and characterizes the combination of resting elasticity and the progressive increase in elasticity related to active contraction. Consider first the tension and undamped shortening characteristics of the Voigt model. (Fig. 4). Both elements are stretched by the presence of resting tension. Release to zero tension involves a

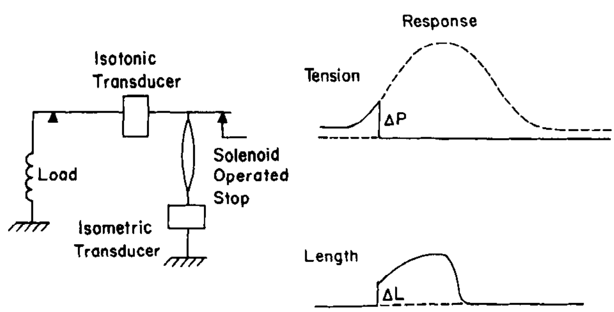


Fig.3. Method of recording isometric and isotonic contraction in a quick release experiment. Typical responses are shown on the right. The load is a long fluid damped spring used to reduce inertial artifacts accompanying the release. Withdrawal of the stop is timed with respect to the stimulus.

change in length of both PE and SE elements. However, as soon as force begins to develop in the CE after excitation the SE element is elongated and the PE is shortened. If the CE were to clamp PE element at a fixed length during a release of the active muscle, i.e. if the CE would support compression, the length change which took place would reflect only the total extension of the SE element. Thus, as active tension increased ΔL would quickly fall to the length dictated by the SE element and then rise along the SE stress-strain curve. If the CE will not support a compression, which is more likely, then a smooth transition occurs in the stress-strain characteristic reflecting first the series combination of the PE and SE elements and finally only the SE element at higher forces when the shortened CE has reduced the PE element contribution to zero.

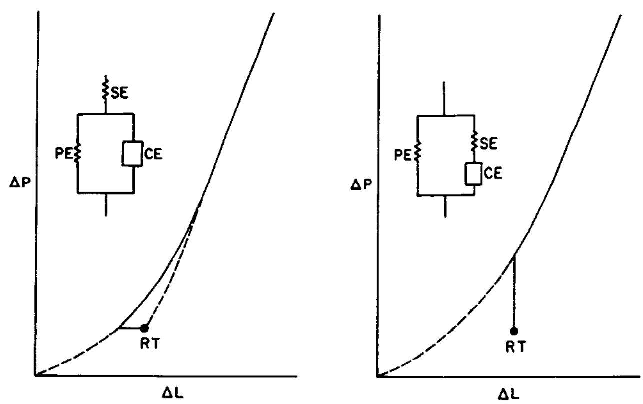


Fig. 4. Sketches of possible responses of the Voigt and Maxwell analogues to quick releases. RT is resting tension. ΔP and ΔL are measured as in Figure 3.

In the Maxwell model, the stress-strain relation has a different course. Release of the resting muscle to zero tension gives a measure of the stiffness of the parallel element alone. Later releases after excitation bring the SE element into parallel combination with the PE element such that the change in tension increases as the release occurs later in the cycle and the SE element is progressively stretched. However, if the SE element is stiffer than the PE element (and there is good evidence that it is at moderate muscle lengths) then there is a range of increments in active tension over which the extension of the SE element by the CE is less than the resting extension of the PE element. Thus, over this range, plotting ΔP vs. ΔL, ΔL will be constant for increasing ΔP until the extension of the SE element equals that of the PE element. Beyond this point the change in length of the SE element upon release should be more than sufficient to reduce the PE tension to zero. Thus, by subtracting resting tension from the total tension, the resulting ΔP- ΔL relation describes only the stress-strain characteristics of the SE element.

At zero tension, the two models are indistinguishable but the higher the resting tension, the more pronounced the differences in the early phase should be. Again, at active forces considerably in excess of resting tension only the SE element characteristics are seen in each model.

When the muscle is released to various loads the elastic characteristics are revealed in a more complex manner (Fig. 5). Consider first the response of the SE element to releases to various loads at the peak of the contraction. At this time the SE element is maximally stretched.

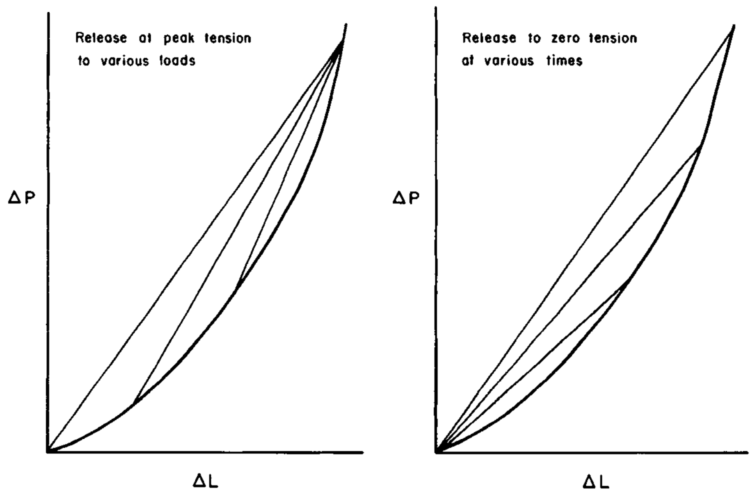


Fig.5. Comparison of release responses of a SE element model. The heavy line represents the theoretical force-extension relation of the element. The thin lines represent the chord stiffness corresponding to the various releases.

Release to heavier loads reveals an apparent increased chord stiffness as the maximum slope of the elastic tension-length characteristic is approached. Contrast these measurements to those in which the release to zero tension occurs at various times as force is built up in the muscle. The release to zero tension, indeed, gives only a chord slope but the end points of the measurements define the curve relative to the origin rather than to the point of maximum stiffness. Now superimpose on the SE element response, the length changes of the PE element. In the Voigt model, by the time peak isometric tension is reached, the PE element force has fallen to zero except at very high resting tensions. A release to a particular load then results primarily in a shortening of the SE element until this load is supported. In the Maxwell model, releases to intermediate and heavy loads will reflect changes in resting tension as well as in the SE element. Early releases involve resting tension complications in both models. Thus releasing a muscle to various loads is of little additional value in differentiating between muscle models. Releases to zero tension, although introducing larger inertial problems, give a more straightforward measurement of muscle elasticity.

