NATIONAL ACADEMY OF SCIENCES

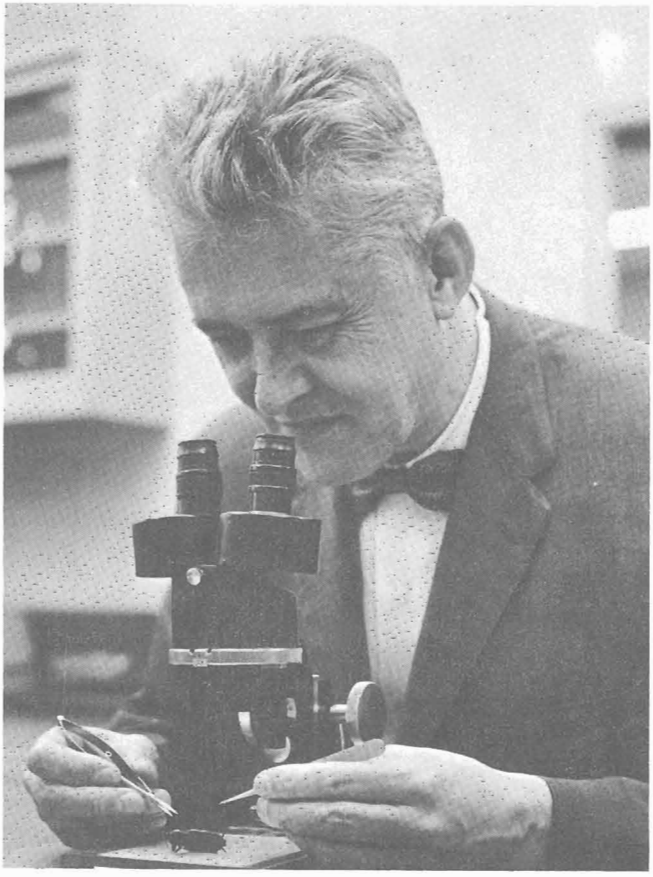
DIETRICH H. F. A. BODENSTEIN

1908—1984

A Biographical Memoir by

JAMES MURRAY

Biographical Memoir



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Dietrich Bodenstein

DIETRICH H. F. A. BODENSTEIN

February 1, 1908–January 5, 1984

BY JAMES MURRAY

THE HALLMARKS OF Dietrich Bodenstein's career were his zest for life, his love of beauty in science, and his enthusiastic encouragement of his younger colleagues. His boundless energy and his uncompromising commitment to scientific truth set him apart from many of his contemporaries. To know Dietrich was to experience a force of nature.

Dietrich Hans Franz Alexander Bodenstein was born in East Prussia on February 1, 1908. He grew up on the family estate at Corwingen, at that time an almost feudal survival of an earlier Europe. During his youth he roamed the forests and fields of the estate with his rifle and insect net in search of natural history specimens for his personal "museum." It was only natural, therefore, that when he entered the University of Konigsberg in 1926 he began his studies with Otto Koehler, the distinguished observer of bird behavior. While still a student he published his first paper on a moth that he had found for the first time in East Prussia.

In 1928 Dietrich moved to the University of Berlin, where he became a research assistant in experimental morphology at the Kaiser Wilhelm Institute for Biology. It was there that he came under the influence of Professor Otto

Mangold, at a time when the most exciting results were forthcoming on the control of development in amphibians. Typically, it was the larger questions and not the experimental material that challenged Dietrich's imagination. Encouraged by Mangold, he began to investigate that most challenging problem, control of molting and metamorphosis in insects. It was a study that was to occupy him to the end of his life. In his last scientific papers, published from 1978 to 1981 on work done while on an Alexander von Humboldt fellowship at the University of Marburg, Dietrich used modern chemical and immunological techniques to confirm his previous deductions on the role of ecdysone in the control of development.

In 1933, however, Dietrich's work at the Kaiser Wilhelm Institute was interrupted by the rise of national socialism in Germany. Warned by Mangold that he might be in political trouble with the Nazis, Dietrich accepted a position as research associate at the Institute of Marine Biology in Rovigno, Italy. From there he moved to a similar post at Stanford University, where he worked from 1934 to 1941. During this time he not only continued his studies on insect hormones but also collaborated with Victor Twitty in experiments on the role of ectodermal structures in the development of amphibia.

