What is "Biological Physics" ? A Resource Letter

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ABSTRACT. The purpose of this resource letter is threefold: To attempt a refinement of the tenuous definition of the term "Biological Physics". To do this via a compendium, albeit inexhaustive and incomplete, of materials which might appropriately be labelled biological physics. To provide a useful introduction to the learning resources in biological physics for college students and their professors.

I. Introduction

Global Definition: Biological Physics. The borderland shared by physics and biology has a long and tenuous history which has been traced (in physics at least) to the works of Cavendish (electric ray), Galvani (frog), Volta (frog muscle), Helmholtz (acoustics and hearing), and so on. So historically it is somewhat surprising that with such an early start biophysics did not become one of the traditional subfields of classical physics. Nevertheless, for a variety of reasons it did not, although the thread has continued, tenuous at times but unbroken, until the present.

After the successes of quantum mechanics in dealing with problems of atomic and molecular physics there was an intensification of interest among physicists in problems traditionally held to be in the realm of biology. Textbooks bearing the term biophysics in their title began to appear and the architects of the new quantum theory contemplated its implications in biology.

Even those of us who now would prepare resource letters in biological physics do not tread virgin territory. Yet, still there remains the fundamental quandary: What is biological physics?

Since this journal has been founded for the purpose of bridging communications between physicists and life scientists, it seems timely and appropriate to attempt the formulation of a global statement which will define the field appropriate to such communications. We hope to bring such a global statement into, if not a workable focus, at least better definition. If the contents of this resource letter lead to controversy, we hope that the controversy will prove productive. We would welcome the opportunity to prepare and publish addenda updating this communication with input from those better informed than us in their specialties.

A (loosely constructed) working definition which seems to enjoy some acceptance is:

Biological Physics — That branch of physics in which the concepts and techniques of experimental and theoretical physics are applied in the study of the problems of biology.

Some critics of such a definition remark, impugning the word "applied", that what has then been defined is biological engineering, or some such, and not a proper field of physics. They hold that the term physics should be reserved to label areas in which new knowledge dealing with the fundamental nature of matter is sought. Some proponents of the definition note that it merely parallels the definition of solid state physics in which the concepts and methods of experimental and theoretical physics are applied in the study of matter in the solid state. Thereby the question is raised: Is biology the study of problems of matter in the Living State?

In bringing more detail to definitions, we note that the explicit details listed depend strongly on the prejudices of the list-maker. In Table I we note, for comparison, five lists prepared in turn by a physicist, a biologist, a physicist's publisher, a biologist's publisher, and a librarian.

At first glance, these lists seem to have little to do with each other. Closer scrutiny, an actual search of publications, and the application of our working definition, suggests the list detailed in Table II

We do not presume to provide the last word on the definition of biological physics, but rather, we intend to carry the work of our predecessors (Loofbourow, Baker, Johnson) one step further. Biological Physics is becoming a prolific and diversified field with the capability of touching most branches of its two parent fields, both very vast in themselves.

The evidence of the literature supports the view that Biological Physics does presently exist as a field of basic scientific research and that it is quite distinct from Biomedical Engineering in which physical principles already known are applied using a system theoretic approach. Biological Physics is characterized by the mathematical emphasis by which a larger body of of physical phenomena, particularly those in biological processes, is brought within the framework of the description of the theories of physics. Although there appears to be general confidence in the article of faith that the processes of living organisms have their basis in quantum electrodynamics, there have as yet been no generally applicable physical formulations of these processes. Herein lies the basic challenge of biological physics: *Living State Physics.*

Eventhough the principles of physics are universal, the applications of theoretical physics that have been made to biological systems have been considered to be quite abstract and intimidating by biologists. Physicists have to realize that many of the methods of theoretical physics do not

Table IA. Biophysics from the point of view of a physicist (John R. Loofbourow, *American Journal of Physics*, 15 (1947) 21.

(i) Physics of living organisms	(ii) Biological effects of physical agents	(iii) Physical methods for studying biological structures and functions
	I. Molecular, Atomic and Nuclear Physics	
Natural radioactivity in living systems.	Lethal effects of gamma-rays, alpha- and beta-particles, neutrons, electrons, etc.; effects on growth, regeneration, etc.	Use of radioactive and nonradioactive isotopes in tracer studies.
Particle size and state of aggregation in living systems (crystalloids, colloids, emulsions, gels, etc.).	Effects of isotopes.	Use of radioactivity to induce genetic changes.
Osmotic phenomena in organisms.	Effects of polymers.	
	Therapeutic applications of natural and induced radioactivity.	
	II. Mechanics, Wave Motion and Sound	
Stress, strain and strenght of materials in relation to the structure and function of organisms.	Geotropisms.	Use of gravitational fields (centrifuge, ultra-centrifuge, microscope centrifuge).
Levers in biological systems.	Effects of abnormal gravitational fields.	Manometric and volumetric methods for studying cell and tissue metabolism.
Relation of surface tensions, viscosity, etc., to living systems.	Effects of abnormal pressures.	
Hydraulics of blood circulation.	Effects of sound and of ultrasonic vibrations.	
Sound production and reception.	Responses to changes of stress.	
	III. Heat	
Temperature maintenance and regulation in organisms.	Effects of normal environmental temperatures; climatological aspects.	Calorimetry of living systems.
	Effects of artificially-controlled temperatures.	Temperature measurement in organisms and tissues.
	Therapeutic applications.	
	IV. Electricity and Magnetism	
Impedance and other electric characteristics of cells and tissues.	Effects of atmospheric ionization.	Use of electrical measuring methods and electronic circuits; for example, in measurements of *p*H, oxidation-reduction potentials, nerve action currents, etc.
Tissue currents, membrane potentials, electric phenomena in nerve conduction, etc.	Effects of electric and magnetic fields.	Electron microscopy.
Electric defense mechanisms in organisms.	Effects of electric currents.	Diagnostic applications (electroencephalography, electrocardiography, etc.).
	Therapeutic applications (diathemy, electric cautery, electrosurgery, etc.).	
	V. Radiation: (a) Hertzian	
	Production of artificial fevers; other effects on cells and tissues.	Microwave spectroscopy in molecular-structure studies of biochemical interest.
	Therapeutic applications.	
	(b) Infra-red	
Infra-red radiation from living organisms.	Lethal effect on small organisms.	Spectroscopy of compounds of biochemical interest.
	Climatological aspects.	Infra-red microscopy and photography.
	Therapeutic applications.	
	(c) Visible	
Phenomena of vision	Phototropisms.	Use of spectroscopy, polarimetry, refactometry and other optical methods in the study of biochemical compounds.
Bioluminescence.	Photoperiodism.	Microscopic methods.
Photo-sensitization of organisms and tissues.	Photosynthesis.	Photography, photomicrography, microcimematography, etc.
	(d) Ultraviolet	
Ultraviolet chemiluminescence in organisms; mitogenetic rays (the existence of which is controversial).	Lethal and stimulative actions on cells, tissues and organisms; other effects.	Spectroscopy of biochemical compounds.
	Relation to vitamin D synthesis, and to health in organisms; climatological aspects.	Ultraviolet microcopy and microspectrophotometry.
	Therapeutic applications.	Photochemical technics applied to biological problems.
	Use in control of microorganisms.	
	Induction of genetic changes.	
	(e) X-ray (see I for gamma-rays)	
	Lethal action on cells and tissues.	Crystallographic studies of biochemical compounds.
	Effects on growth and regeneration.	X-ray structure studies of cells and tissues.
	Therapeutic applications.	Radiography.
	Induction of genetic changes.	

Table IB. Biophysics as seen by a biologist, a physicist's publisher, a biologist's publisher and a librarian

*A BIOLOGIST**	*AMERICAN INSTITUTE OF PHYSICS*	*BIOSCIENCE RESEARCH*	*LIBRARY OF CONGRESS*
A. Molecular Biology (a) Aging; (b) Memory, Behavior and Learning. Nerve network or macromolecules, or both. (c) Macromolecular Synthesis and Function. Enzyme action, DNA denaturation, renaturation and replication, sequence of units, Genetic Code.	BIOPHYSICS 6.50.10. General 6.50.15. Molecular Biophysics *(See also 3.30. Macromolecules)* *(For Structure of Biologically Active Solids, Use 5.10.70)* 6.50.20. Cellular Biophysics 6.50.25. Biotransport and Membrane Physics *(See also 3.40.60.30 Membrane Processes)* 6.50.30. Biothermics and Bioenergetics 6.50.35. Bioelectricity 6.50.40. Biosystems and Control Communications 6.50.50. Bioacoustics	*BIOPHYSICS* Biocybernetics Bioenergetics: Electron Transport and Oxidative Phosphorylation Bioengineering General Biophysical Studies General Biophysical Techniques Membrane Phenomena Molecular Properties and Macromolecules	*BIOLOGICAL PHYSICS* *see also* Absorption (Physiology) Biomedical Engineering Cells Electronics in Biology Fatigue Homeostasis Medical Electronics Radio Biology Rheology (Biology) Molecular Physiology
B. Ecology (a) Evolution and population genetics. (b) Population Dynamics.		*GENERAL BIOLOGY* Bibliography Information, Documentation, Retrievel and Computer Applications	*Biomathematics* *see also* Biometry Genetics - Mathematical Models Information Theory in Biology
C. Control Systems and Rhythmic Phenomena in Biology, Model Building and Compartmental Analysis.		*MATHEMATICAL BIOLOGY AND STATISTICAL METHODS*	*Biomechanics* *see* Human Engineering
D. Assembly of Subunits into Functional Units. (a) Cellular. (b) Subcellular.		*PLANT PHYSIOLOGY, BIOCHEMISTRY AND BIOPHYSICS* Apparatus and Methods Bioluminescence Electric, Magnetic and Gravitational Phenomena Growth, Differentiation Photosynthesis Radiation Effects (includes Light Effects) Temperature	
E. Photosynthesis, Bioluminescence and Radiation Biophysics, (Radiation Radiation Biophysics, (Radiation Damage and Heredity; Simulatory Effects of Radiations).	Physiological and Psychological Optics 6.50.70.10. General 6.50.70.20 Optics and Physiology of the Eye 6.50.70.30. Color Perception 6.50.70.90. Other Topics in Physiological Optics Health Physics *(See also 2.80.80. Radiation Technology)* 6.50.80.10. General 6.50.80.20. Biological Effects of Radiation 6.50.80.30 Radiation Protection 6.50.80.40 Dosimetry 6.50.80.60. Pollution Detection and Control 6.50.80.90. Other Topics in Health Physics	*RADIATION BIOLOGY* General Plant (see Plant Physiology, Biochemistry and Biophysics) Radiation Effects and Protective Measures Radiation Health (see Public Health) Radiation and Isotope Techniques Space Radiation (see Aero-Space and Underwater Biological Effects)	
F. Physiology (a) Cellular; (i) Functioning of Cell; (ii) Membrane, structure and transport; (iii) Origin and Conduction of impulses in nerve cell; (iv) Muscles. (b) Organs; (i) Individual (kidney; ear; heart, electrocardiogram and signal analysis; blood flow; tongue and taste; nose and smell). (ii) Eye and Pattern recognition.	Biomedical Engineering 6.50.85.10. General 6.50.85.20. Bioresearch Instrumentation and Methods 6.50.85.30. Patient Care and Treatment 6.50.85.40 Prosthetics		
G. Evolution and Origin of Life; Physical Foundations; Artificial Synthesis of Cell.	6.50.85.30. Patient Care and Treatment 6.50.85.40. Prosthetics 6.50.85.50. Diagnotic Instrumentation and Methods 6.50.85.90. Other Topics in Biomedical Engineering 6.50.90. Other Topics in Biophysics		
H. Anatomy and Taxonomy.			
* *Private Communication*			

Table II. Biological Physics

A. Subdivisions based on level of biological organization

1. Quantum / Molecular Biophysics
2. Membrane / Transport Biophysics
3. Cellular Biophysics
4. Bioenergetics
5. Biocybernetics

B. Subdivisions based on classical divisions of physics

1. Biomechanics
2. Biophysical Electromagnetics (Non-ionizing)
3. Radiation Biophysics (Ionizing / Charged Particles)
4. Biophysical Thermodynamics
5. Biophysical Rheology
6. Perceptual Biophysics
   - Biooptics
   - Bioacoustics
   - Psychological Physics
7. Theoretical Biophysics
8. Solid State Biophysics

C. Subdivisions based on research techniques

1. Biophysical Instrumentation / Techniques
2. Mathematical / Statistical / Computational Biophysics

in fact provide the most natural description since such methods were developed in contexts quite different from those in biology. The extraordinary degree of interaction between various components of biological systems makes it unnatural for the methods of modern theoretical physics which for the most part were developed for the lowest structural level of physical phenomena, where the statistical rules describing interactions appear to be more straightforward than in biological systems. Attempts so far to deduce biological behavior starting from the basic laws developed to describe the lowest structural level physical phenomena, have not impressed biologists. Thus there is plenty of opportunity for physicists to attempt the development of methods for the natural descriptions of biological systems and then to show that they are also consistent with the more traditional methods of physics.

The situation here is reminiscent of the early years of quantum mechanics when competing representations of it were developed in different situations and their equivalence was shown only much later. It is suggested that the language of theoretical physics may yet have to evolve the natural dialect that will facilitate the description of biological systems.

Organization of this Resource Letter. In preparing this Resource letter, we attempted to emulate the style established by the Committee on Resource Letters of the American Association of Physics Teachers. This resource letter is particularly intended for students and we hope that it will be useful. Our objective is to make as much of the literature as possible available to the reader. This is our justification for printing tables of contents of yearbooks and review journals.

Section II will summarize the principal journals publishing articles of interest in biological physics and note the primary emphasis of each. In Section III fundamental references and monographs will be summarized in four categories: review journals and topical yearbooks; topical books and conference proceedings; reference books and resource materials; and data compilations. Section IV will deal with textbooks at the elementary or general, advanced undergraduate, and graduate levels.

Where appropriate in Sections III and IV we shall use the following indicators of approximate level of sophistication of materials cited.

P = Popular reading, non-technical
E = Freshman liberal arts through sophomore physics and biology
I = Junior and senior level
A = Mainly graduate
R = Rearch Monographs

The categorization of materials as given in the table of contents, is based generally on the Library of Congress scheme as any reasonable subdivision, e.g. by subject content, yielded superfluous fragmentation. The entries are alphabetical by title within each subdivision.

In Section V we will note the areas of current research activity in American universities. This section surveys in a tabular form the graduate training and research programs as determined from the responses to a general letter that we sent out to the various departments as well as from other sources. Finally in Section VI professional organizations/societies relevent to the interests of those working in the area of biological physics will be noted.

Acknowledgement

We acknowledge the cooperation of the staff of the Virginia Polytechnic and State University Library and particularly that of Mr. Saktidas Roy.

II. JOURNALS AND PERIODICALS

Table III lists a selection of the principle journals and periodicals of interest in biological physics arranged according to function and emphasis.

TABLE III

Review Periodicals

1. Quarterly Reviews of Biophysics
2. Reviews of Modern Physics

Primarily Pedagogical

3. Journal of Biological Physics
4. American Journal of Physics

Research Journals, General

5. Biophysical Society Abstracts
6. Biophysical Journal
7. Biophysics
8. Biophysik
9. Dolklady Biophysics

Research Journals, Topical

Cells

10. Cytobios
11. Experimental Cell Research
12. The Journal of Cell Biology

Molecular Biology

13. Journal of Molecular Biology
14. Molecular Biology

Bioelectromagnetics

15. Photochemistry and Photobiology
16. Photophysiology

Techniques and Instrumentation

17. Journal of Experimental Biology
18. Journal of Ultrastructure Research
19. IEEE Transactions on Bio-Medical Engineering

Theoretical

20. Journal of Theoretical Biology

Mathematical/Computational/Statistical

21. The Bulletin of Mathematical Biophysics
22. Mathematical Biosciences

Radiation Physics

23. Health Physics
24. Journal of Membrane Biology

The comments that follow each of the publications cited in Table III are generally condensed or paraphrased versions of the editorial statements taken from the publications being cited. We hope that this will give a useful overview of the state of the archival literature in biological physics which, at present, is quite widely difused — often at great dilution — among a large number of publications. The threshold concentration of biological physics content which qualified a publication for citation here is not defined. Many items occur as occasional articles in several other publications not mentioned.

Because of the special stature and relevance of review articles, the table of one review periodical are explicitly displayed.

1. QUARTERLY REVIEWS OF BIOPHYSICS

(Cambridge University Press, England)

Official publication of the International Union for Pure and Applied Biophysics.