Consider next some data showing the responses of a papillary muscle to quick releases to zero tension (or a very light load) at various times after excitation. If we plot ΔP vs. ΔL we obtain the relation shown in Fig. 6. It can be seen that the region of increased ΔP at constant ΔL expected from the Maxwell model is not present. Neither is the reduction of ΔL soon after excitation relative to the resting state as indicated by the Voigt model if the CE could bear a compressive force. But a Voigt model with a CE that goes slack upon release is feasible.

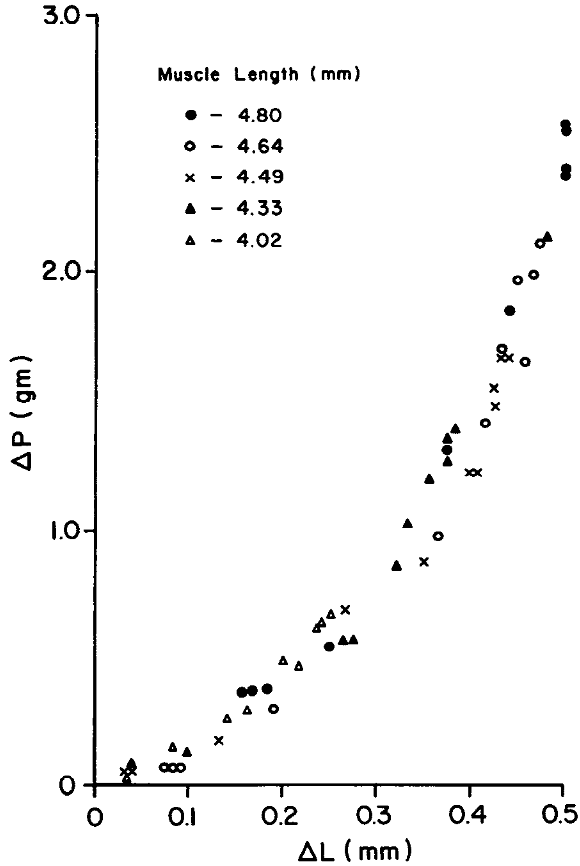


Fig. 6. Quick release responses of a rabbit papillary muscle at different initial muscle lengths. Load, 40 mg.

When the muscle is released to various loads at different times during successive contractions the relations shown in Figure 7 are obtained. On the left, stiffness as a function of time of release is plotted for various loads. On the right, shortening upon release is plotted on the abscissa and a normalized force is plotted on the ordinate. The normalization is achieved by translating the load-extension curves obtained at fixed times during successive contractions along the force coordinate until each maximum coincides with peak twitch tension. The fact that a continuous force-extension relation is obtained indicates that the papillary muscle undamped elasticity is not directly dependent upon the time of release. This observation has interesting implications, but the point here is that releases to various loads do not give data clearly differentiating either model and therefore do not seem to be of any great advantage in this respect. Releases to zero tension give a relatively simple measurement of elasticity of both resting and active muscle, and the continuous increase in ΔL with later releases suggests that an elastic component present in resting muscle is also in series with actively developed tension.

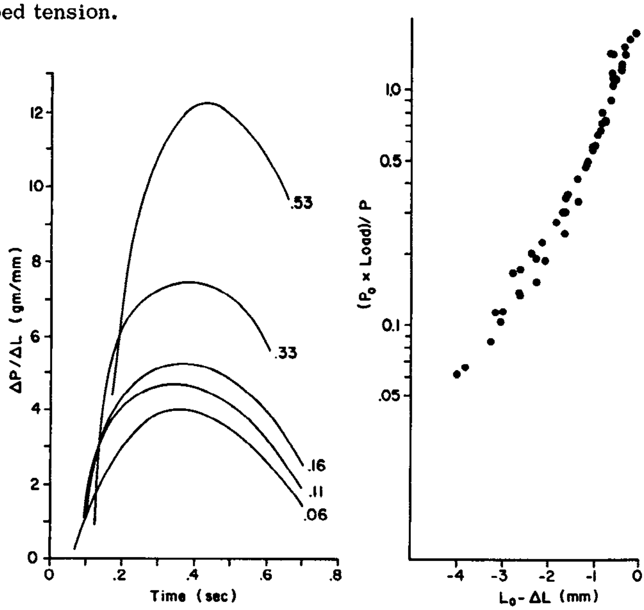
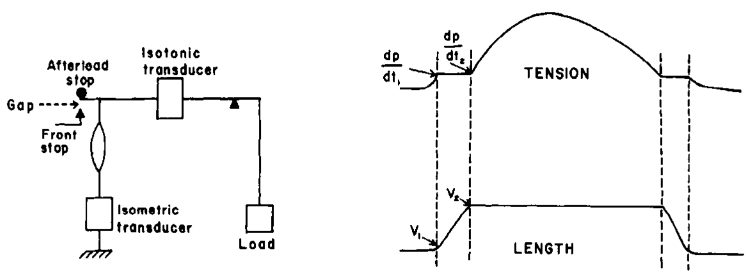


Fig.7. Quick release responses of a rabbit papillary muscle at different times and to different loads. Left, stiffness $\Delta P/\Delta L$ as a function of the time of release. The numbers near the curves indicate the load in gms. Right, normalized force plotted as a function of the change in length upon release. Length change ΔL is measured to the left from L_0 the initial muscle length. The normalized force is calculated by normalizing all the curves at the left to a maximum equal to peak isometric tension (1.60 gm.).

Transitions Between Isometric and Isotonic Contraction

A third measurement of elasticity is based on the assumption that the power of the muscle is constant during the transition between an isometric and an isotonic contraction. Such a transition would take place in an afterloaded contraction or when a muscle is contracting isotonically, but the lever hits a stop before contractile force is maximal (Fig. 8). Under this assumption Power = Pv in the isotonic state where P is the load lifted and v is the velocity with which that load is lifted immediately after the muscle becomes isotonic. During the isometric phase Power = $CP\frac{dP}{dt}$, C is the compliance and K, its reciprocal, is the stiffness of the SE element and P and $\frac{dP}{dt}$ are the force and the time rate of change of force development respectively just before the load is lifted. Since the load and the force at the transition are approximately equal, the two power expressions can be equated giving $\frac{dP}{dt}\over V$ = K. When different afterloads are attached to the muscle, K as a function of P can be determined. The validity of the constant power assumption relative to the heart depends on the assumption that extra energy is not mobilized by the tissue when isotonic shortening occurs. However, a change in power near the transition points is probably not sufficient to grossly invalidate the assumption.