Dietrich's growing scientific reputation was recognized with a Guggenheim fellowship, which he held in the Department of Zoology at Columbia from 1941 to 1943. From there he moved briefly to the Connecticut Agricultural Experiment Station in New Haven before settling down as an insect physiologist at the Army Chemical Center at Edgewood, Maryland, a position he held from 1945 to 1958. There he met and married his lifelong companion, Jean Coon Bodenstein.

It was while Dietrich was at Edgewood that a curious lapse in his scientific career was made good. The declining fortunes of his family had prevented him financially from being examined for the doctoral degree, and up until 1953 there had never been a convenient moment to bring Dietrich's formal title into line with his undoubted stature in the scientific community. It was his former mentor Professor Otto Koehler who made the arrangement for Dietrich's doctoral examination to be held at the University of Freiburg in that year. Nothing was skirted in the process. Dietrich presented a bound copy of his publications numbering some fifty-nine items and was duly examined by each member of the professoriat of the faculty of science. To no one's surprise he was duly awarded the degree of doctor of philosophy. Indeed, his election to the National Academy of Sciences followed only five years later, in 1958.

From 1958 to 1960 Dietrich served as embryologist with the Gerontology Branch of the National Heart Institute, based in the Baltimore City hospitals. He then entered the final stage of his career, accepting the Lewis and Clark Professorship and the chairmanship of the Department of Biology at the University of Virginia. He took over a tiny department, badly housed and poorly equipped. On his retirement from the chairmanship in 1973, the department had trebled in size. It was housed in, and indeed beginning to outgrow, a modern, well-equipped laboratory building. Moreover, with his genius for personal relationships, Dietrich had assembled a group of colleagues who shared his enthusiasm for modern biology, especially those aspects of the subject dealing with genetics, biochemistry, and, above all, development.

Dietrich continued actively in research after giving up

the chairmanship in 1973. The culmination of his career was undoubtedly his receipt of an Alexander von Humboldt Award for senior U.S. scientists. It represented for him not only recognition of his long and fruitful scientific career but also in a very real sense his reconciliation with his native Germany. It was typical that Dietrich did not regard the appointment as some sort of ceremonial sinecure but as an opportunity to undertake new and exciting work with younger colleagues who could add different techniques to his research armamentarium.

Dietrich's scientific reputation will ultimately rest on the elegance and incisiveness of his investigations into the control of insect development. From his earliest days at the Kaiser Wilhelm Institute, he recognized the precision with which the events of molting and metamorphosis take place and wondered about the mechanisms by which they are controlled. His first major set of experiments was designed to find out whether the timing of larval molts and the differences between larval and pupal molts were controlled by time-dependent processes within the cells of the skin itself or by signals from some internal source. He reasoned that he could make this distinction by transplanting skin between larvae of different ages. He taught himself the exceedingly difficult techniques for transplanting larval prolegs from older to younger larvae and performed hundreds of successful transplants. He was rewarded with quite clear-cut results. The transplants invariably molted in synchrony with the host. Moreover, instead of undergoing a pupal molt, the transplants underwent an extra larval molt, indicating control by blood-borne factors that Dietrich insisted should be considered as hormones.

At that time biochemical methods were not sufficiently well developed for the reliable assay of insect hormones in

physiological concentrations. Therefore, it was necessary to develop biological assays for detecting their origin and action. Dietrich used the imaginal discs of *Drosophila* to assess the function of organs thought to be involved in the production of hormones. He reasoned that there would be very little growth hormone in adult animals so that he might use the body cavity of adults as culture chambers. When he transplanted imaginal discs into the body cavities of adult males, they did indeed remain in good condition, although there was no evidence of growth or development. But when he included several ring glands (the suspected hormone-producing organ) with the transplants, the discs enlarged and eventually formed the appropriate adult structures. On the other hand, transplantation of discs into the body cavities of females resulted in growth of the discs without the addition of ring glands. Dietrich concluded, therefore, that his initial assumption was only partly correct and that females, but not males, actually contain growth hormone in the adult stage.