TABLE OF CONTENTS

VOL. 1

No. 1 1. New looks and outlooks on physical enzymology, *M. Eigen.* 2. Regulations in macromolecules as illustrated by haemoglobin, *J. Wyman.* 3. The relation of microscopic structure to molecular structure, *J. D. Bernal.* 4. Modification of specular reflexion and light transmission by biological surface structure, *C. G. Bernhard, G. Gemne and A. R. Moller.* 5. A short history of the foundation of the International Union for Pure and Applied Biophysics, *A. K. Solomon.*

No. 2 1. Dynamics of membrane processes, *A. Katchalsky and R. Spangler.* 2. X-ray diffraction of muscle, *J. Hanson.*

No. 3 1. Preparative particle separation in density gradients, *N. G. Anderson.* 2. Evolution of chromosomes and viruses, derivation of structure, *R. Kilkson.*

No. 4 1. Molecular quantum mechanics in biology, *Inga Fischer-Hjalmars.* 2. Regulation of immunity at the cellular level, *H. Wigzell.* 3. The interpretation of tracer fluxes in terms of membrane structure, *H. H. Ussing.* 4. Factors influencing the polymerization of outer fibre microtubule protein, *R. E. Stephens.*

VOL. 2

No. 1 1. Biophysical contributions to membrane structure, *J. B. Finean.* 2. My image of the retina, *Maarten A. Bouman.* 3. The stereochemical code and the logic of a protein, *A. M. Liquori.*

No. 2 1. High-Voltage Electron Microscopy, *V. E. Cosslett.* 2. The Biochemical Basis of Long-Term Memory, *Richard B. Roberts and Louis B. Flexner.*

No. 3 1. From frog skin to sheep rumen: a survey of transport of salts and water across multicellular structures, *R. D. Keynes.* 2. The neglected interface: the biology of water as a liquid-gas system, *Knut Schmidt-Nielsen.* 3. Non-linear transport behaviour in very thin membranes, *R. Schlogl.*

No. 4 1. A new probe for reaction kinetics — the spectrum of scattered light, *Yin Yeh and R. N. Keeler.* 2. Control of muscle contraction, *Setsuro Ebashi, Makoto*

VOL. 3

No. 1 1. Mössbauer spectroscopy of haem proteins, *G. Lang.* 2. Magnetic resonance studies of enzyme-substrate complexes with paramagnetic probes as illustrated by creatine kinase, *Mildred Cohn.* 3. Physics and chemistry of spin labels, *Harden M. McConnell and Betty Gaffney McFarland.* 4. The current state of high resolution scanning electron microscopy, *A. V. Crewe.*

No. 2 1. Electrical activity of vertebrate photoreceptors, *Tsuneo Tomita.* 2. Theories of associative recall, *H. C. Longuet-Higgins, D. J. Willshaw and O. P. Buneman.*

No. 3 1. The active transport of ions in plant cells, *E. A. MacRobbie.* 2. The universal RNA genetic code, *C. T. Caskey.* 3. Evolution of higher-organism DNA, *David E. Kohne.*

No. 4 1. Microcalorimeters, *Ingemar Wadsö.* 2. The technique of thermal measurements in excitable tissues, *J. V. Howarth.*

VOL. 4

No. 1 1. Hypochromism, *M. Weissbluth.* 2. The coupling between energy-yielding and energy-utilizing reactions in mitochondria, *E. C. Slater.*

Nos. 2 & 3 1. Primordial organic chemistry and the origin of life, *Cyril Ponnamperuma.* 2. Biological order, structure and instabilities, *I. Prigogine and G. Nicolis.* 3. Molecular self-organization and the early stages of evolution, *Manfred Eigen.* 4. An approach to the experimental analysis of precellular evolution, *S. Spiegelman.* 5. Physical theories of biological coordination, *H. H. Pattee.* 6. Aspects on gravity-induced movements in plants, *Anders Johnsson.*

No. 4 1. Structure of water, *E. Forslind.* 2. Coupling of quanta, electrons, fields, ions and phosphorylation in the functional membrane of photosynthesis. Results by pulse spectroscopic methods, *H. T. Witt.*

VOL. 5

No. 1 1. The peripheral auditory apparatus, *B. M. Johnstone and P. M. Sellick.* 2. Coding of sounds in lower levels of the auditory system, *Aage R. Moller.*

No. 2 1. Modification of memory systems: some neurobiological aspects, *James L. McGaugh, Steven F. Zornetzer, Paul E. Gold and Philip W. Landfield.* 2. Ion transport across thin lipid membranes: a critical discussion of mechanisms in selected systems, *D. A. Haydon and S. B. Hladky.*

No. 3 1. Image intensification applied to biological problems, *George T. Reynolds.* 2. Microspectrophotometry of visual pigments, *Stanley D. Carlson.* 3. Antibody-induced conformational changes in proteins, *Franco Celada and Roberto Strom.*

No. 4 1. The theory of multi-stationary state transitions and biosynthetic control processes, *B. H. Lavenda.* 2. Recent advances and applications of diffuse X-ray small angle scattering on biopolymers in dilute solutions, *O. Kratky and I. Pilz.*

2. REVIEWS OF MODERN PHYSICS

American Physical Society (American Institute of Physics, New York)

Review articles in all areas of physics. A special issue devoted to Biological Physics. Also includes listings of tables of contents of other physics review journals.

3. JOURNAL OF BIOLOGICAL PHYSICS

(University Publications, Blacksburg, Virginia)

Solicits articles discussing significant and interesting problems in biological physics for the purpose of stimulating interest of students in biological physics. Directed principally to the physics community, four types of articles are published: Research articles emphasizing the applications and use of experimental and/or theoretical methods of physics, Review articles which critically and extensively examine the literatures on topics of interest to the biological physics community, and graduate students of physics who may be preparing to venture into the interdisciplinary area of biological physics, and Resource articles which emphasize either specific topics or collect summaries and critically evaluate specific data.

4. AMERICAN JOURNAL OF PHYSICS

American Association of Physics Teachers (American Institute of Physics, New York)

Devoted to the instructional and cultural aspects of physical science. Includes occasional topics in biological physics. e.g.: Volume 40 (1972) has the following articles: (1) Introduction to the Thermodynamics of Biopolymer Growth, *C. Kittel* (p. 60); (2) Illustrating Key Problems that Can Lead Towards a Quantitative Physical Biology, *A. S. Iberall* (p. 902); Another Biophysics Course, *J. Glass and G Graf* (p. 471); Analog Computer Solution of the Electrodiffusion Equation for a Simple Membrane, *R. J. Onega* (p. 390).

5. BIOPHYSICAL SOCIETY ABSTRACTS

The Biophysical Society (Rockefeller University Press, New York)

Contains abstracts of papers presented at Biophysical Society meetings.

6. BIOPHYSICAL JOURNAL

The Biophysical Society (Rockefeller University Press, New York)

Official publication of the Biophysical Society.
The aim of the Society is to provide a journal with the most discriminating standards of excellence in all aspects of biophysics. All responsible for its development desire that the Biophysical Journal become the standard medium of communication for biophysicists of both biophysical and physical orientation with broad diversity of interests.

7. BIOPHYSICS

(Pergamon Press, New York)

Cover-to-cover translation from Russian of Biofizika.

8. BIOPHYSIK

(Springer-Verlag, Berlin, Germany)

Publishes the results of experimental and theoretical studies on a broad range of topics in biological physics and seeks to provide a vehicle for European and international cooperation in all the subsidiary areas of biophysics and to encourage scientific contacts between biophysicists, molecular biologists, radiobiologists and medical research workers. Also publishes review articles from time to time.

9. DOKLADY BIOPHYSICS

Academy of Sciences of the USSR (Consultants Bureau, New York)

Translation from Russian of the Biophysics section of the proceedings of the academy of Sciences of the USSR.

10. CYTOBIOS

(The Faculty Press, Cambridge, England)

Publishes original investigations into all aspects of cell organization, including studies on extra-cellular products and on subcellular organelles. Emphasizes work at chemical and molecular levels.
CYTOBIOS has a companion publication entitled MICROBIOS. It is intended that together they will make an increasingly important contribution to biomedical knowledge.

11. EXPERIMENTAL CELL RESEARCH

(Academic Press, New York)

Includes all aspects of cell biology, from the molecular level to the level of cell-interaction and differentiation. Scope includes physical and chemical aspects of cellular and intercellular structure, biosynthesis with reference to cell growth, reproduction and differentiation, mechanism of meiosis and mitosis, cell cycles, membrane function, motility, interactions between cells in tissues or in culture, modulations in cultured cells, environmental relations and adaptations, interactions between genome and cytoplasmic factors, functional role of subcellular particles, energetic aspects of cell structure and function, control and regulation of cellular processes.

12. THE JOURNAL OF CELL BIOLOGY

(Rockefeller University Press, New York)

(Formerly, The Journal of Biophysical and Biochemical Cytology) Publishes reports or original observations on the behavior, structure, and function of cells and cell products. Manuscripts that attempt to correlate the findings of the biophysical and biochemical disciplines with physiological and morpholgical information are solicited. Comprehensive and timely review articles are also invited.

13. JOURNAL OF MOLECULAR BIOLOGY

(Academic Press, New York)

Publishes papers on the nature, production and replication of biological structure at the molecular level, and its relation to function. Suitable subjects are sub-cellular organization, molecular genetics, structure and replication of viruses, molecular structure of muscle, nerve and other tissues, structure of proteins, nucleic acids, carbohydrates, liquids etc., and their synthetic analogues, as investigated by X-rays, light absorption and other methods, problems of inter- and intra-molecular energy transfer.

14. MOLECULAR BIOLOGY

(Consultants Bureau, New York)

Translation from Russian of the Academy of Sciences of the USSR publication Molekulyarnaya Biologiya.

15. PHOTOCHEMISTRY AND PHOTOBIOLOGY

(Pergamon Press, New York)

Original papers, reviews and notes in all branches of photobiology and papers in the photochemistry of substances of interest to photobiologists. The optical properties of matter and of biological systems from ultraviolet to infrared spectra. Papers concerning ionizing radiation are discouraged here.

16. PHOTOPHYSIOLOGY

(Academic Press, New York)

Defines photophysiology as the physiology of action of non-ionizing radiations (ultraviolet visible and infrared) upon living things. The focus is upon the fundamental mechanisms by which non-ionizing radiations affect the living cell, at the molecular level.

17. JOURNAL OF EXPERIMENTAL BIOLOGY

(Cambridge University Press, England)

Publishes experimental papers in all areas of biology. Official publication of the Society for Experimental Biology.

18. JOURNAL OF ULTRASTRUCTURE RESEARCH

(Academic Press, New York)

Publishes papers dealing with the ultrastructural organization of biologic material as analyzed by means of electron microscopy, X-ray diffraction techniques, X-ray microscopy, and polarization optical analysis. Includes papers dealing with techniques and instruments which are of importance for the development of this field. The field covered by the journal extends from the structure of molecules which are of biologic interest to the level of cell and tissue organization at the limit of the range of light microscopy, with emphasis on electron microscopy.

19. IEEE TRANSACTIONS ON BIO-MEDICAL ENGINEERING

The IEEE Engineering on Medicine and Biology Group (Institute of Electrical and Electronics Engineers, Inc., New York)

Promotes the application of the concepts and methods of the physical and engineering sciences to biology and medicine.

20 JOURNAL OF THEORETICAL BIOLOGY

(Academic Press, New York)

Theoretical work in all fields of biology. Appropriate subjects include: generalized theories; theories of specific processes or phenomena, e.g. crossing over, learning, active transport, photosynthesis, carcinogenesis; theoretical discussion of specific projects, e.g. selective mutation, drug design, electronic models; theoretical discussion of methods, e.g. cytochemical methods and instrumentation, amplification techniques. Inclusion of new experimental work will be permitted where this is essential to a theoretical discussion.

21. THE BULLETIN OF MATHEMATICAL BIOPHYSICS

(Mathematical Biophysics, Inc.)

Devoted to publication of research that contributes to the physicomathmatical foundations of biology in their most general scope. Includes physicomathmatical theories as well as any other mathematical treatments of biological phenomena, with the exception of purely statistical studies; mathematical studies in physics or in borderline fields in which a direct connection with biological problems is pointed out; description and discussion of experimental work provided that description or discussion is made in close connection with mathematical developments contained in the same paper.

22. MATHEMATICAL BIOSCIENCES

(American Elsevier, New York)

Publishes explorations in the fields of biology and medicine utilizing methods of mathematics and physics. Also considers applications to biomedical problems of the power of modern mathematics and computers in conjunction with experimentation.

23. HEALTH PHYSICS

(Pergamon Press, New York)

Official journal of the Health Physics Society. Publishes manuscripts concerning original research in radiation, radiological and nuclear physics, dosimetry, internal dose, waste disposal, ecology, radiobiology, etc. and applied and developmental work (monitoring techniques, air sampling, administrative procedures, exposure data, accident evaluations, etc.).

24. JOURNAL OF MEMBRANE BIOLOGY

(Springer-Verlag, New York)

An international journal for studies on the structure, function and genesis of biomembranes and on the physics and chemistry of artificial membranes. Biomembrane models and general considerations of two-dimensional biological structures, including transport, electronic and cybernetic phenomena.

Note added in the proof: The following additional biophysical journals were added after the above list had been compiled.

BIORHEOLOGY

International Society of Biorheology (Pergamon Press, New York)

Studies of deformation and flow of biological systems or of materials directly derived from living organisms.

JOURNAL OF BIOENERGETICS

(Plenum Press, New York)

Papers from a wide variety of fields including biochemistry, biophysics, X-ray crystallography, quantum chemistry, solid-state physics, photochemistry and photobiology provided that the articles are relevant to biological energy transduction.

ANNALS OF BIOMEDICAL ENGINEERING

The Biomedical Engineering Society (Academic Press, New York)

Includes articles on bioinstrumentation and modeling of biological systems.

JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA

The Acoustical Society of America (American Institute of Physics, New York)

Classification of subjects includes physiological and psychological acoustics and bioacoustics.

JOURNAL OF THE OPTICAL SOCIETY OF AMERICA

The Optical Society of America (American Institute of Physics, New York)

Experimental or theoretical investications of optical phenomena including physiological optics and vision.

MEDICAL AND BIOLOGICAL ENGINEERING

(Pergamon Press, London, England)

Promotes the exchange of information between the medical and biological sciences on the one hand, and the engineering and physical sciences on the other.

JOURNAL OF BIOMECHANICS

(Pergamon Press, London, England)

PHYSICS IN MEDICINE AND BIOLOGY

(Taylor and Francis, London, England)

III. YEARBOOKS, REFERENCE BOOKS AND SPECIALIZED MONOGRAPHS

Review Journals and Topical Yearbooks. Finding a recent review article in a yearbook is by far the most convenient method of obtaining initial bibliographic information on a subject of interest. In this section we display the tables of contents of recent *review* journals and topical yearbooks in the field of biological physics listed in Table IV. No effort was made to review the individual articles.

TABLE IV

1. Advances in Biological and Medical Physics.
2. Advances in Biophysics.
3. Advances in Radiation Biology.
4. Annual Review of Biophysics and Bioengineering.
5. Current Topics in Bioenergetics.
6. Physical Techniques in Biological Research.
7. Progress in Biophysics and Molecular Biology.
8. Progress in Theoretical Biology.

ADVANCES IN BIOLOGICAL AND MEDICAL PHYSICS

John H. Lawrence and others, Editors (Academic Press, New York)

Being published at one or two year intervals since 1948. Annual volumes containing topical monographs. Broad in scope, however these volumes tend to concentrate on topics relating to ionizing radiation.