Isometric

Power = $CP\frac{dP}{dt}$

Isotonic

Power = PV

$PV = CP\frac{dP}{dt}$ or $C = \frac{V}{dP/dt}$

$K = \frac{1}{C} = \frac{dP/dt}{V}$

Fig.8. Method and responses in two step experiment. Gap between stops is variable and determines length of isotonic phase. Slopes of tension and length curves are measured by electrical differentiation.

In skeletal muscle Pennycuick (9) found greatly different values of compliance at the two transition points. Compliance measured at the time of afterload in skeletal muscle was strongly dependent upon load. The compliance was high for light loads and tended to fall approaching the more constant compliance obtained from the reverse transition at the second stop. Pennycuick's explanation for the discrepancy attributes the difference in compliance to a contribution of resting tension at the time of afterload. The load lifted by the CE at this time is less than the attached load so that the velocity is high, giving a high compliance. After the interval of isotonic shortening when the resting tension has fallen, the reverse transition gives more constant values of both $\frac{dP}{dt}$ and V. The second transition compliance gave value close to those of the quick release method of Jewell and Wilkie.

In contrast, Sonnenblick (11) found a linear dependence of stiffness on load in cat papillary muscle using only the afterload between SE element force and extension whereas the constant compliance data of Pennycuick describes a linear relation between force and extension. In quick release and controlled release experiments Jewell and Wilkie (7) found the force-extension characteristic of the SE element in frog sartorius to be exponential for forces up to 40 gm. and more linear thereafter. Sonnenblick confined his measurements to relatively short muscle lengths in order to minimize resting tension complications. Figure 9 shows a comparison of elasticities measured with the quick release on the left and two step techniques on the right in the same muscle. At 1 gram force development the quick release data give a slope or stiffness comparable to that obtained from the two step data if a small compensation is made for the difference in initial muscle length.

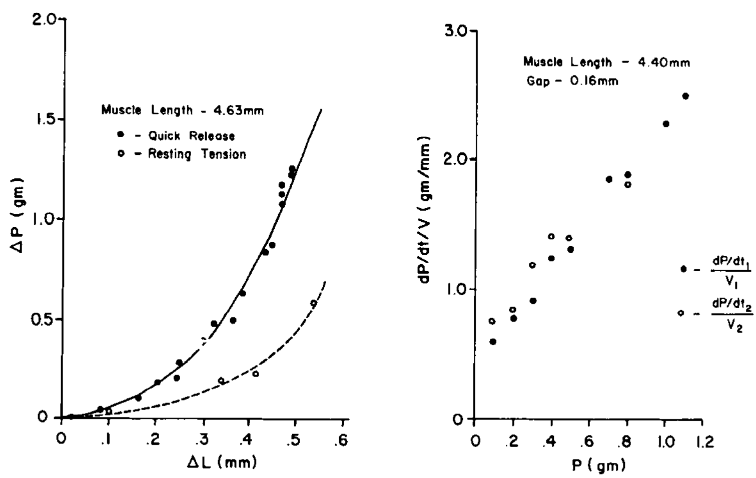


Fig. 9. Comparison of papillary muscle stiffness by different methods. Left, quick release method. Stiffness is given by the slope of the curves. Length changes ΔL are measured as a decrease in muscle length from L_0 for the quick releases and as an increase in muscle length for the resting tension relations. Right, stiffness measured by the two step method and plotted as a function of load.

The apparent difference in stiffness indicated by the data obtained from the afterload and second step transitions may be real and could be attributed to the fact that active state has had longer to develop by the time the second step is reached. Counteracting this increase, however, is the shortening which takes place during the isotonic phase. The net result could depend strikingly on initial muscle length, i.e. the nearness of top of the Starling length-tension relation.

Structural Considerations

Recently an attempt was made by Grimm and Whitehorn (4) to establish the possible contribution of intracellular structure of cardiac muscle to resting elasticity. Comparing muscle extensibility before and after treatment of a papillary muscle with proteolytic enzymes and various extraction solutions, they found the following: 1) Proteolytic enzymes reduced both resting and active tension in proportional amounts. 2) Extraction of myosin in moderate ionic strength salt solutions did not alter resting tension characteristics. 3) Extraction of actomyosin greatly altered resting length tension characteristics. They conclude that a significant part of cardiac resting elasticity in intracellular elements related to a continuity between the thin actin protein elements through the myosin band.

Other evidence implicating an active involvement of resting tension factors has been reported by Scherlag and co-workers (10) in which the resting tension of papillary muscle during certain inotropisms is lower immediately after relaxation than just prior to the succeeding beat. In other words, a diastalic creep in resting tension occurs. Sonnenblick, et al. (12) have interpreted these observations as a result of a series viscosity because they appear only with a force inotropy and are not evident when the total force does not increase as in afterload contractions. Thus, both from structural and physiological evidence it is apparent that we must be prepared to add additional elements to our model of cardiac muscle as longer term mechanical changes are considered.

Conclusions

Our discussion suggests to us that a Maxwell model by itself does not adequately describe a cardiac muscle preparation such as papillary muscle. The Voigt model tends to be more suitable at least qualitatively. However, both Hill (6) and Jewell and Wilkie (7) prefer the Maxwell model for skeletal muscle, based on quantitative considerations. It is not unlikely that a significant fraction of cardiac series elasticity is present also as resting elasticity thus forming a four element model. The studies of Grimm and Whitehorn correlating structure and function in a papillary muscle tend to support the four element model. However, if we admit that resting tension is not likely uniformly shared among all fibers, then a parallel arrangement of Maxwell units of different values could have an overall characteristic consistent with the quick release data. The resolution of our model then must finally come from smaller, more accurately controlled preparations.

REFERENCES

1. Blix, M. Die Länge und die Spannung des Muskels. Skand. Arch. Physiol. 4: 399-409, 1893.
2. Brady, A. J. Onset of contractility in cardiac muscle. J. Physiol. 184: 560-580, 1966.
3. Fick, A. Neue Beiträge fur Kenntniss von der Warmeentwicklung im Muskel. Pflüg. Arch. ges. Physiol. 51: 541-569, 1891.
4. Grimm, A. F., and W. V. Whitehorn. Characteristics of resting tension of myocardium and localization of its elements. Am. J. Physiol. 210: 1362-1367, 1966.
5. Hill, A. V. The maximum work and mechanical efficiency of human muscles and their most economical speed. J. Physiol. 56: 19-41, 1922.