Dietrich continued his investigation of the role of hormones in molting by using the head segment of an early larva transplanted into the abdomen of an adult fly. By observing the number of hooks on the lower jaw, it was possible for him to establish whether molting had taken place. In these experiments molting occurred only when ring glands were included with the transplant, indicating that both growth and molting were controlled by a single hormone.

The next stage of the investigation was to separate the effects of the two hormones now known to control development, the growth and molting hormone and the juvenile hormone. In order to do this Dietrich had to use a different insect. In *Drosophila* the ring gland is actually a

compound organ containing both the prothoracic gland (the source of growth hormone) and the corpus allatum (the source of juvenile hormone). It has not so far been possible to separate the two parts surgically. Dietrich therefore turned to the cockroach, where these organs are separable. By surgically joining a late larva, which was ready to undergo the pupal molt, with a younger larva containing a corpus allatum, he showed that the older larva was induced to undergo an additional molt. The presence of juvenile hormone therefore maintains the juvenile condition and prevents the formation of the pupa. In the control experiment similar pairs without an active corpus allatum both underwent a pupal molt.

All of these experiments were carried out before the chemical identity of these hormones had been established. They clearly show how good experimental technique and logical reasoning can resolve very complex interactions. Dietrich, however, welcomed the advances in biochemistry that made it possible to test his hypotheses about the action of these hormones. His last major work was a collaboration with Scheller and Karlson while on his Humboldt fellowship. They repeated some of the early experiments with imaginal discs to see whether Dietrich's hypothesis about the different levels of growth hormone in male and female flies could be substantiated with modern techniques. They transplanted leg discs into adult blowflies, with or without the addition of ring glands. After nine days the discs were measured and the initial observations confirmed. In males without ring glands the discs showed almost no growth whatsoever; but in males with ring glands and also in females without them, the discs had doubled in size. Using an antibody against growth hormone and a radioactive label, it was possible to show that the concentration of

hormone in the blood of adult females was seven times that in adult males. Dietrich was characteristically delighted to have his pioneering work so decisively confirmed.

In his retirement Dietrich returned to the interests of his early life. He was presented with an ultraviolet light trap with which he assembled a large collection of the moths of Virginia. Each specimen is a tribute to his "good hands" and his meticulous care in mounting them.

Dietrich's zest for life stayed with him to the end. He survived two heart attacks that would have finished off lesser mortals, returning to the full enjoyment of his science, his azalea garden, and his many friends and colleagues. The third attack was, however, too much even for his indomitable spirit. He died quietly at the University of Virginia Hospital on January 5, 1984, leaving a permanent vacancy in the lives of all who knew him. He is survived by his wife, Jean C. Bodenstein, and by a daughter from a previous marriage.

IN THE PREPARATION OF this memoir, I have relied extensively on a memorial address given by I. R. Konigsberg on January 17, 1984, at the University of Virginia and on conversations with Dietrich's family and colleagues.

HONORS AND DISTINCTIONS

DEGREE

Ph.D., 1953, University of Freiburg

PROFESSIONAL RECORD

1928–33	Assistant in Experimental Morphology, Kaiser Wilhelm Institute, Berlin
1933–34	Research Associate in Marine Biology, Rovigno, Italy
1934–41	Research Associate in Biology, Stanford University
1941–43	Guggenheim Fellow, Columbia University
1944	Assistant Entomologist, Connecticut Agricultural Experiment Station
1945–58	Insect Physiologist, Army Chemical Center, Maryland
1958–60	Embryologist, National Heart Institute, Gerontology Branch, Baltimore City Hospitals
1960–73	Lewis and Clark Professor of Biology and Chairman, Department of Biology, University of Virginia
1973–78	Lewis and Clark Professor of Biology, University of Virginia
1978–84	Professor Emeritus, University of Virginia

PROFESSIONAL SOCIETIES

American Society of Zoologists
Genetics Society of America
American Association of Anatomists
Society for the Study of Development and Growth
American Society of Naturalists
American Society for Cell Biology
American Institute of Biological Sciences
American Association for the Advancement of Science