VOL. I 1. Heavy and Radioactive Isotopes in Clinical and Experimental Medicine, *Ellsworth C. Dougherty and John H. Lawrence.* 2. Nitrogen and Carbon Isotopes: Their Application *in Vivo* to the Study of the Animal Organism, *Birgit Vennesland.* 3. The Nature and Production of Artificial Radioactivity, *Waldo E. Cohn.* 4. Fundamentals of Radioactivity and Its Instrumentation, *Robley D. Evans.* 5. Health-Physics, Instrumentation, and Radiation Protection, *H. M. Parker.* 6. The Use of Radioactive Isotopes in the Study of Iron and Hemoglobin Metabolism and the Physiology of the Erythrocyte, *P. F. Hahn.* 7. Radioactive Phosphorus: Its Application to the Study of Phospholipid Metabolism, *I. L. Chaikoff and D. B. Zilversmit.* 8. Iodine Metabolism, *C. P. Leblond.* 9. The Effects of the Atomic Bomb Irradiation on the Japanese, *Joe W. Howland and Stafford L. Warren.* 10. Nucleic Acid Metabolism, *G. Hevesy.*

VOL. II 1. The Biological Effects of Radiations, *Howard J. Curtis.* 2. Molecular Exchange and Blood Perfusion through Tissue Regions, *Hardin B. Jones.* 3. The Application of the Carbon Isotopes to a Study of Animal Metabolism, *Charles Heidelberger.* 4. The Radioautographic Technique, *Dorothy Axelrod Heller.* 5. Carcinogenic Effects of Radiation, *Austin M. Brues.* 6. *In Vivo* Studies with Radioisotopes, *Enrique Strajman and Nello Pace.* 7. Radioactive Isotopes in Clinical Diagnosis, *Edith H. Quimby.* 8. Biophysical Approaches to Atherosclerosis, *John W. Gofman.* 9. Radioactive Sulfur and Its Applications in Biology, *Harold Tarver.*

VOL. III 1. The Dosimetry of Artificial Radioactive Isotopes, *W. V. Mayneord and W. K. Sinclair.* 2. The Kinetics of Biological Processes Special Problems Connected with the Use of Tracers, *A. K. Solomon.* 3. Antibodies as Specific Chemical Reagents, *David Pressman.* 4. Primary Ionization as a Test of Molecular Organization, *Ernest Pollard.* 5. Biological Actions of Ultrasonic Waves, *Pierre Grabar.* 6. Approaches to X-Ray Microscopy, *Paul Kirkpatrick and Howard H. Pattee, Jr* 7. Ultraviolet Microscopy and Ultraviolet Microspectroscopy, *Elkan R. Blout.*

VOL. IV 1. X-Ray Diffraction Applied to Crystalline Proteins, *David Harker.* 2. The Problem of Information Transfer from the Nucleic Acids to Proteins, *George Gamow, Alexander Rich, and Martynas Yčsa.* 3. Materials for the Biophysical and Biochemical Study of Cell Division, *Daniel Mazia.* 4. Lethal Effects of High and Low Temperatures on Unicellular Organisms, *Thomas H. Wood.* 5. Infrared Spectrometry, *Norman K. Freeman.* 6. Kinetics of Iron Metabloism, *Rex L. Huff and Oliver J. Judd.* 7. The Gross Composition of the Body, *William Siri.* 8. A Special Consideration of the Aging Process, Disease, and Life Expectancy, *Hardin B. Jones.*

VOL. V 1. Nuclear and Electron Paramagnetic Resonance and Its Application to Biology, *Power B. Sogo and Bert M. Tolbert.* 2. Action Spectroscopy, *Richard Setlow.* 3. The Genetics of Somatic Mammalian Cells, *Theodore T. Puck.* 4. Partial-Cell Irradiation, *Raymond E Zirkle.* 5. Electrical Properties of Tissue and Cell Suspensions, *Herman P. Schwan.* 6. Quantum Effects in Human Vision, *Albert Rose.* 7. Television Techniques in Biology and Medicine, *V. K. Zworykin.* 8. Studies Directed Toward the Use of Antibodies as Carriers of Radioactivity for Therapy, *William F. Bale and Irving L. Spar.* 9. Studies on Exagenous Cholesterol Metabolism in Human Atherosclerosis with the Aid of Isotopes, *Max W. Biggs.* 10. The Development and Applications of Low Level Counting, *E. C. Anderson and W. F. Libby.* 11. Radioactivity of the Human Body, *F. W. Spiers and P. R. J. Burch.*

VOL. VI 1. Ion and Water Transport in Stomach and Intestine, *Richard P. Durbin, Peter F. Curran and A. K. Solomon.* 2. Artificial and Induced Periodicity in Living Cells, *Erik Zeuthen.* 3. Radiobiological Aspects of the Induction of Lysogenie Bateria to Produce Phage with X-Ray, Gamma Ray, and Ultraviolet Radiations, *Herbert Mqreovich and Raymond Latarjet.* 4. Cell Studies with Microspectrography, *Bo Thorell.* 5. Some Aspects of the Effect of Ionizing Radiation on Tumors in Experimental Animals, *O. C. A. Scott.* 6. Fallout from Nuclear Weapons Tests, *Charles L. Dunham.* 7. Radiological Contrast Enhancing Methods, *B. Jacobson and R. Stuart Mackay.* 8. Quantitative Measurement of Regional Circulation in the Central Nervous System by the Use of Radioactive Inert Gas, *W. H. Freygang, Jr. and Louis Sokoloff.* 9. Intense Ultrasound in Investigations of the Central Nervous System, *William J. Fry.* 10. Isotopic Tracers in the Study of Diabetes, *Solomon A. Berson and Rosalyn S. Yalow.* 11. Application of Light Scattering to Biological Systems: Deoxyribonucleic Acid and the Muscle Proteins, *E. Perter Geiduschek and Alfred Holtzer.* 12. Physical and Chemical Mechanisms in the Injury of Cells by Ionizing Radiations, *Paul Howard-Flanders.*

VOL. VII 1. Genetic and Physiological Effects of the Decay of Incorporated Radioactive Phosphorus in Bacterial Viruses and Bacteria, *Gunther S. Slent and Clarence R. Fucrst.* 2. Micro X-ray Diffraction on Biological Materials, *Diege Carlström.* 3. Autoradiography with Tritium-Labeled Substances, *J. Herbert Taylor.* 4. The *Limulus* Eye as an Information Converter: Mechanisms for the Transfer of Information from the Light Image to the Optic Nerve Discharge, *Leo E. Lipetz.* 5. Physiological Effects of Nuclear Radiations on the Central Nervous System, *N. N. Livshits* 6. Some Isotopic Studies on the Distribution and Metabolism of Plasma Proteins, *David Gitlin and Charles A. Janeway.* 7. Radiation Carcinogenesis, *Lloyd W. Law.*

VOL. VIII 1. Chemical Elements of the Blood of Man in Health X-Ray Spectrochemical Studies, *John W. Gofman.* 2. Neutron Activation Analysis, *Kwan Hsu.* 3. Low Level Gamma-Ray Scintillation Spectrometry: Experimental Requirements and Biomedical Applications, *L. D. Marinelli, C. E. Miller H. A. May and J. E. Rose.* 4. Heavy Ions and Some Aspects of Their Use in Molecular and Cellular Radiobiology, *Tor Brustad.* 5. Hypothalamus and Thyroid, *P. Blanquet and J. Faure.* 6. The Origin of Life on Earth and Elsewhere, *Melvin Calvin.* 7. The Physics of Space Radiation, *Roger Wallace.* 8. Mechanisms of Carcinogenesis, *Niels Arley and Reidar Eker.*

VOL. IX 1. Some Recent Advances in Studies of the Transcription of the Genetic Message, *Thomas H. Jukes.* 2. Human Chromosomal Aberration, *H. N. Robson.* 3. Tissue Transplantation, *E. J. Eichwald.* 4. The Microbeam as a Tool in Radiobiology, *Howard J. Curtis.* 5. Electron Paramagnetic Resonance Studies of Biological Interest, *Bernard Smaller.* 6. Polarimetric Analysis of Protein Structure, *Don Ridgeway.* 7. The Analysis of Biological Similarity, *Walter R. Stahl.*

VOL. X 1. The Effects of Ionizing Radiation on the Nervous System, *H. Gangloff and O. Hug.* 2. Use of Short-Lived Nuclides in Medical Research, *Rune Söremark.* 3. Biological Effects of Laser Radiation, *Samuel Fine and and Edmund Klein.* 4. Tracer Techniques for the Study of Bone Metabolism in Man, *Göran C. H. Bauer.* 5. Elastic Reservoir Theories of the Human Circulation with Applications to Clinical Medicine and to Computer Analysis of the Circulation, *Freeman W. Cope.* 6. Implantable Cardiac Pacemakers, *George J. Haupt and Newton C. Birkhead.*

VOL. XI 1. Kinetics of Cellular Proliferation, *L. G. Lajtha and C. W. Gilbert.* 2. Energy Distribution in the Absorption of Radiation, *Harald H. Rossi.* 3. Phase Transitions in Lipids in Relation to the Structure of Membranes, *F. Reiss-Husson and V. Luzzati.* 4. Human Serum Lipoproteins and Their Interrelationships, *Alexander V. Nichols.* 5. Biological Barriers and Material Transfer, *Leslie F Nims.* 6. Role of the Swimbladder Rete of Fish in Secretion of Inert Gas and Oxygen, *T. Enns, E. Douglas and P. F. Scholander.* 7. Zone Centrifugation, *Verne N. Schumaker.*

VOL. XII 1. The Technique and Application of Freeze-Etching in Ultrastructure Research, *James K. Koehler.* 2. The Scanning Electron Microscope: Principles and Applications in Biology and Medicine, *T. L. Hayes and R. F. W. Pease.* 3. A Model of the Chromosome, *Roger G. Hart.* 4. A Systematic Approach to Kinetic Studies of Multisubstrate Enzyme Systems, *James R. Fisher and Vincent D. Hoagland, Jr.* 5. Some Biophysical Approaches to the Effects of Radiation and Their Repair (Symposium) 6. Introduction, *Cornelius A. Tobias and A. R. Gopal-Ayengar.* 7. The Excited States of DNA, *J. Eisinger, M. Guéron, and R. G. Shulman.* 8. Some Observations on the Effects of Ionizing Radiation on the Metabolism of DNA in Animal Tissues, *L. A. Stocken.* 9. Migration of Radiation Damage in DNA, *B. B. Singh.* 10. Cellular Repair Processes: Survival of Irradiated Yeast, Bacteria, and Phages under Different Postradiation Conditions, *V. I. Korogodin, Yu. G. Kapultcevich, M. N. Myasnik, V. F. Mosin and V. V. Gridnew.* 11. Radiation Sensitivity in Relation to the Physiological State of Yeast Cells, *W. Pohlit.* 12. Photoreactivation of Mutation and Killing in *Escherichia coli, Sohei Kondo and Takesi Kato.* 13. Genes That Control DNA Repair and Genetic Recombination in *Escherichia coli, Paul Howard-Flanders.* 14. Suppressors and Suppressible Mutations in Yeast, *Robert K. Mortimer and Richard A. Gilmore.* 15. The Probable Role of the Cytoplasm in Radiobiology, *Maurice Errera.* 16. Genetic Repair Phenomena and Dose-Rate Effects in Animals, *F. H. Sobels.* 17. Random Factors in the Survival Curve, *Albrecht M. Kellerer and Otto Hug.*

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ADVANCES IN BIOPHYSICS

Masao Kotani, Editor (University of Tokyo Press, Tokyo and University Park Press, Maryland)

Each paper is intended to present systematically an overall account of an author's work on a specified subject in such a way as to be understandable to interested readers in a wide circle, who do not necessarily specialize in biophysics, without the necessity of their referring to other papers by the author and others. Pertinent background information and short reviews of related studies by other scientists will be included.

VOL. I 1. The Lateral-Line Organ of Shark as a Chemoreceptor, *Yasuji Katsuki, Toru Hashimoto and Keiji Yanagisawa.* 2. Ribonuclease T_1 — Structure and Function, *Kenji Takahashi, Tsuneko Uchida and Fujio Egami.* 3. Polymerization of Flagellin and Polymorphism of Flagella, *Sho Asakura.* 4. Spin Changes in Hemoproteins, *Tetsutaro Iizuka and Takashi Yonetani.*

VOL. II 1. Phase Transition in Membrane with Reference to Nerve Excitation, *Yonosuke Kobatake, Ichiji Tasaki and Akira Watanabe.* 2. One-Electron and Two-Electron Transfer Mechanisms in Enzymic Oxidation-Reduction Reactions, *Isao Yamazaki.* 3. The Electrogenic Sodium Pump, *Kyozo Koketsu.* 4. Structure of Tropomyosin and Its Crystal, *Tatsuo Ooi and Sugie Fujime-Higashi.* 5. Stochastic Theory of Reaction Kinetics, *Ei Teramoto, Nakako Shigesada, Hisao Nakajima and Koji Sato.*

VOL. III 1. Quasi-elastic Scattering of Laser Light — A New Tool for the Dynamic Study of Biological Macro-molecules, *Satoru Fujime.* 2. Actions of Transmitter Substances on the Neuromuscular Junctions of Vertebrates and Invertebrates, *Akira Takeuchi and Noriko Takeuchi.* 3. Some Theoretical Studies on Hemorheology, *Syoten Oka.* 4. Primary Processes of Insect Chemoreception, *Hiromichi Morita.* 5. Characteristics of the Excitable *Chara* Membrane, *Uichiro Kishimoto.* 6. Evolution of Cytochrome *c* Molecule, *Tatco Yamanaka.*

VOL. IV 1. Electronic Structure of Nucleic Acid Bases: Their Spectroscopic Properties, Chemical Reactivities and Biological Activities, *C. Nagata, A. Imamura and M. Fujita.* 2. Ca Spike, *S. Magiwara.* 3. Gustatory Receptor Mechanism in Mammals, *M. Sato.* 4. Tension at the Surface of Sea Urchin Eggs on the Basis of 'Liquid-Drop' Concept, *M. Yoneda.* 5. Genetic Study on Transfer RNA, *Y. Shimura and M. Ozeki.*

ADVANCES IN RADIATION BIOLOGY

Leroy G. Augenstein, Ronald Mason and Max Zelle, Editors (Academic Press, New York)

VOL. I 1. Recent Research on the Radiation Chemistry of Aqueous Solutions, *Harold A. Schwarz.* 2. Physical Mechanisms in Photosynthesis, *Gordon Tollin.* 3. Effects of Intracellular Irradiation with Tritium, *Donald E. Wimber.* 4. Effects of Small Doses of Ionizing Radiations, *Arne Forssberg.* 5. The Radiation Chemistry of Amino Acids, *J. Liebster and J. Kopoldová.* 6. The Relative Roles of Ionization and Excitation Processes in the Radiation Inactivation of Enzymes, *Leroy G. Augenstein, Tor Brustad, and Ronald Mason.*

VOL. II 1. Reactivation after Photobiological Damages, *Claud S. Rupert and Walter Harm.* 2. The Study of Labile States of Biological Molecules with Flash Photolysis, *Leonard I. Grossweiner.* 3. Repair of Premutational Damage, *R. F. Kimball.* 4. The Genetic Control of Radiation Sensitivity in Microorganisms, *Howard I. Adler.* 5. Physical Approach to the Visual Receptor Process, *Barnett Rosenberg.* 6. The Role of Genetic Damage in Radiation-Induced Cell Lethality, *D. R. Davies and H. J. Evans.*

VOL. III 1. Low Energy Electron Mean Free Paths in Solids, *R. H. Ritchie, F. W. Garber, M. Y. Nakai and R. D. Birkhoff.* 2. The Molecular Biology of Photodynamic Action: Sensitized Photoautoxidations in Biological Systems, *John D. Spikes and Robert Livingston.* 3. Sensitization of Organisms to Radiation of Sulfhydryl-Binding Agents, *Bryn A. Bridges.* 4. Biological Effects of Radioactive Decay: The Role of Transmutation Effect, *Robert E. Krisch and M. R. Zelle.* 5. Human Radiation Cytogenetics, *Michael A. Bender.* 6. Reflections on Some Recent Progress in Human Radiobiology, *C. C. Lushbaugh.*

ANNUAL REVIEWS OF BIOPHYSICS AND BIOENGINEERING

Manuel F. Morales, Editor (Annual Reviews Inc., California)

This series came into being because the Biophysical Society (US) sought to give its teachers and students the "essence" of modern biophysics, and so to help them find identity and training. Accordingly, this series is frankly didactic, and not merely a report to peers.

The marriage of "Biophysics and Bioengineering" in one review is intended to nurture major developments conceived, in an engineering context as it is often "engineering" which translates the fruits of physics into services to mankind.

VOL. I & II CONCEPTUAL AND PHYSICAL TOOLS FOR ANALYSIS

Mathematical Techniques: 1. Some Ideals and Prospects in Biomathematics, *S. M. Ulam.* 2. Interactive Computer Graphics and Representation of Complex Biological Structures, *L. Katz and C. Levinthal.* 3. Scope, Impact, and Status of Packaged Statistical Programs, *W. J. Dixon and R. I. Jennrich.* 4. Interpretation of Some Microelectrode Measurements of Electrical Properties of Cells, *A. Peskoff and R. S. Eisenberg.* 5. Clustering, *J. A. Hartigan.* 6. Toward Direct Brain-Computer Communication, *J. J. Vidal.*

Techniques for Characterizing Atoms, Molecules, Associations, and Processes Occurring Among Them: 1. Catalytic Configurations, *R. Henderson and J. H. Wang.* 2. Nuclear Magnetic Resonance Studies of the Dynamic Aspects of Molecular Structure and Interactions in Biological Systems, *B. D. Sykes and M. D. Scott.* 3. Physical Procedures for the Separation of Animal Cells, *K. Shortman.* 4. Quasi-Elastic Light Scattering from Macromolecules, *R. Pecora.* 5. Neutron Scattering, *B. P. Schoenborn and A. C. Nunes.* 6. Uses of Fluorescence in Biophysics: Some Recent Developments, *G. Weber.* 7. Structure and Symmetry of Oligomeric Enzymes, *B. W. Matthews and S. A. Bernhard.*

Techniques for Characterizing Organs, Organ Systems, and Organisms: 1. Monitoring of Physiological Data in a Clinical Environment, *R. M. Gardner.* 2. Electric and Magnetic Field of the Heart, *D. B. Geselowitz.* 3. Technology of Multiphasic Patient Screening, *M. F. Collen and J. F. Terdiman.*

PARTICULAR CONSTITUENTS, ASSEMBLIES AND RELATIONS AMONG THEM

Naturally Occurring Assemblies: 1. Plasticity of Biological Membranes, *C. Gitler.*

Relational Features: 1. Conformational Analysis of Biopolymers: Conformational Energy Calculations, *D. A. Brant.* 2. Long-Range Physical Forces in the Biological Milieu, *V. A. Parsegian.*

MOLECULAR MECHANISMS UNDERLYING PROCESSES THAT OCCUR IN CELLS OR AMONG CELLS

Gene Expression: 1. Control of Developing Fields, *A. Robertson and M. H. Cohen.*

Transport: 1. Active Transport of Calcium Ion in Sarcoplasmic Membranes, *G. Inesi.*

Excitation: 1. The Mechanism of Signal Transmission in Nerve Axons, *G. Ehrenstein and H. Lecar.* 2. Molecular Mechanism of Contraction, *Y. Tonomura and F. Oosawa.* 3. Biophysics of Fingellar Motility, *J. J. Bluia and J. Lubliner.*

Interaction with Radiation: 1. The Visual Process, *W. A. Hagins.* 2. Effects of Radiation on Polynucleotides, *R. B. Setlow and J. K. Setlow.* 3. Primary Processes in Bacterial Photosynthesis, *R. K. Clayton.*

PROPERTIES AND REACTIONS OF ORGANS, ORGAN SYSTEMS, AND ORGANISMS

Dynamics of Systems of Interacting Elements: 1. Optimization of the Mammalian Respiratory Gas Transport System, *F. S. Grodins and S. M. Yamashiro.*

Special Aspects of Natural and Artificial Organ Systems: 1. Linear Analysis of the Dynamics of Neural Masses, *W. J. Freeman.* 2. Frequency Dynamics of Peripheral Vascular Blood Flow, *E. O. Attinger and F. M. Attinger.*

CURRENT TOPICS IN BIOENERGETICS

D. Rao Sanadi and Lester Packer, Editors (Academic Press, New York)

Topical volumes being published at one or two year intervals since 1966.