6. Hill, A.V. The heat of shortening and the dynamic constants of muscle. Proc. Roy. Soc. Series B. 126: 136-195, 1938.
7. Jewell, B.R., and D.R. Wilkie. An analysis of the mechanical components in frog's striated muscle. J. Physiol. 143: 515-540, 1958.
8. Levin, A., and J. Wyman. The viscous elastic properties of muscles. Proc. Roy. Soc. Series B. 101: 218-243, 1927.
9. Pennycuick, C.J. II. A method of measuring internal series compliance. J. Exptl. Biol. 41: 113-118, 1964.
10. Scherlag, B.J., H.J. Bartelstone, S.R. Wyte, and B.F. Hoffman. Variable diastolic ventricular compliance: General property of mammalian cardiac muscle. Nature 209: 1246, 1966.
11. Sonnenblick, E.H. Series elastic and contractile elements in heart muscle: Changes in muscle length. Am. J. Physiol. 207: 1330-1338, 1964.
12. Sonnenblick, E.H., J. Ross, Jr., J.W. Covell, and E. Braunwald. Alterations in resting length-tension relations of cardiac muscle induced by changes in contractile force. Circulation Res. 19: 980-988, 1966.

THE LABORATORY OF ENVIRONMENTAL PATHO-PHYSIOLOGY DESERT RESEARCH INSTITUTE, NEVADA SOUTHERN UNIVERSITY

D. B. DILL

This air-conditioned laboratory is within the grounds of the U. S. Bureau of Mines installation, Date and Elm Streets, Boulder City, Nevada. For exercise and other physiological studies there is one large room of 4000 sq. ft. on the ground floor. Also on the ground floor is an adjoining room containing toilets, showers and lockers. There is office space on both the ground floor and second floor, two well-equipped chemical laboratories and one electronics shop on the second floor. All of this is made available to the University by the Bureau of Mines.

D. B. Dill is in charge of the research program funded by two grants, one from the National Science Foundation and the other from the Nevada Heart Association. Dr. Dill is a resident of Boulder City and is busy in the laboratory six days a week. His principal assistant in the summer months is R. J. Alteveer, Indiana University. Consultants include F. G. Hall*, Duke University, S. M. Horvath, University of California, Santa Barbara, and Sid Robinson and R. J. Bullard, Indiana University. Last summer Hall, Alteveer and four scientists from Indiana studied several physiological problems associated with desert heat, high altitude and the transition from one environment to the other. These scientists presented some of their findings at a symposium on desert and mountain physiology at the meeting of the American College of Sports Medicine, Tropicana Hotel, Las Vegas, March 8.

Such studies of man are to be continued next summer, together with studies of two other mammals, Merriam's kangaroo rat and the burro. The former is a nocturnal native rodent with a long tail and hind legs modified for jumping; it thrives in the desert without drinking water. Exploratory studies prove them to be great runners in the wheel cage. The record in the first month was 19,000 revolutions of a 14" wheel - about 13 miles, in 24 hours. The long range interest is in exercise vs. health: some are to be kept in ordinary cages and some in wheel cages.

The burro has escaped from civilization and thrives in the southwestern deserts within grazing distance of water. "Mabel" was a young member of such a herd until captured in August, 1966. She is now domesticated and promises to be a prize subject next summer in studies of man vs. burro in desert walks. Particular interest will be in temperature regulation, water and electrolyte balance, sweat rate and composition.

The Laboratory of Environmental Patho-Physiology has a close working relationship with the Department of Biological Sciences at Nevada Southern University at Las Vegas. Dr. W. Glen Bradley acts as a consultant in ecology and is engaged in research on bats under a National

*Died 19 February, 1967.

Science Foundation Grant. He and a senior student, Michael O'Farrell, are investigating the thermoregulation of bats under different environmental conditions, especially during flight. Glenn Allred and Jack Anderson, students at Nevada Southern University, will assist Dr. Dill in the summer in order to gain experience in the field of environmental physiology.

Perhaps the most unusual feature of the school year activities is that, besides Dr. Dill, the other five scientists are students in the Boulder City High School. Four are seniors with excellent records in science - Stephen Barneby, Robert Parker, Leslie Startin, and Kris Holliday. The fifth, Danny Morris, is a sophomore with an outstanding scholastic record and unusual skill in electronics. They work part time including part of Saturday. Besides helping with data accumulated last summer they are learning techniques and looking forward to being full time research assistants next summer. The four seniors will be entering college next fall. Their scholastic records, character and interests together with their experience in research leads us to predict that more than one of them will seek and find a career in biological research.

ANIMAL SUPPLY

This is to notify all users of animals to encourage their suppliers to apply to the Department of Agriculture for license to sell animals as soon as possible. May 24, 1967 is the date set after which dealers cannot sell animals without a license.

STANDARDIZATION OF SYMBOLS AND UNITS FOR ENVIRONMENTAL RESEARCH

W. C. KAUFMAN

In a meeting called by the National Aeronautics and Space Administration (NASA) and held at NASA Manned Spacecraft Center, Houston, Texas, on 10 March 1966, representatives of the various research centers of NASA and the biological laboratories of the Air Force Systems Command agreed on the desirability of standardizing symbols and units commonly used in environmental research. In line with the system agreed upon many years ago by respiratory physiologists (1) the following set of symbols is recommended.

Three major symbols will be used.

T = temperature

H = rate of heat transfer or production

Q = heat quantity

Upper case subscripts will define physical variables.

A = air

W = wall

R = radiant

E = evaporative

C = convective

D = conductive

DB = dry bulb

WB = wet bulb

Lower case subscripts will define physiological variables.

r = rectal

e = esophageal

t = tympanic

o = oral

s = skin

b = body

m = metabolism

A dash above any symbol will indicate a mean value and Δ will indicate a change in a variable. Should it be desired, a dot above any symbol will indicate a time derivative.

$\bar{s}$ = mean skin

$\bar{b}$ = mean body

ΔT_r = change in rectal temperature

For metabolic or atmospheric designations those suggested by the Federation of American Societies for Experimental Biology should be used.