HONORS

Sigma Xi
Phi Sigma
Honorary Member, Soc. Biol. do Rio Grande do Sul, Brazil, 1952
Member, National Academy of Sciences, 1958

Fellow, American Academy of Arts and Sciences, 1961
Vice-President, Zoology Section, American Association for the Advancement of Science, 1963
Fellow, Society of Fellows, University of Virginia, 1968
Alexander von Humboldt award for Senior U.S. Scientists (West Germany), 1977

POSTDOCTORAL STUDENTS

A. Abdel-Malek
A. R. de la Paz
R. G. Babcock
A. C. S. Crossley
P. Koch
S. Seidel
H. W. Küthe
P. A. Lawrence
M. J. Berridge
A. S. Tombes
S. L. Van Horn
F. M. Butterworth
V. Maul
E. Shaaya
R. Arking
F. E. Schwalm
N. M. Tyrer
J. S. Altman
P. Schweizer

PH.D. STUDENTS

1963 Larry T. Wimer
1964 Edward McCrady III
1964 D. Hugh Puckett
1966 Cornelia A. T. Hyde
1967 Muriel B. Babcock
1968 Stanley B. Kater
1973 Elizabeth G. Baker

MASTER'S STUDENTS

1961 Edward McCrady III
1962 Hope J. Nerangis
1965 J. Louise Walsh

SELECTED BIBLIOGRAPHY

1928

Ein für Ostpreussen neuer Micro. *Int. Entomol. Z. Guben.* 21:401–2.

1930

Einige Raupenkrankheiten im Microphotogramm nebst Bemerkungen dazu. Journal unknown 27:57–66.

Experimentelle Untersuchungen über die Regeneration der Borsten bei *Vanessa urticae. Z. Wiss. Insekten-Biologie* 25:25–35.

Einige Krankheiten der Tritonen und Axolotl (Mit Bemerkungen von Dr. Woltersdorff). *Bl. Aquar. Terrarien.* 41:1–3.

1932

Ein *Triton alpestris* Albine. *Zool. Anz.* 96.

Einige Doppelbildungen von Molch und Froschlarven. Illustr. Zeitschr. "*Das Aquarium*" 180–81.

Praktischer Streckapparat für Paraffinschnitte. *Z. Wiss. Mikrosk. Mikrosk. Tech.* 49:454–55.

1933

Experimentell erzeugue Doppelbildungen von Lepidopterenbeinen. *Zool. Anz.* 102:34–38.

Beintransplantationen an Lepidopteren Raupen. I. Transplantationen zur Analyse der Raupen- und Puppenhäutung. *Roux' Arch. Entw. Mech.* 128:564–83.

Die Unterdruckung der Beinregeneration bei *Dixippus morosus* durch Transplantation von Hypodermis auf die Wundflache. Zugleich eine Methode der Transplantation bei ametabolen Insekten. *Zool. Anz.* 103:209–13.

Zur Frage der Bedeutung hormoneller Beziehungen bei der Insekten-metamorphose. *Naturwissenschaften* 21:861–63.

Beintransplantationen an Lepidopterenraupen. II. Zur Analyse der Regeneration der Brustbeine von Vanessa urticae Raupen. *Roux' Arch. Entw. Mech.* 130:747–70.

1934

Untersuchungen zur Analyse des Haütungsproblemes. *Forsch. Fortschr.* 10.

Die experimentelle Erzeugung chimärischer Schmetterlingsbeine. *Biol. Zentral.* 54:181–85.

1935

Beintransplantationen an Lepidopterenraupen. III. Zur Analyse der Entwicklungspotenzen der Schmetterlingsbeine. *Roux' Arch. Entw. Mech.* 133:156–92.

1936

Das Determinationsgeschehen bei Insekten mit Ausschluss der frühembryonalen Determination. *Ergeb. Biol.* 13:174–234.

1937

Beintransplantationen an Lepidopterenraupen. IV. Zur Analyse experimentell erzeugter Bein-Mehrfachbildungen. *Roux' Arch. Entw. Mech.* 136:745–85.

1938

Untersuchungen zum Metamorphoseproblem. I. Kombinierte Schnürungs- und Transplantationsexperimente an *Drosophila. Roux' Arch. Entw. Mech.* 137:474–505.