VOL. I 1. Kinetics and Intermediates of the Oxygen Evolution Step in Photosynthesis, *Bessel Kok and George M. Cheniae.* 2. Fluorescence Yield in Photosynthetic Systems and Its Relation to Electron Transport, *Warren L. Butler.* 3. Uncoupling and Energy Transfer Inhibition in Photophosphorylation, *Norman Good, Seikichi Izawa and Geoffrey Hind.* 4. The Chemistry of Bioluminescence, *J. W. Hastings.* 5. Structure and Function of the Contracile Protein Myosin, *A. Stracher and P. Dreizen.* 6. Energized Calcium Transport and Relaxing Factors, *Annemarie Weber.* 7. Ion Transport to Mitochondria, *E. J. Harris, J. D. Judah and K. Ahmed.*

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Synthesis in Nuclei, *Thomas E. Conover.* 8. The Oscillation of Insect Flight Muscle, *R. T. Tregear.* 9. Contractile Mechanisms in Cilia and Flagella, *Michael Holwill.* 10. Genesis of the Cochlear Endolymphatic Potential, *Brian M. Johnstone.*

VOL. III 1. A Scrutiny of Mitchell's Chemiosmotic Hypothesis of Respiratory Chain and Photosynthetic Phosphorylation, *G. D. Greville.* 2. Electron Transfer and Energy Conservation, *Robert J. P. Williams.* 3. Translocators in Bimolecular Lipid Membranes: Their Role in Dissipative and Conservative Bioenergy Transductions, *Paul Mueller and Donald O. Rudin.* 4. Energy Relationships and the Active Transport of Ions, *Peter C. Caldwell.* 5. Energy Utilization and Oxidative Recovery Metabolism in Skeletal Muscle, *Frans F. Jobsis.* 6. The Mechanism of the Visual Process, *Sjoerd L. Bonting.* 7. Energy Transduction in Algal Phototaxis, *Gordon Tollin.*

VOL. IV 1. Nonequilibrium Thermodynamics and Its Application to Bioenergetics, *S. Roy Caplan.* 2. The Design and Use of Fluorescent Probes for Membrane Studies, *G. K. Radda.* 3. Energy Transformations in the Respiratory Chain, *V. P. Skulachev.* 4. Profiles of Mitochondrial Monovalent Ion Transport, *Cyril L. Moore.* 5. Coupling of Ion and Electron Transport in Chloroplasts, *Richard A. Dilley.* 6. Energy Conversion Reactions in Bacterial Photosynthesis, *Herrick Baltscheffsky, Margareta Baltscheffsky and Anders Thore.* 7. Electrogenic Ion Pumping in Nervous Tissue, *J. Murdoch Ritchie.* 8. Sequence of Steps in the (Na + K)-Activated Enzyme System in Relation to Sodium and Potassium Transport, *J. C. Skou.*

VOL. V 1. X-Ray Diffraction Studies on Biological Membranes, *C. R. Worthington.* 2. Chlorophyll and Light Energy Transdution in Photosynthesis, *Joseph J. Katz and James R. Norris, Jr.* 3. Chemically and Physically Induced Luminescence as a Probe of Photosynthetic Mechanisms, *Darrell E. Fleischman and Berger C. Mayne.* 4. The Reducing Side of Photosystem I, *James Siedow, Charles F. Yocum and Anthony San Pietro.* 5. The Chemistry of Vertebrate and Invertebrate Visual Photoreceptors, *Edwin W. Abrahamson and Roger S. Fager.* 6. Mechanism of Actomyosin ATPase and Problem of Muscle Contraction, *Edwin W. Taylor.* 7. Energy-Transducing Components in Mitochondrial Respiration, *David F. Wilson, P. Leslie Dulton and Michal Wagner.* 8. Kinetics of Cytochromes b, *Maria Erecinska, Michal Wagner and Britton Chance.* 9. Mitochondrial Coupling Factors, *R. Brian Beechey and Kenneth J. Cattell.*

PHYSICAL TECHNIQUES IN BIOLOGICAL RESEARCH (In Six Volumes)

A. W. Pollister, Editor (Academic Press, New York)

First volume published in 1955.

VOL. I 1. Photochemistry and Luminescence, *Jerome L. Rosenberg.* 2. Light Scattering, *Gerald Oster.* 3. Absorption Spectroscopy, *C. F. Hiskey.* 4. Ultraviolet Absorption Spectrophotometry, *Jesse F. Scott.* 5. Infrared Spectrophotometry, *Carl Clark.* 6. The Light Microscope, *L. C. Martin.* 7. Phase and Interference Microscopy, *H. Osterberg.* 8. Birefringence and Diehroism, *Gerald Oster.* 9. Electron Microscopy, *V. E. Cosslett.*

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VOL. VI 1. Fundamentals of Digital and Analog Computers, *William Siler and Kenneth King.* 2. Operational Amplifiers, *John W. Moore.* 3. Analysis of Complex Waveforms, *Herbert Dern and John B. Walsh.* 4. Cable Theory, *Robert E. Taylor.* 5. Voltage Clamp Techniques, *John W. Moore and Kenneth S. Cole.* 6. Determination of Biological Impedances, *Herman P. Schwann.*

PROGRESS IN BIOPHYSICS AND MOLECULAR BIOLOGY

J. A. U. Butler and others, Editors (Pergamon Press Ltd., England; Academic Press, New York) (Formerly Progress in Biophysics and Biophysical Chemistry) Published annually since 1950.

The application of the methods of physics to the study of the characteristics of life-proteins, nucleoproteins, lipoproteins and other complex molecules of many and mostly unexplored varieties, is a study which should perhaps be strictly regarded as an aspect of biophysical chemistry. On the other hand there is the application of physical methods and instruments to the study and elucidation of living structures in the field now widely known as Molecular Biology. Mainly concerned with biological structure and function at the macremolecular level, and in relation to heredity, to protein synthesis and to muscular contraction. Critical reviews of recent progress in selected subjects which may be read with profit by many who are not experts and which will provide scientists with a general survey of recent work and ideas.

VOL. I 1. Properties of Solutions of Large Molecules, *H. Gutfreund.* 2. Fundamental Structures in Biological Systems, *K. M. Rudall.* 3. Scattering of Visible Light and X-rays by Solutions of Proteins, *G. Oster.* 4. Bioelectric Potentials, their Maintenance and Function, *E. E. Crane.* 5. Phase-contrast Microscopy in Biological Research, *A. F. W. Hughes.* 6. Local Refractometry: the Observation of Transparent Inhomogeneous Matter, *J. St. L. Philpot.* 7. Use of Soft X-rays in the Assay of Biological Materials, *A. Engstrom.* 8. The Tolerance of Man for Radioactive Isotopes, *J. F. Loutit.* 9. Mechanical Properties of Fibres and Muscles, *M. G. M. Pryor.*

VOL. II 1. Birefringence of Cytoplasm and Cell Membranes, *M. M. Swann and J. M. Mitchison.* 2. Biophysical Aspects of Polysaccharide Structure in Plants, *R. D. Preston.* 3. Physicochemical Properties of the Nucleic Acids, *D. O. Jordan.* 4. Physical Principles Underlying the Clinical Use of Radioactive Isotopes, *W. K. Sinclair and L. F. Lamerton.* 5. Biophysical Aspects of Nervous Function, *B. D. Wyke.* 6. Quantum Physics of Vision: Theoretical Discussion, *M. H. Pirenne.* 7. Electron Microscopy of Developing Bacteriophage, and other Viruses, *R. W. G. Wyckoff.* 8. Biological Actions of Ionizing Radiations, *L. H. Gray.*

VOL. III 1. Autoradiography, *I. Doniach, Alma Howard and S. R. Pelc.* 2. Polarised Ultraviolet Microspectrography and Molecular Structure, *W. E. Seeds.* 3. The Infra-red Spectrum of Biologically Important Molecules, *R. D. B. Fraser.* 4. Some Physicochemical Studies on Viruses, *Roy Markham.* 5. Mechanisms of Biological Action of Ultraviolet and Visible Radiations, *Maurice Errera.* 6. Recent Work on the Application of the Theory of the Ionic Double Layer to Colloidal Systems, *F. Booth.* 7. Microspectrometry of Living and Fixed Cells, *H. G. Davies and P. M. B. Walker.* 8. Methods of Determining the Form and Dimensions of Particles in Solution: A Critical Survey, *C. Sadron.* 9. Transport Processes and Electrical Phenomena in Ionic Membranes, *Torsen Teorell.*

VOL. IV 1. Polyelectrolyte Gels, *A. Katchalsky.* 2. The Transference of the Muscle Energy in the Contraction Cycle, *H. H. Weber and Heldegard Portzehl.* 3. The Submicroscopic Structure of Nerve Fibres, *H. Fernández-Morán.* 4. The Nucleoprotein Complex of the Cell Nucleus and its Reactions, *P. F. Davison, B. E. Conway and J. A. V. Butler.* 5. Chromosome Breakage, *P. C. Koller.* 6. The Crystalline Proteins: Recent X-ray Studies and Structural Hypothesis, *J. C. Kendrew.* 7. Facts and Theories about Muscles, *D. R. Wilkie.*

VOL. V 1. Reaction Patterns of a Coliform Organism, *A. C. R. Dean and Sir Cyril Hinshelwood.* 2. The Physical Chemistry of Haemolysis and Bacteriolysis by Surface Active Agents and Antibioties, *J. H. Schulman, B. A. Pethica and A. V. Few.* 3. The Direct Action of Ionizing Radiation on Enzymes and Antigens, *E. C. Pollard, W. R. Guild, F. Hutchinson and R. B. Setlow.* 4. Structure and Function of the Chloroplast, *J. B. Thomas.* 5. The Theory of X-ray Fibre Diagrams, *A. R. Stokes.* 6. Recent Studies on the Reversible Denaturation of Proteins, *M. Joly.*

VOL. VI 1. Protamines and Nucleoprotamines, *K. Felix, H. Fischer and A. Krekels.* 2. The Structure of Chromosomes, *E. J. Ambrose.* 3. The Donnan Equilibrium, *J. Th. Overbeek.* 4. Biology and Biophysical Properties of Transforming Principles, *Stephen Zamenhof.* 5. Biophysical Aspects of Neuro-muscular Transmission, *J. del Castillo and B. Katz.* 6. Models for Biological Excitation Processes, *U. F. Franck.* 7. Physical Aspects of the Sense Organs, *Hl. De Vries.*

VOL. VII 1. The Mechanisms of Discharge of the Electric Organs in Relation to General and Comparative Electrophysiology, *H. Grundfest.* 2. Thermodynamic Study of the Isohaemagglutinins, *R. Wurmser and S. Fillitti-Wurmser.* 3. Use of Labelled Plasma Proteins in the Study of Nutritional Problems, *A. S. McFarlane.* 4. The Use of Isotopes in the Study of Intermediary Metabolism, *H. R. V. Arnstein and P. T. Grant.* 5. The X-ray Crystal Analysis of Bone, *S. M. Clark and J. Iball.* 6. Muscle Structure and Theories of Contraction, *A. F. Huxley.* 7. Chloroplast Structure and Energy Conversion in Photosynthesis, *C. P. Whittingham.*

VOL. VIII 1. The Physiology of Hearing, *I. C. Whitfield.* 2. Human Colour Vision, *G. S. Brindley.* 3. The Electrochemistry of the Bacterial Surface, *A. M. James.* 4. Effect of Radiation on DNA Synthesis in Mammalian Cells, *L. S. Kelly.* 5. The Axon Surface, *F. O. Schmitt and N. Geschwind.* 6. The Biosynthesis of Some Connective Tissue Components, *R. H. Smith.* 7. The Ionic Permeability of the Red Cell Membrane, *I. M. Glynn.* 8. The Physical Chemistry of Deoxyribosenucleic Acid, *K. V. Shooter.* 9. The Biosynthesis of Protein, *R. B. Loftfield.*

VOL. IX 1. The Kinetics of Reactions between Haemoglobin and Gases, *Q. H. Gibson.* 2. Diffusion and Simultaneous Chemical Reaction Velocity in Haemoglobin Solutions and Red Cell Suspensions, *F. J. W. Roughton.* 3. The Hydrodynamics of the Arterial Circulation, *D. A. McDonald and M. G. Taylor.* 4. Determination of Molecular Dimensions from Light Scattering Data, *Anton Peterlin.* 5. Visual Pigments in Man and Animals and their Relation to Seeing, *W. A. H. Rushton.* 6. Mechanical into Electrical Energy in Certain Mechanoreceptors, *J. A. B. Gray.* 7. Gradient Centrifugation of Cell Particles: Theory and Application, *C. de Duve.*

VOL. X 1. The "High Energy Phosphate Bond" Concept, *P. George and R. J. Rutman.* 2. The Structure and Physical Chemistry of Nucleic Acids and Nucleoproteins, *A. R. Peacocke.* 3. Mechanisms for Enzyme-Catalysed Transfer Reactions, *S. A. Bernhard and H. Gutfreund.* 4. Oxygen Tension and Oxidation-Reduction Potentials in Living Tissues, *D. B. Cater.* 5. The Configuation

Configuration of Proteins in Solution, *E. M. Shooter.* 6 *In Vitro* Studies on the Radiation Biology of Mammalian Cells, *T. T. Puck.* 7. Thermodynamics and the Interpretation of Biological Heat Measurements, *D R Wilkie.* 8. Recent Investigations on Tobacco Mosaic Virus, *A. Gierer* 9. The Molecular Structure and Contact Relationships of Cell Membranes, *J. D. Robertson.*

VOL. XI 1. The Natural Radioactivity of the Human Body, *W. V. Mayneord.* 2. The Engineering Approach to the Problem of Neural Organization, *A. M. Uttley.* 3. Effects of X-rays on Nucleic Acid Biosynthesis and on the Activity of Nucleases in Mammalian Cells, *R. Goutier* 4. The Effect of Ionizing Radiations and Tumour-chemotherapeutic Agents on the Bone Marrow, *I. G. Lajtha.* 5. Some Factors Influencing the Dispersion of Indicator Substances in the Mammalian Circulation, *P. I. Korner.* 6. The Buoyancy of Fish and Cephalopods, *E. J. Denton.* 7. Cytoplasmic Particles and their Role in Protein Synthesis, Abstracts.