$\dot{V}_{O_2}$ = rate of oxygen consumption

P_B = barometric pressure

A second subscript will be used, if necessary, to indicate the time of the observation.

i = initial

f = final

Examples:

$Q = H_R + H_C + H_D + H_E + H_m$

Q = quantity of heat

H_R = radiative heat transfer

H_C = convective heat transfer

H_D = conductive heat transfer

H_E = evaporative heat transfer

H_m = metabolic heat production

Q_b = quantity of body heat storage

T_A = air temperature

T_W = wall temperature

T_{WB} = wet bulb temperature

T_r = rectal temperature

T_e = esophageal temperature

T_t = tympanic temperature

T_o = oral temperature

$T_{\bar{s}_i}$ = initial mean skin temperature

$T_{\bar{b}_f}$ = final mean body temperature

Less universally accepted terms such as "effective" or "operative" temperature, "index of strain," "heart rate," etc. should be defined in publication as necessary. Symbols used should be abbreviations or, in any event, clearly distinguished from those such as T_e (esophageal temperature) or T_o (oral temperature).

Units used in publications should always be in the metric system. The author is well aware of the impact units such as the newton and the joule will have on biologists in general and particularly on those who are clinically oriented. However, in the interest of standardization and uniformity, the Systeme International d'Unites as agreed upon at the 1960 Eleventh General Conference on Weights and Measures (2), is recommended to the courageous.

REFERENCES

1. Federation of American Societies for Experimental Biology. "Standardization of Definitions and Symbols in Respiratory Physiology." Federation Proc. 9: 602-605, 1950.
2. Mechtly, E. A. The International System of Units, Physical Constants and Conversion Factors. NASA SP-7012, Scientific and Technical Information Div., National Aeronautics and Space Administration, Washington, D. C., 1964.

PARTICIPATION BY HUMAN BIOLOGISTS IN THE INTERNATIONAL BIOLOGICAL PROGRAM

INTRODUCTION

The International Biological Program (IBP) will focus on "the study of the biological basis of productivity and human welfare." Because human welfare depends both on biological productivity and on man's capacity to adapt to new and rapidly changing environmental circumstances one major emphasis in IBP will be the study of adaptability of human populations. In these studies there will be a key role for the human biologist interested in environmental physiology or exercise physiology. The unique aspect of IBP is that it affords an opportunity to enlarge and extend studies of human adaptability from the laboratory to the habitats of human populations and to investigate these processes in an ecological context. Scientists interested in many aspects of human biology are encouraged to consider active participation in IBP.

The IBP was born in July, 1964 when the International Council of Scientific Unions established a Special Committee (SCIBP) to coordinate the activities of some 40 nations which agreed to participate by developing and implementing national programs. Early in 1965 Dr. F. Seitz, President of the National Academy of Sciences, appointed the U.S. National Committee for IBP; Dr. Roger Revelle was named the Chairman. This Committee established nine subcommittees assigning to each specific tasks in the formulation of a U.S. National Program. The subcommittee primarily responsible for human biology has been identified as the Human Adaptability (HA) Subcommittee.

The focus of the HA Program is on biological populations rather than on individual human beings. "The goals of this HA Subcommittee are to measure the distribution and identify the sources of variability of man's adaptive capacity and to elucidate the processes of adaptability. In fulfilling these goals, the subcommittee will undertake studies on a variety of human populations ranging from hunting and gathering groups to industrialized societies which exhibit significant contrasts in genetic background habitat, and culture ..." (USNC Report No. 2, pp 4.).

In recent months the Human Adaptability Subcommittee completed the preparation of a "Program Statement" providing details of the nature of the HA program and how the subcommittee planned to implement it. This statement is given below. The members of the HA Subcommittee are indebted to the Editor for providing an opportunity to bring this material to the attention of members of the American Physiological Society.

PROGRAM STATEMENT OF THE SUBCOMMITTEE ON HUMAN ADAPTABILITY

The evolutionary success of the human species is based on genetic, morphologic, physiologic, and behavioral variation. The processes and mechanisms of human adaptability are the special concern of this Subcommittee. The term "adaptability" is here used in several senses, including the adaptability of populations and individuals and genetic and phenotypic adaptability.

Human adaptability has multiple bases, with consequences for human survival. However, neither the distribution nor the sources of man's variability have been rigorously measured. The International Biological Program presents a unique opportunity for determining the relative importance of these aspects of variability, and of establishing underlying mechanisms on the basis of closely comparable studies of different groups - groups having contrasting genetic, social, nutritional, and climatic backgrounds.

THE DYNAMICS OF HUMAN POPULATIONS

The range of human populations available for this type of investigation should provide the IBP with possibilities for thoroughly assessing sources of variability. At one extreme are few surviving examples of hunting-gathering and incipient agricultural populations, which represent what were the norms of adaptation until relatively recent times. At the other extreme are diverse industrialized populations.

Some of the primitive groups - e.g., the South African bushman, the Australian aborigines, the Eskimos, certain tribes of Central and South American Indians - are disappearing rapidly, culturally if not biologically. IBP studies of these groups would provide invaluable baselines for investigations of a variety of other populations that exhibit significant contrasts in genetic background, habitat, and culture. Many of the primitive populations have limited resources and have, therefore, been exercising control of population size for centuries. Thus, the study of primitive populations will shed light on processes by which populations control their sizes. The study of such groups is not only extremely timely, but because of their location, may provide unusual opportunities for international cooperation.

Special attention should be paid to biological adaptation of racial isolates of industrialized societies and migrant groups moving from one environment to another. Studies of short-term and long-term migrations by different racial groups to similar environments are desirable. The studies should include baseline studies in the original environments and comparative measurements in the new location; such measurements on the same individuals would be particularly valuable.

Careful descriptions of individual micro-environments and actual behavior need to be included in all population studies. And, before any study is chosen as an IBP project, consideration should be given to whether it would provide opportunity for international cooperation and for making international comparisons. The subcommittee anticipates that studies will focus on three areas - population genetics; adaptation to stress; and morphology, growth, and aging.

POPULATION GENETICS

Mankind possesses great diversity both within and between populations.

This diversity has been the basis of both the evolutionary success and many of the present problems of the species.

It is obvious that long-term changes in the human population have occurred and that the environment of man is changing rapidly both physically and culturally. Description and explanation of the underlying processes of change are essential to understanding population dynamics. Whereas individuals succumb to critical changes in environment, populations adapt, natural selection being the principal process leading to this adaptation.