Untersuchungen zum Metamorphoseproblem. II. Entwicklungsrelationen in verschmolzenen Puppenteilen. *Roux' Arch. Entw. Mech.* 137:636–60.

Untersuchungen zum Metamorphoseproblem. III. Ueber die Entwicklung der Ovarien im thoraxlosen Puppenabdomen. *Biol. Zentral.* 58:329–32.

1939

With V. C. Twitty. Correlated genetic and embryological experiments on *Triturus.* III. Further transplantation experiments on pigment development. IV. The study of pigment cell behavior in vitro. *J. Exp. Zool.* 81:357–98.

Investigations on the problem of metamorphosis. IV. Developmental relations of interspecific organ transplants in *Drosophila. J. Exp. Zool.* 82:1–30.

Imaginal differentiation inaugurated by oxygen in *Drosophila* pupae. *Proc. Natl. Acad. Sci. USA* 25:14–16.

Investigations on the problem of metamorphosis. V. Some factors

determining the facet number in the *Drosophila* mutant Bar. *Genetics* 24:494–508.

Investigations on the problem of metamorphosis. VI. Further studies on the pupal differentiation center. *J. Exp. Zool.* 82:329–56.

1940

Growth regulation of transplanted eye and leg discs in *Drosophila*. *J. Exp. Zool.* 84:23–37.

1941

Investigations on the problem of metamorphosis. VII. Further studies on the determination of the facet number in *Drosophila*. *J. Exp. Zool.* 86:87–111.

With V. C. Twitty. Experiments on the determination problem. I. The roles of ectoderm and neural crest in the development of the dorsal fin in amphibia. II. Changes in ciliary polarity associated with the induction of fin epidermis. *J. Exp. Zool.* 86:343–80.

Investigations on the problem of metamorphosis. VIII. Studies on leg determination in insects. *J. Exp. Zool.* 87:31–53.

1942

Hormone controlled processes in insect development. *Cold Spring Harbor Symp. Quant. Biol.* 10:17–26.

1943

An analysis of balancer development in *Triturus torosus*. *Physiol. Zool.* 16:44–60.

Factors influencing growth and metamorphosis of the salivary gland in *Drosophila*. *Biol. Bull.* 84:13–33.

Hormones and tissue competence in the development of *Drosophila*. *Biol. Bull.* 84:34–58.

1944

With V. C. Twitty. The effect of temporal and regional differentials on the development of grafted chromatophores. *J. Exp. Zool.* 95:213–31.

The induction of larval molts in *Drosophila*. *Biol. Bull.* 86:113–24.

1945

With R. C. Botsford. Mosquito control. *Conn. State Dept. of Health* pp. 1–12.

The corpora allata of mosquitoes. *Conn. Agric. Exp. Stn. Bull.* 488:396–405.

1946

Investigation on the locus of action of DDT in flies (*Drosophila*). *Biol. Bull.* 90:148–57.

With R. Gillette. Specific developmental inhibitions produced in amphibian embryos by a nitrogen mustard compound. *J. Exp. Zool.* 103:1–32.

Developmental relations between genital ducts and gonads in *Drosophila. Biol. Bull.* 91:288–94.

A study of the relationship between organ and organic environment in the post embryonic development of the yellow fever mosquito. *Conn. Agric. Exp. Stn. Bull.* 501:100–14.

1947

The effect of nitrogen mustards on proliferating embryonic tissues. *Cancer Res.* 7:49–50.

Investigations on the reproductive system of *Drosophila. J. Exp. Zool.* 104:101–51.

The effects of nitrogen mustard on embryonic amphibian development. I. Ectodermal effects. *J. Exp. Zool.* 104:311–41.

Chemical alteration of development in *Drosophila. Anat. Rec.* 99:34.

1948

With A. A. Kondritzer. The effect of nitrogen mustard on nucleic acids during embryonic amphibian development. *J. Exp. Zool.* 107:109–21.

With A. Goldin. A comparison of the effects of various nitrogen mustard compounds on embryonic cells. *J. Exp. Zool.* 108:75–91.

The effects of nitrogen mustard on embryonic amphibian development. II. Effects on eye development. *J. Exp. Zool.* 108:93–125.