VOL. XII 1. Cell Division Synchronization, *V. W. Burns.* 2. The Nucleolus, *J L. Sirlin.* 3. Ribosomes and the Synthesis of Proteins, *K. McQuillen.* 4. Taste Receptor Stimulation, *L. M. Beidler.* 5. Quantitative Staining in Histo- and Cytochemistry, *D. Shugar.* 6. The Histones, *D. M. P. Phillips.* 7. Progress in Tritium Autoradiography, *A. Lima-de-Faria.* 8. Addendum to the Nucleolus, *J. L. Sirlin.*

VOL. XIII 1. Radiobiological Mechanisms: Comparative Distribution and Role of Ionization, Excitation, and Energy and Charge Migration, *L. G. Augenstein.* 2. The Radiation Chemistry of Aqueous Solutions of Nucleid Acids and Nucleoproteins, *G. Scholes.* 3. X-ray Small Angle Scattering with Substances of Biological Interest in Diluted Solutions, *O Kratky.* 4. Enzymatic Synthesis of Nucleid Acids, *M. Grunberg Manago.* 5. Ultrastructure and Kinetic Aspects of Solute Translocation in the Stems of Plants, *R. D Preston.* 6. The Mechanochemistry of Muscular Contraction; A Critical Revaluation of *in vivo* Studies, *F. D. Carlson.*

VOL. XIV 1. Photosynthesis, *L. N. M. Duysens.* 2. The Subcellular Localization of the "Lysosomal" Enzymes and Its Biological Significance, *G. A. Levvy and J. Conchie.* 3. Enzymatic Aspects of Active Linked Transport of Na^+ and K^+ through the Cell Membrane, *J. C. Skou.* 4. Relaxing Factor and the Relaxation of Muscle, *Wilhelm Hasselbach.* 5. The Mechanism of Action and the Active Centre of the Alcohol Dehydrogenases, *J. S. McKinley-McKee.* 6. The Physical Chemistry of Phospholipids, *D. G. Dervichian.*

VOL. XV 1. The Biosynthesis of Proteins, *P. N. Campbell.* 2. The Application of Subcellular Fractionation Techniques to the Study of Brain Function, *V. P. Whittaker.* 3. The Role of Nucleic Acids in Morphogenesis, *Jean*

Brachet. 4. Ultrastructure in Chromatin, *B. B. Hyde* 5. The Structure and Development of Animal Viruses, *D. S. Bocciarelli.* 6. X-ray Diffraction Studies on Polypeptide Conformations, *D. R. Davies.*

VOL. XVI 1. Recognition of Antigen by Cells, *N. A. Mitchison.* 2. Genetic Transcription of DNA-dependent RNA Synthesis, *A. Sibatani.* 3. Cybernetic Interactions in Epigenetics, *G. V. Sherbet.* 4. The Organization and Function of the Sarcoplasmic Reticulum and T-system of Muscle Cells, *D. R. Smith.* 5. The Molecular Organization of Cell Membranes, *J. B. Finean.* 6. Progress in High-resolution Autoradiography, *L. Caro.* 7. Molecular Genetics of Bacteria and Bacteriophages, *S. Silver.* 8. Electrophoretic Behaviour of Cells, *E. J. Ambrose.*

VOL. XVII 1. The Contractile Mechanism of Insect Fibrillar Muscle, *J. W. S. Pringle.* 2. Ribonucleic Acid and Hormonal Control of Protein Synthesis, *A. Korner.* 3. The Formation of Radicals in Nucleic Acids, Nucleoproteins, and Their Constituents by Ionizing Radiations, *A. Müller.* 4. Genes and Cellular Differentiation, *Heinrich Ursprung and Ru-Chih C. Huang.* 5. The Photochemical and Macromolecular Aspects of Vision, *E. W. Abrahamson and S. E. Ostroy.* 6. The Determination of Molecular Weights of Biological Macromolecules by Ultracentrifuge Methods, *J. M. Creeth and R. H. Pain.* 7. The Effects of Radiation on DNA Biosynthesis and Related Processes, *K. V. Shooter.* 8. The Structure and Interactions of Myosin, *S. V. Perry.*

VOL. XVIII 1. Acoustic Transmission and Transduction in the Peripheral Hearing Apparatus, *L. Naftalin.* 2. Membrane Models with Phospholipids, *A. D. Bangham.* 3. The Ionic Currents and the Nervous Impulse in Myelinated Nerve, *B. Frankenhaeuser.* 4. Information Transfer in Embryonic Development, *R. L. Brahmachary.* 5. Calcium Ion and Muscle Contraction, *S. Ebashi and M. Endo.* 6. Some Biophysical Aspects of Ultrasound, *A. R. Peacocke and N. J. Pritchard.* 7. Recent Investigations on Histones and Their Functions, *J. A. V. Butler, E. W. Johns and D. M. P. Phillips.* 8. Cell Population Kinetics in Normal and Malignant Tissues, *L. F. Lamerton and G. G. Steel.* 9. The Replication of RNA-containing Bacteriophages, *H. F. Lodish.*

VOL. XIX Part 1 1. X-ray Studies of Crystalline Proteins, *A. C. T. North and D. C. Phillips.* 2. Structure of the Ribosome, *A. S. Spirin.* 3. Punctuation in the Genetic Code in *Escherichia coli, M. S. Bretscher.* 4. Transcription and Translation in the Lactose Operon of *Escherichia coli* Studied by *in vivo* Kinetics, *A. Kepes.* 5. Synthesis of Nucleic Acids in Giant Chromosomes, *Claus Pelling.*

Part 2 1. The Changing Concept of Organism in Microbiology, *M. R. Pollock.* 2. Lymphatic Tissue Germinal Centers in Immune Reactions, *C. C. Congdon.* 3. Rectification in Muscle Membrane, *R. H. Adrian.* 4. The Excitation of Photoreceptors, *G. B. Arden.* 5. Passive Ion Permeability of the Erythrocyte Membrane, *H. Passow.*

VOL. XX 1. Three-dimensional Electrical Field Problems in Physiology, *Robert S. Eisenberg and Edward A. Johnson.* 2. Organization of the Cellular Membranes, *S. K. Malhotra.* 3. The Replication of DNA-containing Viruses, *Alan B. Stone.* 4. Nuclear Magnetic Resonance in the Study of Biophysics and Their Interaction with Ions and Small Molecules, *B. Sheard and E. M. Bradbury.* 5. Mechanisms of Enzyme Action, *S. Doonan, C. A. Vernon and Barbara E. Banks.*

VOL. XXI 1. Ionic Channels in Nerve Membranes, *Bertil Hille.* 2. Mechanism of Transmitter Release, *John I. Hubbard.* 3. The Mechanism of Photosynthesis and the Structure of the Chloroplast, *C. P. Whittingham.* 4. The Evolution of Bioenergetic Processes, *E. Broda.* 5. Structure and Evolution of Immunoglobulins, *C. Milstein and J. R. L. Pink.* 6. The Geometry of

Nucleic Acids, *Struther Arnott.* 7. The Regulation of Enzyme Activity and Allosteric Transition, *Edward Whitehead.*

VOL. XXII 1. Arterial Elasticity and Fluid Dynamics, *D. H. Bergel and D. L. Schultz.* 2. Heat Production and Chemical Change in Muscle, *R. C. Woledge.* 3. Structure of the Myosin Filament of Straited Muscle, *F. A. Pepe.* 4. Primary Sequences of Proteins and Their Evolution, *P. Jolles and Jacqueline Jolles.* 5. The Structure and Formation of Ribosomes in Animal Cells, *B. E. H. Maden.* 6. The Structure of Transfer RNA, *S. Arnott.*

VOL. XXIII 1. Nuclear Magnetic Resonance and the State of Water in Cells, *J. A. Walter and A. B. Hope.* 2. Short-lived Free Radicals in Aqueous Solutions of Biomolecules, *B. B. Singh and Cl. Nicolau.* 3. Structure and Function of DNA-dependent RNA-polymerase, *V. S. Sethi.* 4. DNA, RNA and Protein Interactions, *P. C. Huang.* 5. "Repetitive" DNA in Higher Organisms, *P. M. B. Walker.* 6. Informational Macromolecules during the Early Development of Sea Urchins, *V. Glišin and Ana Savic.*

VOL. XXIV 1. Physical Studies of Membrane Structure, *Y. K. Levine.* 2. The Physics and Biology of Animal Reflectors, *M. F. Land.* 3. Protein Volume in Solution, *A. A. Zamyatnin.* 4. The Mitochondrial Membrane System, *J. M. Palmer and D. O. Hall.* 5. Transport and Metabolism of Calcium Ions in Nerve, *P. F. Baker.*

VOL. XXV 1. Molecular Aspects of the Mammalian Cell Surface, *J. N. Mehrishi.* 2. T Cells and the Immune Response, *H. Cantor.* 3. X-Ray Studies of Crystalline Proteins, *C. C. F. Blake.* 4. Biosynthesis of Immunoglobulins, *M. J. Bevans, R. M. R. Parkhouse, A. R. Williamson and B. A. Askonas.*

VOL. XXVI 1. Divalent Cations as Charge Carriers in Excitable Membranes, *Harald Reuter.* 2. Membrane Ultrastructure at Mammalian Intercellular Junctions, *N. Scott McNutt and Ronald S. Weinstein.* 3. Water and Nonelectrolytes Permeability in Mammalian Red Cell Membranes, *R. I. Sha'afi and C. M. Gary-Bobo.* 4. Energetic Aspects of Nerve Conduction: The Relationships between Heat Production, Electrical Activity and Metabolism, *J. M. Ritchie.* 5. Glycoproteins as Components of Cellular Membranes, *R. C. Hughes.* 6. Structure and Strategy in Phage RNA, *J. Hindley.* 7. DNA Synthesis in Prokaryotes: Replication, *Douglas W. Smith.* 8. Cellular Responses to Cyclic AMP, *Mark W. Bitensky and Ronnie E. Gorman.*

PROGRESS IN THEORETICAL BIOLOGY

Academic Press (New York)

VOL. I 1. Chemical Evolution, *Melvin Calvin.* 2. Biological Self-Replicating Systems, *Harold J. Morowitz.* 3. Quantitative Aspects of Goal-Seeking Self-Organizing Systems, *Hans Bremermann.* 4. Statistical Thermodynamics of Polymerization and Polymophism of Protein, *Fumio Oosawa and Sugie Higashi.* 5. The Role of Models in Theoretical Biology, *Walter R. Stahl.*

VOL. II 1. Living Aggregates of Nonliving Parts: A Generalized Statistical Mechanical Theory, *Karl Kornacker.* 2. Theoretical Methods in Systematic and Evolutionary Studies, *G. F. Estabrook.* 3. Waves, Pulses, and the Theory of Neural Masses, *Walter J. Freeman.*

Topical Books and Conference Proceedings. In this section we cite the biological physics material sources available in the form of topical books and conference proceedings. Only specific chapters from such sources are likely to be used as text in classroom study or research. The commentary, when supplied, is intended to provide general guidance only and does *not* represent critical review of the materials.

R 1. **Biological Interfaces: Flows and Exchanges.** (Little, Brown and Company, Boston, 1968.) Proceedings of a Symposium sponsored by the New York Heart Association. Published simultaneously as a supplement to the Journal of General Physiology, 52, no. 1, pt. 2, 1968. Includes bibliographies.

R 2. **Biological Membranes.** Robert M. Dowben, Editor. (Little, Brown and Company, Boston, 1969.)

E 3. **Biology and the Physical Sciences.** Samuel Devons, Editor. (Columbia University Press, New York, 1969.) Outgrowth of a continuing symposium on the relationship between biology and the physical sciences held at Columbia University during 1965-1967. Indicates areas of biology in which physical sciences can play a role. Very general: useful as supplementary readings.

R 4. **Biomechanics.** Y. C. Fung, Editor. (American Society of Mechanical Engineers, New York, 1966.) Proceedings of a symposium sponsored by the Applied Mechanics Division of the ASME at the annual meeting of the year 1966.

G 5. **Biomedical Physics and Biomaterials Science.** Harry E. Stanley, Editor. (MIT Press, Cambridge, Mass., 1972.) Notes from a summer conference held at MIT in 1971.

R 6. **Biophysical Science, a Study Program.** John L. Oncley, Editor. (John Wiley, New York, 1960.) These selections of articles covering various topics on the forefront of research of that time were also published in the Reviews of Modern Physics, Vol. 31, Nos. 1 and 2 (1959).

G,R 7. **Biophysics and Physiology of Excitable Membranes.** William J. Adelman, Editor. (Van Nostrand Reinhold, New York, 1971.)

G,R 8. **Current Topics in Membranes and Transport** (2 volumes). Felix Bronner and Arnost Klein Zeller, Editors. (Academic Press, N.Y., 1970-1971.)

G 9. **Energy Transfer in Radiation Processes: Chemical, Physical and Biological Aspects.** Glyn O. Phillips, Editor. (Elsevier Pub Co., New York, 1966.) Proceedings.

I,G 10. **Future Goals of Engineering in Biology and Medicine.** James F. Dickson III and J. H. U. Brown, Editors. (Academic Press, New York, 1969.) Contains resource materials. Proceedings of an international conference held at Washington, D. C. in 1967.

R 11. **Gibbs Ensemble: Biological Ensemble: The Application of Statistical Mechanics to Ecological, Neural, and Biological Networks.** Edward H. Kerner, Editor. (Gordon and Breach, New York, 1972.) A reprint volume with comments by the editor.

R 12. **IEE Medical Electronics Monographs.** In six volumes. B. W. Watson, Editor. (Peter Peregrinus, London, 1971.)

G 13. **Magnetic Resonances in Biological Research.** Cafiero Franconi, Editor. (Gordon and Breach, New York, 1971.)

R 14. **Magnetic Resonance in Biological Systems.** A. Ehrenberg, B. G. Malmstrom and T. Vanngard, Editors. (Pergamon Press, New York, 1967.) Proceedings of a conference held at Stockholm in 1966.

R 15. **Mathematical Problems in the Biological Sciences.** (American Mathematical Society, Providence, R. I., 1962.) Proceedings of the 14th symposium in applied mathematics held at New York in 1961.

G,R 16. **Membrane and Ion Transport** (3 volumes). Edward E. Bittar, Editor. (John Wiley, New York, 1970.)

G,R 17. **Membrane Molecular Biology.** C. Fred Fox and A. D. Keith, Editors. (Sinauer Associates, Stamford, Conn., 1972.)

I,G 18. **Models and Analogues in Biology.** Edited. (Academic Press, N. Y., 1961.) Proceedings of the 14th symposium of the society for experimental biology.

R 19. **Panel on Radiobiological Applications of Neutron Irradiation.** (IAEA, Vienna, 1972.) Proceedings of a panel organized by the International Atomic Energy Agency and held in Vienna in December 1971.

I 20. **Physical Problems in Biological Systems.** Cecile DeWitt, Editor. (Gordon Breach, N. Y., 1970.)

R 21. **Physicomathematical Aspects of Biology.** N. Rashevski, Editor. (Academic Press, New York, 1962.) Contains contents of the course sponsored by the Italian Physical Society in 1960.

R 22. **Proceedings of the 1957 National Biophysics Conference.** (Yale University Press, New Haven, Conn., 1959.) The momentum generated by this first conference led to the formation of the Biophysical Society in 1960.

R 23. **Radiation Research, Supplement 2, 1960; Bioenergetics.** Lewy G. Augenstine, Editor. (Academic Press, New York, 1960.) Preceedings of a symposium held at Brookhaven National Laboratory in 1959. Considerations of processes of absorption, stabilization, transfer and utilization of electromagnetic energy.

R 24. **Spectroscopic Approaches to Bimolecular Conformation.** D. W. Urry, Editor. (American Medical Association, Chicago, 1970.) Review articles on techniques and methods.

R 25. **Stochastic Models in Medicine and Biology.** John Gurland, Editor. (University of Wisconsin Press, Madison, Wisconsin, 1964.)

R 26. **Structural Chemistry and Molecular Biology.** Alexander Rich and Norman Davidson, Editors. (W. H. Freeman, San Francisco, 1968.) Some chapters of interest at the interface between biochemistry and biological physics.

I,G 27. **Systems Analysis in Ecology.** Kenneth E. Watt, Editor. (Academic Press, N. Y., 1966.)

R 28. **Theoretical Physics and Biology.** M. Marois, Editor. (American Elsevier, New York, 1969.) Proceedings of the first conference held at Versailles in 1967.

R 29. **Theoretical Physics and Biology.** M. Marois, Editor. (centre National de la Recherche Scientifique, Paris, 1971.) Proceedings of the second conference held at Versailles in 1969.

Reference Books and Resource Materials.

1. **A Dictionary of Biology,** (Paperback), M. Abercrombie, C. J. Hickman and M. L. Johnson. (Penguin Books, 1951.)
2. **A Directory of Information Resources in the United States: Biological Sciences.** (Library of Congress, Washington, 1972.) Compiled by the National Referral Center, Science and Technology Division, Library of Congress. Listed in the directory's 2,230 entries are the address, telephone number, areas of interest, holdings, publications, and information services of a wide variety of organizations capable of meeting specific information needs, including libraries, information centers, professional societies, universities, industrial firms willing to extend their services beyond their own organization, and Federal, State, and local government offices. A subject index is included.
3. "**Biophysics**", John R. Loofbourow, Am. J. Phys., Vol. 15, 21 (1947). Mainly of historical interest. Foresighted for its time.
4. **Dictionary of the Biological Sciences.** Peter Gray. (Van Nos Reinhold, New York, 1968.)
5. **Dictionary of Biology** (Paperback). Edwin B. Steen. (Harper Row, PA, 1972.)
6. "**Education in Biomedical Engineering**", Edwin R. Lewis, Proc. IEEE, Vol. 59, 868 (1971). Contains 142 items of reference and bibliography.
7. **Medical Physics.** (in three volumes), Otto Glasser, Editor. (Year Book Publishers, Chicago, 1962.) Volumes 1 and 2 published in 1944 and 1950 respectively. Encyclopedic. Some of the articles are detailed enough to provide good introduction.
8. **Resource letter BE-1 on "Biomedical Engineering"**, Curtis C. Johnson, Am. J. Phys., 39, 1423 (1971).
9. **Resource letter PB-1 "Physics and Biology"**, D. James Baker, Jr., Am. J. Phys., 34, 83 (1966). This resource letter represents the starting point for the summary presented here and should be consulted for more references prior to 1965.
10. **The Use of Biological Literature,** R. T. Bottle and H. U. Wyatt, Editors. (Butterworths, London.)

Data Compilations. Extensive data compilations that could be useful in biological physics research are almost nonexistent. The following compilations have some material of relevance.