A partial listing of forces and processes entering into population dynamics follows, each of which is a problem for IBP research:

1. Mating choices and patterns, including inbreeding, outbreeding and assortative mating.
2. Fertility.
3. Fetal wastage.
4. Postnatal natural selection.
5. Fluctuation and disappearance of populations.
6. Hybridization between populations.
7. Behavior genetics.
8. Genetic drift and founder's principle.

Of crucial relevance are the processes determining transmission of genetic material from one generation to the next.

ADAPTATION TO STRESS

Stresses may be defined as those conditions which impose measurable consequences upon individuals and populations. Stresses involve both stimulus deficiencies and excesses, are specific to individuals, and are recognizable by behavioral, physiological, morphological, and ultimately, genetic manifestations.

An inventory of stresses significant to historical and current phenotypical adaptation and selection in man includes large numbers of physical, nutritional, disease, and behavioral factors. Studies of interest to the Subcommittee on Human Adaptability encompass virtually all, although in some areas, such as noise, work to date has been initiated only in limited ways. Studies of the following areas are proposed:

1. Environmental Stresses

   a. Cold tolerance

      Comparative studies of whole body cooling and metabolic adjustments to standard cold stresses, local vascular adjustments to cold, and cold pressor tests.

   b. Heat tolerance

      Comparative studies of temperature, regulatory responses of limited numbers of subjects under standard work-heat stress, and of larger groups of subjects performing standard work (marching) under field conditions in hot climates, with standardized subjects serving as controls.

c. High altitudes

Comparative studies of hematology, body fluid components, metabolism, respiratory function, and circulatory responses of subjects under basal conditions and in standard work tests.

d. Working capacity

Metabolic, respiratory, and circulatory adjustments of subjects to a standard aerobic work test, and to strenuous work tests designed to determine both aerobic and anaerobic capacities.

2. Nutritional Stresses

Research in human nutrition is critical to any understanding of other aspects of human adaptation and to human welfare generally.

a. Nutritional requirements

These are modified by a variety of individual characteristics, such as genetic endowment, age weight, and sex; the physical environment; and by activity levels. The role of these factors in determining the nutritional requirements of a particular population is poorly understood, and an extensive research program in this area is highly desirable.

b. Nutrition and stress resistance

The role of nutritional history in determining the stress resistance of a population is very poorly understood. Research should include specific investigations of the relations between nutrition and disease resistance, and between nutrition and thermal regulatory processes. These investigations should take advantage of the breadth of the IBP by emphasizing genetically distinct populations. They would be most valuable when directed toward young children.

c. Adjustments to under-nutrition

By morphological, behavioral, physiological, and bio-chemical changes, human populations and individuals are able to survive in nutritional circumstances which by most criteria are considered inadequate. Such groups and individuals may be considered adapted to undernutrition. The consequences of the adaptations are not well known and a critical world-wide problem is their determination in order to understand world population potentials and also to serve as a baseline for predicting the consequences of particular nutritional regimens.

All studies of human nutrition should be developed in collaboration with the Subcommittee on Use and Management of Biological Resources.

3. Disease

Investigations of adaptative processes in relation to disease are relevant to geographical pathology. Three major problems are pertinent to the Human Adaptability program.

First, disease as an agent of natural selection: Among, the diseases that might be studied in this context are tuberculosis, malaria, syphilis, Hanson's disease, Chagas' disease, trypanosomiasis, trichinosis, schistosomiasis, and other helminthioses. Investigations of these diseases, within the framework of the Human Adaptability program, should be multidisciplinary, emphasizing intensity of infection and differential epidemology in selected populations.

Among the related materials to be accumulated on these intensively studied populations are genetic data and data on nutritional and other stresses experienced by the populations.

Coordination with the Subcommittee on Conservation of Ecosystems is highly desirable.

Second, overall morbidity patterns within selected populations: In these investigations, one objective should be to gain information regarding differential susceptibility - e.g., data on exposure to disease as indicated by titers of antibodies and data on reactivity to disease as indicated by development of clinical illness.

Third, the allergic diseases: These conditions are in many instances consequences of civilization, manipulation of the ecosystem, and even preventive and therapeutic practice. In a sense, allergic diseases are due to failures of adaptation. Thus, intensive investigations of these conditions are most relevant to the Human Adaptability program.

4. Biological Consequences of Human Activity

The human activity cycles have been discovered to depart markedly from idealized accounts. We have virtually no observed and quantified information on other than limited groups within western societies. Therefore, the Human Adaptability program will include studies of:

a. Activity cycles in peoples of different cultures.
b. Human energy costs of specific activities.

c. The skills involved in various activities, such as ecological exploitations, hunting, running, and burden bearing.

These studies should be designed to provide information on the consequences of these activities to both the individual and the population.

MORPHOLOGY, GROWTH, AND AGING

Data on morphology, physical growth, and aging will be collected in the context of other studies on human adaptability. However, our knowledge of the relation between developmental and environmental factors is so inadequate that special studies are also recommended. Suitable topics include:

1. Early (perinatal to young child) human development in relation to environmental stress.
2. The relation between physical and behavioral development.
3. The adaptive aspects of child development.
4. Man's physiological adjustments to such stresses as heat, cold, hypoxia and work.

These studies would be particularly valuable if they would compare genetically distinct populations. Longitudinal studies should be favored over cross-sectional ones, although both are necessary.

PROGRAM PLANNING

The elements of program planning are:

1. Statement of specific questions within a hypothetical context.
2. Selection of appropriate technical methodology.
3. Selection of appropriate human populations.
4. Site selection.
5. Construction of experimental design.
6. Development of logistics, instrumentation, and training.

Because the Human Adaptability program envisages undertaking complex multidisciplinary investigations, the Human Adaptability Subcommittee will convene several carefully structured planning conferences to elaborate details of problem-oriented research projects, typologically and regionally. At the same time, the Subcommittee encourages interdisciplinary groups to come forward with additional ideas and program projects consistent with the objectives of the IBP.

REGIONAL PLANNING CENTERS

Planning should be undertaken by interdisciplinary groups composed of individuals who will ultimately engage in the research. Potential groups within the U.S. should be identified and funded. Such groups presumably would be centered at academic institutions having a nucleus of competent biologists and appropriate facilities. The biologists of these centers should bring into the advanced planning the facilities of those institutions located in the vicinity of the centers. The biologists involved in this phase of development of IBP should be selected according to their willingness and competence to contribute and not according to their relation to a particular section of IBP, for the aim would be to develop a program of research consistent with the objectives of the IBP.