1949

With A. Abdel-Malek. The induction of aristapedia by nitrogen mustard in *Drosophila virilis. J. Exp. Zool.* 111:95–115.

1950

The effect of ryanodine on the development and respiration of amphibian embryos. *J. Exp. Zool.* 113:601–20.

The postembryonic development of *Drosophila.* In *Biology of Drosophila,* ed. M. Demerec, pp. 275–367. New York: John Wiley & Sons.

1952

With B. Sacktor. Cytochrome c oxidase activity during the metamorphosis of *Drosophila virilis. Science* 116:299–300.

Studies on the development of the dorsal fin in amphibians. *J. Exp. Zool.* 120:213–45.

With B. Sacktor. Cytochrome c oxidase activity of various tissues of the American cockroach, *Periplaneta americana* (L.). *J. Cell. Comp. Physiol.* 40:157–61.

1953

Embryonic Development; Postembryonic Development; Regeneration; The Role of Hormones in Moulting and Metamorphosis. In *Insect Physiology,* ed. K. D. Roeder, pp. 780–931. New York: John Wiley & Sons.

Endocrine control of metamorphosis with special reference to holometabola. *Trans. IXth Int. Cong. Entomol.* 2:58–62.

Studies on the humoral mechanisms in growth and metamorphosis of the cockroach, *Periplaneta americana.* I. Transplantations of integumental structures and experimental parabioses. *J. Exp. Zool.* 123:189–232.

Studies on the humoral mechanisms in growth and metamorphosis of the cockroach, *Periplaneta americana.* II. The function of the prothoracic gland and the corpus cardiacum. *J. Exp. Zool.* 123:413–33.

Studies on the humoral mechanisms in growth and metamorphosis of the cockroach, *Periplaneta americana.* III. Humoral effects on metabolism. *J. Exp. Zool.* 124:105–15.

1954

Effects of radiomimetic substances on embryonic development, with special reference to nitrogen mustards. *J. Cell. Comp. Physiol.* 43 (Suppl. 1):179–205.

Endocrine mechanisms in the life of insects. *Recent Prog. Horm. Res.* 10:157–82.

Aspects of synthesis and order in growth. XI. Humoral agents in insect morphogenesis. *Symp. Soc. Study Dev. Growth* 13:257–68.

1955

Embryogenesis: Progressive differentiation. Ch. 4, Insects, in *Analysis of Development*, eds. B. H. Willier, P. A. Weiss, and V. Hamburger, pp. 337–45. Philadelphia: W. B. Saunders Co.

Contributions to the problem of regeneration in insects. *J. Exp. Zool.* 129:209–24.

1957

Humoral dependence of growth and differentiation in insects. In *Recent Advances in Invertebrate Physiology*, ed. B. T. Scheer, pp. 197–211. Eugene: Univ. of Oregon Publications.

Studies on nerve regeneration in *Periplaneta americana*. *J. Exp. Zool.* 136:89–115.

1958

With V. G. Dethier. Hunger in the blowfly. *Z. Tierpsychol.* 15:129–40.

1959

The role of hormones in the regeneration of insect organs. (Le role des hormones dans la regeneration des organes des insects.) *Scientia* 53:1–6.

Comments in *Physiology of Insect Development*, ed. F. L. Campbell. Chicago: Univ. of Chicago Press.

Contributions to the problem of eye pigmentation in insects: Studied by means of intergeneric organ transplantations in Diptera. *Smithson. Misc. Collect.* 137:23–41.

With J. R. Larsen. The humoral control of egg maturation in the mosquito. *J. Exp. Zool.* 140:343–81.

With I. B. Sprague. The developmental capacities of the accessory sex glands in *Periplaneta americana*. *J. Exp. Zool.* 142:177–202.

1961

With R. R. Cowden. A cytochemical investigation of striated muscle differentiation in regenerating limbs of the roach, *Periplaneta americana*. *Embryologia* 6:36–50 (Mangold Festschrift).

1962

Regeneration in insects. *Symposia Genetica et Biologica Italica* 9:3–19 (Celebrazione Spallanzaniana).