1. **Biology Data Book.** Philip L. Altman and Dorothy S. Dittmer, Editors. Published by Federation of American Societies for Experimental Biology, Washington, D.C., (1964).
2. **Growth Including Reproduction and Morphological Development.** Philip L. Altman and Dorothy S. Dittmer, Editors. (Federation of American Societies for Experimental Biology, 1962.)

3. **Handbook of Biological Data.** William S. Spectro, Editor. (W. B. Saunders Philadelphia, PA, 1956)
4. **The Handbook of Biochemistry and Biophysics.** Henry C. Damm. (World Pub. Co., Cleveland, 1966.) About one fourth of it contains biophysics theory and data.

IV. Text Books

The letter classification regarding level of sophistication measures only the physical content of the material listed. Many of the texts classified as elementary or intermediate are done so on the basis of their usefulness to physicists. Otherwise, we realize that a majority of them document progress on the forefront of their respective fields. An asterisk shows material recommended for physicists. The titles listed below without a letter classification were obtained from a variety of sources including publishers' catalogues. They were not available to the authors for perusal.

It is noteworthy that high quality texts in the area of biological physics are only recently appearing and are conspicuously absent before about 1970. Some fields, such as biophysical instrumentation, have seen a far more rapid progress than other fields. The effect is that books only five or six years old seem quite obsolete.

Books on the General Subject of Biological Physics.

E 1. **Bioenergetics.** Albert Szent-Gyorgyi. (Academic Press, New York, 1957.)

G 2. **Biology and Information; Elements of Biological Thermodynamics.** Karl S. Trincher. (Consultants Bureau, New York, 1965.) Translated from the expanded and updated Russian text.

*G 3. **Biophysical Principles of Structure and Function.** Fred M. Snell, S. Shulman, R. P. Spencer and C. Moos. (Addison-Wesley, Palo Alto, Calif., 1965.)

G 4. **Biophysical Science.** Eugene Ackerman. (Prentice-Hall, Englewood Cliffs, N. J., 1962.)

*E 5. **Biophysical Science Activities for the High School.** Wayne A. Moyer. (Parker Pub. Co., West Nyack, N.Y., 1972.) This is what high school students could be doing under the supervision of dedicated teachers. Can be used with a PSSC course.

E 6. **Biophysics: Concepts and Mechanisms.** Edmund J. Casey. (Reinhold, New York, 1962.) Aimed at pre-med students.

E 7. **Cell and Molecular Biology; An Appreciation.** Eugene Rossenberg. (Holt, Rinehart and Winston, New York, 1971.) An introductory biology text for the non-specialist. Might be useful as a quick, qualitative introduction to the vocabulary.

8. **Complementarity in Biology: Quantization of Molecular Motions.** James P. Isaacs and John C. Lamb. (John Hopkins Press, Baltimore, 1969.)

E 9. **Elementary Biophysics: Selected Topics** (Paperback). Herman T. Epstein. (Addison Wesley, Reading, Mass., 1963.)

E 10. **Elements of Biophysics** (2nd edition). James Edwin Randall. (Year Book Medical Publishers, Chicago, 1962.) No exercises. Outdated but might be useful as an elementary resource.

E 11. **Engineering and Living Systems; Interfaces and Opportunities.** David D. Rutstein and Murray Eden. (MIT Press, Cambridge, Mass., 1970.) Based on the report to the National Academy of Engineering committee on the interplay of engineering with biology and medicine entitled: Harvard-MIT program in engineering and living systems, 1968. 16 original task group summaries are reproduced verbatim from the report. Non-technical. Progress reports and prognostications.

I 12. **First and Last Experiments in Muscle Mechanics.** A. V. Hill. (Cambridge University Press, London, 1970.)

E 13. **Information Theory and the Living System.** Lila L. Gatlin. (Columbia University Press, New York, 1972.)

P 14. **Life and the Physical Sciences; Introduction to Biophysics.** Harold J. Morowitz. (Holt, Rinehart and Winston, New York, 1963.) More chemistry and biology than physics.

P 15. **Mechanical Man; the Physical Basis of Intelligent Life.** Dean E. Wooldridge. (McGraw Hill, New York, 1968.)

*G 16. **Physical Biochemistry.** Kensal E. Van Holde. (Prentice Hall, Englewood Cliffs, N.J., 1971.) The author gives more than the usual emphasis on physics.

*I 17. **Physics for Biology and Medicine.** I. W. Richardson and Eljer B. Neergard. (Wiley-Interscience, New York, 1972.) The first chapters could be used at the elementary level in an introductory physics course.

P 18. **The Biological Clock.** F. W. Brown, Jr., J. W. Hastings and J. D. Palmer. (Academic Press, New York, 1970.)

P 19. **The Machinery of Life.** Dean E. Wooldridge. (McGraw Hill, New York, 1966.) Presents a physical point of view regarding the basis of living organisms: "....that the regular and predictable operation of a single body of physical law is sufficient to account for all aspects of human experience."

E 20. **The Physical Foundation of Biology.** Walter M. Elsasser. (Pergamon Press, New York, 1958.) Subtitled, "An Analytical Study".

P 21. **What is Life? The Physical Aspect of the Living Cell.** Erwin Schrodinger. (Cambridge University Press, London, 1944. Reprinted 1955.) A classic. Based on lectures delivered at Trinity College in February 1943.

Bioenergetics

1. **Biochemical Energetics and Kinetics.** A. Rae Patton. (Saunders, Philadelphia, Pa., 1965.)

I,G 2. **Bioenergetics.** (2nd ed.) Albert Lehninger. (Benjamin, New York, 1971.)

E 3. **Bioenergetics.** Albert Szent-Gyorgyi. (Academic Press, New York, 1957.)

G 4. **Energy Flow in Biology; Biological Organization as a Problem in Thermal Physics.** Harold J. Morowitz. (Academic Press, New York, 1968.)

5. **Introduction to Bioenergetics: Theromodynamics for the Biologist.** Halvor M. Christensen and Richard A. Cellarius. (Saunders, Philadelphia, Pa., 1972.)

P 6. **Life and Energy.** Isaac Asimov. (Doubleday, Garden City, N.Y., 1962.)

Biological Control Systems

1. **Biological Control Systems Analysis.** John H. Milsum. (McGraw Hill, New York, 1966.)
2. **Control Theory and Biological Systems.** Fred S. Grodins. (Columbia University Press, New York, 1963.)
3. **Control Theory and Physiological Feedback Mechanisims.** (Paperback) Douglas S. Riggs. (Williams and Wilkins, Baltimore, 1970.)
4. **Living Control Systems.** Leonard E. Bayliss. (W. H. Freeman, San Francisco, 1966.)
5. **Neurological Control Systems - Studies in Bioengineering.** Lawrence Stark. (Plenum, New York, 1968.)

Biological Transport

1. **Cell Membrane Transport: Principles and Techniques.** Arnost Kotyk and Karel Janacek. (Plenum, New York, 1970.)

I 2. **Elementary Rheology.** G. W. Scott Blair. (Academic Press, New York, 1969.)

3. **Ion Transport & Membranes: A Biophysical Outline.** A. B. Hope. (University Park Press, Baltimore, MD, 1971)

E 4. **Physiology and the Biophysics of the Circulation,** 2nd edition. Alan C. Burton. (Yearbook Medical Publishers, Chicago, 1972.) For premed students.

G 5. **Rheology of the Circulation.** R. L. Whitmore. (Pregamon Press, New York, 1968.)

G 6. **Simple Membrane Electrodiffusion Theory.** Richard A. Arndt and L. D. Roper. (Physical Biological Sciences Ltd., Blacksburg, VA , 1972.)

I,G 7. **The Conduction of the Nervous Impulse.** A. L. Hodgkin. (Liverpool University Press, England, 1964.)

G 8. **Transcellular Membrane Potentials & Ionic Fluxes.** F. M. Snell and W. K. Noell. (Gordon & Breach, New York, 1964.)

9. **Transport and Accumulation in Biological Systems** (3rd edition). E. J. Harris. (University Park Press, Baltimore, MD)

G 10. **Transport Phenomena in Membranes.** N. Lakshminarayanaiah. (Academic Press, New York, 1969.)

Elementary Physics from a Biological or Medical Viewpoint. Part of the responsibility of the biological physics community is that of the articulation of the principles of physics in the context of their applications in biology and medical science.

There is a growing number of elementary texts which attempt the presentation of elementary physics in form appropriate to the biological sciences community. The idea appears to be to present "standard physics" but to take specific application and examples from biological or medical science. We list a selection of these texts here.

*E 1. **An Introduction to Physics in Nursing.** (6th edition). H. H. Flitter. (The C. V. Mosby Co., St. Louis, 1972.) A careful introduction to the elements of physics explicitly relevant to nursing. Many references.

E 2. **College Physics.** Donald E. Tilley and Walter Thumm. (Cummings, Menlo Park, CA., 1971.)

E 3. **First-Year Physics for Radiographers.** George A. Hay and Douglas Hughes. (Bailliere Tindall, London.)

E 4. **Physical Science for Biologists.** J. A. Edington and H. J. Sherman. (Hutchinson University Library, London.)

I 5. **Physics Applied to Anaesthesia** (2nd edition). Dennis W. Hill. (Butterworths, London, 1972.) Instrumentation and techniques.

E 6. **Physics for Biology and Pre-medical Students.** D. M. Burns and S. G. MacDonald. (Addison Wesley, Reading, Mass., 1970.)

E 7. Physics in Botany. John A. Richardson. (Pitman, New York, 1964.) Physicists will probably not find this useful as the biologists view and terminology prevails

Biological Electronics and Instrumentation.

I 1. **Biomedical Electronics** (2nd edition). Howard M Yanof. (F A. Davis Co., Philadelphia, 1972.) Introduction to biomedical instrumentation and techniques.

I 2. Biomedical Engineering Systems. Manfred Clynes and John H. Milsum. (McGraw Hill, New York, 1970.) Contains results of research and development at the graduate level that can be useful reading even at the intermediate level. Many of the systems discussed in this book will be of interest to experimentally oriented biological physicists

E 3. Biomedical Instrumentation and Measurements. Leslie Cromwell and others (Prentice Hall, Englewood Cliffs, N.J , 1973.) Up-to-date introduction to techniques including applications of computers.

I 4. **IEE Medical Electronics Monographs** (six volumes). B. W. Watson, Editor. (Peter Peregrinns, London, 1971.)

I 5. **Principles of Applied Biomedical Instrumentation.** L. A. Geddes and L E. Baker. (John Wiley, New York, 1968)

Mathematical Biophysics.

G 1. **A Physical Theory of the Living State: The Association-induction Hypothesis; With Consideration of the Mechanisms Involved in Ionic Specificity. . . .** Gilbert N. Ling. (Blaisdell, New York, 1962.)

2. **Biomathematics.** M. S Bartlett. (Oxford U. Press, England, 1968.)

*I,G 3. Data Analysis in Biochemistry and Biophysics. Magar E. Magar. (Academic Press, New York, 1972.) Considers a varied scope of topics, using rigorous statistical methods.

G 4. **Dynamical Systems Theory in Biology: Stability Theory and Its Applications.** Robert Rosen. (John Wiley, New York, 1970.)

I,G 5. **Elements of Mathematical Biology.** Alfred J. Lotka. (Dover, New York, 1957.)

I,G 6. **Introduction to Mathematical Ecology.** E. C. Pielou. (John Wiley, New York, 1969.)

*I 7. **Introduction to Mathematics for Life Scientists.** E. Batschelet. (Springer Verlag, New York, 1971.) A course in mathematical methods with illustrations from life sciences.

8. **Mathematical Approach to Biology and Medicine.** Norman T. Bailey. (John Wiley, New York, 1967.)

I 9. **Mathematical Approach to Physiological Problems:** A Critical Primer. Douglas S. Riggs. (Williams & Wilkins, Baltimore, 1963.)

I 10. **Mathematical Biology of Social Behavior.** N. Rashevsky. (University of Chicago Press, Chicago, 1951.) A revised edition published in 1959.

I,G 11. **Mathematical Biophysics; Physicomathematical Foundations of Biology.** N. Rashevsky. (originally published by University of Chicago Press in 1938. Revised edition of this pioneering work republished by Dover in two paperback volumes in 1960.)

I 12. **Mathematical Ideas in Biology.** J. Maynard Smith. (Cambridge U. Press, England, 1968.)

I,G 13. **Mathematical Principles in Biology and Their Application.** N. Rashevsky. (C. C. Thomas, Springfield, IL., 1961.)

14. **Mathematical Theory of Epidemics.** N. T. Bailey. (Hafner, New York, 1957.)

I 15. **Mathematics for Biologists.** A. Crowe and A. Crowe. (Academic Press, New York, 1969.)

I 16. **Matrix Algebra for the Biological Sciences.** S. R. Searle. (John Wiley, New York, 1966.)

I,G 17. **Modern Algebra for Biologists.** Howard M. Nahikian. (U. of Chicago Press, Chicago, 1964.)

G 18. **Optimality Principles in Biology.** Robert Rosen. (Plenum Press, New York, 1967.)

19. **Prospects for Mathematics in the Life Sciences.** L. Bass (U. of Queensland Press) (International Scholarly Book Service, Portland, OR, 1969.)

I 20. **Some Mathematical Problems in Biology.** Egbert R. Leigh *et. al.* (American Mathematical Society, Providence, R.I., 1968.)

I,G 21. **Some Medical Aspects of Mathematical Biology.** N. Rashevsky. (C. C. Thomas, Springfield, IL., 1964.)

22. **Some Vistas of Modern Mathematics: Dynamic Programming, Invariant Imbedding and the Mathematical Biosciences.** Richard Bellman. (U. of Kentucky Press, Lexington, Ky., 1968.)

*G 23. **Systems Physiology.** Samuel Armstrong Talbot and Urs Gessner. (John Wiley, New York, 1973.)

*G 24. **Theoretical Foundations of Medical Physics** (two volumes). William Klip. (University of Alabama Press, University, 1969.) A rigorous treatment of the fundamentals of theoretical physics with biological applications. The first volume consists of the mathematics for the basic sciences and clinical research and the second volume gives an introduction into medical physics.

Molecular Biophysics.

P 1. **DNA: At the Core of Life Itself.** Lawrence Lessing and the editors of Fortune. (MacMillan, New York, 1967.)

R 2. **Molecular Biophysics.** Bernard Pullman and Michael Weissbluth. (Academic Press, New York, 1965.)

G 3. **Molecular Biophysics.** Richard B. Setlow and Ernest C. Pollard. (Addison Wesley, Reading, MA., 1962.)

*G 4. **Molecules and Life; An Introduction to Molecular Biology.** Mikhail V. Volkensktein. (Plenum Press, New York, 1970.) Translated from Russian. Highly recommended.

I 5. **The Cellular Role of Macromolecules.** P. H. Jellinck. (Scott, Foresman, Glenview, IL., 1967.) Introduces molecular biology at an elementary level. Organic chemistry is a prerequisite.

P 6. **The Thread of Life; An Introduction to Molecular Biology.** John C. Kendrew. (Harvard University Press, Cambridge, MA.) Based on the series of B.B.C. television lectures.

Radiation Biology.

I 1. **An Introduction to the Physics of Diagnostic Radiology.** Edward E. Christensen, Thomas S. Curry III and James Nunnally, (Lea and Febiger, Philadelphia, 1972.)

I 2. **Ionizing Radiation and Life: An Introduction to Radiation Biology and Biological Radiotracer Methods.** Victor Arena. (Mosby, St. Louis, 1971.)

G 3. **Molecular Radiation Biology: The Action of Ionizing Radiation on Elementary Biological Objects.** Hermann Dertinger and Horst Jung. (Springer Verlag, New York, 1970.) Translated from German.

E 4. **Radiation Biology.** Alison P. Casarett. (Prentice Hall, Englewood Cliffs, N.J., 1968.)

I 5. **Radiotracer Methodology in Biological Science.** C. H. Wang and David L. Willis. (Prentice Hall, Englewood Cliffs, N.J., 1965.) Discusses principles of radiotracer methodology and the basic experiments in measurements of radioactivity. Illustrative radiotracer experiments and bibliography.

Monographs on Miscellaneous Topics of Biological Physics.

I 1. **Biological Ultrastructure.** A. Engström and F. B. Finean. (Academic Press, New York, 1967.) Reference; methods and techniques for the study of ultrastructure.

E 2. **Electromagnetic Fields and the Life Environment.** Karel Martha, Jan Musil and Hana Tuha. (San Francisco Press, San Francisco, 1971.) Translated from the Czech.

I 3. **Light: Physical and Biological Action.** Howard H. Selinger and William D. McElroy. (Academic Press, New York, 1965.)

G 4. **Temporal Organization in Cells; A Dynamic Theory of Cellular Processes.** Brian C. Goodwin. (Academic Press, New York, 1963.) Applications of statistical mechanics.

G,R 5. **The Auditory Periphery; Biophysics and Physiology.** Peter Dallos. (Academic Press, New York, 1973.)

Book Chapters and Review Articles. This section cites particularly relevant chapters from textbooks and some review articles of which the authors have a knowledge of, which could be incorporated into courses in biological physics.