CONFERENCES

At a regional center a group will be established which will take the initiative in organizing conferences and in seeing that detailed planning is accomplished. The participants in these regional conferences should be persons who are likely to participate actively in the research under discussion.

At least two conferences will be necessary. The purpose of the first conference will be to state the specific questions that should be studied, decide on methods, select populations for study, outline experimental design, and create working parties to develop details and budgets. These parties will prepare working papers for the large group prior to the second conference. At the second conference the detailed planning will be completed with the development of an integrated program and a comprehensive budget. Selected foreign scientists should be included in these conferences; their presence is necessary for coordination and collaboration. Representatives of granting agencies should be invited to attend as observers.

METHODOLOGY

Although many investigations now in progress relate to the questions raised by the IBP human adaptability program, few have the scope here envisioned and few have adopted a standard methodology for assessing human adaptability. In this program, new multidisciplinary studies will be carried out. They will assess the sources of variation in human adaptability and determine the adaptative processes by a battery of agreed upon standardized procedures.

Several requirements must be applied to selection of methods for conducting the studies.

First, the methods should provide discriminatory measures of the biological and environmental factors relating to human adaptability.

Second, the methods should be capable of field application on representative stratified samples of the population selected for study.

Third, the methods should yield a maximum of information with a minimum disturbance of the groups investigated.

It is proposed that appropriate methodologies meeting these requirements be carefully tested and validated in institutions already well equipped and experienced in this work. The detailed findings and recommendations of the study groups will be published for the guidance of IBP and other investigators.

Among the methods that must be standardized in this fashion are those concerned with the evaluation of working capacity; physiological reactions to heat, cold, and altitude; nutritional status; and other relevant demographic, genetic, medical, and behavioral factors.

Early attention must be given to development of instrumentation suitable for use in studies of human populations. It is essential that serious consideration be given to the cost-effectiveness of all instrumentation. Equally important in the planning is the matter of logistics.

It is essential for understanding human adaptability that there be more experimentation on human volunteers. Wherever human experimentation is the method chosen, the projects must be consistent with the ethical codes governing the experimental use of human subjects (e.g., Declaration of Helsinki. Recommendations guiding doctors in clinical research adopted by the World Medical Association in 1964; population genetics in primitive groups. WMO Tech Report No. 32, 1964) and fulfill the conditions stated in PPO #129 (dated July 1, 1966) from the Surgeon General of the U.S. Public Health Service.

RESEARCH DESIGN

The details of each investigation should be designed to sort out the key aspects of interest to the several regional groups. The size of the populations chosen for study should be appropriate to the nature of each problem. Site selection should be made in collaboration with the IBP Subcommittee on Conservation of Ecosystems. Attention must be given to details of recording observations and storing and processing information. Provision should also be made for storing human biological materials in appropriate banks, (e.g., sera and other body fluids) for future immunological or genetic study. Where appropriate, the storage should be coordinated with WHO and with the IBP Subsommittee on Use and Management of Biological Resources.

A broad overriding consideration is that, where feasible, the research design for human adaptability should be integrated with broader planning for the IBP.

TRAINING

In order to accomplish the research proposed in this program, it will be necessary to involve not only seasoned investigators but also graduate students aspiring to become human biologists or human ecologists. These graduate students will have to be recruited from a group that is under pressure to follow other courses of action. Graduate education and advanced research training under the IBP must, therefore, be integrated into other programs to enlarge the manpower pool of "environmental health scientists." It is urged that interinstitutional cooperation be utilized so that faculties can be pooled in the training. Arrangements should be made for interinstitutional movements of students, for in this way they could take advantage of unique facilities and specialized talents available within the regional centers.

ENDORSEMENT OF THE HUMAN ADAPTABILITY SUBCOMMITTEE

Investigations of human adaptability of the type referred to here are already being considered by various groups in the U.S. and will be developed and submitted to Federal agencies for support whether or not there is an IBP. USNC-IBP will encourage and support these investigations, will provide for appropriate liaison with other national groups, and will seek funds for the planning and conduct of the investigations. The purpose of these efforts is to insure maximum coordination of investigations of human adaptability.

The Human Adaptability subcommittee will review each proposal submitted to it with a view to making two determinations:

1. Relevance of the proposal to IBP, and
2. possession of scientific merit of a high order.

PROGRAM PROGRESS

The Human Adaptability subcommittee has instituted several project-planning conferences:

1. Human adaptability in Israel. Convenors: J. Magnes (Israel), O. E. Edholm (U.K.), and G. M. Briggs (U.S.). The planning is being coordinated with Use and Management of Biological Resources Subcommittee.

2. A study of circumpolar peoples. Convenors: J. A. Hildes (Canada) and F. A. Milan (U.S.).

3. Ecology of migrant populations. Convenors: A. F. Ostfeld and D. B. Shimkin (U.S.).

4. Problems of adaptability among human populations residing in high mountains. Convenor: P. T. Baker (U.S.).

Two other project-planning conferences have been discussed, but firm plans for meeting have not been formulated. F. Sargent, W. S. Laughlin, and R. H. Osborne (U.S.) and S. Kondo (Japan) have considered a project on study of the ecological problems facing migrant racial and hybrid groups residing in the Western Hemisphere. R. A. Audy (U.S.) has begun to plan studies on the socio-cultural aspects of health in the Pacific area, with special reference to a longitudinal investigation of child maturation in Southeast Asia. Under his direction a working group of the Pacific Science Association is also developing plans for establishing an information exchange center.

Human Adaptability is currently screening several hundred research projects on file with Science Information Exchange with a view to identifying on-going studies that might be relevant to the IBP.

Members of Human Adaptability have also participated in international conferences on methodology and on the identification of major problems of human adaptability. Publications have resulted from these conferences and are important references.

Biology of Human Adaptability, (edited by P. T. Baker and J. S. Weiner), was published by Oxford University Press in 1966.

Conference on Methodology in Human Adaptability (conference held in Kyoto, Japan, in 1965) is to be published by the Japanese Society for the Promotion of Science.

Conference on Human Adaptability (conference held in Warsaw in 1965) is to be published by the Polish Academy of Sciences.