Humoral conditions and cellular interactions in the development of the insect eye. In *Insect Physiology (Proceedings of the Twenty-third Biology Colloquium, Oregon State Univ., 1962)*, ed. V. Brooks, pp. 1–12. Corvallis: Oregon State Univ. Press.

1963

With R. C. King. Autonomy of *fu* and *fes* ovarian implants. *Drosoph. Inf. Serv.* 37:65.

With F. M. Butterworth and R. C. King. Adipose tissue of *Drosophila melanogaster*. I. An experimental study of larval fat body. *J. Exp. Zool.* 158:141–54.

1965

With R. C. King. The transplantation of ovaries between genetically sterile and wild type *Drosophila melanogaster*. *Z. Naturforsch.* 20b:292–97.

With P. A. Smith and R. C. King. Autonomy of *fu* and fu^{59} ovarian implants with respect to rate of tumor production. *J. Exp. Zool.* 159:333–36.

With M. L. Wolbarsht and H. G. Wagner. Origin of electrical responses in the eye of *Periplaneta americana*. In *The Functional Organization of the Compound Eye*, ed. C. G. Bernhard, pp. 207–17. Stockholm: Wennergren Symposium.

1966

With R. C. King and S. K. Aggarwal. The comparative submicroscopic cytology of the corpus allatum-corpus cardiacum complex of wild type and *fes* adult female *Drosophila melanogaster*. *J. Exp. Zool.* 161:151–76.

With R. C. King and S. K. Aggarwal. The comparative submicroscopic morphology of the ring gland of *Drosophila melanogaster*

during the second and third larval instars. *Z. Zellforsch.* 73:272–85.

1967

With F. M. Butterworth. Adipose tissue of *Drosophila melanogaster.* II. The effect of the adult internal environment on growth, protein deposition, and histolysis in the larval fat body. *J. Exp. Zool.* 164:251–66.

1968

With W. S. Klug and R. C. King. Oogenesis in the suppressor of Hairy-wing mutant of *Drosophila melanogaster.* I. Phenotypic characterization and transplantation experiments. *J. Exp. Zool.* 167:151–56.

With F. M. Butterworth. Adipose tissue of *Drosophila melanogaster.* III. The effect of the ovary on cell growth and the storage of lipid and glycogen in the adult tissue. *J. Exp. Zool.* 167:207–17.

With E. Shaaya. The function of the accessory sex glands in *Periplaneta americana* (L). I. A quantitative bioassay for the juvenile hormone. *Proc. Natl. Acad. Sci. USA* 59:1223–30.

1969

With E. Shaaya. The function of the accessory sex glands in *Periplaneta americana* (L.). II. The role of the juvenile hormone in the synthesis of protein and protocatechuic acid glucoside. *J. Exp. Zool.* 170:281–92.

With F. M. Butterworth. Adipose tissue of *Drosophila melanogaster.* IV. The effect of the corpus allatum and synthetic juvenile hormone on the tissue of the adult male. *Gen. Comp. Endocrinol.* 13:68–74.

1971

Milestones in Developmental Physiology of Insects. New York: Appleton-Century-Crofts.

1972

For the 70th birthday of Ernst Hadorn. In *Results and Problems in Cell Differentiation,* vol. 5, eds. H. Ursprung and R. Nothiger, pp. 7–9. Berlin: Springer-Verlag.

1975

With P. Schweizer. Aging and its relation to cell growth and differentiation in *Drosophila* imaginal discs: Developmental response to growth restricting conditions. *Proc. Natl. Acad. Sci. USA* 72:4674–78.

1978

With K. Scheller and P. Karlson. Effects of ecdysterone and the juvenile hormone analogue methoprene on protein, RNA and DNA synthesis in wing discs of *Calliphora vicina. Z. Naturforsch.* 33c:253–60.

1979

With J. Koolman and K. Scheller. Ecdysteroids in the adult male blowfly *Calliphora vicina. Experientia* 35:135.

1981

With K. Scheller. Effects of ecdysterone and the juvenile hormone analogue methoprene on protein, RNA and DNA synthesis in brains of the blowfly, *Calliphora vicina. Zool. Jahrb. Abt. Allg. Zool. Physiol. Tiere* 85:1–19.