G 1. *"Biomechanics"*, Y. B. Fung, **App. Mech. Rev. 21**, 1 (1968). Excellent review article on the application of continuum mechanics; contains a detailed bibliography.

E 2. *"Body Mechanics, Strength of Materials and Lever Systems"*, Chapter 19 of **Physics: Understanding Our Physical Environment,** by C. H. Bachman. (Bogden and Quigley, Inc., New York, 1970.)

G,R 3. *"Hemodynamics"* by A. Noordergraaf, Chapter 5 of **Biological Engineering,** Herman P. Schwan, Editor. (McGraw Hill, New York, 1969.)

G,R 4. *"Mathematical Model of Excitation and Propagation in Nerve"*, by Richard Fitzhugh, Chapter 1 of **Biological Engineering,** Herman P. Schwan, Editor. (McGraw-Hill, New York, 1969.)

G 5. **Physiology and Biophysics.** Theodore C. Ruch and Harry D. Patton, Editors. 19th edition. (Saunders, Philadelphia, 1965.) A physiology text with some chapter (e.g. Ch. 1: The Cell Membrane: Ionic and Potential Gradients and Active Transport, Ch. 2: Action Potential: Properties of Excitable Membranes, Ch. 27: Hemodynamics and the Physics of Circulation, Ch. 39: Anatomy and Physics of Respiration, Ch. 40: Gas Exchange and Transportation, Ch. 43: Passive and Active Transport) emphasizing physical concepts.

E 6. *"Scaling - The Physics of Lilliput"*, PSSC. Chapter 4 of **Physics** (2nd edition). (D. C. Heath & Co., Boston, 1965.) p. 48.

P 7. *"The Relationship Between Biology, Physics and Chemistry"*, W. Heisenberg. Chapter 9 of **Physics and Beyond.** (Harper Row, New York, 1971.) Recollection of conversations with Bohr, Kramers and others dating back to early 30's.

Other Sources.

1. **McGraw-Hill Encyclopedia of Science and Technology,** Latest edition published in 1971 by McGraw-Hill, Inc. Contains informative short articles on many biophysical topics, such as biopotentials and electrophysiology, cell surface ionization, biological applications of information theory, muscles, etc. See the topical index in Volume 15.
2. Short articles on a number of biophysical topics are also included in **Encyclopedia Britannica.** Look under specific title.

Always informative and a pleasure to read, the best of Scientific American articles in life sciences are available in:

1. **Scientific American Resource Library,** Readings in the Life Sciences, (in seven volumes) (W. H. Freeman, San Francisco, 1969.)
2. **39 Steps to Biology.** G. Hardin, Editor. (W. H. Freeman, San Francisco, 1968.)
3. **The Biosphere.** Edited. (W. H. Freeman, San Francisco, 1970.)

V. GRADUATE STUDY AND RESEARCH PROGRAMS

At present, graduate studies and research in fields that can appropriately be called biological physics could be done in one or more of the following departments of a college or a university: biochemistry, bioengineering, biology, biometrics, biophysics, biostatistics, cellular and molecular biology, chemistry, physics, physiology, etc. For the purpose of this resource letter, however, we tabulate the various programs in only two tables. Entries in Table V-A refer to programs in the physics departments, whereas those in Table V-B cover programs in other departments of the U. S. educational institutions. The research program entries of any particular department should be taken only as an indication of some of the research interests of the faculty of that department. Information for these tables was compiled from a variety of sources.

Sources: (1) Replies to a personal survey letter sent earlier this year; (2) *Graduate programs in physics and astronomy* (American Institute of Physics, New York, 1971). The data in there referred to the 1969-70 academic year; (3) *Annual guides to graduate study* (Peterson's Guides Inc., Princeton, N. J., 1971.)

Note Regarding Tables VA & VB: Detailed programs in biophysics/ bioengineering could be obtained only for a few of those departments known to have such programs from the above mentioned sources. The biophysics/ bioengineering programs of many of the Universities listed in tables VA and VB are new and sometimes sketchy. Information on them can be best obtained by contacting the individual department chairman.

Current Research in Progress: Information on research projects in biological physics currently in progress may be obtained by consulting the following sources

1. Science and Technology Research in Progress (in 12 volumes), (Academic Media, Orange, NJ, 1973)
2. Public Health Service Grants and Awards (in 7 parts), U.S. Govt. publication.

Table V A. Programs in the Physics physics departments (U. S. Universities Only)

INSTITUTION (Arranged by state in alphabetical order)	RESEARCH PROGRAMS IN RECENT YEARS E: Experimental T: Theory † The department has related program in biological physics / biophysics with other departments
U. of Alabama, *Birmingham, AL*	E: Multiple vector model for EKG, light ion super-conducting accelerator for Bragg-peak radiation therapy
	T: Interaction of charged particles with tissue; hemodynamics
Auburn U., *Auburn, AL*	E: Light scattering from biological cells
	T: scattering
Arizona State U., *Tempe, AZ*	E
Arizona U., *Tucson, AZ*	E: Analysis of organic remnants in fossils, microstructure of tooth and bone
U. of California, *Berkeley, CA*	E
Riverside, CA	E: Bioelectric phenomena in membranes, electric phenomena in biopolymers
La Jolla, CA	E: Resonance and other techniques from physics applied to biological problems such as photosynthesis; high speed data processing techniques for X-ray structure analysis
† *Los Angeles, CA*	
Santa Cruz, CA	E
San Diego, CA	
† Stanford U., *Stanford, CA*	
† Colorado State U., *Fort Collins, CO*	E: Structure of proteins
U. of Colorado, *Boulder, CO*	E
	T
U. of Connecticut, *Storrs, CT*	E: U.V. spectra of macromolecules
U. of Delaware, *Newark, DE*	E: Molecular Biophysics
George Washington U., *Washington, DC*	T: Replication of cells, Specificity of molecular interactions
Georgetown U., *Washington, DC*	E: Ultrasonic applications

U. of Florida, *Gainesville, FL*	E: Ultrastructure of nerve tissue
† Emory U., *Atlanta, GA*	T: Quantum Genetics
Georgia Inst. of Tech., *Atlanta, GA*	T: Molecular Biophysics, Medical Physics
† U. of Chicago, *Chicago, IL*	E
	T: Mathematical Biology; Theory of organization of development in biological systems: Control of development by organizing waves
† Illinois Inst. of Tech., *Chicago, IL*	E: Investigation of fast processes in the irradiation of biological molecules; Inactivation of enzymes by ultraviolet light and visible light in the presence of photodynamic dyes; Investigation of membrane properties with spin label ESR method; Mechanism of radiosensitization and protection at the molecular level in connection with the development of more effective radiation methods for treating cancer; Radiation chemistry of pyrimidine dimers with emphasis on the implications in the photolytic steps of photoreactivation.
† U. of Illinois, *Urbana, IL*	E: Biochemical substances and enzymes; Applications of mössbauer effect
Northwestern U., *Evanston, IL*	E: High resolution electron microscopy of biomolecules; X-ray diffraction study of X phage DNA structure
	T: Application of Ising model to allosteric proteins; structure of biological macromolecules
Southern Illinois U., *Carbondale, IL*	T: Ion transport, Stability of ecological systems
	E: Radiation damage in crystals; molecular genetics; electroanesthesia
† Purdue U., *Lafayette, IN*	E: Bioelectric phenomena in tissues
U. of Louisville, *Louisville, KY*	T
U. of Maryland, *College Park, MD*	E
Harvard U., *Cambridge, MA*	T
	E
MIT, *Cambridge, MA*	
† Northeastern U., *Boston, MA*	
Michigan State U., *East Lansing, MI*	E
	T
U. of Michigan, *Ann Arbor, MI*	E: Physical methods applied to study molecular organization in biosystems; analysis of macromolecular structures; correlation between structure and biological function
† Montana State U., *Bozeman, MT*	

	U. of Nevada, *Las Vegas, NV*	E
		T
	Dartmouth College, *Hanover, NH*	T: Diffusion of ions in membranes, tissue elasticity
	Princeton U., *Princeton, NJ*	E
	Stevens Inst. of Tech., *Hoboken, NJ*	T
	New Mexico State U., *Las Cruces, NM*	E: Double resonance study of large molecular structures
	U. of New Mexico, *Albuquerque, NM*	E: Biological effects of ionizing radiation
		T: Radiation dosimetry, tumor growth and dissemination
	City U. of New York, *New York, NY*	E: Electrical characteristics of tissues, radiobiology, DNA spin resonance
		T: enzyme systems, radiobiology
†	Columbia U., *New York, NY*	E: Experimental programs involving light-scattering studies of biological macromolecules, viruses, and cells are being initiated. Use of laser light-scattering spectroscopy to investigate the behavior of macromolecules of biological interest; Intensity correlation spectroscopy of biological systems; Generation and study of beams of macromolecules. Research in the physical properties of collagenous tissues; specific areas of interest include the piezoelectric and pyroelectric effects, thermal and elastic characteristics, and dielectric constant.
†	Fordham U., *Bronx, NY*	
	New York U., *New York, NY*	
	Rensslaer Poly. U., *Troy, NY*	E: Measurement of physical properties of biological materials such as connective and calcified tissues; Use of ultrasonic techniques; Studies of conformation and interaction of globular and fibrous proteins
	St. Johns U., *Jamaica, NY*	T: DNA repair efficiency
	SUNY, *Albany, NY*	T: Many body quantum theory of biologically important molecules
†	*Buffalo, NY*	E: Cell growth; Metabolism; Electric charge on living cells; Crystallography and spin resonance studies of organic molecules
†	Syracuse U., *Syracuse, NY*	
†	North Carolina State U., *Raleigh, NC*	
	U. of Cincinnati, *Cincinnati, OH*	E: Ballistocardiography; Metabolism in plants
	Kent State U., *Kent, OH*	E: Sodium transport properties in cells; Membrane structure;
		T: Diffusion processes in cells
	Ohio State U., *Columbus, OH*	E: Charge carrier separation and migration in organic cells
	Oklahoma State U., *Stillwater, OK*	E: Study of living cells in nonuniform electric fields; organic semiconductors and nomadic polarization; biological studies of electron spin resonance.
		T: Biophysical studies of statistical nature.

	Oregon Graduate Center, *Portland, OR*	
†	Oregon State U., *Corvallis, OR*	
	U. of Oregon, *Eugene, OR*	
†	Portland State U., *Portland, OR*	
	Bryn Mawr College, *Bryn Mawr, PA*	
†	Penn State U., *University Park, PA*	
	Carnegie Mellon U., *Pittsburgh, PA*	
	U. of Pennsylvania, *Philadelphia, PA*	
†	U. of Pittsburgh, *Pittsburgh, PA*	
†	Temple U., *Philadelphia, PA*	
	Brown U., *Providence, RI*	
†	U. of Rhode Island, *Kingston, RI*	
	Clemson U., *Clemson, SC*	
†	U. of Tennessee, *Knoxville, TN*	
†	U. of Texas, *Austin, TX*	
	Dallas, TX	
	William Marsh Rice U., *Houston, TX*	
	Brigham Young U., *Provo, UT*	
	U. of Utah, *Salt Lake City, UT*	
†	U. of Vermont, *Burlington, VT*	
†	Virginia Polytechnic Inst., *Blacksburg, VA*	
†	U. of Virginia, *Charlottesville, VA*	
†	West Virginia U., *Morgantown, WV*	
†	Washington State U., *Pullman, WA*	
†	U. of Wisconsin, *Madison, WI*	
		T: Neurophysics, polymers, photosynthesis
		E: X-ray structural studies of biologically interesting small molecules and of macromolecules
		E
		T: Theoretical models of excitable membranes including nerve fibers
		E: Structure of membranes, nerves and retinal photoreceptors
		E: Molecular details of sexual processes in bacteria; the mechanism of pairing of cells of opposite mating type; the processes of chromosomal transfer between donor and recipient cells; the integration of parental DNA strands into a functional recombinant chromosome; the effects of ionizing radiations; and the general theory of genetic linkage; biological inactivation at high and low temperatures, control of DNA replication, and the effects of unbalanced growth on cellular control processes.
		E. Electron distributions in molecules of biological importance
		E The biophysical research faculty have active interest in such areas as thermal and radiation effects on biological molecules and cells, protein structure, repair of damage to DNA, and cell kinetics.
		E: Spectrographic investigation of human tissue ash for trace elements to determine concentration
		E: Treatment of cancer by pion dosiometry
		E: Structure of water in cells
		E: Small angle X-ray scattering studies of complex organic molecules
		E
		T
		E: Physical processes in biological materials and living systems; Acoustical techniques
		T: Electrodiffusion theory for membranes
		E
		E: (1) Ultrasonic identification of foreign particles in human blood; (2) Computer image processing methods applied to biomedical problems.
		E: Structure of proteins and nucleo-proteins from X-ray scattering, electron microscopy and ultra-centrifugation; Macromolecular beams; virus studies; function and control of host cell biosynthetic mechanism

Table V B. Programs in departments other than physics

INSTITUTION (Arranged by state in alphabetical order)	DEPARTMENT	RESEARCH PROGRAMS IN RECENT YEARS
U. of Arizona, *Tucson, AZ*	Molecular Biophysics Bioengineering	
California Institute of Technology, *Pasadena, CA*	Biophysics	
Loma Linda U. School of Medicine, *Loma Linda, CA*	Biophysics	
Stanford U. School of Medicine, *Stanford, CA*	Biophysics	
Stanford University, *Stanford, CA*	Bioengineering	
U. of California, *Berkeley, CA*	Biophysics Bioengineering	
Davis, CA	Biophysics	
Los Angeles, CA	Molecular Biophysics	
San Diego, CA	Biophysics Molecular Biophysics Bioengineering	
U. of Cal. San Diego School of Medicine, *La Jolla, CA*	Bioengineering	
U. of Cal. San Francisco Med. Center, *San Francisco, CA*	Biophysics	
U. of Southern California, *Los Angeles, CA*	Bioengineering	Bioengineering faculty research interests include identification and modeling of cardiovascular and neuromuscular systems, biological control systems, control theory and applications, regulation and control in biological systems, mathematical modeling and computer simulation of biological systems, renal dynamics, active transport, membrane biophysics, neuronal signals and systems, mathematical models of neurophysiological processes, models of the neuromuscular system, mathematical modeling of fluid and electrolyte balance, control of artificial kidneys, dynamics of endocrine systems and simulation of biological systems.

Colorado State University, *Fort Collins, CO*	Biophysics	
U. of Colorado, Denver Med. Center, *Denver, CO*	Biophysics	
U. of Connecticut, *Storrs, CT*	Biophysics	
	Bioengineering	
Yale University, *New Haven, CT*	Biophysics	
	Molecular Biophysics	
Georgetown U. School of Medicine, *Washington, DC*	Biophysics	
George Washington University, *Washington, DC*	Biophysics	
Florida State University, *Tallahassee, FL*	Biophysics	Areas of biophysical research are molecular genetics, enzyme mechanisms and kinetics, macromolecular structure, functions, and metabolisms, molecular physiology, sensory biophysics, photosynthesis, spectroscopy and quantum theory, protein and virus properties, and instrumentation and special techniques.
	Molecular Biophysics	
U. of Miami, *Coral Gables, FL*	Bioengineering	
U. of Miami School of Medicine, *Coral Gables, FL*	Biophysics	
U. of Hawaii School of Medicine, *Honolulu, HI*	Biophysics	
Chicago Medical College, *Chicago, IL*	Biophysics	
Loyola U. Stritch School of Medicine, *Maywood, IL*	Biophysics	
U. of Chicago, *Chicago, IL*	Biophysics	The research interests include molecular genetics; biosynthesis of macromolecules; regulatory mechanisms in biosynthesis; the structural and functional analysis of macromolecules, multienzyme complexes, viruses, membranes, motile and contractile systems, chromosomes, and other cellular organelles; the electronic structure and optical properties of macromolecules; photobiology; mitosis and cell division; and the biological applications of X-ray diffraction, electron microscopy, optical and computer techniques.
U. of Illinois Urbana-Champaign, *Urbana, IL*	Biophysics	Current research interests of the biophysics faculty include cell membrane behavior, excitable membranes, action potentials, and synaptic activity; radiobiology,

		photoreactivation mechanisms; bioacoustics, ultrasonics; photosynthesis; electrical properties of lipids and lipid bilayers, artificial membrane, nuclear magnetic resonance studies of lipids; dynamics of circulation; electrobiology, contractile tissue, smooth muscle; contractility, excitable tissues, excitation-contraction coupling, cardiac muscle; photobiology, bioenergetics; cybernetics; nuclear magnetic resonance studies of biological macromolecules; optical properties of proteins; physical properties of nucleic acids; and active transport.
Indiana U. School of Medicine, *Indianapolis, IN*	Biophysics	
Purdue University, *Lafayette, IN*	Bioengineering	
Rose Hulman Institute of Technology, *Terre Haute, IN*	Bioengineering	
U. of Notre Dame, *Notre Dame, IN*	Biophysics	
Iowa State University, *Ames, IA*	Biophysics	
U. of Iowa College of Medicine, *Iowa City, IA*	Biophysics	
Kansas State University, *Manhattan, KS*	Biophysics	
U. of Kansas, *Lawrence, KS*	Biophysics	Areas of research include: mechanisms of radiation repair in microbial cells and in mammals, radiation effects from internal emitters, modification of radiosensitivity in microbial cells and in mammals, radiation chemical dosimetry, mechanisms of radiation damage to DNA and constituents, radiation effects in the solid state, and solid state dosimetry, medical radiation shielding, chemical radiation protection, and medical physics or radiobiology as related to diagnostic and therapeutic radiology and to nuclear medicine.
U. of Kentucky, *Lexington, KY*	Bioengineering	
U. of Kentucky School of Medicine, *Lexington, KY*	Biophysics	
U. of Louisville School of Medicine, *Louisville, KY*	Biophysics	
Johns Hopkins University, *Baltimore, MD*	Bioengineering	
Johns Hopkins U. School of Medicine, *Baltimore, MD*	Biophysics	
U. of Maryland, *College Park, MD*	Bioengineering	