GUIDELINES FOR PARTICIPATION

In addition to the plans described in the "Program Statement" individual scientists, groups, and societies are encouraged to submit proposals for research to the U.S. National Committee. The mechanism whereby such submissions are accomplished is described in Report No. 2 of U.S. National Committee. The Report contains broad guidelines for judging the relevance of specific proposals to IBP. The HA Subcommittee has established its own guidelines within the broader frame of reference. These guidelines are summarily stated below:

1. There should be a biological focus.
2. The project should be timely.
3. The work contemplated should be basic or fundamental.
4. The proposal should envisage international work. Substantive evidence should be presented of cooperation, collaboration, and/or coordination.
5. Multidisciplinary studies which emphasize longitudinal and repetitive observations are preferred. Studies with narrow focus that are appropriate to IBP, however, are not excluded.

Members of Human Adaptability Subcommittee

J. R. Audy	J. Mayer
P. T. Baker	J. V. Neel
E. R. Buskirk	S. Robinson
L. D. Carlson	F. Sargent II (Chairman)
O. Kempthorne	D. B. Shimkin
W. S. Laughlin	C. Tietze

REFERENCE

U. S. Participation in the International Biological Program. Report No. 2 of U. S. National Committee. NAS-NRC, Washington, D. C. (January 1967). (Copies of Report No. 2 may be obtained by writing M. R. DeCarlo, National Research Council-National Academy of Sciences, 2101 Constitution Avenue, Washington, D. C. 20418).

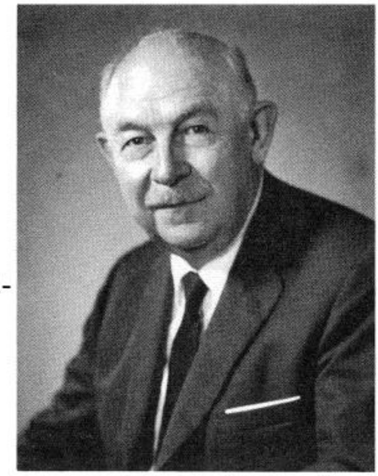
MONOGRAPH ON AUDITORY INPUT CONTROL

"The Morphology and Function of Auditory Input Control" a monograph by G. Filogamo, L. Candiollo, and G. Rossi of Turin, Italy, is soon to be issued by the Beltone Institute for Hearing Research as Number 20 in the series of Translations in the field of hearing research. The monograph (154 pages, 69 figures) appeared originally in Italian in 1965. It represents the first serious attempt to give a summarizing account of the complex control mechanisms that govern the reception of auditory signals by the central nervous system from its sensory receptors within the ear.

The monograph can be secured from:

Executive Secretary
Beltone Institute for Hearing Research
108 North State Street - Room 1200
Chicago, Illinois 60602

FRANK GREGORY HALL



Frank Gregory Hall was born on February 12, 1896, in Johnstown, Wisconsin, the son of Frank Dexter Hall and Evelyn Kidder Hall. His early years were spent on farms in Wisconsin and Nebraska. Orphaned by the age of sixteen, he worked his way through high school and college, threshing wheat and punching cattle. An early marriage to Beth Marie Davis, granddaughter of the founder of Milton, Wisconsin, ended tragically with her death in 1920 after the birth of a daughter, Elizabeth Ann, now Mrs. F. Kent Boutwell of Santa Barbara, California. On August 14, 1923, he married Stephanie Daland, daughter of William Clifton Daland, president of Milton College, and a classmate and close friend of his first wife. On October 26, 1926, she bore him a son, Kenneth Daland Hall.

After receiving the B. A. degree from Milton College in 1917, Greg Hall taught for one semester in the Biology Department there before joining the Army Signal Corps during World War I. He taught at Milton College until 1920, when he left to do graduate work at the University of Wisconsin, receiving the M. A. in 1921 and the Ph. D. degree in 1923. He returned to Milton College, where he taught biology for three more years.

In 1926, when Trinity College in Durham, North Carolina, was being enlarged to become Duke University, Hall's Ph. D. professor, Dr. A. S. Pearse, was summoned from Wisconsin to chair the Department of Zoology. His first move was to insist that Hall join him on the staff at Duke. Greg Hall devoted the rest of his career to Duke University, rising to the rank of full professor, first in the Department of Zoology and later, from 1946 onwards, in the Department of Physiology of Duke Medical School. He was Chairman of the Department from 1946 to 1962, when he retired from the chair to devote his full time to teaching and research.

A sabbatical leave at Cambridge, England, in 1933 afforded Greg Hall the opportunity to study and work with Sir Joseph Barcroft, who stimulated his early interest in high altitude respiratory physiology. He also worked in Copenhagen with August Krogh. The Carnegie Institution and Duke University Biological Expedition took him to Yucatan in 1932. In 1935 he was a member of the International High Altitude Expedition to the Chilean Andes. Here he became fascinated with the concept of acclimatization, the understanding of which became fundamental to his later contributions towards making it possible for man to survive in space.

Immediately after Pearl Harbor, Hall was recalled to active duty in the Army Air Corps. He was stationed at Wright Field, continuing the work he had been doing there as a civilian consultant, and becoming Chief of the Physiology Branch of the Aero Medical Laboratory. Later he served as Acting Chief of the Laboratory, and rose to the rank of Lt. Colonel before his discharge in 1946. He saw the development of the BLB oxygen mask, demand regulator, pressure breathing regulator, and the partial pressure space suit during his tour of duty, while his trips as an Air Corps trouble shooter took him around the world. His contribution to the development of the anti-G suit, which was one of the deciding factors in the successful air cover of the English Channel on D-Day, won him the Legion of Merit, the highest non-combatant service award.

His high-altitude research continued at Duke University after the war with installation of a six-man low pressure chamber in his laboratory, which was used in studying partial pressure suits, explosive decompression, and useful consciousness time.

In 1957 Professor Hall was honored by his Alma Mater, Milton College with a Doctor of Science degree.

After his retirement, his investigations involved the study of the relationship between environment and respiratory gases in small animals, resulting in six papers published during the last year of his life. He continued to participate in desert and high altitude expeditions with Dr. D. B. Dill, the last expedition less than a year before his death.

In addition to his wife and two children, he is survived by two sisters, Mrs. Joseph Christie of Chetek, Wisconsin, and Mrs. Joseph Weber of Dorchester, Wisconsin, and eight grandchildren.