U. of Maryland School of Medicine, *Baltimore, MD*	Biophysics	
Boston University, *Boston, MA*	Biophysics	
Brandeis University, *Waltham, MA*	Biophysics	Biophysical research areas currently active include structure and function of biopolymers (proteins and nucleic acids), photobiology (photosynthesis, vision, photomorphogenesis, photomutation), mechanisms of enzyme action and related fast chemical reactions, mechanisms of muscle action, molecular genetics, cell division, virology, invertebrate and vertebrate development, radiation biology.
Clark University, *Worcester, MA*	Bioengineering	
Harvard Medical School, *Boston, MA*	Biophysics	
Harvard University, *Cambridge, MA*	Biophysics	Current research interests of the biophysics faculty include ion transport across biological membranes, membrane structure, biological kinetics, studies on the regulation of bacterial gene expression, relationships between molecular structure and biological function of proteins, synthesis and physical chemistry of polypeptides which serve as protein models, mathematical biology, aspects of energy conversion, coupling phenomena in model membranes, thermodynamics of biological processes, molecular mechanisms in bioluminescent reactions, circadian rhythms and biological clocks, chemistry and physics of photosynthesis and its genetic control, mechanisms of protein synthesis, and X-ray crystallography and the study of macromolecular structure.
Massachusetts Institute of Technology, *Cambridge, MA*	Biophysics	
Worcester Polytechnic Institute, *Worcester, MA*	Bioengineering	
Michigan State University, *East Lansing, MI*	Biophysics	The main emphasis is on two general areas of biophysical research — the relationship between the properties and organization of macromolecules and their biological function, and the molecular bases of nerve and brain functioning. Research projects are under way in photophysical processes in biological

Michigan State U. College of Human Medicine, *East Lansing, MI*	Biophysics
U. of Michigan, *Ann Arbor, MI*	Bioengineering
U. of Michigan Medical School, *Ann Arbor, MI*	Bioengineering
U. of Minnesota, *Minneapolis, MN*	Biophysics
Mississippi State University, *State College, MS*	Bioengineering
U. of Mississippi Medical Center, *Jackson, MS*	Biophysics
Washington University, *St. Louis, MO*	Biophysics Bioengineering
Washington U. School of Medicine, *St. Louis, MO*	Biophysics
U. of Nebraska College of Medicine, *Omaha, NB*	Biophysics
Rutgers University, *New Brunswick, NJ*	Bioengineering
Albany Medical College of Union University, *Albany, NY*	Biophysics
Albert Einstein College of Medicine, *Bronx, NY*	Biophysics
Columbia University, *New York, NY*	Bioengineering
Columbia U. College of Physicians and Surgeons, *New York, NY*	Biophysics
Cornell U. Medical College, *New York, NY*	Biophysics
CW Post Center, *Greenvale, NY*	Biophysics
New York U. School of Medicine, *New York, NY*	Biophysics
New York U. School of Engineering and Sciences, *New York, NY*	Bioengineering
Polytechnic Institute of Brooklyn, *Brooklyn, NY*	Bioengineering
Rensselaer Polytechnic Institute, *Troy, NY*	Bioengineering

systems (vision and photosynthesis); the solid-state electrical properties of biological materials; energy transfer in biological systems; molecular architecture critical for biological function; applications of quantum theory of problems in biological specificity; behavior of macromolecules at interfaces and gels; electrical activity and information processing in nervous systems; neural activity involved in learning; the physics and chemistry of bimolecular lipid membranes, biological sensory models using lipid bilayers; and the biochemical bases of learning in lower animal forms.

Rockefeller University, *New York, NY*	Biophysics	Mechanisms relating energy sources to cellular processes requiring energy; relations between oxidative metabolism and electrochemical properties of nerve cells; study of physical and chemical processes related to transport across physiological membranes and relevant model systems; excitation processes in nerve and muscle membranes. Physiology of vision — how light acts on the receptor elements of the eye to generate nervous activity in the optic pathway; synaptic mechanisms; neural interactions that modify the patterns of receptor activity and that underlie the perception of form, color, and motion. The understanding of the photochemical reactions in photobiological systems; biosynthetic control mechanisms of heme and heme proteins studied in tissue culture; control mechanisms of chlorophyll biosynthesis and chloroplast development.
SUNY at Buffalo-Medical School, *Buffalo, NY*	Biophysics	The principal areas of research are (1) supramolecular organization, (2) molecular structure, (3) transport processes and membrane phenomena, (4) radiation biophysics, (5) theoretical biophysics and mathematical models, and (6) electrophysiology.
-**Downstate Medical Center**, *Brooklyn, NY*	Biophysics	
-**Roswell Park**, *Buffalo, NY*	Biophysics	
U. of Rochester School of Medicine, *Rochester, NY*	Biophysics	Research opportunities are varied and exist at all levels of biological organization from submolecular to animal behavior. Research projects are available in radiology, medicine, biochemistry, pharmacology, psychology, brain research, pathology, biomathematics, pediatrics, biology, chemistry, anatomy, physiology, and microbiology.
Yeshiva University, *New York, NY*	Biophysics	
Duke University, *Durham, NC*	Bioengineering	
Duke U. School of Medicine, *Durham, NC*	Biophysics	
North Carolina State University, *Raleigh, NC*	Bioengineering	
Case Western Reserve U. School of Medicine, *Cleveland, OH*	Bioengineering	

Ohio State University, *Columbus, OH*	Biophysics Bioengineering	The present program is offering opportunities for for study and specialization in the following seven areas of biophysics — molecular, subcellular, cellular, cell networks and organs, organ systems, visual biophysics, and theoretical biophysics.
Ohio University, *Athens, OH*	Biophysics	
University of Cincinnati, *Cincinnati, OH*	Bioengineering	
Oklahoma State University, *Stillwater, OK*	Bioengineering	
U. of Oklahoma, *Norman, OK*	Biophysics Bioengineering	
Oregon State University, *Corvallis, OR*	Biophysics	
Carnegie-Mellon University, *Pittsburgh, PA*	Bioengineering	The Biotechnology Program offers training in membrane transport theory, biological flows, biological materials, physiological systems, physiological information processing, biological electrical measurements, artificial intelligence and biological systems, biological flow hydrodynamics, biological mass transfer, bioenergetics, physiology, and experimental electrophysiology.
Drexel University, *Philadelphia, PA*	Bioengineering	
Hahneman Medical College, *Philadelphia, PA*	Biophysics	
Medical College of Pennsylvania, *Philadelphia, PA*	Biophysics	
Pennsylvania State University, *University Park, PA*	Biophysics	Biophysical research interests include theoretical biology, radiation biology, cell biology, molecular biology and genetics, electrophysiology, solid state biology, ion transport, molecular basis of learning and memory, developmental biology, biophysical chemistry, and instrumentation.
U. of Pennsylvania, *Philadelphia, PA*	Bioengineering	Biophysics faculty research interests include spin-label studies; structure and function of biological membranes; electron transport systems, photosynthesis; correlation of structure and function of allosteric enzymes; mechanisms of enzyme action, electron spin and nuclear magnetic resonance;

		conformations of nucleic acids, spectroscopic properties of biopolymers, optical rotation and circular dichroism; photolysis and photobiology; quantum theoretical aspects of electron transport; computer simulation of biochemical, physiological and ecological systems, computer applications to medical science, metabolic control; X-ray crystallography; structure of small biological molecules; control and regulation in biological systems, applications of thermodynamics; systems physiology; mechanisms of ion accumulations and of permeability; cooperative phenomena; bioelectric phenomena; quantum biology; relaxation studies of conformational changes in muscle and yeast pyruvate kinase; biochemical and biophysical basis of vision; light-induced electron transport in photosynthetic bacteria, development of advanced laser systems for fast biophysical processes; biological timing mechanisms; dielectric relaxation of biological polymers; theoretical investigation of pi electron polarization; determination of the structures of biologically interesting molecules by X-ray crystallography; effects of radiation on microorganisms; influence of temperature and protective agents; cellular freezing; bacterial conjugation; genetic recombination; and magnetic (electron paramagnetic resonance and magnetic susceptibility) studies of hemoproteins.
U. of Pennsylvania School of Medicine, *Philadelphia, PA* **U. of Pittsburgh,** *Pittsburgh, PA*	Biophysics Biophysics	Biophysics faculty research interests include biophysical characterization of viruses and nucleic acids; biologically active structure of TMV-RNA; structure-function of proteins and membranes; regulation of gene functions; biophysical characteristics of TMV; psychological physics; photobiology; structure of nucleic asids and proteins; and bioluminescence.

Brown University, *Providence, RI*	Biophysics, Molecular Biophysics, Bioengineering	
Brown U. Division of Medical Science, *Providence, RI*	Biophysics	
U. of Rhode Island, *Kingston, RI*	Biophysics, Bioengineering	Biophysics faculty research interests are in electron microscopy; control of enzyme snythesis in virus-infected cells; regulation of RNA synthesis; structure of RNA and ribosomes; spectroscopic studies of RNA and protein structure; electron microscopy; contract inhibition of protein synthesis; and virus-cell interactions.
Clemson University, *Clemson, SC*	Bioengineering	Bioengineering faculty research interests include biomaterials, mass transfer in biological fluids, gas absorption in biological systems, biomechanics, mathematical modeling, structure and properties of materials for application in physiological environments, dialysis, ion exchange and ultrafiltration as applied to body fluids, compatibility of physiological fluids with materials, and hemodynamics and properties of blood as a fluid.
U. of Tennessee Medical Center, *Memphis, TN*	Biophysics	
Rice University, *Houston, TX*	Bioengineering	
Southern Methodist University, *Dallas, TX*	Bioengineering	
Texas A & M University, *College Station, TX*	Biophysics	
U. of Houston, *Houston, TX*	Biophysics	
U. of Texas Southwestern Medical School, *Dallas, TX*	Biophysics	
U. of Utah, *Salt Lake City, UT*	Bioengineering	
U. of Utah College of Medicine, *Salt Lake City, UT*	Biophysics	
U. of Vermont, *Burlington, VT*	Biophysics	
Medical College of Virginia, *Richmond, VA*	Biophysics	
U. of Virginia, *Charlottesville, VA*	Bioengineering	The four areas of research in biomedical engineering are analysis of biological systems and their controls, biomedical technology (e.g., instrumentation, computer applications, or materials) theoretical

U. of Virginia School of Medicine, *Charlottesville, VA*	Biophysics
Virginia Commonwealth University, *Richmond, VA*	Biophysics
U. of Washington School of Medicine, *Seattle, WA*	Biophysics
West Virginia U. School of Medicine, *Morgantown, WV*	Biophysics
Marquette University, *Milwaukee, WI*	Bioengineering
Medical College of Wisconsin, *Milwaukee, WI*	Bioengineering
U. of Wisconsin, *Madison, WI*	Biophysics Bioengineering
U. of Wyoming, *Laramie, WY*	Bioengineering

biology, and generalized systems analysis. Specific projects range from study of the physiological dynamics of oxygen transport or of blood flow and diffusional transport in capiliary beds to devices and techniques for continuous computer-based monitoring in the care of the critically ill, development of prosthetic and assistive devices, transfer of technology to biomedicine, mathematical modeling of neural nets and growth phenomena, and to analysis of health care as it interrelates with regional and global education and economy, and investigation of the man-machine interface in short-haul air transport systems.

Biophysics research is oriented toward studies of the effects of ionizing and nonionizing radiation on biological systems. Areas of study include the biological effects of microwave, infrared, ultraviolet, laser, and ionizing radiations as well as photobiology, X-ray crystallography and the study of the relationship of structure and function of proteins and nucleic acids.

VI. Professional Societies

This list of professional societies includes only U. S. and Canadian societies. The comments relate to the nature of the membership and include indications of committees, divisions and publications of relevance to the biological physicist.

ACOUSTICAL SOCIETY OF AMERICA

New York, N. Y. 10017

Members: Physicists and engineers. Covers Psychological and Physiological Acoustics.
Publication: Journal of the Acoustical Society of America, monthly.

NATIONAL ASSOCIATION OF BIOENGINEERS

Chicago, Ill. 60618

Members: Professionals actively working in bioengineering or related area.

AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES

Washington, D. C. 20016

Members: Individuals with an interest in the life sciences and biological research.
Committees: Bioinstrumentation.
Publications: (1) BioScience, monthly; (2) Directory of Bioscience Departments in the U. S. and Canada.

AMERICAN SOCIETY FOR CELL BIOLOGY

Bronx, N. Y. 10461

Members: Scientists in cell biology or an allied field.
Publication: Journal of Cell Biology, monthly.

BIOPHYSICAL SOCIETY

Washington, D. C. 20007

Members: Professional society of scientists (biophysicists, physical biochemists, physical and biological scientists) interested in the application of physical laws and techniques to the analysis of biological or living phenomena.
Subgroups: Bioenergetics; Biology of Survival; Contractility; Membrane Biophysics; Photochemistry and Photobiology.
Publications: (1) Biophysical Journal, monthly; (2) Biophysical Society Newsletter, annual; (3) Biophysical Society Abstracts, annual; (4) Annual Reviews of Biophysics.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS

New York, N. Y. 10017

Members: Engineers and scientists in electrical engineering, electronics, and allied fields.
Groups and Scieties: Engineering in Medicine and Biology.
Publications: IEEE Transactions on Bio-Medical Engineering.

SOCIETY FOR NEUROSCIENCE

Bethesda, Md. 20014

Members: Scientists doing research relating to the nervous system.
Publications: Newsletter, quarterly.

AMERICAN NUCLEAR SOCIETY

Hinsdale, Ill. 60521

Members: Include life scientists, with professional experience in nuclear science.

OPTICAL SOCIETY OF AMERICA

Washington, D. C. 20037

Members: Persons interested in any branch of optics or physiological optics.
Publications: (1) Journal, monthly; (2) Optics and Spectroscopy (Russian translation journal), monthly.

AMERICAN PHYSICAL SOCIETY

New York, N. Y. 10017

Members: Scientists working in physics and related fields.
Divisions: Biological physics.

AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE

New York, N. Y. 10017

Members: Persons professionally engaged in application of physics to medicine and biology. Affiliated with American Institute of Physics.
Publications: (1) AAPM Quarterly Bulletin; (2) Physics in Medicine and Biology, quarterly.

NATIONAL ASSOCIATION OF BIOLOGY TEACHERS

Washington, D. C. 20005

Members: Teachers interested in teaching of biology at elementary, secondary, and college levels.
Publication: American Biology Teacher, 9/year.

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Washington, D. C. 20036

Members: Professional society of college and university engineering teachers, and others interested in engineering education.
Committees: Biomedical Engineering.

AMERICAN ASSOCIATION OF PHYSICS TEACHERS

Washington, D. C. 20036

Members: Teachers of physics in colleges, universities and secondary schools.
Committee: Physics in Biomedical Education.
Publication: American Journal of Physics, monthly.

BIOMEDICAL COMPUTING SOCIETY

Bethesda, Md. 20014

Members: Biological, medical, behavioral, and computer scientists.
Publications: SIGBIO, quarterly.

AMERICAN NEUROLOGICAL ASSOCIATION

Cincinnati, Ohio 45229

Members: Physicians and scientists interested in the form, functioning and disorders of the nervous system.
Publications: Transactions, annual.

SOCIETY OF NUCLEAR MEDICINE

New York, N. Y. 10017

Members: Professional society of scientists interested in nuclear medicine and the use of stable and radioactive isotopes in clinical practice, research and teaching.
Publication: Journal of Nuclear Medicine, monthly.

HEALTH PHYSICS SOCIETY

E. Weymouth, Mass. 02189

Members: Persons devoted to the protection of man and his environment from unwarranted ionizing radiation exposure.
Publication: Health Physics Journal, monthly.

RADIOLOGICAL SOCIETY OF NORTH AMERICA

Syracuse, N. Y. 13210

Members: Radiologists and scientists in fields closely related to radiology.
Promotes study and application of radiology, radium, electricity and other branches of physics related to medical science.
Publication: Radiology, monthly.

AMERICAN INSTITUTE OF ULTRASONICS IN MEDICINE

Kingston, Ontario, Canada

Members: Physicians and surgeons interested in the use of ultrasonic radiation clinically and in research.
Publications: (1) Newsletter, semiannual; (2) Scientific proceedings, annual.

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